Paths to Blue Bins:
A System Dynamics Approach to Individual- and Population-Level Factors in Pro-Environmental Recycling Behavior

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VOX CLAMANTIS IN DESERTO

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Introduction

Why did you recycle today? Why didn't you recycle yesterday? What runs through your subconscious when you throw something into the blue recycling bin? What physical elements around you construct your behavior?

This thesis project examines the individual-level and population-level factors that influence an individual's pro-environmental behavior. There are many factors that make people act or not act in a certain way. I take a system dynamics approach to understanding the interplay and outcome of the factors that influence recycling behavior. Theory of planned behavior claims that there is a link between beliefs and behavior. Extending the theory, the actions people take or are willing to take on environmental subjects (energy usage, sustainable purchasing habits, eating local) are linked to the beliefs that they hold. This thesis identifies sets of beliefs that drive or oppose pro-environmental behavior on an individual level—what informs a person's beliefs and how social and physical circumstances affect behavior. There is extensive literature on both the morals and norms that drive pro-social behavior (any action intended to help others) and the gap between intention and action. My research builds and evaluates a dynamic model of pro-environmental behavior that generates population's recycling behavior based on different static and dynamic factors. My model is informed by existing literature on behavioral structures and empirical studies on recycling behavior. I test population behavior during three phases pf recycling program development and apply a range of treatments to determine effective points of intervention. Figure 1 illustrates the general framework of my model, how the system generally fits together, and the dynamics of interest. The driving research questions are: How do internal factors (attitude, subjective norms, and perception of behavioral control) and external factors (physical barriers and social pressure) manifest in an individual's pro-environmental behavior? How do these factors contribute to a discrepancy between intent and action? What are effective ways to promote pro-environmental behavior in a small population?

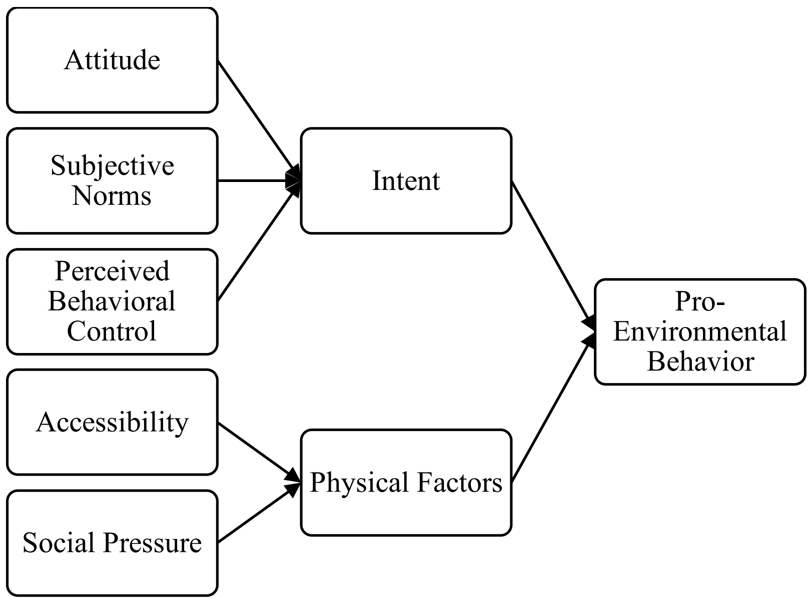


Figure 1: Preliminary concept map of factors that affect Pro-Environmental Behavior. This structure shows the relationships that are examined.

This project is motivated by the idea that environmentalism is a privileged cause—one in which socioeconomic factors systematically enable one group's environmentalism but not others' (Carrier *et al.* 2004). It is easy to care about your carbon footprint when the price difference between an organic tomato and a regular tomato is not prohibitive. Why should a family struggling to pay for their child's education buy organically grown, expensive produce? How can environmental issues, as large and looming as they are, compare to a stack of medical bills? I seek to understand how individuals of different races, socio-economic classes, and geographic locations interact with environmental issues. I endeavor to learn how to best promote pro-environment behavior without putting undue burden on individuals or relying on social and moral drivers that are specific to certain groups. I take a system dynamics approach to understanding the relationship between moral factors and socioeconomic factors in intended and enacted pro-environmental behavior (Weller *et al.* 2014).

The first goal of this project is to construct a comprehensive STELLA model of the internal factors (social norms, attitude, and perceived behavioral control) and external factors (physical barriers, and social pressure) that define an individuals' pro-environmental behavior. STELLA (Structural Thinking and Experiential Learning Laboratory with Animation) is a system dynamics modeling tool built by ISEE and used in many field to simulate and analyze complex social system problems (Ouyang *et al.* 2015; Semeniuk *et al.* 2010; Ouyang 2008). There is no existing work that uses STELLA models to address the intersection of beliefs and pro-environmental behavior. Generally, structural equation models are used in this type of work, but STELLA is a common tool for examining dynamic models. The population dynamics in the case of recycling behavior make it an interesting problem for system dynamics.

The STELLA model is based on the canonical models of the value-belief-norms theory and the theory of planned behavior. I use recycling as my proxy for Pro-Environmental Behavior. Recycling is a commonly studied Pro-Environmental Behavior and offers ample empirical data. The model is mathematically informed and structurally substantiated. STELLA is a dynamic systems modeling program based on a stock and flow structure. The base unit is a person and the system determines flow based on system equation models of intent factors and behavior. The individual-based model—the stock is one person—feeds into a population-based model to examine societal and group behavior in simulations. Empirical data is collected from existing research on beliefs, values, and norms held on Pro-Environmental Behavior, specifically, the pool of meta-data from Bamber and Moser's work (2006). Although no original data is collected, an extensive appraisal of empirical studies of recycling behavior was conducted to find datasets that best fit the relationships being modeled. The model is built to mimic this data and is evaluated based on its accuracy. This evaluation of the model for baseline behavior is essential for defining the mathematical relationships between each factor in the system. The advantage of STELLA modeling in social systems is to build a system that mimics real-life behavior when parameters are at an empirical baseline and when parameters are at empirical extremes.

The second goal is to use system dynamics to understand the different phases of establishing recycling behavior and to test intervention strategies. I run simulations of the model under different treatments, or sets of parameters, to investigate points of intervention and test effect of policy and projects. After the model was built, I add an interactive component for selected parameters. This allows me to run simulations as well as enable user-interaction. Parameters for the simulations are defined by empirical environmental behavioral and policy studies. Each simulation examines behavioral response to proposed environmental program and policy intervention. The simulations are categorized empirically (similar to stress-tests) and imitations of existing or hypothetical policy and programs. The treatments that are tested are moral-based education, process-based education, and life-style marketing.

I examine the interplay of factors that determine recycling intent and behavior and the effectiveness of treatment options by taking a system dynamics approach. First, I build a STELLA model based on Taylor and Todd's empirically-informed structural equation model and test its accuracy with step and stress tests. Second, I examine the STELLA model under different static parameters to understand behavior during different phases, or ages, of recycling program. Third, I design and apply different interventions to increase recycling in populations by engaging different intent factors. Finally, I discuss the practicality of using system dynamics modeling in a study of intervention methods in recycling behavior.

Chapter 1: Literature Review of Pro-Environmental Behavior and Agent-Based Modeling Methods

A substantial body of academic work is dedicated to Pro-Environmental Behavior (PEB). Previous literature considers a number of questions, such as what internal, moral characteristics of a person affect PEB? What societal, external factors influence individuals' PEB? What is the relationship between intent and behavior? My work seeks to examine the intersection of these fields through literature review and original modeling. The following discussion is divided into three sections: a discussion of the main theories of behavior, methods in agent-based modeling, and the use of recycling as a PEB and structural equation models of recycling behavior.

Theories of Pro-Environmental Behavior

There is an established correlation between moral norms and PEB. Based on the assumption that one's values, beliefs, and morals influence one's actions, research has sought to understand the factors within an individual that contribute to his or her PEB. These theories attempt to understand a person's intent, they do not extend to behavior—the theory of the intent-action gap will be introduced later. Intent means that a person believes a certain thing and would act in favor of their beliefs if all barriers were inconsequential. For example, if one believes that humankind should not leave a mark on the Earth, that person is more likely to recycle. However, if that person does not see or understand the benefit of recycling, then they might not recycle, even if they hold the belief that humans should not impact the Earth. The core beliefs that inform intent are the subject of extensive research in sociology, psychology, environmental behavior, and ecological economics. The three leading theories in environmental economics about intent and pro-environmental behavior are the norm-activation theory of moral decision-making, the value-belief-norms theory, and the theory of planned behavior.

Shalom Schwartz's norm-activation theory is based on the idea that activating moral norms leads to pro-social behavior (Schwartz 1970, 1973, 1977). Two preconditions to the mechanism of personal moral norms initiating pro-social behavior are awareness of consequences and ascription of responsibility (Schwartz 1970). Awareness of consequences is an individual’s understanding that their actions impact the welfare of others. Ascription of responsibility is the individual-level feeling of obligation to take action. A violation of a personal norm causes guilt whereas compliance with a personal norm results in pride and improved self-esteem (Schwartz 1977).

Schwartz's norm-activation theory originated as an explanation for pro-social behavior but was later applied to PEB. Kent Van Liere and Riley Dunlap's study applied norm-activation theory to yard burning (Van Liere and Dunlap 1978). They observed a strong relationship between ascription of responsibility, awareness of consequences, and PEB, in accordance with Schwartz (1978). Empirical studies of pro-environmental behavior have generally distinguished between two types of behaviors: household behaviors and support for environmental protection behaviors. Household behaviors are actions taken to mitigate one's impact on the environment or resources, such as conserving energy, buying compostable products, or producing less waste. Support behaviors are demonstrations in agreement with pro-environmental ideals, like signing a petition against the Keystone pipeline or voting for a willingness to pay tax.

The application of norm-activation theory in household PEB is, however, constrained, and support for the theory is limited. Black, Stern, and Elworth performed a path-analysis on subjects who made household energy adaptation decisions (1985). Their work found limits to the generalizability of Schartz's theory to PEB. The study found that economic factors—high and rising fuel prices—had a greater impact on spending behavior than did personal variables (Black, Stern, Elworth 1985). Purchasing gas does not have the same physical and retention impact as yard burning, so the impact on the subject was less effective. Schwartz would argue that the ascriptions of responsibility in this study are not strong enough to apply the theory (Black, Stern, Elworth 1985). In addition to Schwartz's critique, another study by Turaga *et al*. (2010) discussed the limitations and parameters of norm-activation theory and PEB by surveying empirical studies. While there is general consensus between norm-activation theorists and their critics that if an individual has high awareness of consequences of their actions and demonstrates some ascription of responsibility, they are likely to engage in PEBs, many studies do not test the causality of the relationship between awareness of consequences and ascription of responsibility and behavior. Many studies assume the relationship is driven by the activation of personal norms concerning the behavior in question (Turaga *et al.* 2010).

Value-belief-norms theory expands on the norm-activation theory by considering a wider range of core-human motivations. Norm-activation theory assumes humans are fundamentally altruistic and concerned with their impact on the well-being of others. Value-belief-norms theory states that a stable set of underlying values that are relevant to action creates personal norms (Stern *et al.* 1993). These values come from central elements of personality and an individuals' belief structure. Stern *et al.* (1993) incorporate three value orientations—egoistic, social-altruistic, and biospheric—to evaluate subjects' PEB. Their work offers insights into how different belief structures play out when subjects are asked to respond to an environmental issue. Similarly, value-belief-norms theory proposes that core ventral beliefs which individuals hold on human and environment interactions informs awareness of consequences and ascription of responsibility beliefs (Stern *et al.* 1993). Stern *et al.*'s study also considers demographic factors, such as gender, that affect one's awareness of consequence. The findings suggest that women have stronger beliefs about consequences than men (Stern *et al.* 1993).

The application of value-belief-norms theory by others has expanded the understanding of the fundamental set of beliefs that shape the relationship between awareness of consequences and ascription of responsibility, namely the influence behavior. Dunlap and Van Liere (1978) consider the New Environmental paradigm as a set of beliefs that creates a specific awareness of consequences and ascription of responsibility relationship. Schwartz (1994) applied his own work to value-belief-norms theory by examining the awareness of consequence-ascription of responsibility relationship under a more structured set of basic human beliefs. The sets of values he studied includes self-transcendence, self-enhancement, and tradition. This work, along with Turaga *et al.* (2010) has cultivated an understanding of the causal ordering of variables in value-belief-norms theory. Stern *et al.* (1999) produced a causal flow chart of value-belief-norms theory in the context of PEB, and this is described in Figure 2. The flow chart shows that the three classes of values—altruistic, egoistic, and traditional—determine an individual's score on the New Ecological Paradigm scale. This score is then affected by awareness of consequences and ascription of responsibility, which produce Pro-Environmental Personal Norms. These norms then manifest in four classes of pro-environmental behavior: Environmental Activism, Environmental Citizenship, Policy Support, and Private-Sphere Behaviors.

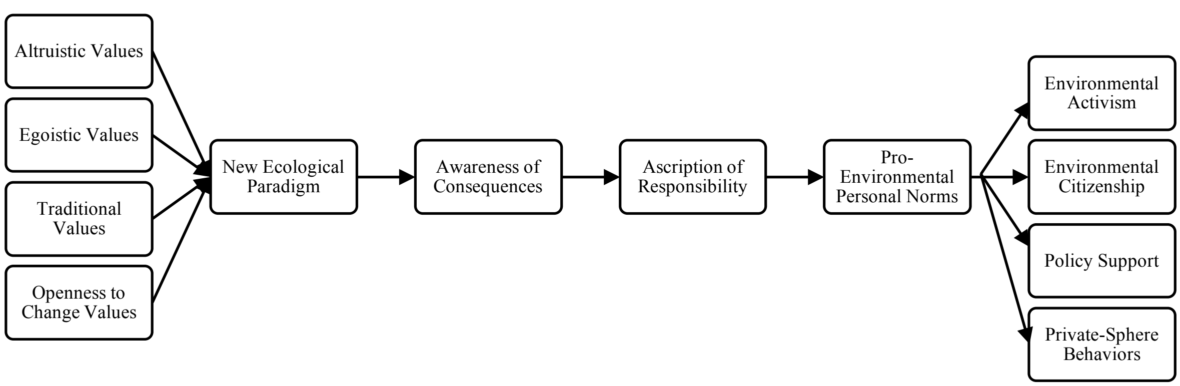


Figure 2: Concept flow-chart of the variables in value-belief-norm theory as Stern *et al.* applies it to environmentalism. Arrows show causal relationships between sets of variables.

Stern *et al.* (1999)

The third core theory that is applied to pro-environmental behavior is the theory of planned behavior. Theory of planned behavior is the understanding of motivational factors behind intent and focuses on rational decision-making (Ajzen 1991; Turaga *et al.* 2010). It proposes that intention drives behavior and that intention is composed of an individual's attitude toward behavior, subjective norms, and perceived behavioral control (Ajzen 1991). These three core drivers are related to specific sets of behavioral beliefs, normative beliefs, and control beliefs, respectively (Ajzen 1991), Figure 3. An advantage of the theory of planned behavior over norm-activation and value-belief-norms theory is that it acknowledges a diversity of belief categories — behavioral, normative, and control (Turaga *et al.* 2010). Turaga *et al.*'s work also touches on the difference behind intention and actual behavior. Turaga *et al*.'s adaptation of Ajzen's causal relationship figure is shown in Figure 3 (2010).

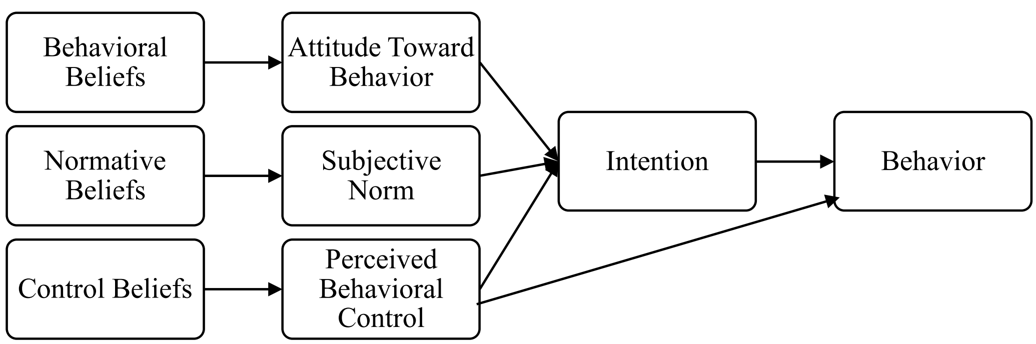


Figure 3: Causal relationships between variables in the theory of planned behavior.
(Turaga *et al*. 2010)

There are two important differences in comparing value-belief-norms theory and theory of planned behavior causal relationship models. Understanding these distinctions allows the theories to be incorporated into the proposed project and model. First, value-belief-norms theory assumes the individual values all PEB equally (there is no variation in what the behavior is—be it installing solar panels or recycling) while theory of planned behavior assigns different values to different behaviors. Value-belief-norms theory uses the New Ecological Paradigm, a survey-based metric, to determine an individual's "pro-ecological" world-view (Anderson 2012). An advantage to value-belief-norms theory is that every individual has one reaction-input. However, equalizing all household pro-environmental behaviors could pose limitations to the questions addressed in this proposal and the application of results. Theory of planned behavior addresses this problem by using behavioral beliefs to inform an individual's attitude toward the behavior in question. This theory avoids over-generalizing behaviors and requires more empirical research. Second, the two theories deal with the gap between intent and action differently. Value-belief-norms theory does not explicitly acknowledge this gap. It uses awareness of consequences and ascription of responsibility as causal factors that shape pro-environmental personal norms, which subsequently cause behavior. Research on the relationship between a person's awareness of consequences and ascription of responsibility impacts his or her behavior (Turaga *et al.* 2010). Theory of planned behavior addresses the issue of the intent-action gap by making it an explicit relationship in the model and studying perceived behavioral control as a catalyst.

These three theories, norm-activation theory, value-belief-norms theory, and the theory of planned behavior, contribute to the structure of the proposed model. There is literature on the overlap and convergence of these theories, so a portion of the project will be dedicated to understanding the overlap and incorporating the most relevant and supported system dynamics to include in the predictive model. There is substantial empirical and analytical work affiliated with each of these of moral and rational behavior theories to guide the construction of a mathematical model for this project.

Agent-Based Modeling Methods in PEB

Work that models the causal relationships between variables in PEB complements the literature on pro-environmental behavioral theory is. The research of Jody Hines, Harold

Hungerford, and Audrey Tomera (1986) introduces a meta-analysis of PEB that quantifies the variables that influence behavior. Hines *et al.* gathered empirical data from a range of studies on intent and beliefs surrounding PEB and compared cognitive, psycho-social, and demographic variables to produce an Environmental Behavior Model (1986). Twenty years after Hines, Hungerford, and Tomera, and Bamberg and Moser performed their own meta-analysis of the psycho-social determinants of PEB in an attempt to update Hines, Hungerfor, and Tomera's model. Schwartz's norm-activation theory and Ajzen's theory of planned behavior provides a basis for their model's framework (Bamberg and Moser 2006). Using this framework, Bamberg and Moser apply a meta-analysis of empirical data and calculate path-coefficients between causal factors (Bamberg and Moser 2006). Figure 4 summarizes the causal relationships and correlation between factors of the Bamberg-Moser model. The core of Bamberg and Moser's analysis is to quantify the relationship between factors the influence PEB, specifically how strong of a predictor one element is of another.

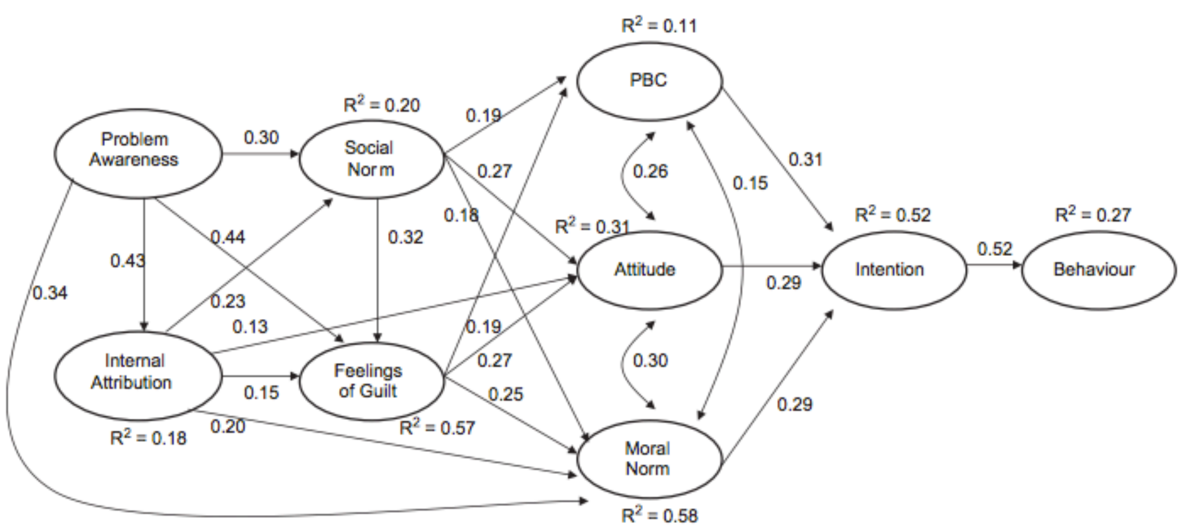


Figure 4: Results of the MASEM based on pooled random-effects correlations, PBC = perceived behavioral control, single-headed arrows = standardized path-coefficients; double-headed arrows = correlations, R^2 = explained variance.

(Bamberg and Moser 2006)

Structural equation models, like the Bamberg-Moser model, are a common method of analyzing empirical data for latent variables. A latent variable is a variable that is not observable, so it is often inferred and structural equation models calculate the relationship between these variables. My work takes Taylor and Todd's structural equation model (with is introduced in the next section) and builds a system dynamics model from it to generate simulation data.

System dynamics is the study of complex social, managerial, economic, or ecological systems that have interdependent factors, circular causality, mutual interaction, and information feedback. System dynamics is a common approach to agent-based modeling, and is the foundational concept of my project. Various computer-assisted modeling programs have been designed to build complex, dynamic and logically flowing systems. A tool employed in some ecological-social systems modeling is Structural Thinking Experimental Learning Laboratory with Animation (STELLA). Oni *et al.* used STELLA in a 2012 analysis of the impact of climate change and power flow management. They articulate that STELLA's primary advantage to their work is the ease with which they can address "what if" scenarios, or simulations (Oni *et al.* 2012). A 2015 study performed by Ying Ouyang *et al.* uses STELLA to estimate water and nitrogen in a woody crop plantation. They synthesized empirical data from previous biological research to inform the structure and exact relationships of their model (2015). Then, they designed simulations to test long-term effects of current ecological patterns, potential conservation interventions, and disaster scenarios (Ouyang *et al.* 2015). The work in STELLA primarily includes ecological systems. There is some work (Florian Weller *et al.* 2014) that incorporates social systems and human behavior into a model of a physical system. My project expands the application of STELLA to study systems of environmental behavior by building a STELLA model informed by structural equation models of latent variables and physical parameters and systems.

Recycling Behavior as a Proxy for PEB & Structural Equation Models for Recycling Behavior

There is extensive literature that use recycling behavior as a proxy for PEB. This body of work informs my decision to use recycling as a proxy in this model. Recycling is a clear cut, well-defined pro-social and pro-environmental behavior. The literature on recycling includes curbside recycling, which happens at one's house and is a long-term behavior, and blue-bin recycling, which happens every time one throws something away and is a short-term behavior. The combination of these two types of recycling makes this an interesting problem to address using system dynamics.

Household-level recycling takes planning and requires greater activation energy. Researchers focus on the morals and values that influence behavior because the necessity of planning makes it easier to survey people. Studies performed by Valle *et al.* (2005), Harland *et al.* (1999), Chu and Chiu (2003), Werner and Makela (1998), and Knussen *et al.* (2004) examine the long-term, slow-changing factors that contribute to household recycling behavior. These studies generally look at morals, norms, and perception of control as internal, static indicators of recycling behavior and social pressure that modifies that constructed intent. All of these studies found significant correlations among morals, norms, perception of control and intent. Much of this work culminated in a structural equation model.

Individual-level recycling is much more dependent on physical barriers and strength of morals than household recycling. The high frequency and changing conditions make individual recycling behavior susceptible to other factors. Studies that focus on individual recycling behavior generally focus on information salience, awareness of control, consequences, and responsibility, and social pressure. Those who have contributed to this body of work are Mannetti *et al.* (2004), Corbett (2005), Manstead (2000), Bratt (1999), and Tanner (1999). Similar to the work on household recycling behavior, much of the research by these authors has been synthesized and combined into meta-analyses and structural equation models.

Recycling behavior is a good proxy for PEB in a system dynamics model and analysis because it allows multiple levels of feedback to study. There is extensive research on the individual-level belief, moral, and norm structure on recycling behavior which has been re-examined and re-confirmed by many empirical and meta-analyses. The same is true for household recycling, which then creates the layer of population dynamics, and system dynamics is very useful in examining thy type of system. Structural equation models are confirmatory rather than exploratory, and means that they test the strength of correlation between two or more variables. They also offer causal and path analysis, which allows models to include directional connections. The main benefit of structural equation models is their handling of latent variables, second order factors, and covariance. Especially in this project, the integrated understanding of latent variables offered by structural equation models is extremely important. The factors discussed in the theories of PEB, morals, norms, values, and beliefs, are latent variables. A moral is not observable, so researchers derives studies to test observable variables that related to the latent variable of interest. Structural equation models test a hypothesized relational structure of variables.

The primary structural equation model I use to build my system dynamics model is taken from Taylor and Todd's 1995 study of recycling behavior in a small population and is shown in Figure 5. The arrows indicate causality between factors and the values on the connections show the magnitude of influence. For example, the path coefficient between *Relative Advantage* and *Attitude* is 0.38, which means for every standard deviation that a person's *Relative Advantage* changes, *Attitude* changes by 38% of a standard deviation in that direction. The questionnaire used to gather empirical data, which was then used to calculate the structural equation model, can be read in full in Appendix A. The questionnaire is divided into seven categories: *Relative Advantage*, *Complexity*, *Internal Normative Beliefs*, *External Normative Beliefs*, *Self-Efficacy*, *Compatibility*, and *Resource-Facilitating Conditions.*

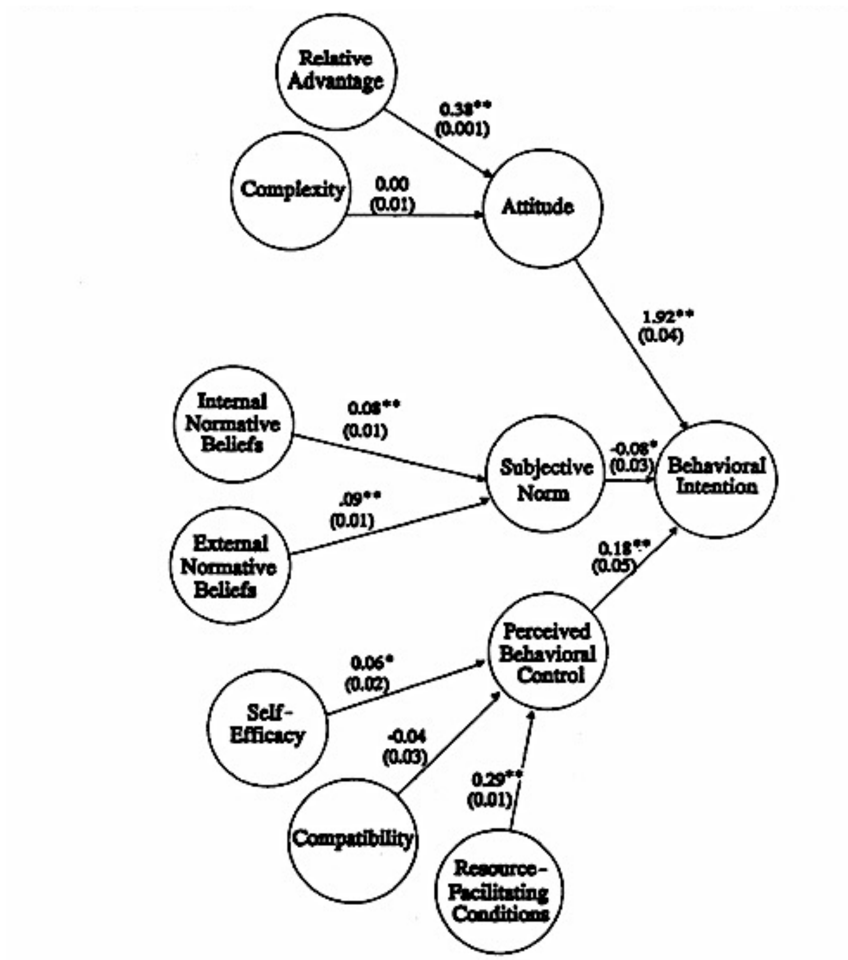


Figure 5: Structural equation model of path coefficients for Recycling behavior. Standard errors are shown in parentheses.

**p < .01; **p < .001.*

(Taylor and Todd 1995)

Chapter 2: Methods

Model development

This section describes in detail the development of a dynamic model of individual-level and population-level factors in recycling behavior. The model was constructed in STELLA and can be seen in full in Appendix B. There are three layers of this model: the user interface, the model map, and the equations. The user interface allows anyone to pick the starting state or population they wish to examine and apply different tests. The map of the model determines the structure and causality of the model and is largely based on the Taylor and Todd structural equation model (1995). The equations layer quantifies the connections and factors on the map layer. A full equations list can be found in Appendix B.

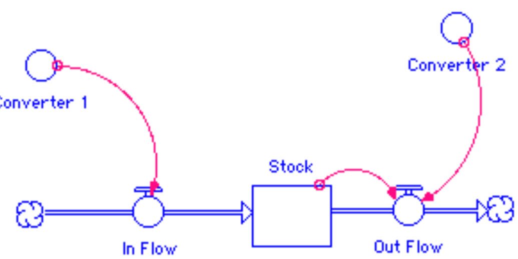


Figure 6: A schematic diagram using the four main features in STELLA's system dynamic modeling: (1) Stock, (2) Flow, (3) Converter, and (4) Connector.

The STELLA software package consists of four key building blocks, shown in Figure 6. The features are: (1) **Stocks**, which are the base structural component and state variables, are given a starting value and accumulate units over time. The change in stock accumulation over time is determined by the (2) **Flows**, the equations that define the dynamics, that direct stock units into and out of them. Flows are the exchange variables; they determine the rate at which the state variables change. (3) **Converters** are auxiliary variables and represent discrete constants or values based on variables, curves, or functions. Finally, (4) Connectors relate the three categories of variables, modeling features, and elements.

The model build in this project combines two types of factors: individual level and population level. The individual level factors are *Attitude*, *Subjective Norms*, and *Perceived Behavioral Control*. Each of these factors are composed of more latent variables and are discussed in the following section. The population level factors are physical barriers and social pressure.

Overview of model structure

The model takes a simulated population of one hundred hypothetical people, randomly picks their basic individual, internal characteristics (*Attitude*, *Subjective Norm*, and *Perceived Behavioral Control*), calculates their intent and injects them into a physical system dynamics model of recycling behavior. The two-dimensional map shows the internal structure of one person in the population. The model is arrayed by one hundred and each person acts independently. This means the model has one hundred layers stacked on top of each other and each layer representing one person in the population. Within each person's internal structure, the model is broken down into latent factors that calculate that person's *Intent* score. The *Intent* score determines an individual's intent to recycle, which determines their recycling behavior.

The bare-bones system dynamics model is a 3-stock bi-flow, which means that there are two systems of connected stocks that influence each other. In system dynamics modeling, especially when using STELLA, it is important to begin with a basic foundation structure because it allows for valid expansion in the model as more factors and elements are added. The general structure used in this project is shown in Figure 7. The *Intent* and *Behavior* stock and flow structures are based on categories of intent to recycle and recycling behavior. For example, an individual in the "Intent: never" stock never or very rarely intends to recycle, an individual in the "Behavior: sometimes" stock sometimes recycles, and an individual in the "Behavior: always" stock always or very frequently recycles.

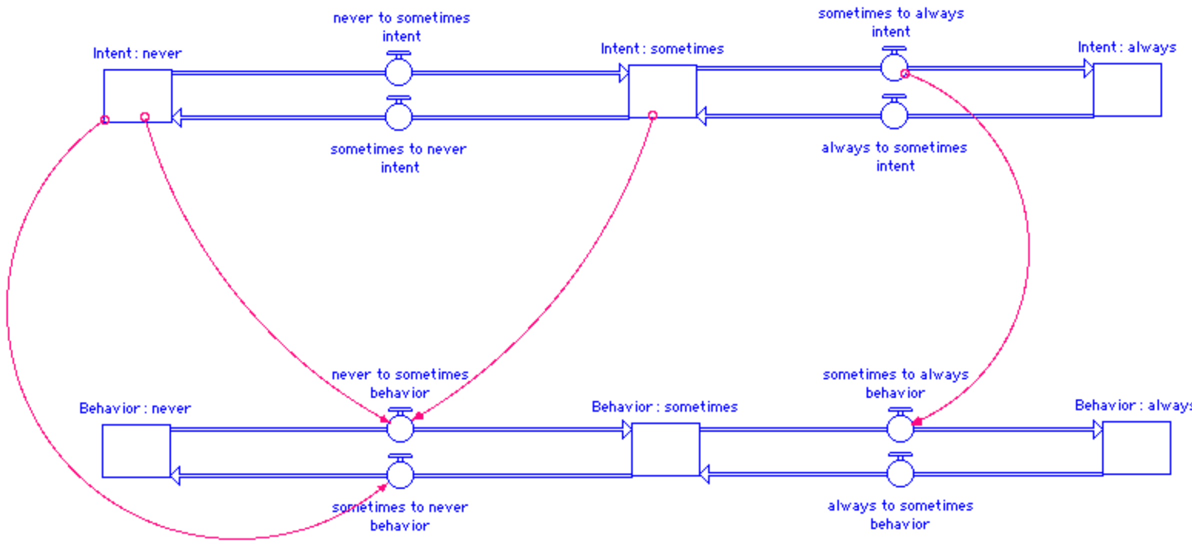


Figure 7: A simplified version of the 3-stock bi-flow structure used in the full model. Example connectors are shown but do not reflect actual connectors used.

Figure 7 shows one person's *Intent* and *Behavior*. The entire model is later arrayed by one hundred to create a population. The total stock in the *Intent* stock-flow is one and the total stock in the *Behavior* stock-flow is one because a person can only exist in one *Intent* category and one *Behavior* category. At each time interval, one week, the person's *Intent* and *Behavior* are calculated and the flows are assed to determine whether or not the person moves to a different category of *Intent* or *Behavior*.

Individual level factors

The STELLA model I build is based on Taylor and Todd's structural equation model, shown in Figure 5. The causal paths connecting factors provided a foundation for the final model. The model incorporates three elements of prior work: Taylor and Todd's questionnaire and the responses from it, equations derived from theory of planned behavior, and Taylor and Todd's calculated path coefficients.

First, the model takes every question of the questionnaire as an input variable for an individual. Each individual generates a simulated response to the 34-question survey. The questions are categorized into seven sub-factors: *Relative Advantage*, *Complexity*, *Internal Normative Beliefs*, *External Normative Beliefs*, *Self-Efficacy*, *Compatibility*, and *Resource-Facilitating Conditions*. The sub-factors are then grouped into factors, as shown in Figure 8, which are *Attitude*, *Subjective Norm*, and *Perceived Behavioral Control*. All of the questions are paired—one determining the subject's reaction (strongly agree, strongly disagree) to a statement and one addressing the strength of causality assumed in the previous question. For example, one pair of questions asks, "I will help to reduce out landfill waste by recycling (strongly disagree, strongly agree)" and "helping to reduce out landfill waste is an (extremely unimportant, extremely important) part of my decision to recycle" (Taylor and Todd 1995). Both questions are answered on a scale from negative nine to nine or negative twenty-one to twenty-one, depending on the category of question. The questions are scaled according to Azjen and Fishbein's suggestions in their 1980 paper. The full questionnaire can be read in Appendix A.

The questions extend the tree structure that is shown in Figure 8 and incorporate the relational equations of theory of planned behavior. As seen in Appendix A, each of the seven factors shown in Figure 2 is informed by two to ten questions on the questionnaire. For example, the four questions that inform *Internal Normative Beliefs* are, "My family thinks that I should recycle (strongly disagree, strongly agree)"; "With respect to waste management behaviors, I want to do what my family thinks I should do (strongly disagree, strongly agree)"; "People in my household think that I should recycle (strongly disagree, strongly agree)"; and "With respect to waste management behaviors, I want to do what people in my household think I should do (strongly disagree, strongly agree)". The relationships between the questions asked on the questionnaire and the person's *Attitude*, *Subjective Norm*, and *Perceived Behavioral Control* equations are derived from Ajzen's theory of planned behavior (Taylor and Todd 1995).

Formally, the equation for *Attitude* (A) is the attitudinal belief that performing a certain action will lead to a particular outcome (b_i), multiplied by the strength of causality between that behavior and outcome (e_i). These factors are asked in the previously mentioned pairs of questions and address the subject's perception of *Relative Advantage* and *Complexity* of recycle. *Attitude* is calculated as

$$A = \sum b_i e_i.$$

Subjective Norm (SN) is defined as an individual's internal and *External Normative Beliefs* (nb_j) concerning the influence of a certain party (family or friends, for example), multiplied by the importance of complying with that party's wishes (mc_j). The paired elements that influence *Subjective Norm* are categorized as either *Internal Normative Beliefs* or *External Normative Beliefs*. *Subjective Norm* is calculated as

$$SN = \sum nb_j mc_j.$$

Perceived Behavioral Control (PBC) is defined as the summation of an individual's control beliefs (cb_k) multiplied by their perceived facilitation (pf_k) of the control in preventing or encouraging the behavior. The pared questions are categorized as *Self-Efficacy*, *Compatibility*, or *Resource-Facilitating Conditions*. The equation for *Perceived Behavioral Control* is

$$PBC = \sum cb_k pf_k.$$

The connections between the belief structures and determinants of *Intent* (*Attitude*, *Subjective Norm*, and perceived behavior control) are not especially well understood (Ajzen 1991). However, many researchers use a general formula to calculate influence. The following equation for behavioral intent (*BI*) holds all determinants equal and offers a simple sum

$$BI \cong A + SN + PBC.$$

There are undoubtedly limitations to these simple equations. For example, all of these factors are assumed to be static and constant. These equations ignore the impact that time could have on any of the factors and the changes that may occur recycling conditions in the population shift. Another shortcoming is that the belief structures are unidimensional. This means that belief and strength of belief are combined into a single metric. The advantage to these behavior structural equations is that they allow factors to influence each other. This characteristic is paramount for system dynamics modeling. This system of equations is translated into a system dynamics model in order to test the causality and interactions that they theorize.

Model structure of individual level factors

The design structure of internal level factors is an elaboration based on Taylor and Todd's structural equation model using the equations from the theory of planned behavior. The tree diagram is extended to include the individual questionnaire responses as determinants of the *Behavior* determinants. In order to convert Taylor and Todd's empirical work into a simulated population, the mean and standard deviation of responses are set parameters for the simulated population. The population is generated, rather than prescribed, because the raw data from Taylor and Todd's work is not publicly available. My model generates a simulated population based the findings from Taylor and Todd's study.

The model's structures of the *Intent* determinates are shown in Figures 8, 9, and 10 for *Attitude*, *Subjective Norm*, and *Perceived Behavioral Control*, respectively.

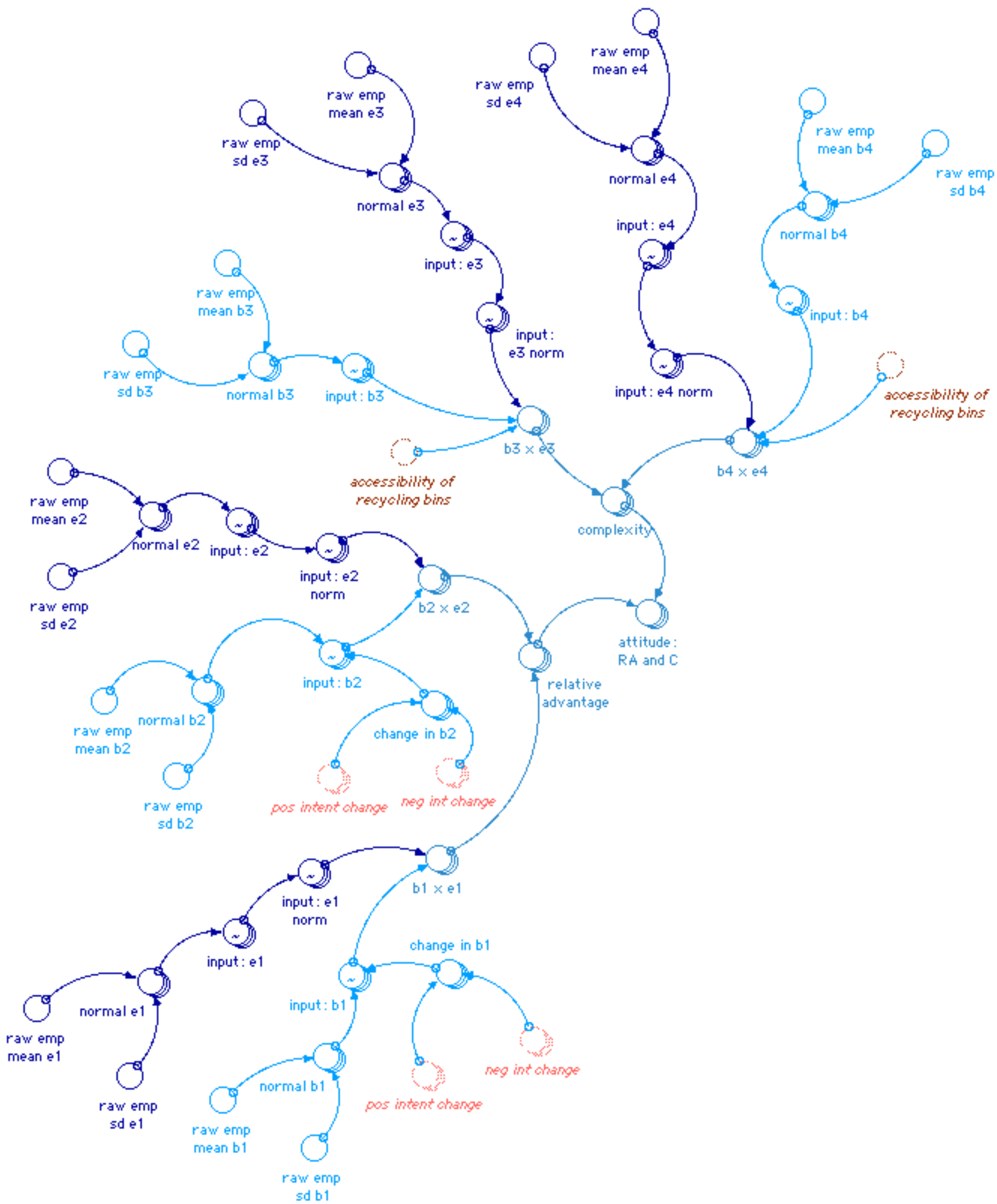


Figure 8: *Attitude* is calculated for each individual in the population by generating responses to survey questions that examine *Relative Advantage* and *Complexity* of recycling. Questions are grouped into topical (b_i) and strength (e_i) pairs. Appendix A contains the full list of survey questions used to generate simulated data.

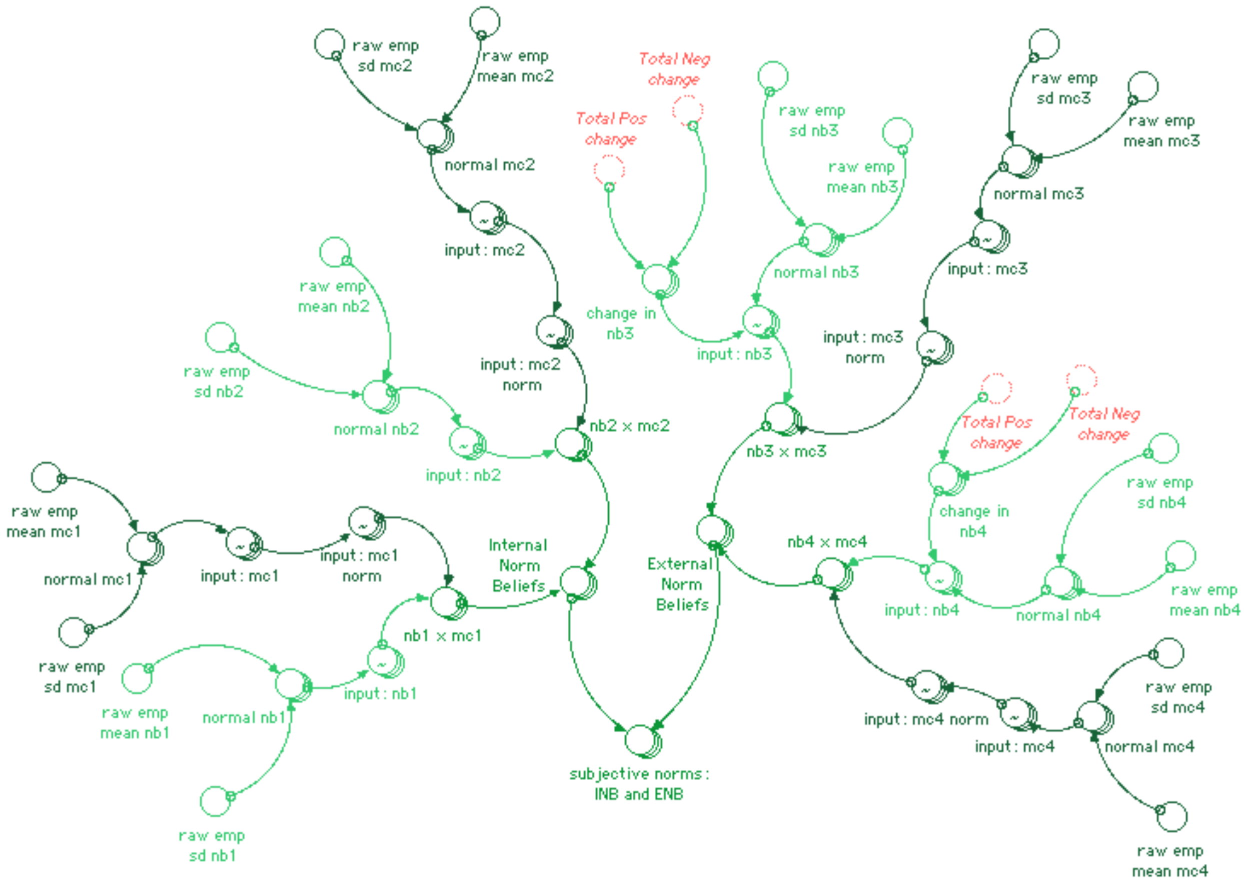


Figure 9: *Subjective Norm* is calculated for each individual in the population by generating responses to survey questions that examine *Internal Normative Beliefs* and *External Normative Beliefs* on recycling. Questions are grouped into topical (nb_j) and strength (mc_j) pairs. Appendix A contains the full list of survey questions used to generate simulated data.

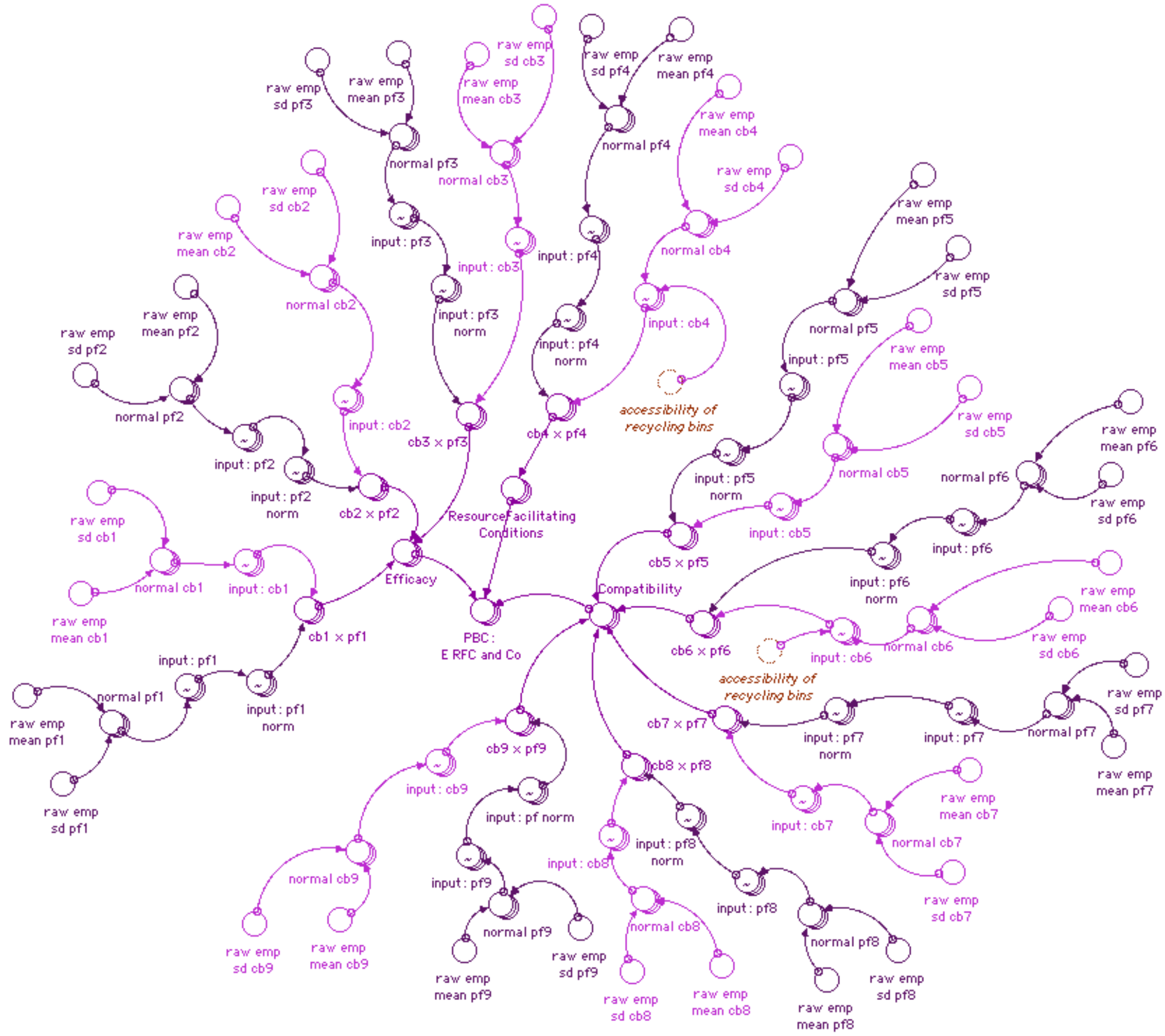


Figure 10: *Perceived Behavioral Control* is calculated for each individual in the population by generating responses to survey questions that examine *Self-Efficacy*, *Resource-Facilitating Conditions* and *Compatibility* of recycling. Questions are grouped into topical (cb_k) and strength (pf_k) pairs. Appendix A contains the full list of survey questions used to generate simulated data.

The "raw emp mean" and "raw emp sd" converters are the raw empirical means and standard deviations that Taylor and Todd published as their results. These are set parameters, taken from Taylor and Todd's 1995 empirical study. They were calculated based on the survey responses that were collected from a sample of 761 individuals. The sample was taken from a city with a population of 120,000 people where a recycling program had been in effect for four years (Taylor and Todd 1995). Surveys were distributed to and collected from households over a two-week period over the summer of 1993 (Taylor and Todd 1995). The researchers limited responses to one individual per household and, to encourage respondents with a variety of views of environmental behaviors, offered participants the opportunity to win prizes ranging in value from $25 to $300.

The model in this project simulates the population Taylor and Todd studied by taking the summary statistics published in Taylor and Todd's paper and generating hypothetical individuals in a population. The mean and standard deviation are set for each survey question and then the score is picked using the normal distribution function. This process is built into the model for every survey question and repeated for each of the one hundred individuals in the population. Then, the simulated survey responses are combined to calculate intent. As discussed above, each survey question is paired with a questions of causal strength and the responses are multiplied and added to responses from the same sub-factor section of the questionnaire. Questions are organized by their sub-factors and then combined into the three main categories: *Attitude*, *Subjective Norm*, and *Perceived Behavioral Control*.

The individual's simulated response to a survey question is generated, normalized to stay within the bounds of possible responses, and then multiplied by its paired question. The pair question is one that asks about causal strength or importance of the corresponding question. That simulated response is rescaled from a negative nine to nine scale to a zero to one scale. This conversion takes the questions about causal strength and makes them proportions to make calculations easier. A score near zero dampens the impact of the counterpart question. This is because a statement with low causal strength or impact holds less importance in determining behavioral intent. My method incorporates all the information from question pairs while keeping the eventual sums on a manageable scale.

Question pairs are summed to give sub-factor score. Then sub-factors are combined to calculate factor score. At this point, the path coefficients shown in Figure 5 become important. Path coefficients in structural equation models refer to the impact that change to one factor has on another. The initial survey responses and sub-factor scores are most influential in calculating a factor score, but the path coefficients inform the dynamic relationship between sub-factors and factors. Generally, two factors are connected by a directional arrow indicating which factor acts on the other. Path coefficients mean that if the acting factor changes by one standard deviation then the acted upon factor will change by that number of standard deviations. For example, consider the relationship between *External Normative Beliefs* and *Subjective Norms*. The path coefficient is 0.09, which means that if a person's *External Normative Beliefs* score increases by one standard deviation (which is 6.61 on the [-21, 21] scale as reported by Taylor and Todd), then that person's *Subjective Norm* score will increase by 0.09 standard deviations (which is 1.51 as reported by Taylor and Todd).

The path coefficients that are represented in structural equation models are very important to system dynamics modeling because they deal with dynamic change. They define the change to factors between time periods. Building in these feedbacks allows the system to be dynamic and react to change. Figure 11 shows an example of the structure used to incorporate path coefficients. This structure is used to represent all of the relationships shown in Figure 5. The calculations in Figure 11 implement the path coefficient between *Resource-Facilitating Conditions* and *Perceived Behavioral Control.*

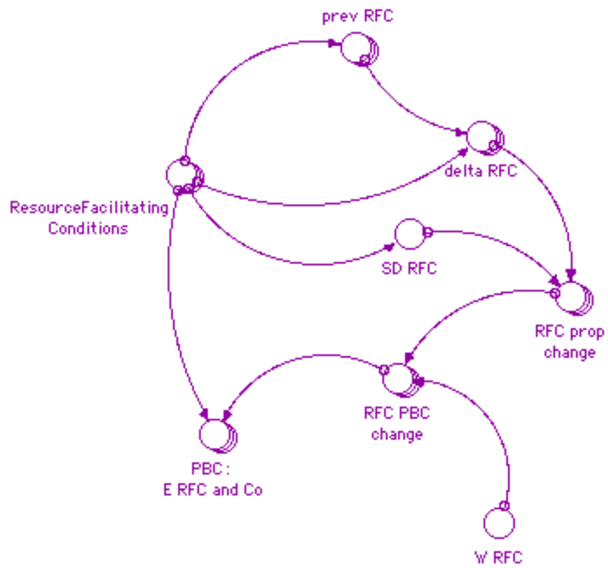


Figure 11: Path coefficient integration, *Resource-Facilitating Conditions* and *Perceived Behavioral Control*.

The relationship highlighted in Figure 11 is the connection between *Resource-Facilitating Conditions* (labeled in the model as “ResourceFacilitating Conditions”) and *Perceived Behavioral Control* (labeled in the model as “PBC: E RFC and Co”). The other six converters shown in Figure 11 calculate the path coefficient from Taylor and Todd’s structural equation model, shown in Figure 2, which is 0.29. The model takes the previous value of each individual’s *Resource-Facilitating Conditions* score in “prev RFC”. Then “delta RFC” finds the difference between the current and previous RFC score. “SD RFC” calculates the standard deviation of the population’s *Resource-Facilitating Conditions* scores, and “RFC prop change” calculates how many standard deviations the score has changed in the past time interval. The “W RFC” constant is the corresponding path coefficient from Figure 2. Finally, “RFC PBC change” takes the proportional change to each score and calculates the proportional change to the *Perceived Behavioral Control* score based on the path coefficient. And that change is added to each person’s *Perceived Behavioral Control* score. This same logic and framework is applied to the following factor relationships: *Relative Advantage-Attitude, Complexity-Attitude, Attitude-Behavioral Intent, Internal Normative Beliefs-Subjective Norm, External Normative Beliefs-Subjective Norm, Subjective Norm, Subjective Norm-Behavioral Intent, Self-Efficacy-Perceived Behavioral Control, Compatibility-Perceived Behavioral Control, Resource-Facilitating Conditions-Perceived Behavioral Control, and Perceived Behavioral Control-Behavioral Intent.*

As mentioned in the discussion of Taylor and Todd's application of the theory of planned behavior, *Attitude*, *Subjective Norm*, and *Perceived Behavioral Control* are combined to generate each person's *Intent* score. In my model, the three factors are given equal weight. This is done by standardizing the output scores for the number of question pairs asked on the survey and the scale on which the answers were requested. For example, there are two pairs of questions asked about *Relative Advantage* and two about *Complexity* on the negative nine to nine response scale. *Attitude* is then standardized by four for the questions and nine for the scale. The advantages to this standardization are that scale is manageable and all three main factors are given equal weight. The *Intent* score is the sum of the standardized *Attitude, Subjective Norm,* and *Perceived Behavioral Control* scores.

Intent

As previously discussed, the core of this model is based on two three-stock systems. The first is the *Intent* category system. Once the *Intent* score for each of the one hundred people in the population, their *Intent* states are determined. There are three possible *Intent* states that any person can fall into. They can be in "Intent: always" meaning they always plan to recycle, "Intent: sometimes" meaning they sometimes plan to recycle, and "Intent: never" meaning they never plan to recycle. A person can only be in one state at a time. There are no inflows or outflows in the *Intent* category system because the total number of stock (people) does not change, and each arrayed layer represents one person. The calculated *Intent* score turns flows between stocks in the system on and off. This process aligns each person's *Intent* category to *Intent* score.

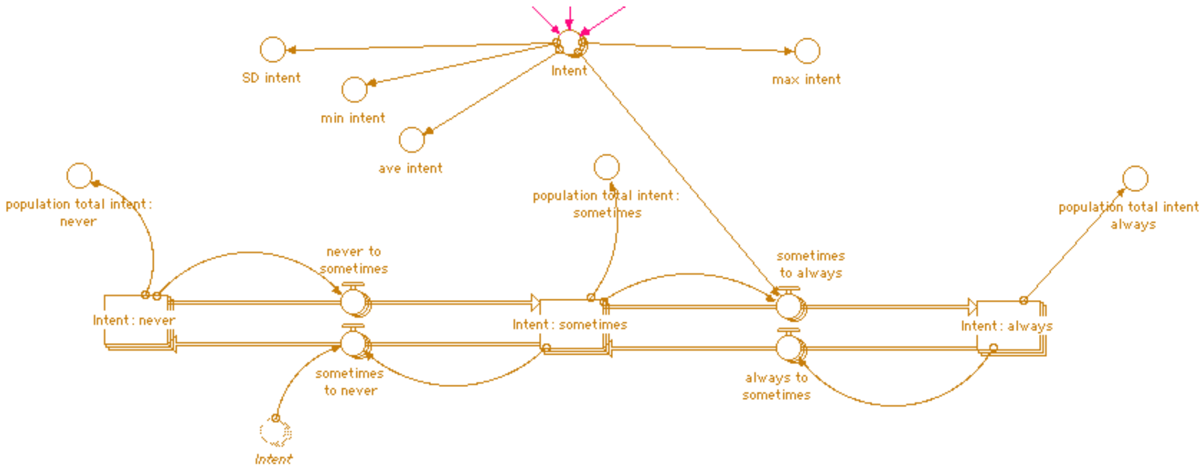


Figure 12: *Intent* state structure. There are three possible *Intent* categories that a person can be in: always intending to recycling, sometimes intending to recycle, and never intending to recycle.

Action: Recycling or Not Recycling

Each person's recycling action is simulated based on *Intent* category, physical barriers, and a binomial draw. First, each *Intent* category is assigned a percentage that corresponds to the likelihood of someone in that category recycling. "Intent: always" is assigned 75%, "Intent: sometimes" is assigned 50%, and "Intent: never" is assigned 25%. The probabilities assigned to each of the *Intent* categories was chosen based on the numerical definitions of the category. These probabilities allow for the complications that life provides—perhaps a person is on vacation and does not have access to a recycling service or someone is doing a major house-cleaning and is not diligent about sorting their trash. The structural flow of the action system is shown in Figure 13.

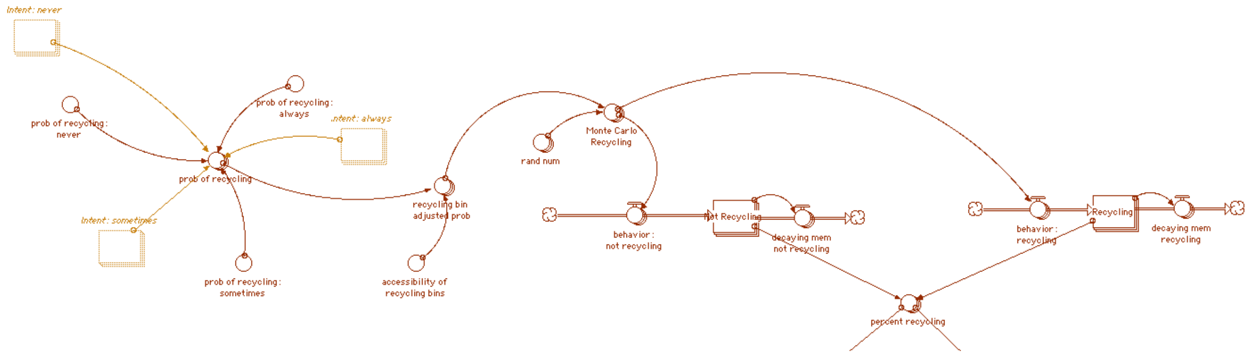


Figure 13: Structure of recycling or not recycling action.

The "prob of recycling" converter uses if-then statements to adopt the appropriate probability for each individual. If individual A is in the "Intent: sometimes" category, then the probability of them recycling is 50%, and if individual B is in the "Intent: never" category, the probability of them recycling is 25%. The base probability for each individual is then adjusted based on the physical barriers that apply to the entire population. The "accessibility of recycling bins" converter is the overall ease of recycling in a population. This parameter is represented as a proportion, so if accessibility is set to one, every time that a person could recycle, there is a recycling bin available. If the proportion of accessibility is 0.3, then there is a 30% chance that each attempted recycling action also has a recycling bin available to complete the act. The physical barrier parameter adjusts the probability of recycling in "recycling bin adjusted prob". The value in that converter is the product of the base probability and the population's accessibility to recycling bins.

That probability is then used to generate Monte Carlo simulations. A Monte Carlo simulation takes a given probability (recycling bin adjusted probability) and takes independent, random, binary draws of one or zero with that probability of being a one. Continuing the example of individual A, who has a base 50% probability of recycling and lives in a community with only 30% accessibility to recycling bins, their final probability of recycling (which is used in the Monte Carlo draw) is 15%. If individual A does not recycle, it is counted in the "Not Recycling" stock of actions. The corresponding “Recycling” action stock counts the times each person recycles. These stocks have decaying outflows, which accounts for weighted memory. The idea of weighted memory is that people tend to remember what they did yesterday more clearly than what they did five weeks ago. The social science term for this concept is salience, which refers to the strength of something’s importance (usually an action or story) and the decay time in people’s memory of it. The time unit in this model is one week, so the decay factor of recycling salience is set as the number of weeks until a memory of recycling is completely forgotten. The baseline is set at ten, so the memory of recycling exists for ten weeks but is strongest in the time immediately following the action and weakest in week ten.

The final calculation in the action system is calculating each person’s percentage of recycling behavior. The “percentage recycling” is the proportion of times, in a person’s memory, that they have recycled out of all their opportunities to recycle. The incorporation of salience, means that this percentage is of active, accessible memory. When actions are forgotten, they are no longer accounted for. The percentage of times a person recycles in their accessible memory determines their behavioral category.

Behavior

The *Behavior* category system has the same foundational structure as the *Intent* structure. A person can belong to one of the three categories at a given time. The category of each individual is determined by the percentage of times they remember recycling in the past ten weeks. That converter, “percent recycling”, turns the flows between stock categories on and off. The percent a person recycles solely determines the person’s *Behavior* category.

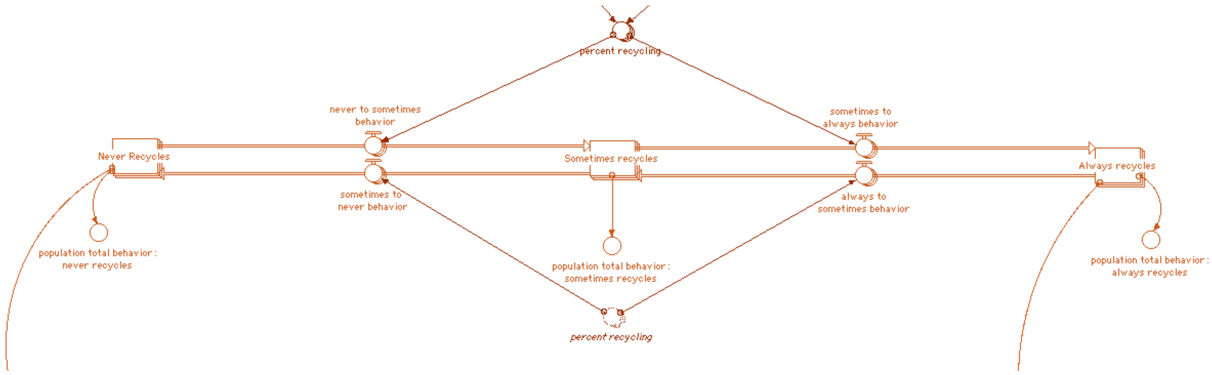


Figure 14: *Behavior*.

Feedback Loops

Feedback loops are the final element to build into the model. In system dynamics, feedback loops take the output of a system into consideration in future *Behavior* while the system is running. They effectively create the 'dynamics' in system dynamics. Feedback loops are extremely powerful determinants of a system's *Behavior*. The feedback loops incorporated in this model are from *Behavior* category to *Intent* category, *Behavior* category to *Attitude*, and population-level *Behavior* to *Subjective Norm*.

Behavioral category to Intent category

If a person's *Behavior* category does not match their *Intent* category for a consistent and extended period of time, then their *Intent* category will shift to reflect their *Behavior*. An individual's *Intent* and *Behavior* need not be consistent throughout a give time period. For example, a person's *Intent* can be to always recycle but their actions put them in the sometimes recycling *Behavior* if recycling bin accessibility is limited or if the Monte Carlo draws are unfavorable. A single time period of mismatch does not reflect a change in a person's intent, rather it is an indicator of other barriers. However, if *Intent* and *Behavior* categories are mismatched for ten time intervals in a row, then *Intent* will shift to match *Behavior*.

As discussed in the action structure, salience deals with the impact and duration of a memory. So, if an individual's *Intent* and *Behavior* categories are mismatched for ten weeks in a row, that person's *Intent* category shifts in the direction of the *Behavior* category. This structure is shown in Figures 15 and 16. Figure 15 shows the accumulation of mismatched *Intent* and *Behavior*. The conveyors have a length of ten, meaning a stock exists for ten time units and then flows out. In this structure, the stocks of the top rows of conveyors are weeks spent in a given *Behavior* category. Then, in the second row of conveyers, the mismatch is counted. When the sum of those conveyers equals ten, the feedback loop is activated. Figure 16 shows the feedback into the *Intent* category structure. The conveyors that are connected to the flows between *Intent* categories activate when the sum of the conveyor stock is ten. Similar to how the *Intent* score turns flows on and off to change *Intent* category, so does this feedback loop.

The feedback from *Behavior* category and *Intent* category mismatch acts as a positive feedback loop between *Intent* and *Behavior*. As *Behavior* becomes more or less extreme, *Intent* is pulled to follow. Given the specific parameters of this simulation model, this feedback loop influences much of the population in the sometimes *Intent* and *Behavior* categories.

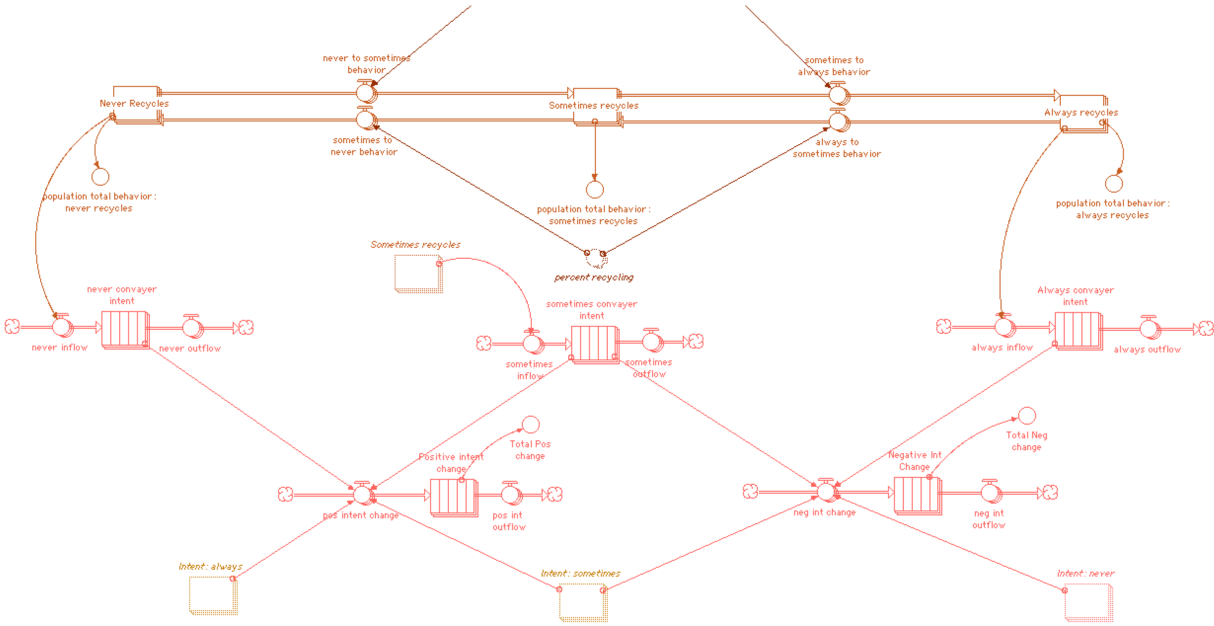


Figure 15: *Behavior* category feedback conveyor structure.

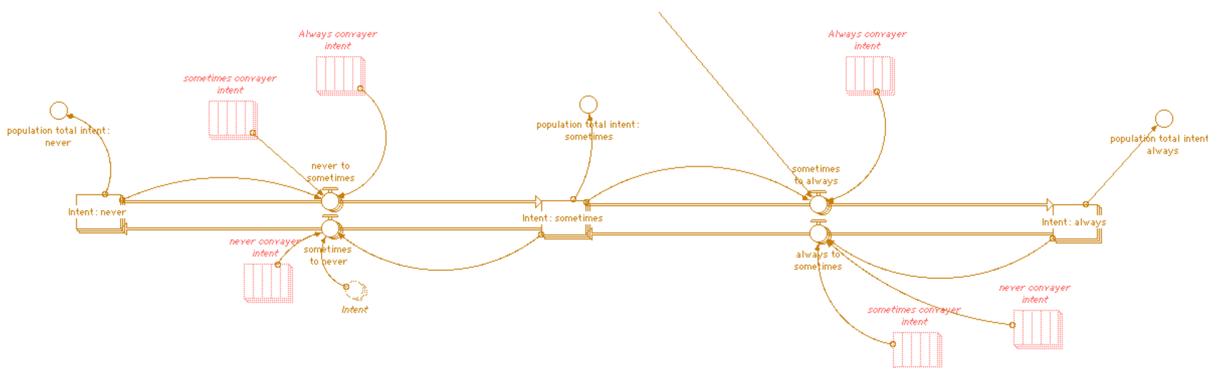


Figure 16: *Behavior* category feedback into *Intent* category.

Behavioral category to Attitude

The feedback loop described above and shown in Figure 15 also influences the calculation of *Attitude*. The consistent change in *Behavior* category influences an individual's response to certain survey questions. The two questions influenced by *Behavior* shifts are, "I will help to protect the environment by recycling (strongly disagree, strongly agree)" and "I will help to reduce out landfill waste by recycling (strongly disagree, strongly agree)" (Taylor and Todd 1995). The logic behind this feedback is that if someone answers this question saying they strongly intend to recycle in order to protect the environment and their behavioral pattern is consistently “sometimes recycle” then their response to that question would change. This is a prime example of the process of taking an structural equation model and making a system dynamics model.

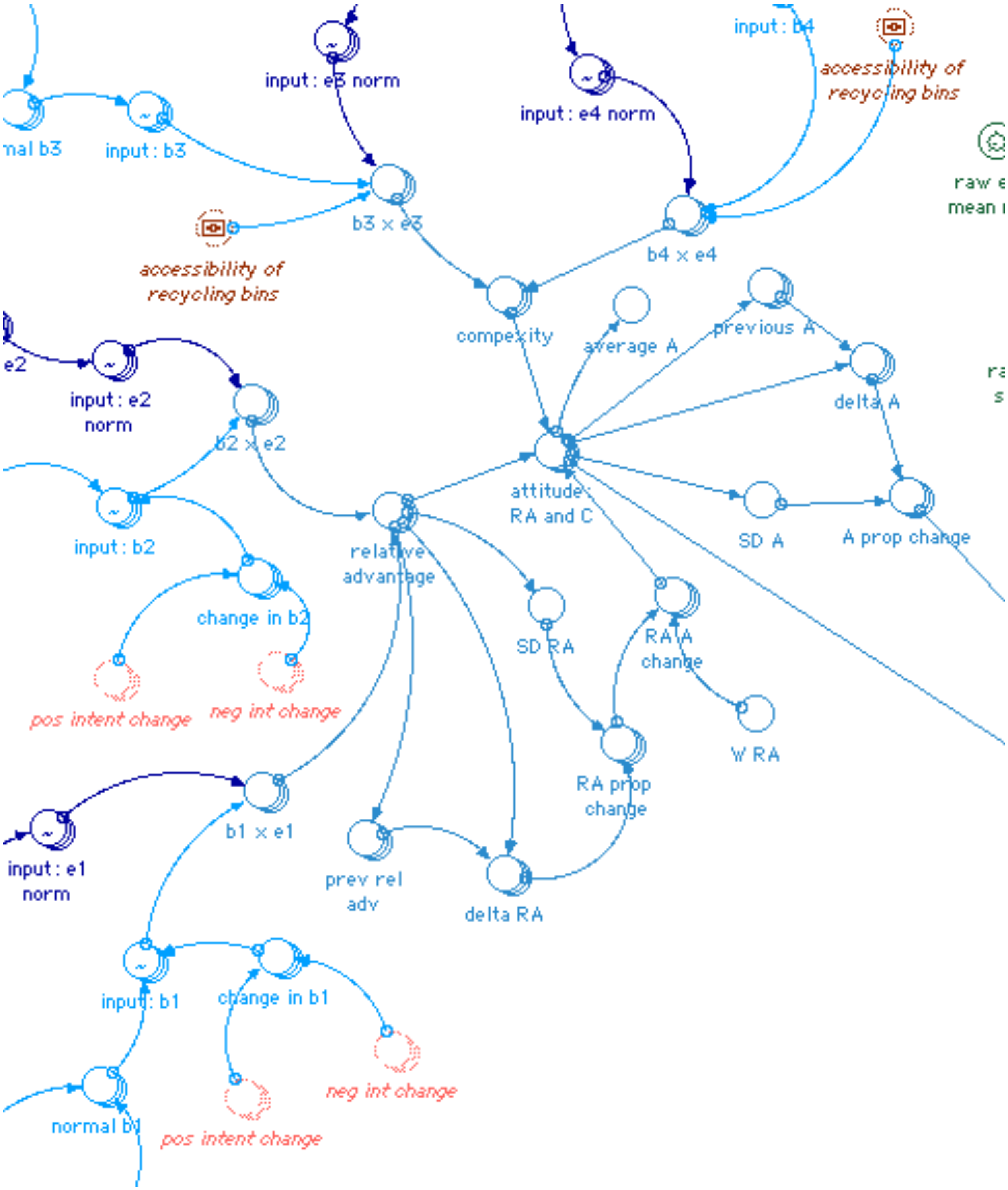


Figure 17: *Behavior* category feedback into *Attitude* calculation.

Population behavior to external norm beliefs

Figure 10 shows the accumulation of long-term mismatches between *Intent* and *Behavior* and the previous two sections discuss how that impacts the individual. This feedback loop is concerned with population-level change and the influence of social pressure. The converters “Total Pos change” and “Total Neg change” keep track of the number of people who have changed their *Intent* in one direction or the other due to *Behavior* and *Intent* mismatch. When there is a significant change in the population in either direction, the entire population’s *Subjective Norm* scores are impacted. The questions this loop feeds into are, “My friends think that I should recycle (strongly disagree, strongly agree)” and “My neighbors think that I should recycle (strongly disagree, strongly agree)”. When the *Behavior* of the population changes significantly, so do the individual responses to these questions.

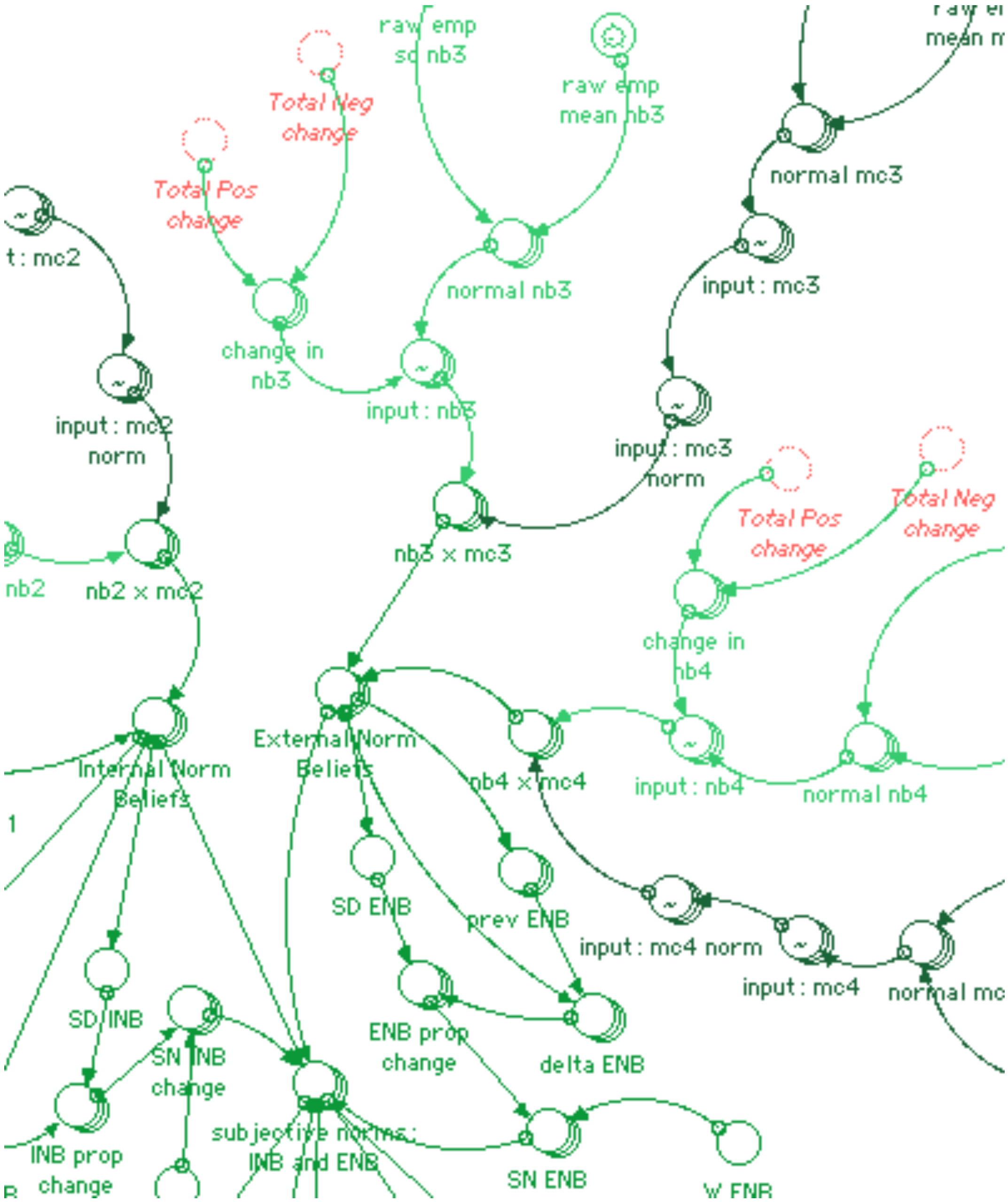


Figure 18: Population-level feedback loop into External Norm Beliefs.

Sensitivity Tests

After building the model, sensitivity tests are run to ascertain baseline *Behavior*. In STELLA, running the model repeatedly to collect and compare the different outcomes from each simulation is a basic sensitivity test. Each run of the model generates a unique sample population—one possible outcome given the structure and parameters of the model. The model is run one-hundred times and the results are collected. This output is more informative than a single run because it produces a range of steady state outcomes, rather than just one. Sensitivity tests also calculate the range and cohesion of responses. These tests define the characteristics of the baseline model and demonstrate the population's resilience and reaction to change. It is also important to run these sensitivity tests to build a baseline with which to compare other simulations.

Step tests

Step tests examine how the model responds to different parameter values. These tests hold all factors at their baseline values and runs the model with a range of values plugged into the variable of interest. With complex models, with more than 5 input parameters (like this one), step tests function as a test of causality and impact. Realistically, a group of one hundred people does not uniformly change one element of their moral beliefs while holding all others constant. However, these tests determine if each factor has an impact on the simulated *Behavior*. Step tests are performed by systematically adjusting a set of parameters. The parameters that will be step tested are *Relative Advantage*, *Complexity*, *Internal Normative Beliefs*, *External Normative Beliefs*, *Self-Efficacy*, *Resource-Facilitating Conditions*, *Compatibility*, *Accessibility of Recycling Bins*, and *Salience*.

Pulse tests

Pulse tests asses the elasticity and response of the system to disturbance. A pulse test forces a system into a state of extreme *Behavior* for a set period of time and examines how the system reacts. For example, in this model one important pulse test to run is to move all of the individuals into the "Intent: always" stock. This essentially addresses the question, "if every person in the population is pressured into always intending to recycle for ten weeks, and then the pressure is removed, do they all keep recycling?" Pulse tests are test of resilience. Does a forced change in *Intent* or *Behavior* activate permanent change? Is the temporary impact on people's morals and beliefs effectively promote permanent change? The pulse tests are applied to *Attitude*, *Subjective Norm*, *Perceived Behavioral Control*, *Intent*, and *Behavior*. For each of the listed factors, a pulse up and a pulse down will be applied. A pulse up is an increase in the given factor, meaning every person's recycling *Behavior* is increased. A pulse down is a decrease in the given factor, which means each person's aversion to recycling is increased.

Simulations

A driving question in this project, and in much of the work on PEB, is how do groups of people change their behavior. What are the stages that a population goes through to adapt pro-environmental behaviors? After the baseline *Behavior* of the model is understood, simulations will be designed to examine the phases of PEB adaptation. The empirical work that Taylor and Todd did on recycling behavior is paired with a study of composting behavior in the same population, using the same questionnaire. The recycling program in the studied community is 4-years-old and considered well-established. The composting program in the studied community is only 1-year-old, which is relatively young and still has not been widely adapted. The responses to the recycling-specific questions in the Taylor and Todd study are used as the baseline, which is the adapted recycling program. The responses to the composting questions are used in the intermediate phase of the population adapting recycling behavior. Those survey results are close to what they would have been if the same questionnaire had been used three years earlier to asses the adoption of a 1-year-old recycling program. The final simulation will be of a population with no established recycling program. This three-phase simulation assesses the *Behavior* in the adaptation of PEB and examines the limitations and possibilities of transitioning from one phase to another.

Chapter 3: Results

Scenario 1: Well-Established Recycling Behavior

The baseline behavior of this model tells us how the simulated population acts under the initial parameters. The scenario used to generate baseline behavior is the recycling behavior questionnaire and structural equation model produced by Taylor and Todd (1995). This scenario is a small city that has a well-established recycling program. The program has been active and successful for four years and the community has, by all appearances, internalized this positive recycling behavior. This shows the maximum change in *Intent* and *Behavior* when physical barriers are eliminated. The input parameters of the population's *Attitude*, *Subjective Norm*, and *Perceived Behavioral Control* are the product of implementing a recycling program in their community. There have been no educational, motivational, or logical campaigns applied to try to change how people think about recycling.

When modeling in STELLA, understanding the baseline, steady state of a model is paramount to interpreting simulations. The following sections examine the output from the *Intent*, *Behavior*, and *Recycling/Not Recycling* sections. The exact inputs for this scenario are detailed in the Methods chapter, the complete equations list can be seen in Appendix B, and the complete list of inputs and outputs can be seen in Appendix C. Table 1 shows the input means and standard deviations for the seven sub-sub-factors, and Table 2 shows the transition matrix of path coefficients used in this simulation.

Factor	Mean	Standard Deviation
Relative Advantage	6.99[a]	2.92
Complexity	1.51[a]	5.38
Internal Normative Belief	9.66[b]	8.17
External Normative Belief	4.65[b]	6.61
Self-Efficacy	-0.01[a]	5.29
Compatibility	-1.99[a]	4.32
Resource-Facilitating Conditions	3.86[a]	1.38

a. Scaled from -9 to 9.
b. Scaled from -21 to 21.

Table 1: Baseline parameters for STELLA model of recycling behavior. Parameters are informed by the empirical work done by Taylor and Todd (1995).

Factor (source)	*Factor (target)*	*Path Coefficient*
Relative Advantage	Attitude	*0.38***
Complexity	Attitude	*0.00**
Internal Normative Belief	Subjective Norm	*0.08***
External Normative Belief	Subjective Norm	*0.09***
Self-Efficacy	Perceived Behavioral Control	*0.06**
Compatibility	Perceived Behavioral Control	*-0.04**
Resource-Facilitating Conditions	Perceived Behavioral Control	*0.29***
Attitude	Intent	*1.92***
Subjective Norm	Intent	*-0.08**
Perceived Behavioral Control	Intent	*0.18***

**p <.01; **p<.001.*

Table 2: Path coefficients between factors in STELLA model, adapted from the structural equation model in Taylor and Todd's work (1995).

Intent

The *Intent* output of the baseline scenario simulations shows that the population settles into a steady state of *Intent* quickly and does not deviate much thereafter. The steady state distribution of *Intent* categories is about 90% of the population intending to sometimes recycle, about 9% intending to always recycle, and 1% never intending to recycle. Figure 19 shows the population sums of the *Intent* categories for all 100 simulations of scenario 1. When looking at the map of the model, the three outputs shown in Figure 19 are "population total intent: always", "population total intent: sometimes", and "population total intent: never". What is most striking about these results is how consistent they are. There is a range of steady state values, but when a simulation begins with an initial calculation of *Intent* and distribution into categories, the behavior does not change significantly after the first time interval. This is to be expected because no tests are being applied, but it does indicate that this population is not moving in a certain direction. For example, there could be a population that reaches a tipping point if the initial *Intent* distribution is on the edge between never and sometimes or sometimes and always. In that case, if enough people happened to move to one of the extreme *Intent* categories, the social pressure could eventually push more people into the extreme *Intent* category. However, this population exists in a steady state with an average of 87 people sometimes intending to recycle, 12 people always intending to recycle, and 1 person never intending to recycle. Full ranges of the steady state are presented in Table 3.

The first ten time intervals are stagnant because the feedback loop from *Behavior* does not kick in until after ten weeks. As discussed in the Methods section, in order for *Behavior* to influence *Intent*, there must be a consistent mismatch between a person's *Intent* and *Behavior*. The definition of "consistent" in this model is ten continuous weeks of a mismatch. This is the reason all of the simulations are flat before t=10 and there is some motion after that time.

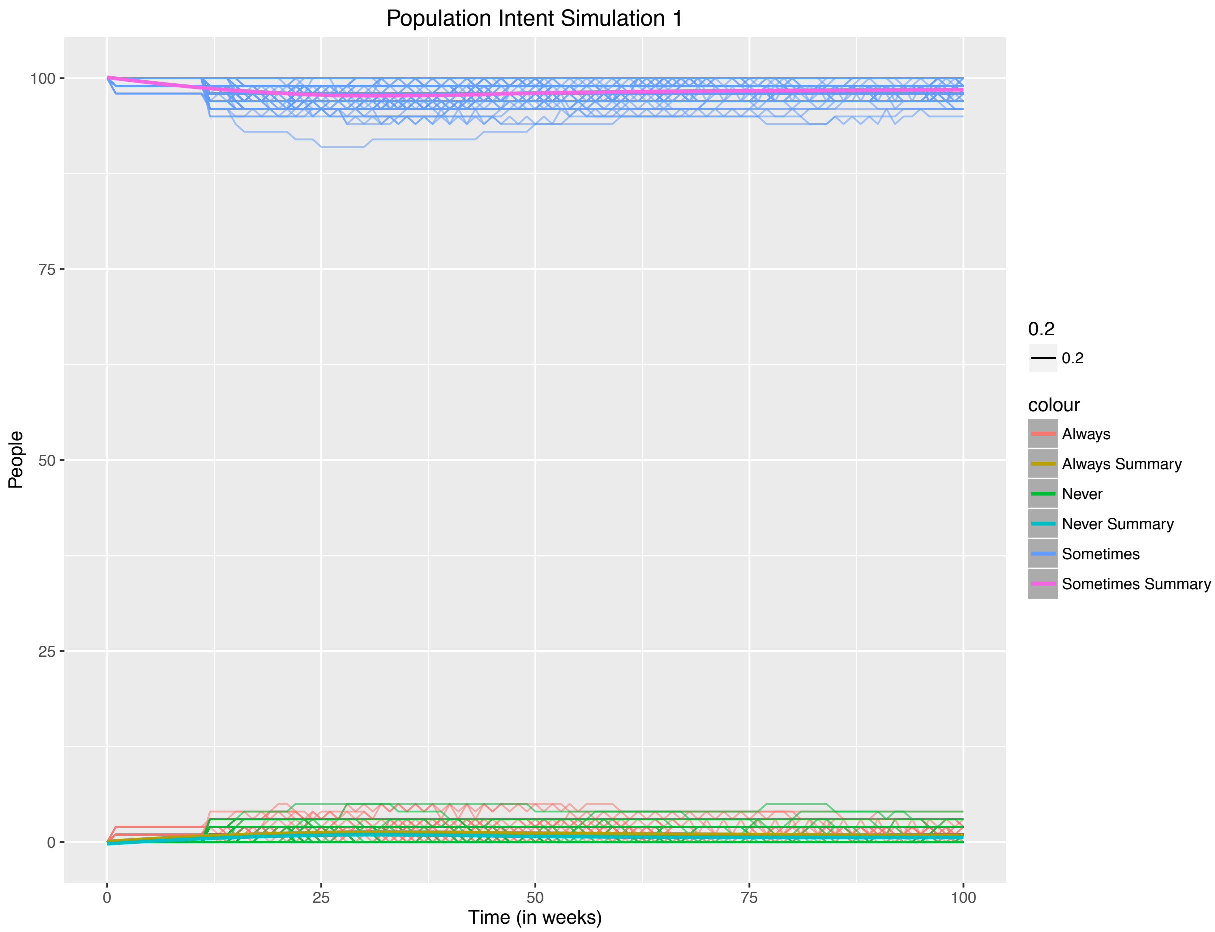


Figure 19: Population-level *Intent* results in scenario 1. The simulation is run 100 times to perform a sensitivity test and the results and trends are recorded.

Intent Category	*Mean*	*Standard Deviation*	*Minimum*	*1st Quartile*	*3rd Quartile*	*Maximum*
Always	1.10	0.98	0	0	2	5
Sometimes	98.15	1.34	91	97	99	100
Never	0.75	0.92	0	0	1	5

Table 3: Summary statistics from *Intent* category outputs in scenario 1.

Behavior

The complimentary output to *Intent* is the population distribution into *Behavior* categories. The *Behavior* output shown in Figure 20 follows the same structure at the *Intent* output in Figure 19. Scenario 1 was run 100 times as a sensitivity test and the population level outputs of *Behavior* categories were collected. The factors from the model map that are shown in Figure 20 are "population total behavior: always", "population total behavior: sometimes", and "population total behavior: never”. There are also trend lines added to show the average steady state of these factors. Similar to the *Intent* output, *Behavior* finds a steady state relatively quickly and does not change dramatically in all of the 100 simulations. There is considerable noise in the early time intervals, but that is likely due to the way that “percent recycling” is calculated. As explained in the Methods section, “percent recycling” is the number of times a person recycles out of the total instances they could have recycled. “Percent recycling” also considers memory; it weights recent behavior more heavily than far-past behavior. This method allows for recent action to be weighed more heavily in a person’s memory than distant action, but it means that the first ten calculations are very volatile and have a substantial impact on a person’s *Behavior* category. The model does smooth out considerably after the tenth time step. The steady states for *Behavior* category are shown in full in Table 4. On average, 90 people sometimes recycle, 8 people always recycle, and 2 people never recycle.

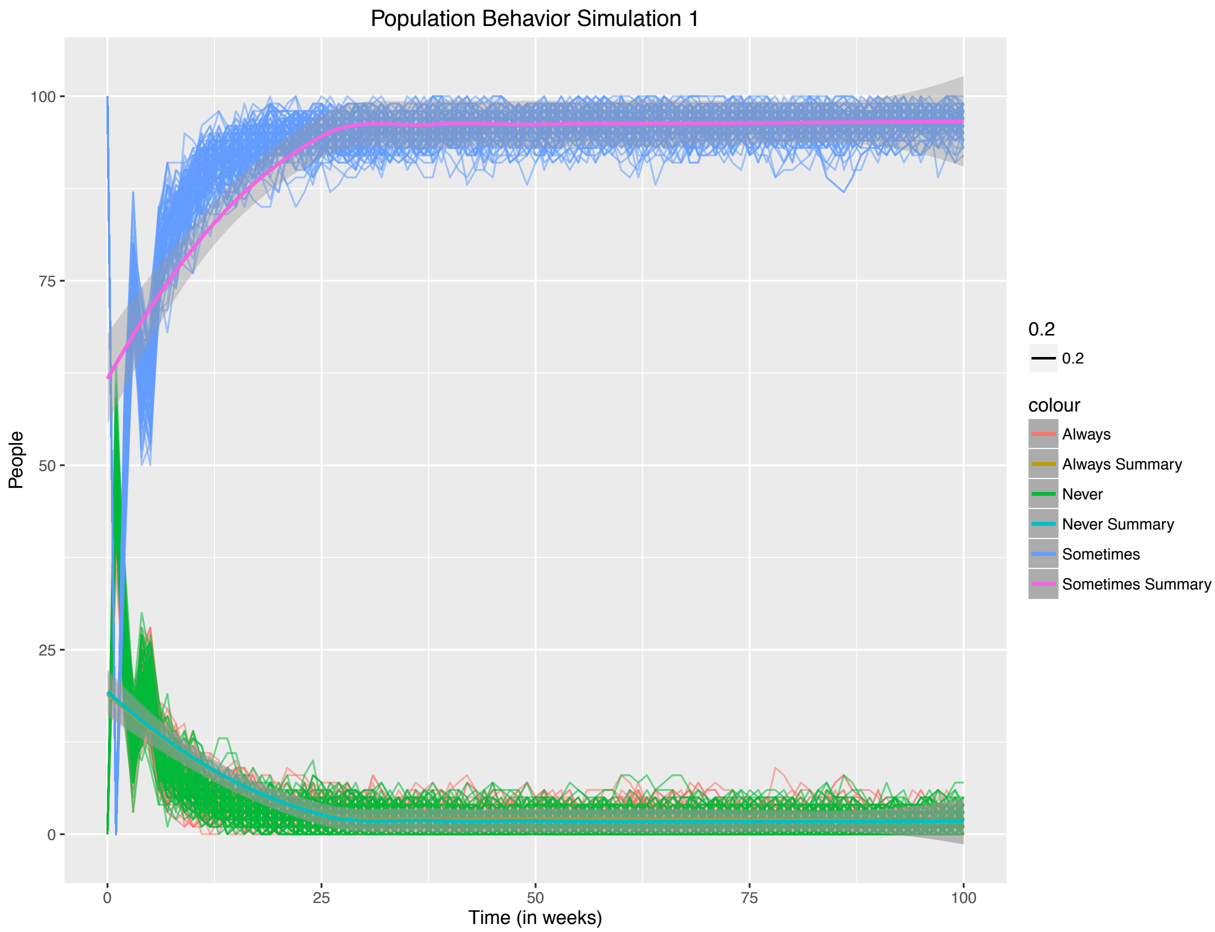


Figure 20: Population-level *Behavior* results in scenario 1. The simulation is run 100 times to perform a sensitivity test and the results and trends are recorded.

Behavior Category	*Mean*	*Standard Deviation*	*Minimum*	*1st Quartile*	*3rd Quartile*	*Maximum*
Always	2.31	1.71	0	1	3	14
Sometimes	95.52	2.70	76	94	97	100
Never	2.17	1.73	0	1	3	14

Table 4

Discrete Action

It is important to understand the individual-level *Behavior* patterns. The "Recycling" and "Not Recycling" stocks summarize the discrete action section of the model. This section determines if each person in the population recycles in each time period. The "Recycling" and "Not Recycling" stocks calculate individuals' memory of that behavior. That probability and the degree of physical barriers (accessibility of recycling bins, for example) determine the probability and whether or not each person recycles in that time period. If someone recycles, the flow into their “Recycling” stock is one for that time period. The flow represents when a person recycles and the stock calculates the active memory of that behavior. The probability of a person recycling in a certain time period is determined by their *Intent* category in each time period. This is where salience comes into play. The stocks of “Recycling” and “Not Recycling” decay over time, imitating memory and the preference of recent memory over distant memory. Salience equals 10 in this model, which means a memory decays over 10 weeks and is then gone. Figure 3 shows one individual drawn randomly from each of the 100 sensitivity simulations of scenario 1 and their “Recycling” and “Not Recycling” stocks at each time interval. The *Behavior* shown in Figure 3 is that the two behaviors are conversely related, which makes sense because if you are recycling, you are not “not recycling”. Generally, the “Recycling” stock is larger than the “Not Recycling” stock. This means that people are recycling more than half of the time, but with salience equal to 10, the memory of recycling fades relatively quickly. When salience equals 10, the proportion of recycling to not recycling behavior can change rather quickly and is sensitive to change.

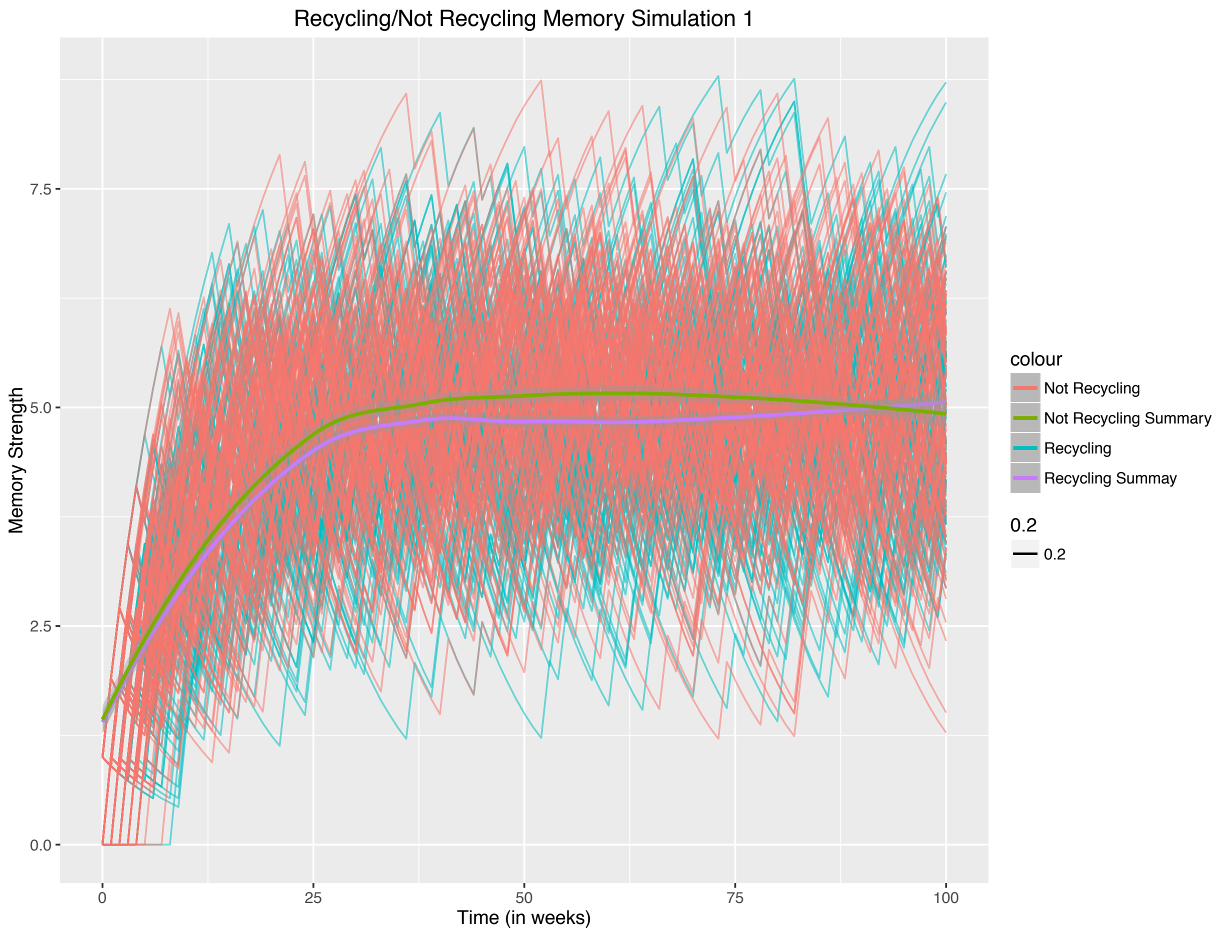


Figure 21: Sample of discrete action from scenario 1 sensitivity tests. One person is picked randomly from each of the 100 runs of the sensitivity test and their “Recycling” and “Not Recycling” memory stock is shown.

Tests

Step Tests

Step tests are performed to understand the reaction of the model the changes in key parameters. These tests are applied to scenario 1 because it is the baseline and those parameters were used while building the model. The results from a step test should show that the model responds to changes in each parameter tested and that no one parameter has complete control over the model’s behavior. Step tests are run on the low-level moral *Intent* factors (*Relative Advantage*, *Complexity*, *Internal Normative Beliefs*, *External Normative Beliefs*, *Self-Efficacy*, *Compatibility*, and *Resource-Facilitating Conditions*), salience, and physical barriers and full results can be seen in Appendix C.

The low-level moral *Intent* factors all have small but proportional impacts on *Intent* and *Behavior*. *Relative Advantage*, *Complexity*, *Internal Normative Beliefs*, *External Normative Beliefs*, *Self-Efficacy*, *Compatibility*, and *Resource-Facilitating Conditions* do not have significant impacts on *Intent* or *Behavior* outcomes. This is likely due to the complex nature of the *Intent* calculation. A change in one of these sub-sub-factors is not enough to sway a large portion of the population's morals or behavior. *Intent* does increase when any of these factors increases, but the impact of any single sub-sub-factor is not enough to drive an individual's *Intent* category.

Salience and the accessibility (physical barriers) of recycling bins have a significant impact on the behavior of the model. The accessibility factor impacts the intent-behavior gap. *Behavior* is first effected by the changing accessibility factor because it changes the probability of each person recycling and then *Intent* is impacted after the feedback loop is activated. The step tests of salience impact *Intent* and *Behavior* in a similar way—the test is applied in the intent-behavior gap so *Behavior* is effected first and that change causes *Intent* change. There appears to be a tipping point between 5 and 10 weeks, however on further examination the impact appears to be confounded. Salience impacts the sensitivity of *Behavior* categories to changes in the *Intent* categories.

Pulse Tests

The pulse tests that were run on the baseline parameters of scenario 1 show, overwhelmingly, that the population is resilient and comes back to its steady state. The tests run are summarized in Table 5 and full results can be seen in Appendix C. The results from the pulse tests indicate that a temporary change in Intent, *Behavior*, *Attitude*, *Subjective Norm*, or *Perceived Behavioral Control* is not enough to effect lasting recycling behavior. The population does respond when a forced pulse is implemented, but in every test the population returned to the original steady state. The real life interpretation of these tests is that if a recycling or anti-recycling campaign is implemented on this population, it will only be effect for as long as the campaign runs. There is constant pressure for this type of forceful change to have a lasting effect.

Pulse Test	Result
Intent UP	Eventual return to steady state in Intent and Behavior.
Intent DOWN	Eventual return to steady state in Intent and Behavior.
Behavior UP	Eventual return to steady state in Intent and Behavior.
Behavior DOWN	Eventual return to steady state in Intent and Behavior.
Attitude UP	Eventual return to steady state in Intent and minimal impact on Behavior.
Attitude DOWN	No impact on Intent or Behavior.
Subjective Norm UP	Eventual return to steady state in Intent and minimal impact on Behavior.
Subjective Norm DOWN	No impact on Intent or Behavior.
Perceived Behavioral Control UP	Eventual return to steady state in Intent and minimal impact on Behavior.
Perceived Behavioral Control DOWN	No impact on Intent or Behavior.

Table 5: Summary of the results from the pulse tests run on scenario 1.

Scenario 2: New Recycling Program

Scenario 2 examines the state in recycling programs that precedes the well-established program that is represented in scenario 1. This scenario takes a population with a new recycling program, one that has only been in effect for one year. This intermediate stage (between no recycling program and a well-established program) is an important phase to understand because there is a potential for important intervention. Scenario 1 shows us that an established recycling program only causes so much recycling—most of the population is still in the "sometimes" *Intent* and *Behavior* categories. However, an added educational or promotional treatment to a population with a new, budding recycling program could activate more enthusiastic and committed recycling.

The parameters of this scenario are set using Taylor and Todd's composting questionnaire results. In that study, the population that is being studied has a composting program that is one-year-old. The means and standard deviations for *Relative Advantage*, *Complexity*, *Internal*

Normative Beliefs, *External Normative Beliefs*, *Self-Efficacy*, *Compatibility,* and *Resource-Facilitating Conditions* are adjusted to reflect those shown in Table 6. Table 7 shows the path coefficients used in Simulation 2, the new recycling program.

Factor	*Mean*	*Standard Deviation*
Relative Advantage	6.17[a]	3.16
Complexity	1.39[a]	4.64
Internal Normative Belief	7.06[b]	9.00
External Normative Belief	3.67[b]	6.17
Self-Efficacy	-0.14[a]	5.12
Compatibility	-2.00[a]	3.85
Resource-Facilitating Conditions	3.57[a]	5.32

a. Scaled from -9 to 9.
b. Scaled from -21 to 21.

Table 6: Scenario 2 parameters for STELLA model of recycling behavior. Parameters are informed by the empirical work done by Taylor and Todd (1995).

Factor (source)	*Factor (target)*	*Path Coefficient*
Relative Advantage	Attitude	*0.35**
Complexity	Attitude	*-0.05**
Internal Normative Belief	Subjective Norm	*0.07***
External Normative Belief	Subjective Norm	*0.11***
Self-Efficacy	Perceived Behavioral Control	*0.64**
Compatibility	Perceived Behavioral Control	*-0.89**
Resource-Facilitating Conditions	Perceived Behavioral Control	*0.15***
Attitude	Intent	*1.38***
Subjective Norm	Intent	*0.20**
Perceived Behavioral Control	Intent	*0.33***

**p <.01; **p<.001.*

Table 7: Path coefficients between factors in STELLA model, adapted from the structural equation model in Taylor and Todd's work (1995).

Intent

The *Intent* outputs from simulation 2 are similar in structure and behavior to simulation 1. The response is flat and reaches a steady state at t=1. This is consistent with what is hypothesized because there are not temporal tests being applied, so the population's *Intent* remains consistent. There is a little oscillation between categories, which is also to be expected. This oscillation shows that there are some people on the edge of the sometimes *Intent* category, on both ends, and as their

Behavior fluctuates one way or the other, so does their intent. The steady state has an average of 93 people sometimes intending to recycle, 6 people always intending to recycle, and 1 person never intending to recycle. The full calculation of the steady state range, is shown in Table 8.

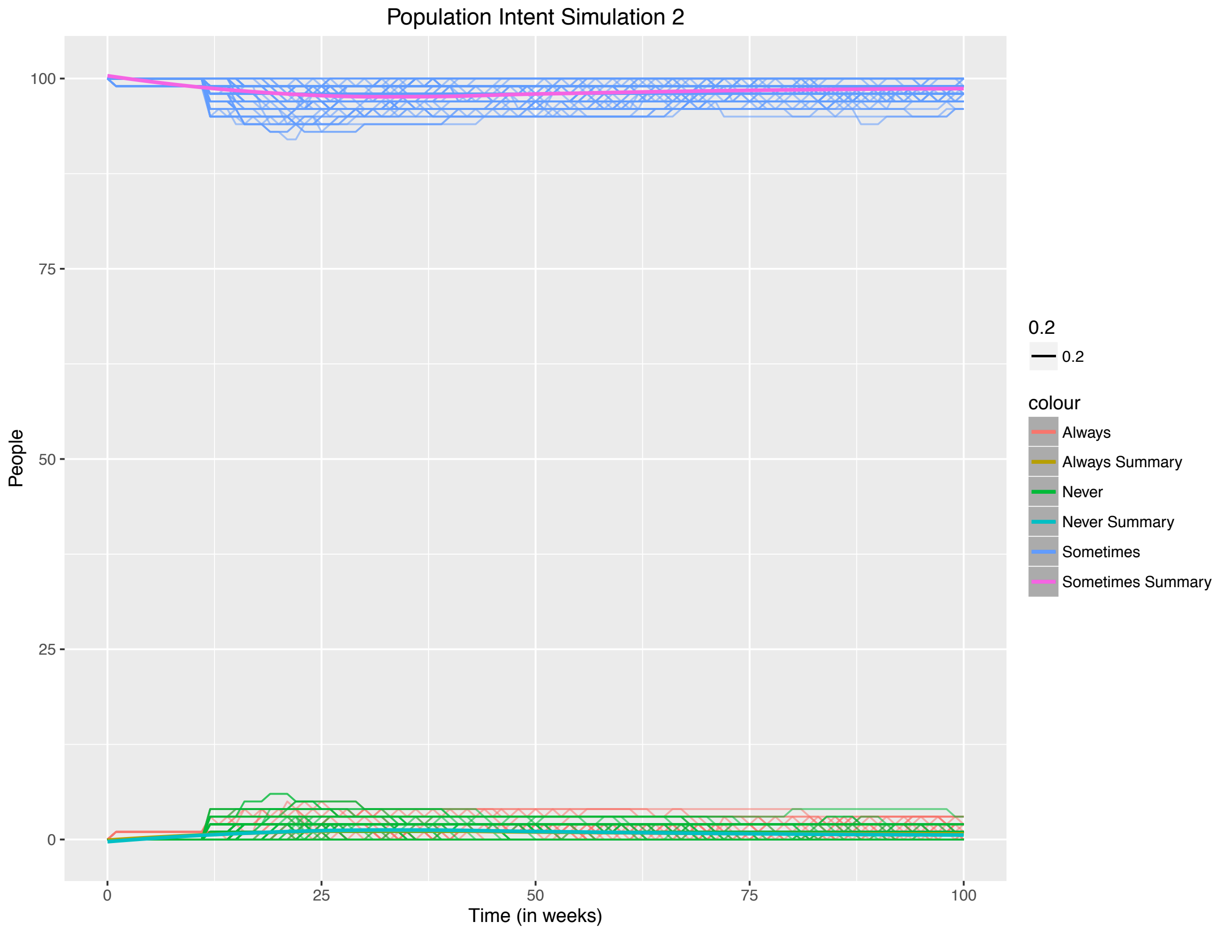


Figure 22: Population-level *Intent* results in scenario 2. The simulation is run 100 times to perform a sensitivity test and the results and trends are recorded.

Intent Category	*Mean*	*Standard Deviation*	*Minimum*	*1st Quartile*	*3rd Quartile*	*Maximum*
Always	0.92	0.97	0	0	1	5
Sometimes	98.16	1.41	92	97	99	100
Never	0.92	0.96	0	0	2	6

Table 8: Summary statistics from *Intent* category outputs in scenario 2.

Behavior

The *Behavior* output from simulation 2 is, again, very similar to the output from simulation 1. The steady state of *Behavior* in simulation 2 has 93 people sometimes recycling, 5 people always recycling, and 2 people never recycling.

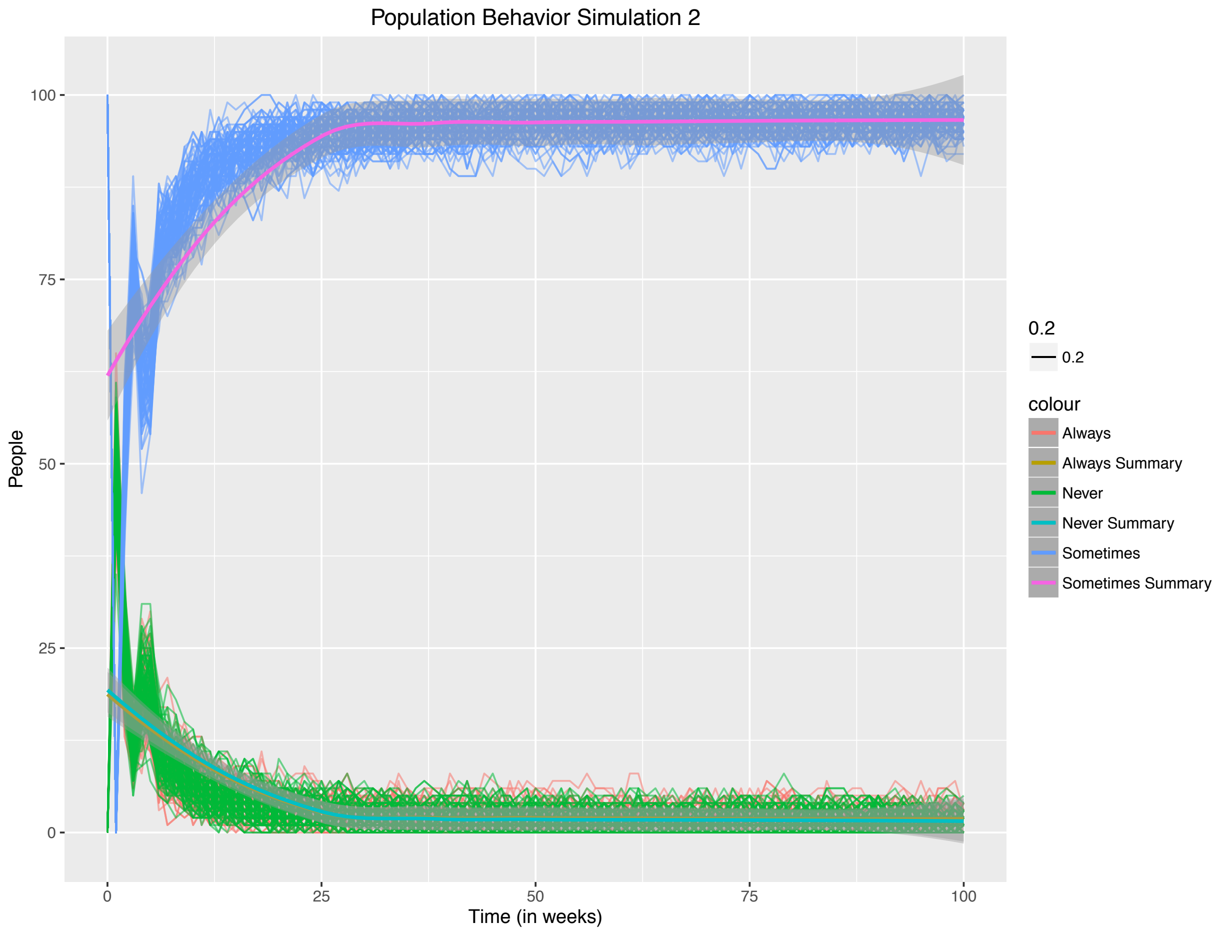


Figure 23: Population-level *Behavior* results in scenario 2. The simulation is run 100 times to perform a sensitivity test and the results and trends are recorded.

Behavior Category	*Mean*	*Standard Deviation*	*Minimum*	*1st Quartile*	*3rd Quartile*	*Maximum*
Always	2.28	1.71	0	1	3	13
Sometimes	95.51	2.74	77	94	97	100
Never	2.21	1.77	0	1	3	14

Table 9: Summary statistics from *Behavior* category outputs in scenario 2.

Discrete Action

The proportion of recycling to not recycling behavior, is more equal in simulation 2 than simulation 1. There is a lower proportion of recycling in simulation 2. This is interesting because the *Intent* and *Behavior* categories do not show significant differences between simulation 1 and 2, in both the majority of people are in the sometimes *Intent* and *Behavior* categories. However, understand how those categories are defined is important. “Sometimes” encompasses everyone who recycles between 25% and 75% of the time. Figure 24 offers insight into the granularity between simulations that is not perceived in Figures 22 and 23. The individual level behavior sampled in Figure 24 indicates that in simulation 2, when the recycling program is still young, people are recycling less than when the recycling program is established—even though both behaviors classify as “sometimes”.

Figure 24: Sample of discrete action from scenario 2 sensitivity tests. One person is picked randomly from each of the 100 runs of the sensitivity test and their "Recycling" and "Not Recycling" memory stock is shown.

Scenario 3: No Recycling Program

The final scenario is a population before any recycling program exists. The factor values are adjusted to reflect a population that has no formal recycling program. The "accessibility of recycling bin" parameter is adjusted from 1 to .5. This means that half of the time, when a person has waste they could recycle, there is a recycling bin available. Table 10 shows the full parameters used in scenario 3. Table 11 shows the transition matrix of path coefficients used in this scenario. The path coefficients are the same as those in scenario 2 because there is no comparable data to inform a change to those parameters and those coefficients are the closets representation of a "no recycling program" situation.

Factor	Mean	Standard Deviation
Relative Advantage	3.01[a]	3.16
Complexity	-3.25[a]	4.64
Internal Normative Belief	-1.94[b]	9.00
External Normative Belief	-2.50[b]	6.17
Self-Efficacy	-5.26[a]	5.12
Compatibility	-3.85[a]	3.85
Resource-Facilitating Conditions	-1.75[a]	5.32

a. Scaled from -9 to 9.
b. Scaled from -21 to 21.

Table 10: Scenario 3 parameters for STELLA model of recycling behavior. Parameters are informed by the empirical work done by Taylor and Todd (1995).

Factor (source)	*Factor (target)*	*Path Coefficient*
Relative Advantage	Attitude	*0.35**
Complexity	Attitude	*-0.05**
Internal Normative Belief	Subjective Norm	*0.07***
External Normative Belief	Subjective Norm	*0.11***
Self-Efficacy	Perceived Behavioral Control	*0.64**
Compatibility	Perceived Behavioral Control	*-0.89**
Resource-Facilitating Conditions	Perceived Behavioral Control	*0.15***
Attitude	Intent	*1.38***
Subjective Norm	Intent	*0.20**
Perceived Behavioral Control	Intent	*0.33***

*$p < .01$; **$p < .001$.*

Table 11: Path coefficients between factors in STELLA model, adapted from the structural equation model in Taylor and Todd's work (1995).

Intent

The *Intent* category distribution in this scenario is distinct from that of scenario 1 and 2. Most noticeably, the number of people never intending to recycle is very high and that it crosses the number of people sometimes intending to recycle. The crossing behavior of never and sometimes categories indicates that it takes time for the population to reach a steady state and that the original distribution of people in the simulations is not sustainable given the parameters of the scenario. The two things are changed in this scenario are the mean response to the *Intent* factor questions and the accessibility of recycling bins. The initial *Behavior* is similar to that in scenarios 1 and 2 and then moves toward a steady state indicates that the accessibility factor is driving the change in this behavior. *Intent* informs each person's *Behavior*, however it is not perfectly predictive and accessibility of recycling bins is a major factor in the intent-behavior gap. This points to accessibility having a greater impact on *Behavior* and *Intent* in this scenario than the moral factors. *Intent* is dynamically connected to *Behavior* —the feedback loop based on mismatch—so as *Behavior* is impacted, *Intent* follows suit. Compared to the behavior in Figure 8, the behavior in Figure 25 is delayed, which is a result of the delay built into the feedback loop from *Behavior* category to *Intent* category. The *Intent* categories distribution trend toward a distribution with 84 people intending to never recycle, 16 people intending to sometimes recycle, and 0 people intending to always recycle. In the defined time period of 100 weeks, the system does not reach a steady state, and it appears that the whole population could end up in the never intending to recycle stock.

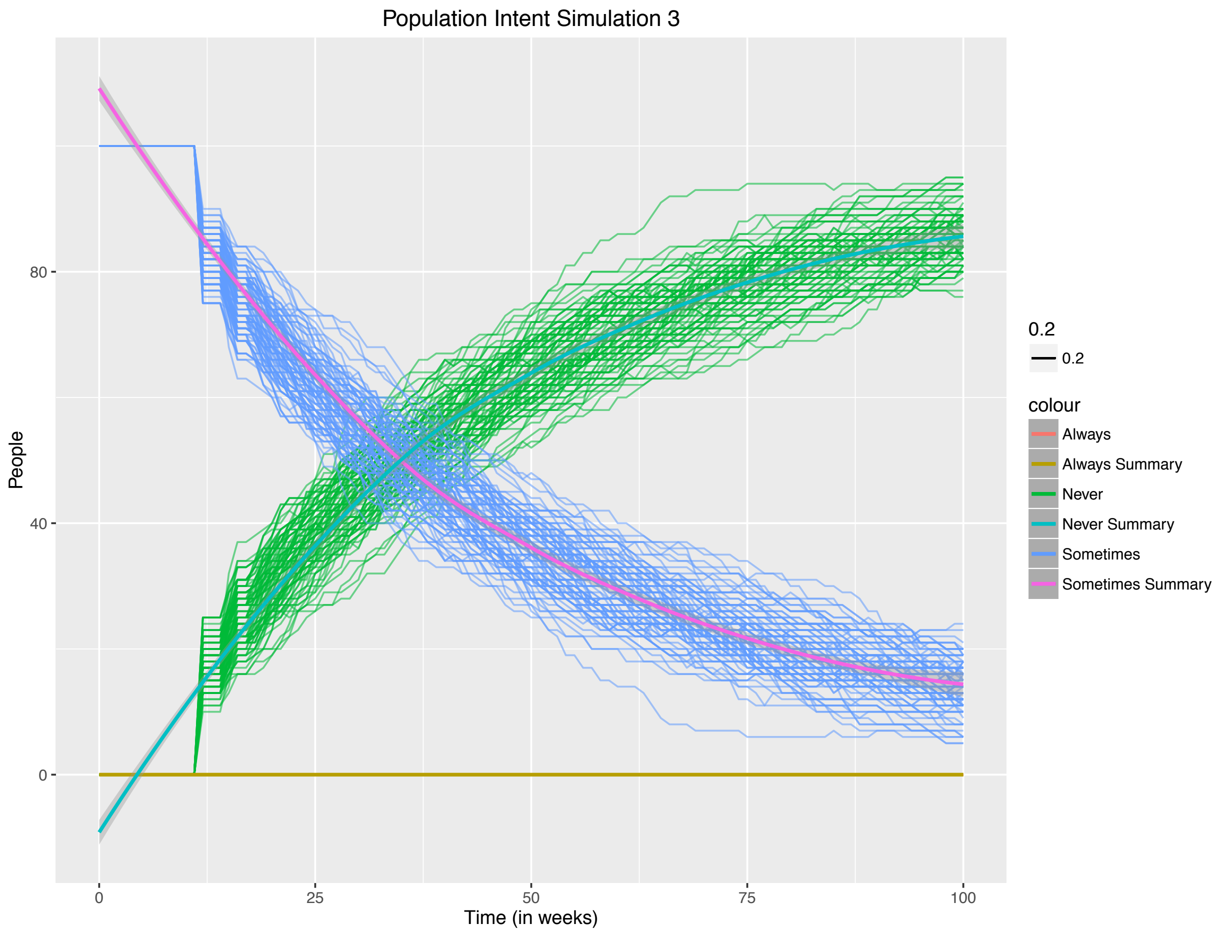


Figure 25: Population-level *Intent* results in scenario 3. The simulation is run 100 times to perform a sensitivity test and the results and trends are recorded.

Intent Category	*Mean*	*Standard Deviation*	*Minimum*	*1st Quartile*	*3rd Quartile*	*Maximum*
Always	0.00	0.00	0	0	0	0
Sometimes	17.02	4.57	5	14	20	32
Never	82.98	4.57	68	80	86	95

Table 12: Summary statistics from *Intent* category outputs in scenario 3.

Behavior

Similar to the output in the *Intent* category distribution, *Behavior* is much more skewed toward not recycling in this scenario than in the previous two. *Behavior* categories approach a more distinct steady state than *Intent* categories. This steady state has 84 people never recycling, 16 people sometimes recycling, and 0 people always recycling. It appears that the increase of physical barriers—the lack of recycling bins or a recycling program—greatly impacts the intent-barrier gap. The first 10 weeks in this simulation demonstrate critical behavior. Examining Figures 7 and 8, it is clear that *Intent* to recycle is high in the first ten weeks and when the feedback from *Behavior* (after week 10) kicks in, *Intent* distinctly begins to drop. Figure 26 shows that the *Behavior* distribution is largely not recycling from the onset of the simulations. This indicates that the reason for the drive of *Intent* to never is the large number of people in the never *Behavior* category. This is a positive feedback loop, meaning that the behavior that the loop reinforces *Behavior*. So, in this scenario the high number of people never recycling reinforces the number of people never intending to recycle and both stocks—never intending to recycle and never recycling—are driven up while the sometimes and always stocks are driven down.

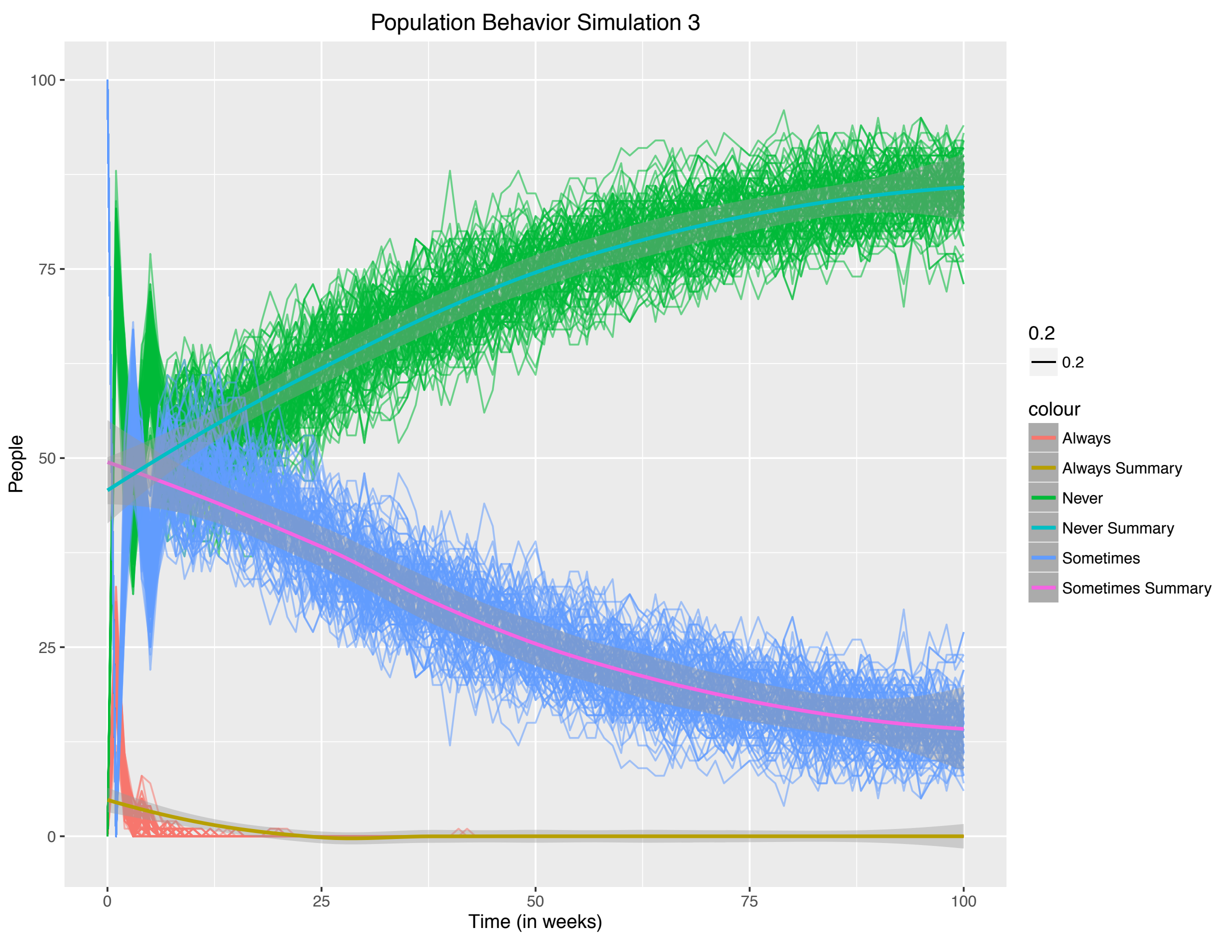


Figure 26: Population-level *Behavior* results in scenario 3. The simulation is run 100 times to perform a sensitivity test and the results and trends are recorded.

Behavior Category	*Mean*	*Standard Deviation*	*Minimum*	*1st Quartile*	*3rd Quartile*	*Maximum*
Always	0.00	0.00	0	0	0	0
Sometimes	15.52	3.91	4	13	18	30
Never	84.48	3.91	70	82	87	96

Table 13: Summary statistics from *Behavior* category outputs in scenario 3.

Discrete Action

The behavior discussed in the previous two sections is reinforced by Figure 27. This graph picks one person at random from each of the 100 simulations and looks at their discrete recycling behavior. In this scenario, not recycle—and the memory of not recycling—is very high.

Figure 27: Sample of discrete action from scenario 3 sensitivity tests. One person is picked randomly from each of the 100 runs of the sensitivity test and their “Recycling” and “Not Recycling” memory stock is shown.

This behavior is to be expected because if people cannot recycle, even if they want to, their future *Behavior* and *Intent* will be in some way informed by that. The main driver of difference between scenario 3 and scenarios 1 and 2 is the accessibility factor.

Treatments

Now that we understand how different populations behave given different recycling programs, I explore how to impact a population's behavior within the physical parameters it exists. The following treatments are designed to test different points of intervention. Each one takes an educational or promotional strategy and tests its impact on populations in scenario 1 and scenario 2. All treatments are applied evenly to the population—every person is impacted equally effected. Treatments are applied at week 40 and it is assumed that the impact remains. For example, if one treatment targets the perception of time commitment needed to recycle, the treatment is applied at week 40 and everyone's time commitment score is increased for the remainder of the simulation.

Treatment Design

Treatment 1: Normative Education

The first treatment is a normative education strategy. Messaging is moral or "should"-based. Tangibly, this treatment would be executed by signs and advertisements about the importance of environmental health and recycling's role in it as a duty to future generations, or responsibility as global citizens, or a religious imperative. To apply this treatment to the model, the values of *Complexity* and *Subjective Norm* are effected. Table 14 shows the full description of and changed to the factors targeted in this treatment.

Factor Name	*Factor Question*	*Treatment (applied between t=40 and t=60)*
b_1	I will help to protect the environment by recycling (strongly disagree/strongly agree).	Increase mean to 8.[a]
e_1	Helping to protect the environment is an (extremely unimportant/extremely important) part of my decision whether to recycle.	Increase mean to 8.[a]
b_2	I will help to reduce our landfill waste by recycling (strongly disagree/strongly agree).	Increase mean to 8.[a]
e_2	Helping to reduce our landfill waste is an (extremely unimportant/extremely important) part of my decision whether to recycle.	Increase mean to 8.[a]
nb_1	My family thinks that I should recycle (strongly disagree/strongly agree).	Increase mean by 6.[b]
nb_2	People in my household think that I should recycle (strongly disagree/strongly agree).	Increase mean by 6.[b]
nb_3	My friends think that I should recycle (strongly disagree/strongly agree).	Increase mean by 12.[b]
nb_4	My neighbors think that I should recycle (strongly disagree/strongly agree).	Increase mean by 12.[b]

a. Scaled from -9 to 9.
b. Scaled from -21 to 21.

Table 14: Detailed breakdown of factors and changes in treatment 1.

Treatment 2: Processed-based Education

The second treatment is a process-based education and promotional campaign strategy. The signs and campaigns used would tell people what they can and cannot recycle. The implementation of this treatment would include an educational program that explains what happens to materials when they are recycled and how that contributes to ameliorating environmental problems. The factors that are targeted in this treatment are *Complexity*, *Self-Efficacy*, and *Resource-Facilitating Conditions*.

Factor Name	*Factor Question*	*Treatment (applied between t=40 and t=60)*
b_3	Recycling is difficult (strongly disagree/strongly agree).	Decrease mean to -8.[a]
b_4	Recycling is easy (strongly disagree/strongly agree).	Increase mean to 8.[a]
cb_1	I cannot figure out what is and what is not to be recycled (strongly disagree/strongly agree).	Decrease mean to -8.[a]
pf_1	Being able to figure out what is to be recycled is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.	Increase mean by 4.[a]
cb_2	I do not what know what should be recycled (strongly disagree/strongly agree).	Decrease mean to -8.[a]
pf_2	Knowing what should be recycled is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.	Increase mean by 4.[a]
cb_3	I cannot figure out how to recycle effectively (strongly disagree/strongly agree).	Decrease mean to -8.[a]
pf_3	Figuring out how to recycle effectively is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.	Increase mean by 4.[a]
cb_4	I have convenient access to a blue box (strongly disagree/strongly agree).	Increase mean to 8.[a]
pf_4	Having convenient access to a blue box is an (extremely unimportant/extremely important) part of my decision whether to recycle.	Increase mean by 4.[a]

a. Scaled from -9 to 9.
b. Scaled from -21 to 21.

Table 15: Detailed breakdown of factors and changes in treatment 2.

Treatment 3: Life Style Marketing

The third treatment focuses on marketing recycling as a positive life style choice. It focuses on strategies that promote the integration of recycling into one's identity. I would target the way a population identifies and demonstrates the ease and importance of incorporating recycling into that identity. The factor that is targeted in this treatment is *Compatibility*.

Factor Name	Factor Question	Treatment (applied between t=40 and t=60)
cb_5	Recycling does not fit with my lifestyle (strongly disagree/strongly agree).	Increase mean to 8.[a]
pf_5	Whether or not recycling fits with my lifestyle is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.	Increase mean by 4.[a]
cb_6	Recycling is inconvenient (strongly disagree/strongly agree).	Decrease mean to -8.[a]
pf_6	Whether or not recycling is inconvenient is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.	Increase mean by 4.[a]
cb_7	I do not have time to recycle (strongly disagree/strongly agree).	Decrease mean to -8.[a]
pf_7	Having the time to recycle is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.	Increase mean by 4.[a]
cb_8	Recycling does not fit with my daily routine (strongly disagree/strongly agree).	Decrease mean to -8.[a]
pf_8	Whether or not recycling fits with my daily routine is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.	Increase mean by 4.[a]
cb_9	For me, recycling take too much effort (strongly disagree/strongly agree).	Decrease mean to -8.[a]
pf_9	Whether or not recycling takes too much effort is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.	Increase mean by 4.[a]

a. Scaled from -9 to 9.
b. Scaled from -21 to 21.

Table 16: Detailed breakdown of factors and changes in treatment 3.

Scenario 1 Results

Treatment 1

The application of normative education, treatment 1, to the population with a well-established recycling program increases the number of people who always *Intent* to recycle and the number of people who always recycle. Figures 28 and 29 show the impact of treatment 1 on the baseline *Intent* and *Behavior* results from simulation 1.

The *Intent* to always recycle increases significantly after the treatment is applied at week 40. There is an oscillating relationship between the always and sometimes intents, which indicates that a number of people were pushed to the edge of the sometimes *Intent* category by the treatment and it took some time for the model to smooth out. The *Intent* distribution of the population approaches a steady state 150 weeks after the treatment has been applied. The *Intent* steady state is 78 people always intending to recycle, 22 people sometimes intending to recycle and 0 people never intending to recycle. Treatment 1 is an effective strategy to impacting the *Intent* of people in the population of scenario 1.

The *Behavior* of this population is also impacted by treatment 1, although the change is less dramatic. *Behavior* reaches a steady state faster than *Intent* under the same circumstances. The *Behavior* steady state of scenario 1 with treatment 1 is 37 people always recycling, 63 people sometimes recycling, and 0 people never recycling. This is a substantial improvement from the baseline of scenario 1 and reinforces that a normative educational approach would be an effective one applied to a population with a well-established recycling program.

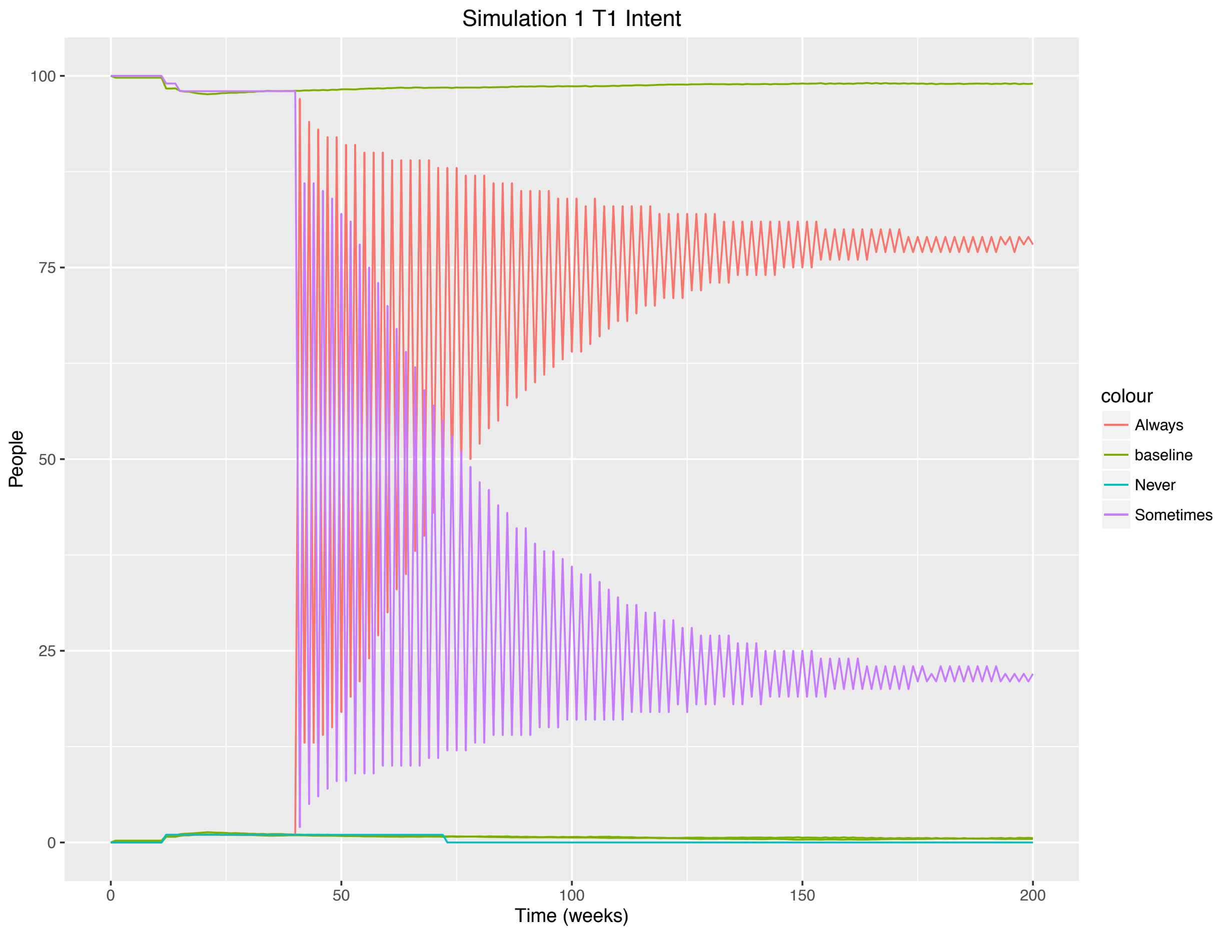


Figure 28: Average *Intent* results from simulation 1 under baseline and treatment 1 parameters.

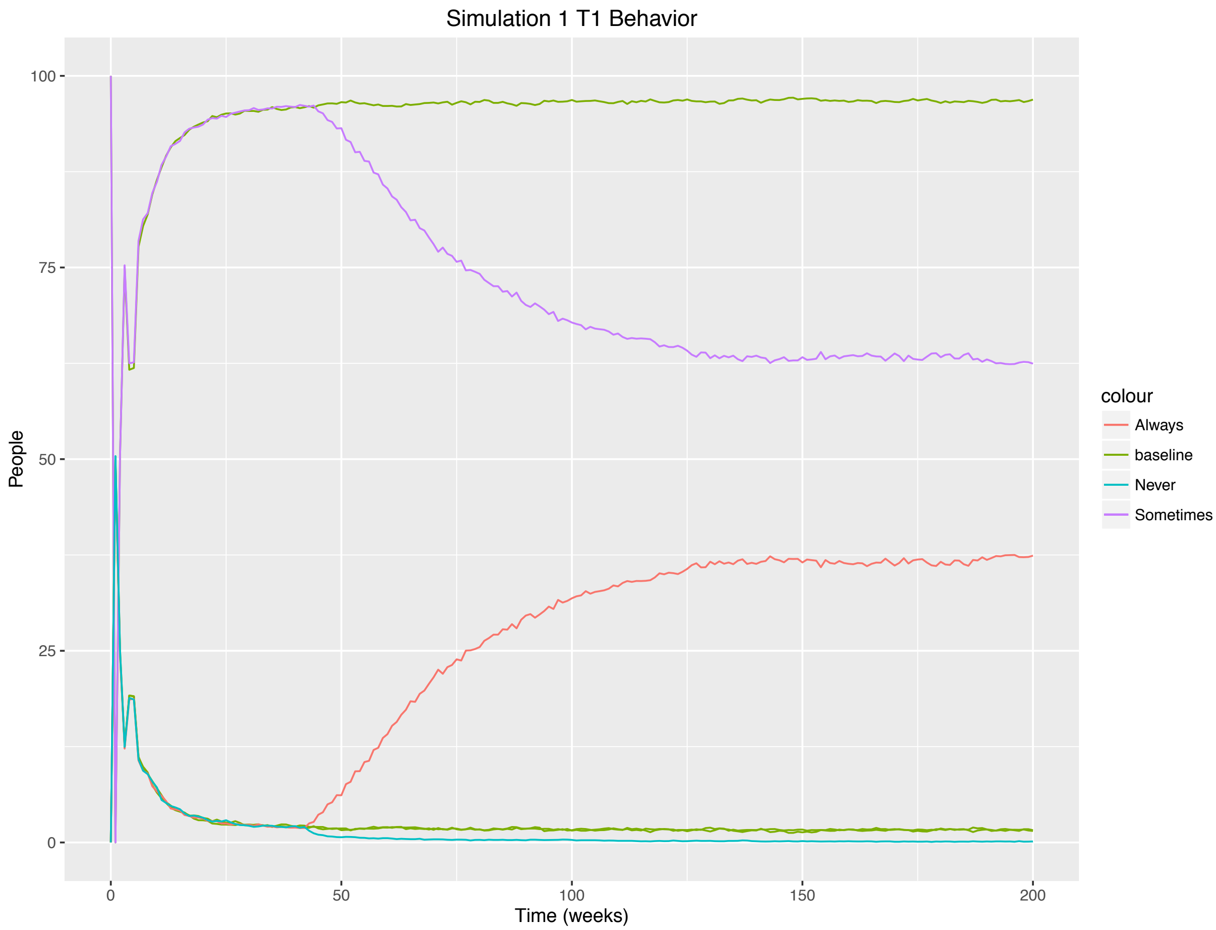


Figure 29: Average *Behavior* results from simulation 1 under baseline and treatment 1 parameters.

Treatment 2

When treatment 2, process-based education, is applied the the population in scenario 1 the impact on *Intent* and *Behavior* are very similar to the results from treatment 1. The *Intent* category steady state when treatment 2 is applied is 77 people always intend to recycle, 23 people sometimes intend to recycle, and 0 people never intend to recycle. The steady state of the *Behavior* is 36 people always recycle, 64 people sometimes recycle, and 0 people never recycle.

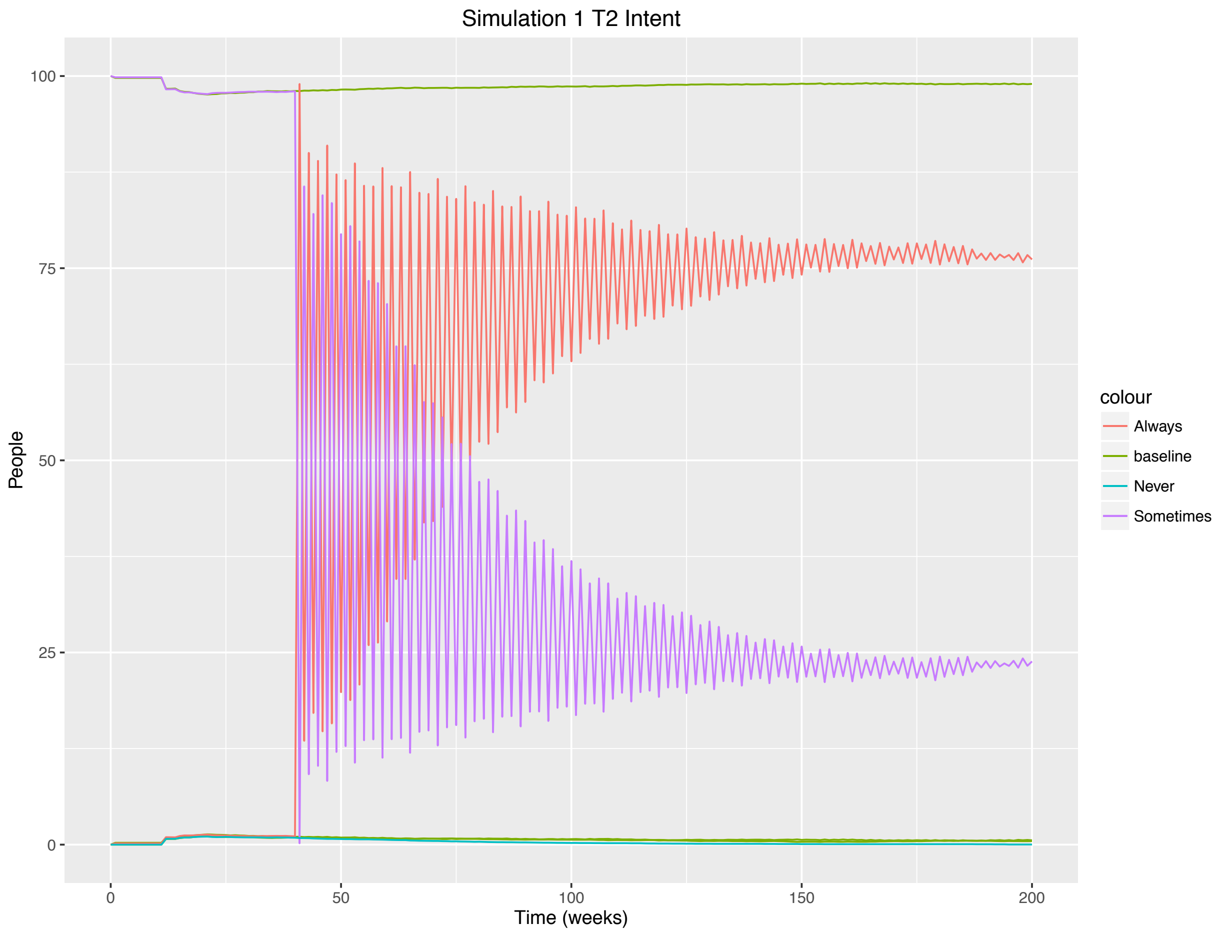


Figure 30: Average *Intent* results from simulation 1 under baseline and treatment 2 parameters.

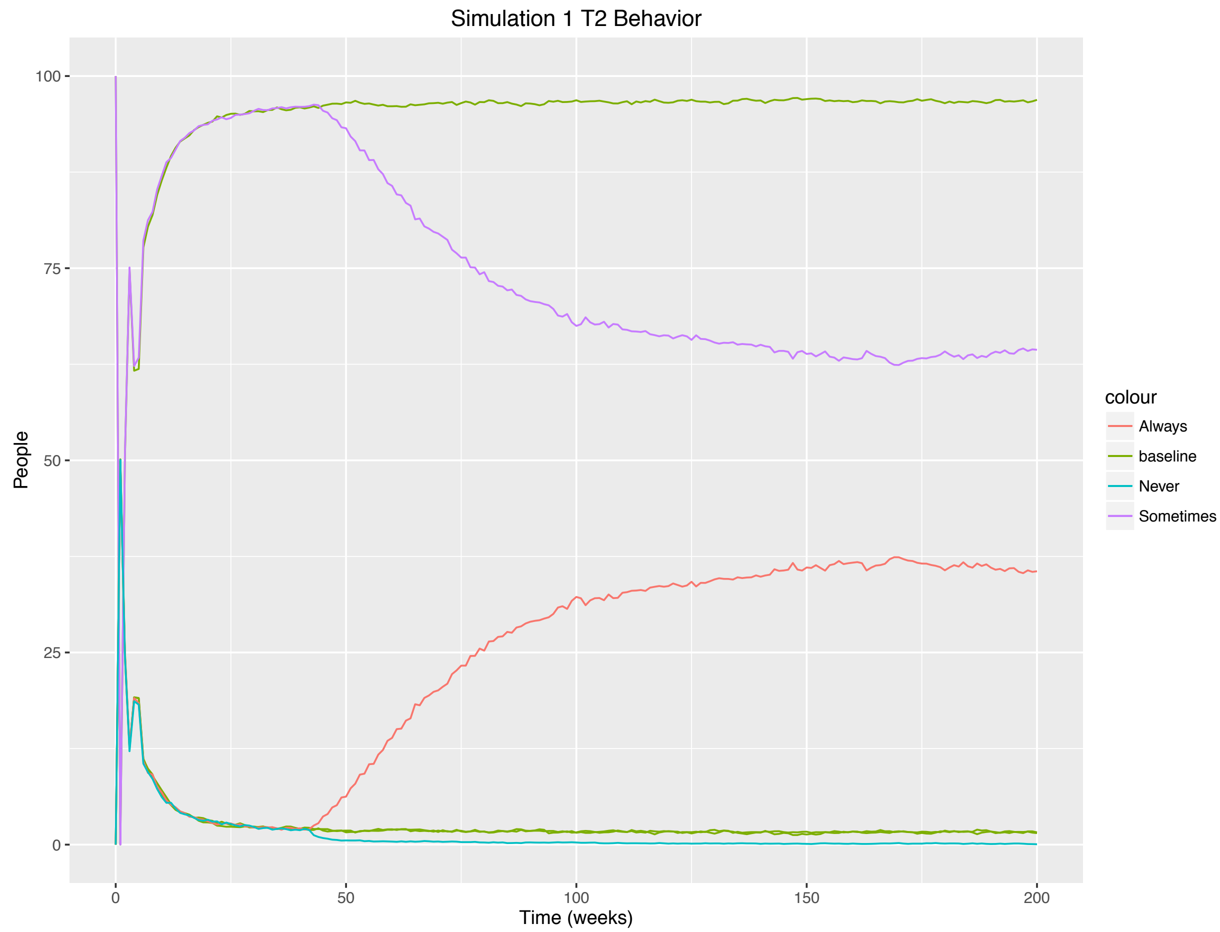


Figure 31: Average *Behavior* results from simulation 1 under baseline and treatment 2 parameters.

Treatment 3

Treatment 3, life style marketing, is the least impactful of the three treatment. It has a small impact on both *Intent* and *Behavior*. The steady state of the *Intent* category distribution is 10 people always intend to recycle, 90 people sometimes intend to recycling, and 0 people never intend to recycle. The *Behavior* steady state is 6 people always recycle, 93 people sometimes recycle, and 1 person never recycles.

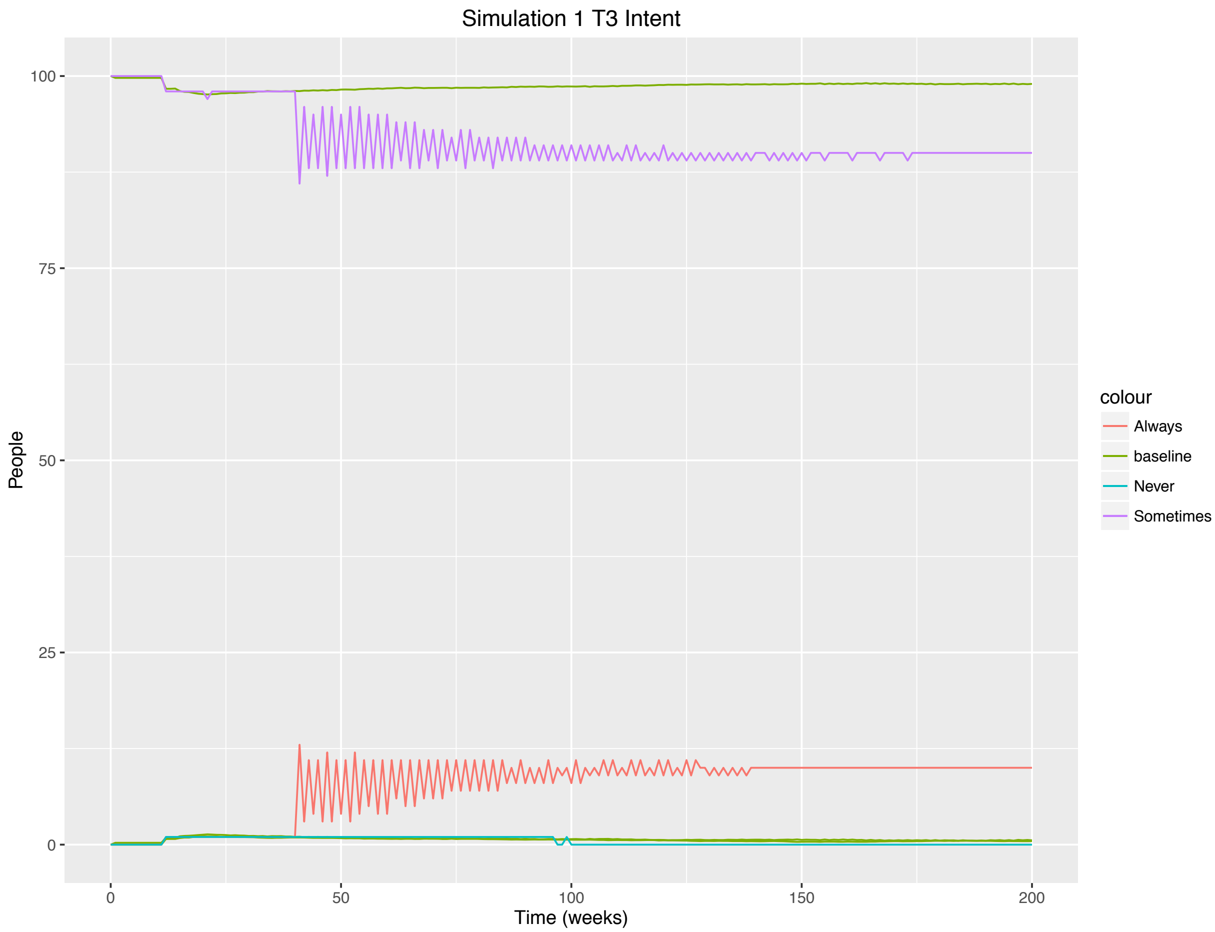


Figure 32: Average *Intent* results from simulation 1 under baseline and treatment 3 parameters.

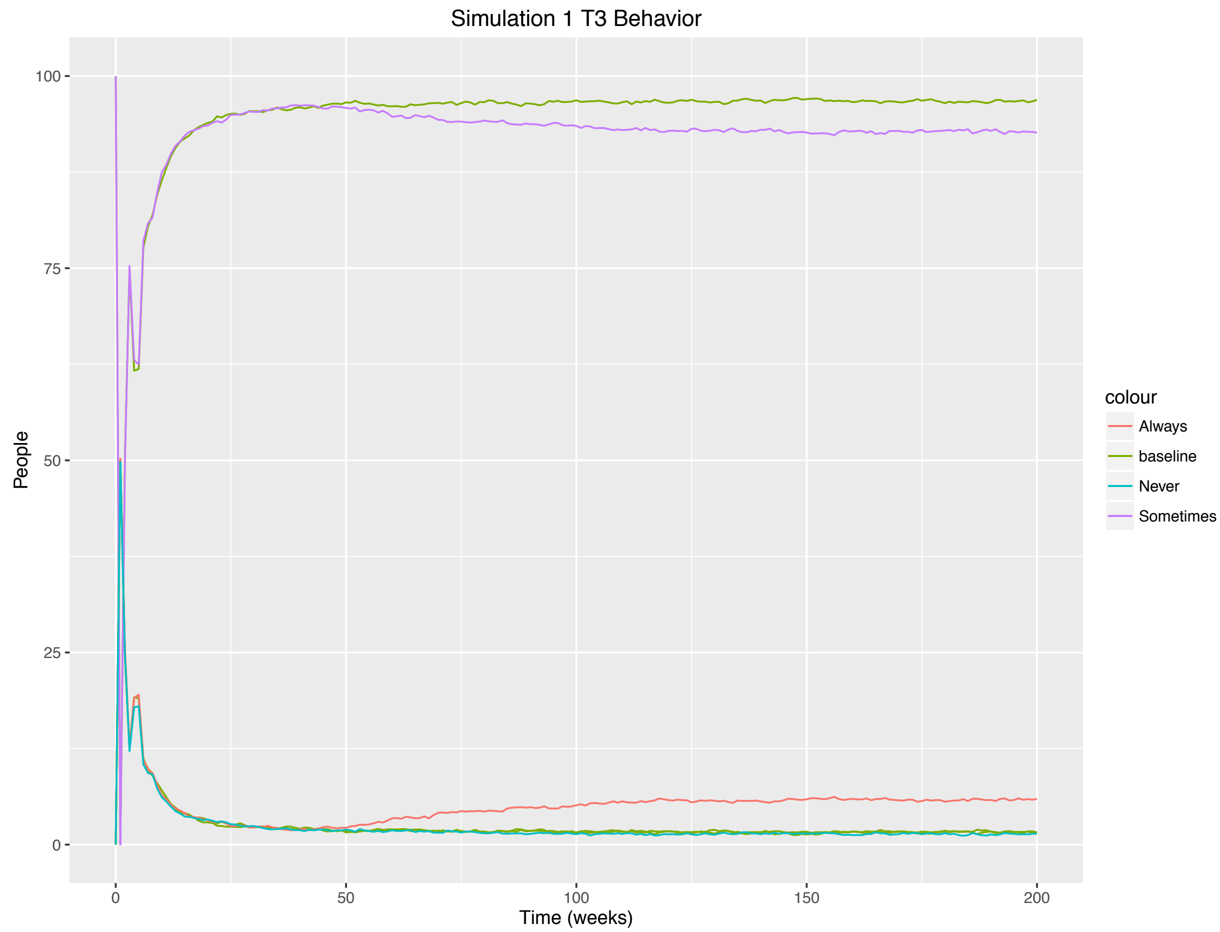


Figure 33: Average *Behavior* results from simulation 1 under baseline and treatment 3parameters.

Summary

In scenario 1, where there is a well-established recycling program in a community, the large majority of the population intend and behave in the “sometimes” categories. The goal is the move people, using the most impactful communication strategy into the “always” *Intent* and *Behavior* categories. Treatment 1 and treatment 2 are most effective in changing the model *Behavior*. They have very similar steady states, but treatment 1 has a marginally better output. Treatment 3 has a small positive impact on the baseline *Intent* and *Behavior*. Figure 34 and Table 17 summarize the treatment results on *Intent*. Figure 35 and Table 18 summarize the treatment results on *Behavior*. The overall impact of treatments is greater on *Intent* than on *Behavior* — meaning it is easier to change peoples’ minds than their actions. Treatments 1 and 2 are most effective, so normative and process-based education strategies and add campaigns are more effective than life style marketing in changing peoples' recycling *Intent* and *Behavior*.

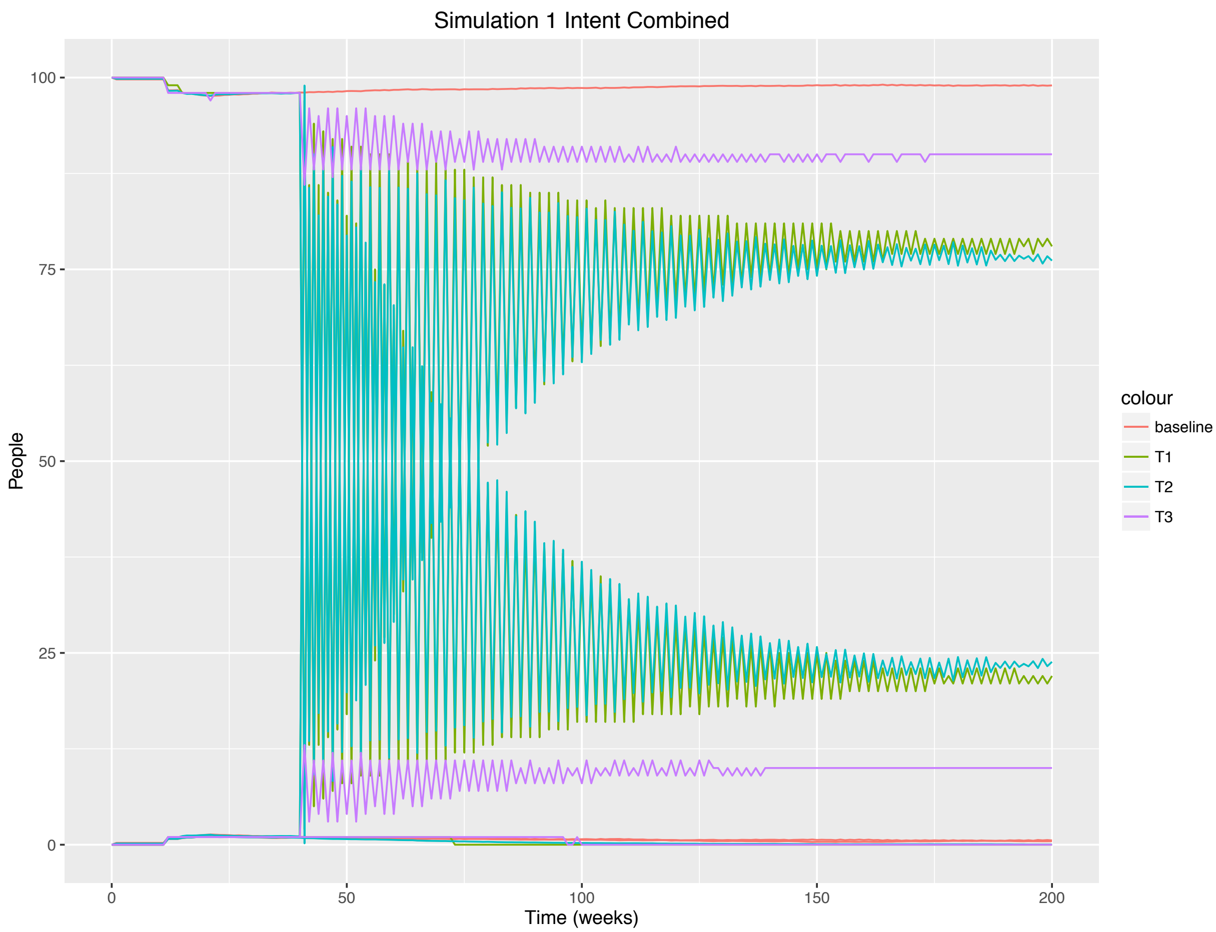


Figure 34: Average *Intent* results from simulation 1 under baseline, treatment 1, treatment 2, and treatment 3 parameters.

	Always	*Sometimes*	*Never*
Baseline	1	98	1
Treatment 1	78	22	0
Treatment 2	77	23	0
Treatment 3	10	90	0

Table 17: *Intent* summary of treatments applied to scenario 1.

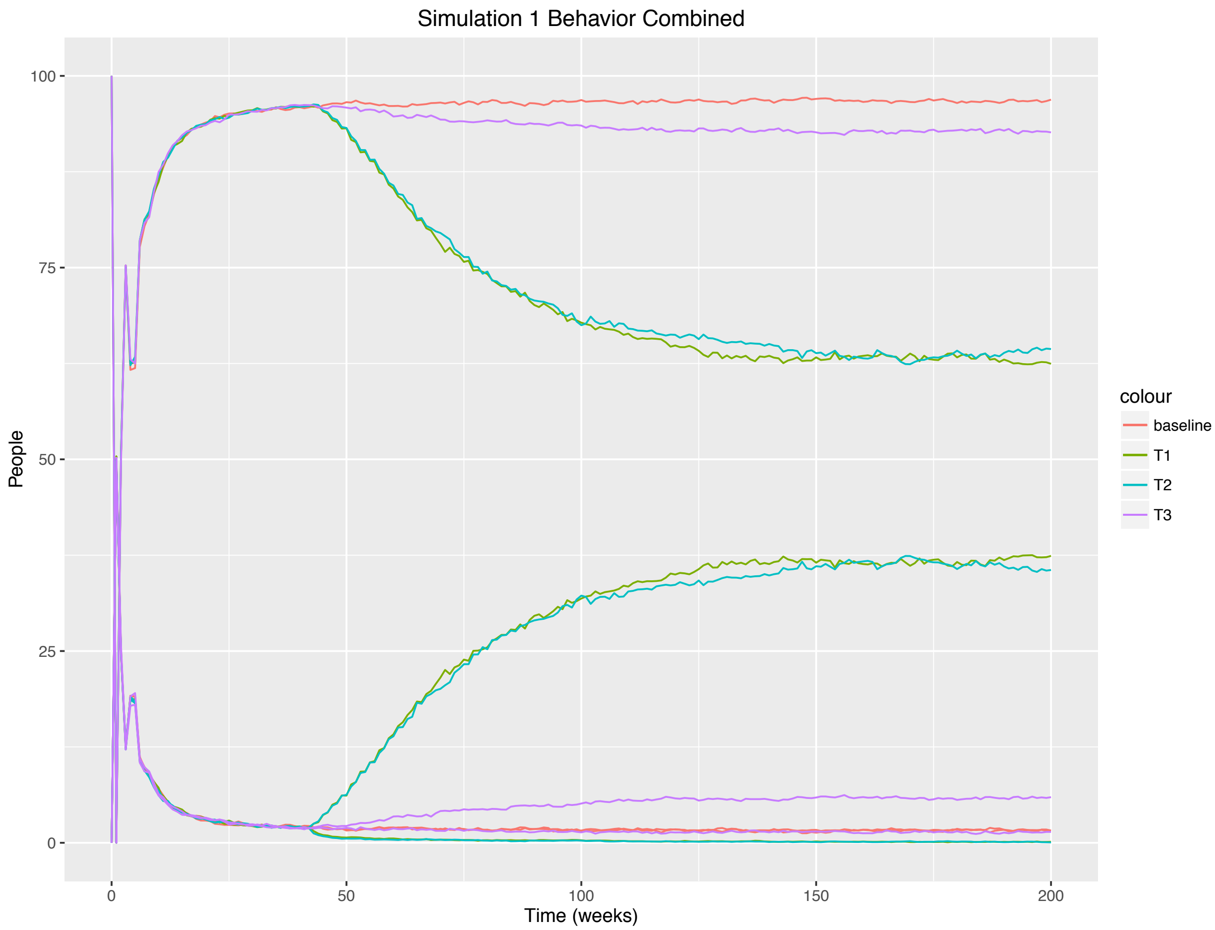


Figure 35: Average *Behavior* results from simulation 1 under baseline, treatment 1, treatment 2, and treatment 3 parameters.

	Always	*Sometimes*	*Never*
Baseline	2	96	2
Treatment 1	37	63	0
Treatment 2	36	64	0
Treatment 3	6	93	1

Table 18: *Behavior* summary of treatments applied to scenario 1.

Scenario 2 Results

Treatment 1

When treatment 1, normative education, is applied to the second scenario, a new recycling program, the number of people who always intend to recycle increases. Figure 36 and 37 show the baseline *Intent* and *Behavior* of scenario 2 and the application of treatment 1. The *Intent* steady state is 78 people always intending to recycle, 22 people sometimes intending to recycle and 0 people never recycling. The *Behavior* steady state is 36 people never recycling, 64 people sometimes recycling, and 0 people never recycling. Treatment 1 is effective at increasing the number of people that both intend to and actually recycle. The impact of treatment 1 is substantial, the *Intent* of 79 people is changed—77 more people always intend to recycle and one person transitioned from never to sometimes intending to recycle. This treatment also changed the *Behavior* of the population, 34 more people always recycle after treatment 1 has been applied.

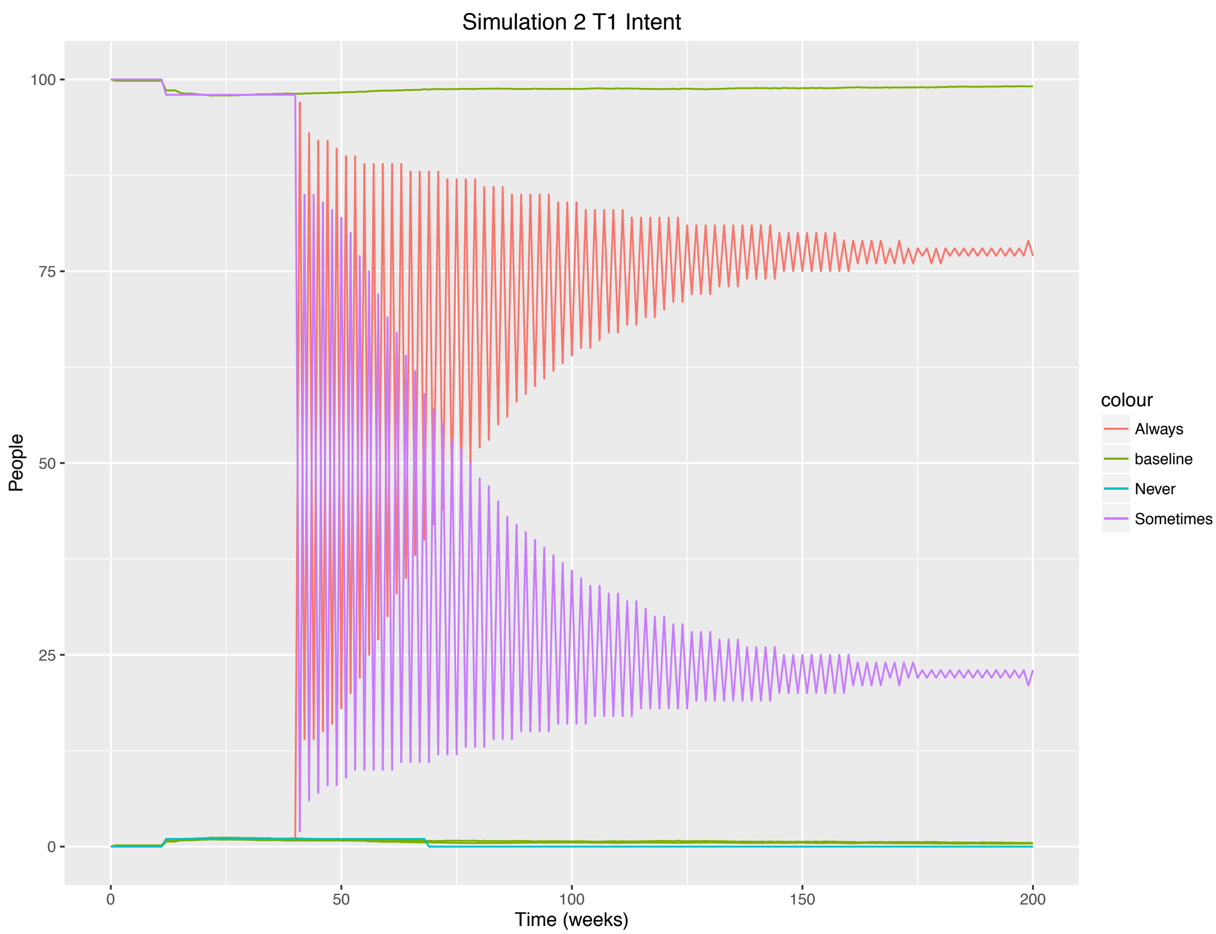


Figure 36: Average *Intent* results from simulation 2 under baseline and treatment 1 parameters.

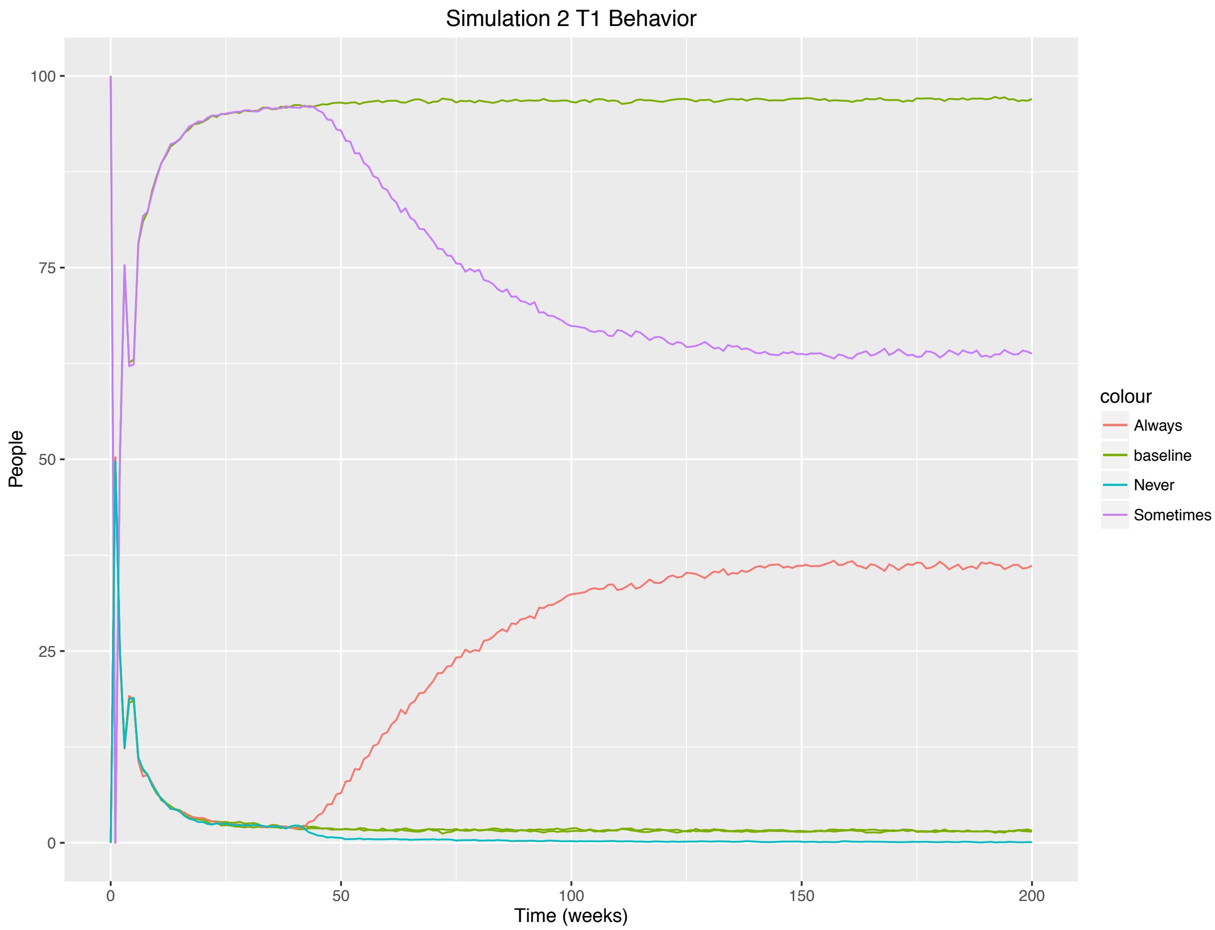


Figure 37: Average *Behavior* results from simulation 2 under baseline and treatment 1 parameters.

Treatment 2

The application of treatment 2, process-based education, to scenario 2 causes more people to always *Intent* and act on recycling. The *Intent* steady state under treatment 2 is 70 people intending to always recycle, 30 people never intending to recycle, and 0 people always intending to recycle. The *Behavior* steady state under treatment 2 is 33 people actually recycling, 67 people sometimes recycling and 0 people never recycling. Treatment 2 has a substantial impact on the *Intent* of the population—69 more people always intend to recycle and one person transitioned from never to sometimes intending to recycle. The population's *Behavior* is also effected by treatment 2—31 more people always recycle.

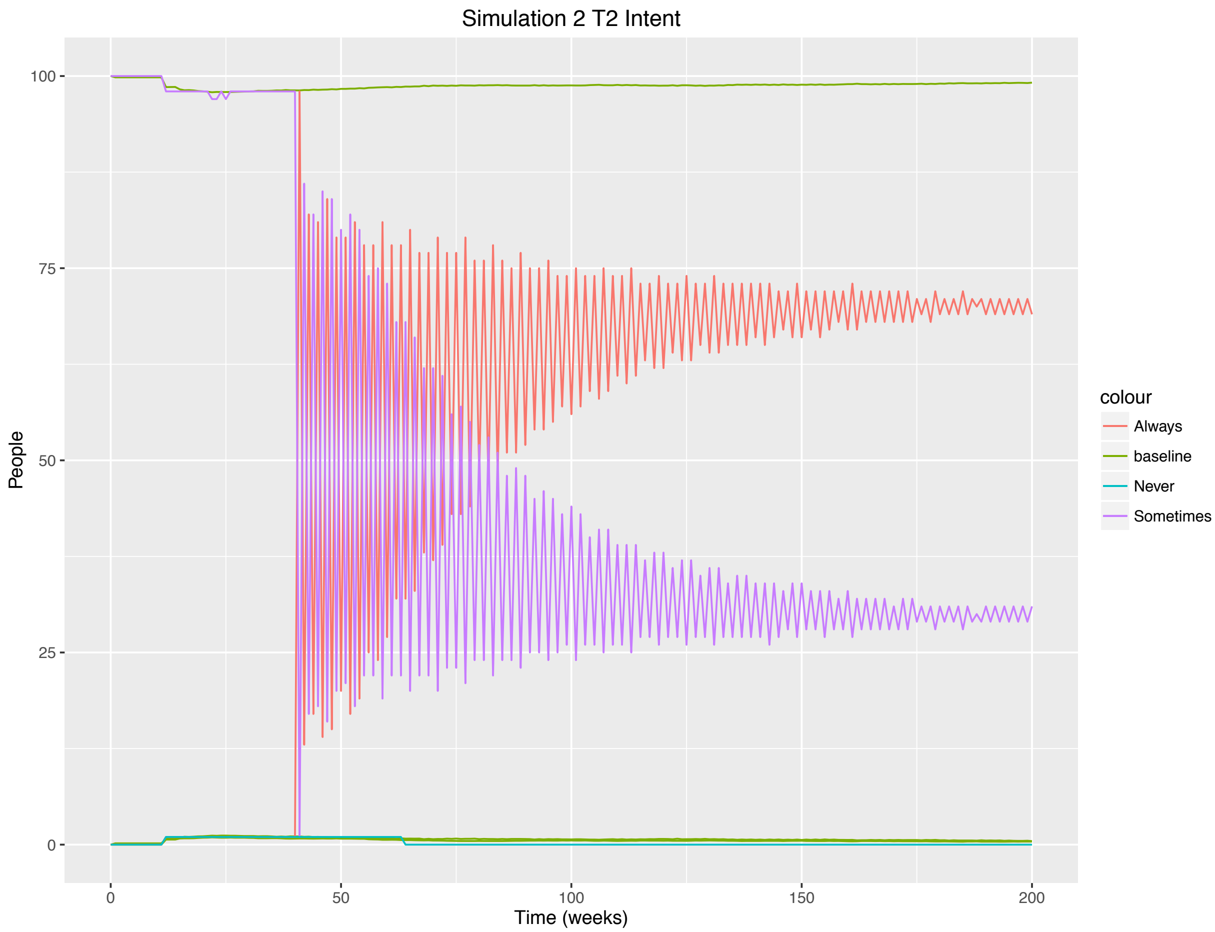


Figure 38: Average *Intent* results from simulation 2 under baseline and treatment 2 parameters.

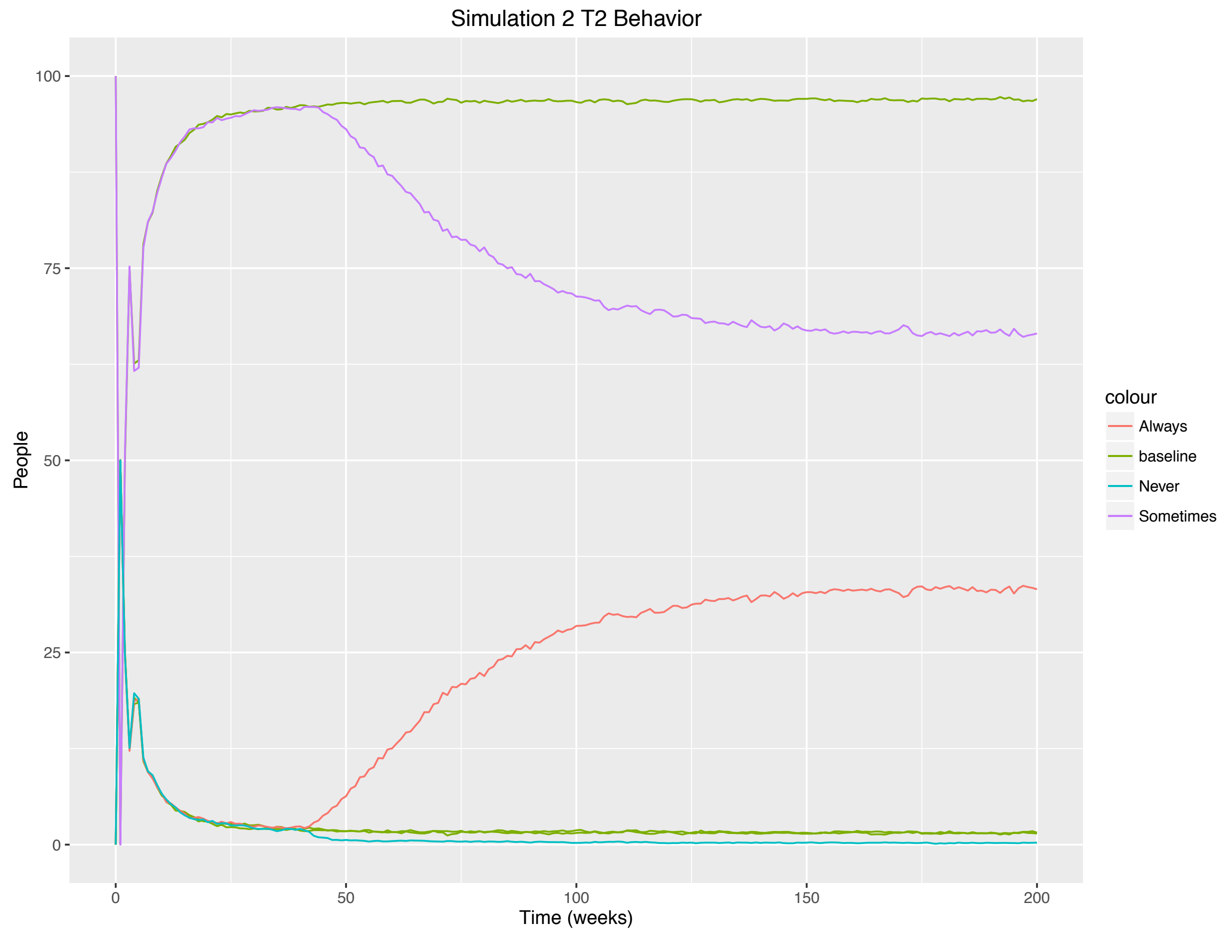


Figure 39: Average *Behavior* results from simulation 2 under baseline and treatment 2 parameters.

Treatment 3

The third treatment is the least effective treatment on scenario 2. The steady state of *Intent* distribution is 4 people always intending to recycle, 96 people sometimes intending to recycle, and 0 people never intending to recycle. The *Behavior* steady state is 3 people always recycling, 95 people sometimes recycling, and 2 people never recycling. The impact of treatment 3 is minor, only changing the *Behavior* of one person.

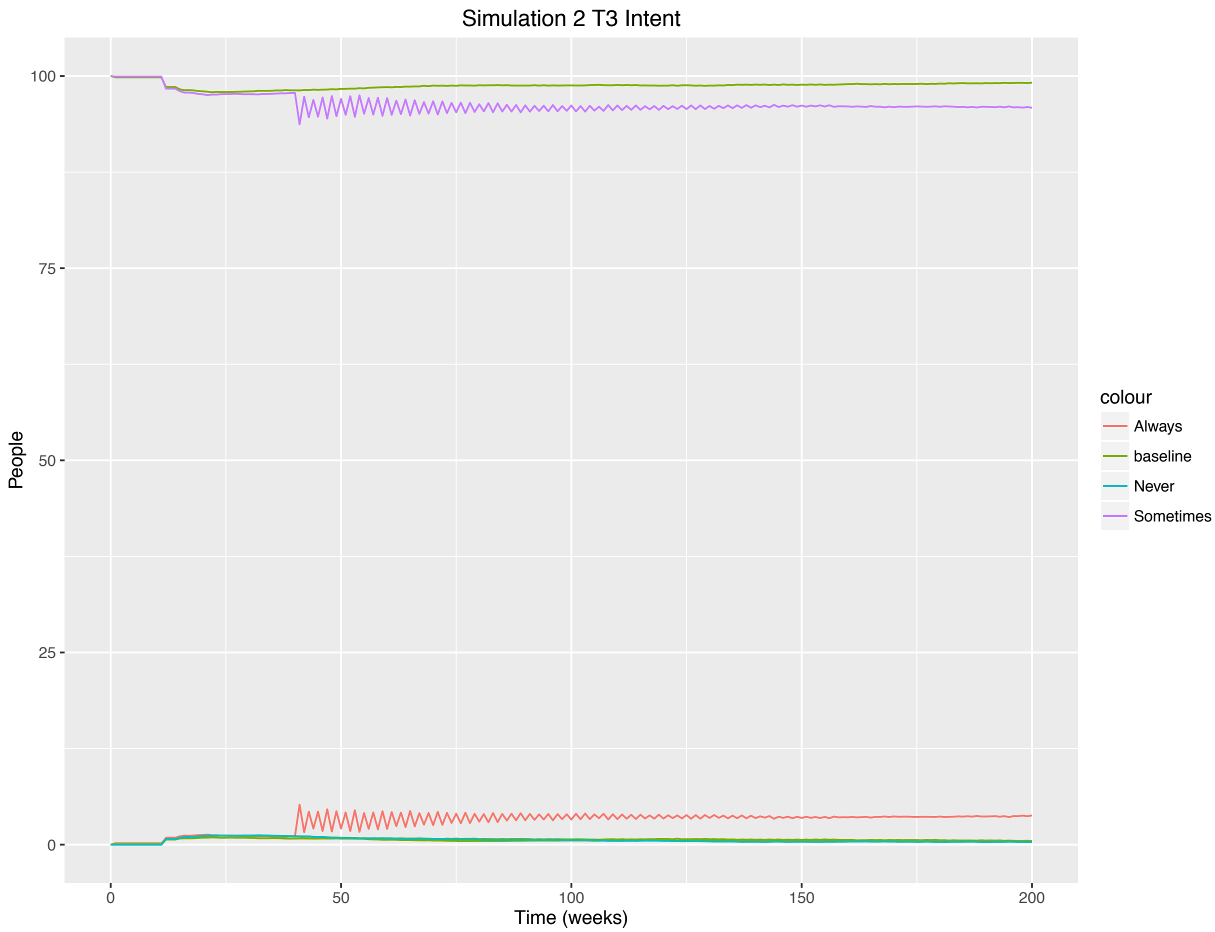


Figure 40: Average *Intent* results from simulation 2 under baseline and treatment 3 parameters.

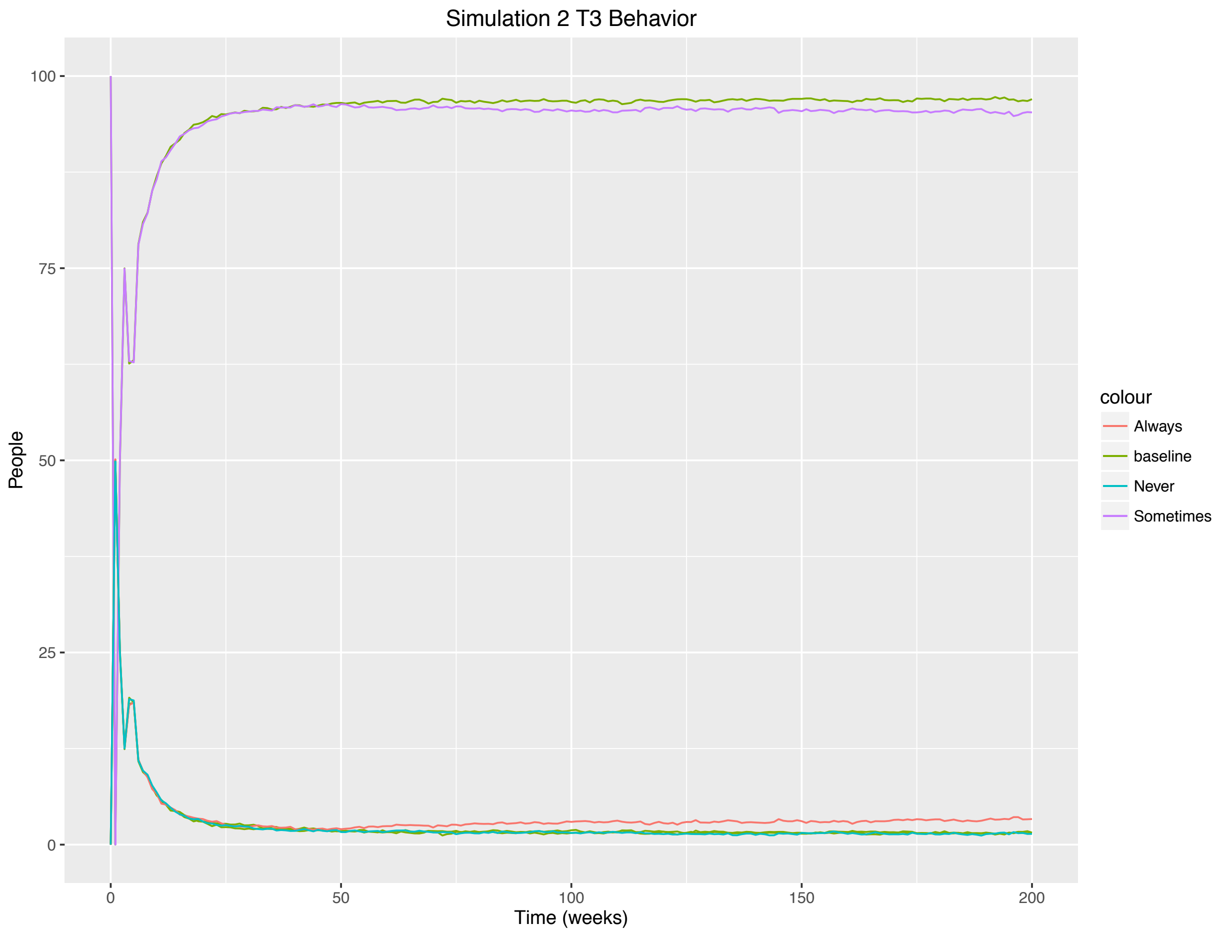


Figure 41: Average *Behavior* results from simulation 2 under baseline and treatment 3 parameters.

Summary

The most effective treatment to apply to scenario 2, to get the most people to change their recycling behavior, is treatment 1. Both treatment 1 and 2 cause substantial shifts toward recycling *Intent* and *Behavior* of the population. These results suggest that when a population is adapting a new recycling program, a normative *Behavior* campaign is most effective method to maximize the shift in the population's *Intent* and *Behavior*. The scenario analysis shows that physical accessibility to recycling bins is the most important factor in deciding a population's recycling behavior. This treatment analysis, however, suggests that treatments 1 and 2 are productive supplements to physical changes that would promote more recycling *Intent* and *Behavior*.

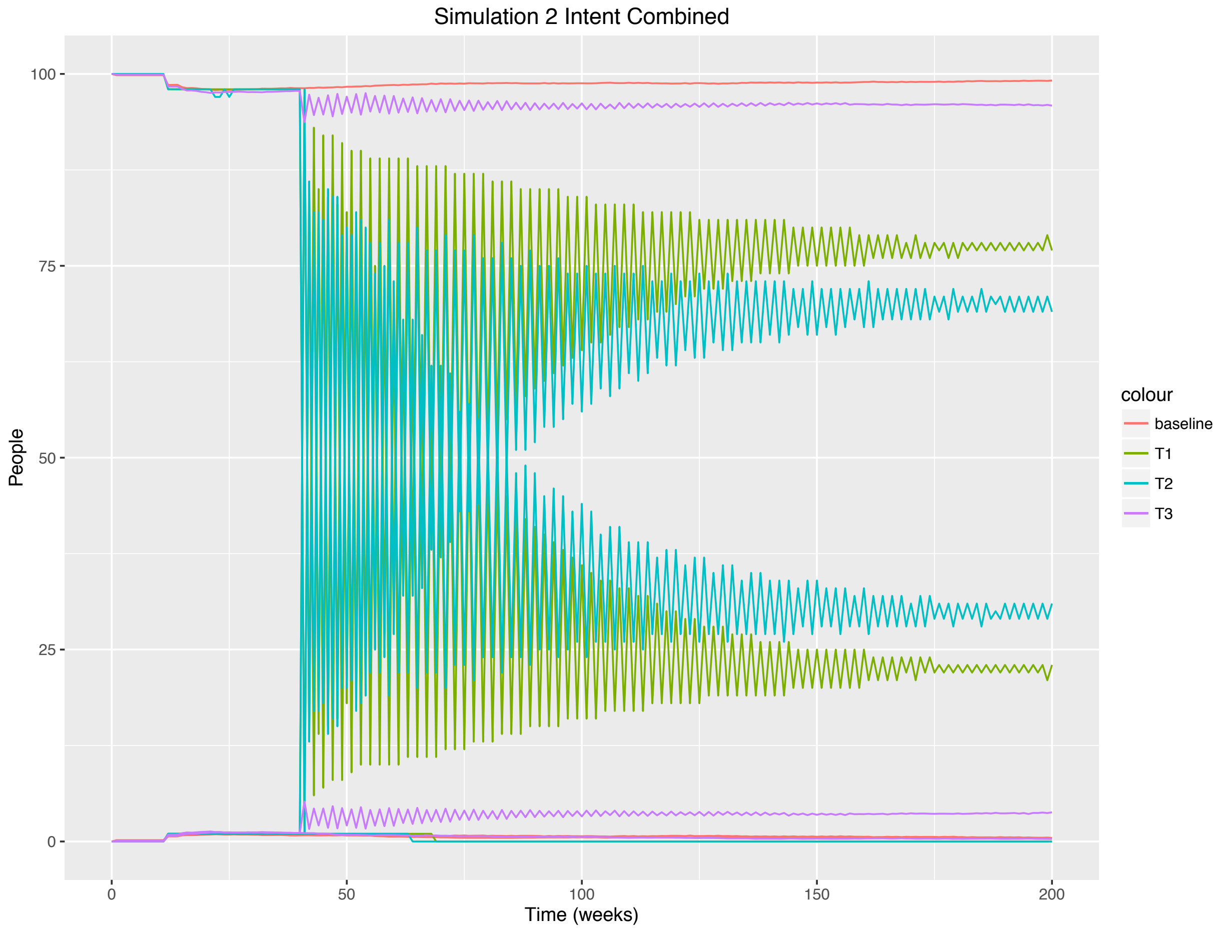


Figure 42: Average *Intent* results from simulation 2 under baseline, treatment 1, treatment 2, and treatment 3 parameters.

	Always	*Sometimes*	*Never*
Baseline	1	98	1
Treatment 1	78	22	0
Treatment 2	70	30	0
Treatment 3	4	96	0

Table 19: *Intent* summary of treatments applied to scenario 2.

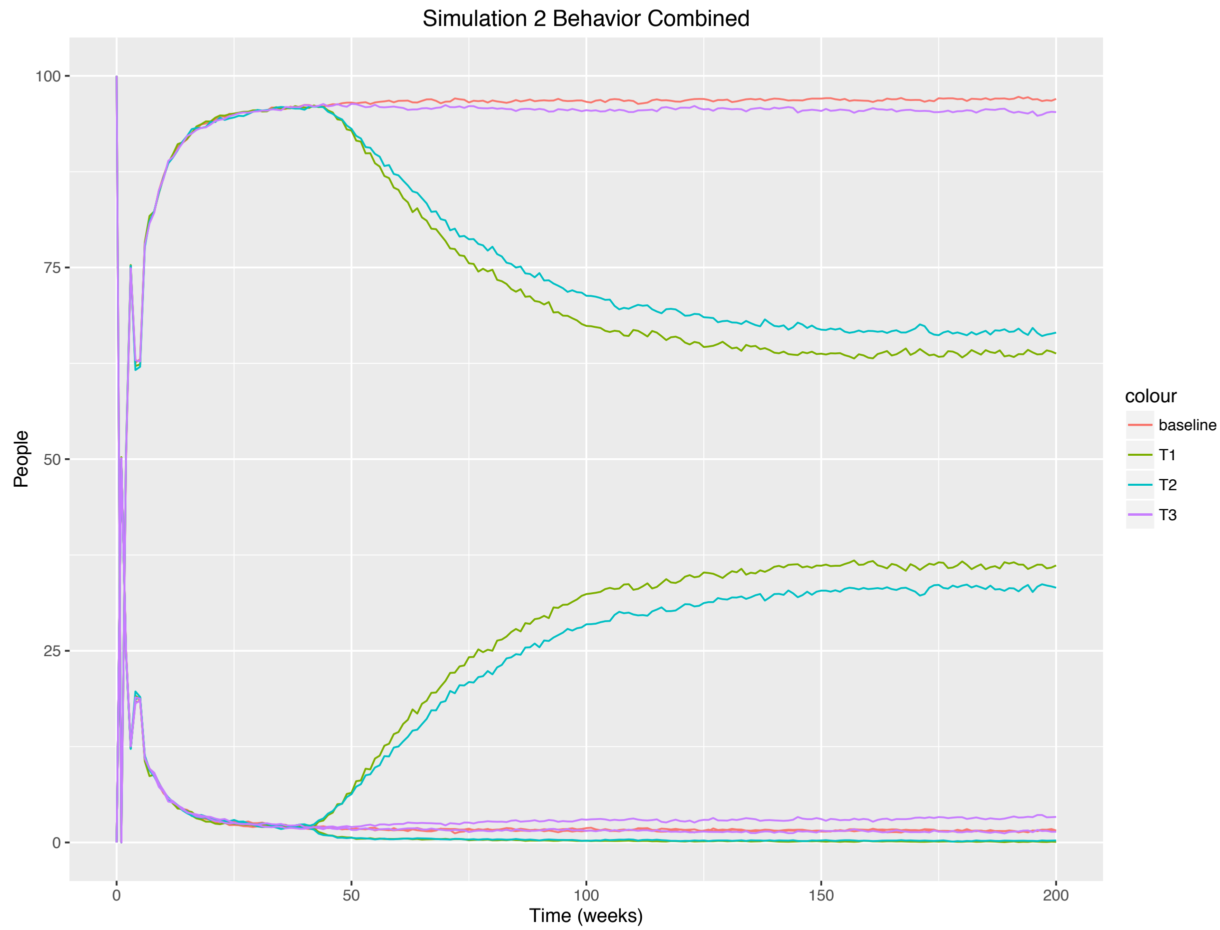


Figure 43: Average *Behavior* results from simulation 2 under baseline, treatment 1, treatment 2, and treatment 3 parameters.

	Always	*Sometimes*	*Never*
Baseline	2	96	2
Treatment 1	36	64	0
Treatment 2	33	67	0
Treatment 3	3	92	2

Table 20: *Behavior* summary of treatments applied to scenario 2.

Conclusion

Recycling behavior is impacted by a person's *Attitude*, *Subjective Norm*, *Perceived Behavioral Control*, *Accessibility of Recycling Bins,* and *Social Pressure*. The STELLA model confirms the causal relationships between these factors that Taylor and Todd's structural equation model claims. In the three phases of recycling program (no program, new program, established program) the biggest impact on behavior is physical barriers to recycling. The most effective methods to increasing recycling behavior are moral-based education and process-based education.

Scenario Behavior

Recycling behavior is most limited by a person's accessibility to recycling bins. Physical barriers impact the intent-behavior gap, which means that even when a person always intends to recycle, if their accessibility is 0.5 they can only recycle half of the time because their physical options are limited. This parameter is tested in the scenario tests that examined the three phases of recycling program. Although *Attitude, Subjective Norm,* and *Perceived Behavioral Control* inputs are adjusted according to Taylor and Todd's empirical work, those changes were not large enough to initiate substantial differences between steady states for the different scenarios. Accessibility to recycling bins is set equal to one for scenarios 1 and 2 and equal to 0.5 for scenario 3. That change proved a significant hurdle to the population in scenario 3 and shifted about 80% of the population to the "never recycle" *Behavior* category.

The different scenarios that were simulated using the STELLA model offered insight into the main phases of adapting pro-environmental behavior. Each of the scenarios represents a different phase: no recycling program, a new recycling program, and a well-established recycling program. The steady states of these scenarios showed that physical accessibility of recycling bins, or the existence of a recycling program, is the dominant driver of *Intent* and *Behavior*. The results from scenario 3 showed that without a recycling program, the intent-behavior gap caused a dampening in behavior. Even if people thought recycling was important, the difficulty of doing so was discouraging and ultimately fed back and reduced the population's *Intent* to recycle.

A main take away from this analysis is that there is not a huge difference between scenario 1 and 2—the new and well-established recycling programs. This indicates that the shift in *Intent* and *Behavior*, as demonstrated by the significant difference in scenario 3, occurs when a recycling program is established and reaches its full peak relatively quickly. This means that when a recycling program is established in a community, the *Intent* and *Behavior* of that group of people changes around it and remains relatively constant over time. This is aligned with the empirical research that Taylor and Todd did because they did not find huge changes in population morals when examining the difference between a new and well-established program.

Treatment Implications

Normative education and process-based education are effective ways to increase a population's recycling *Intent* and *Behavior*. The treatment analysis examined the impact of three types of education and marketing strategy on recycling intent and behavior. When applied to scenarios 1 and 2, the well-established and new recycling programs, treatments 1 and 2 proved more impactful. Treatment 1 is moral-based education, for example, signs, marketing, and pamphlets contain information and arguments that emphasize why recycling is moral. Treatment 2 is process-based education, which means signs, marketing, and pamphlets focus on explaining what to recycle and how a single action compounds into larger change. These treatments out performed treatment 3, which is a life style marketing campaign.

This analysis shows the benefit of effective educational programs or campaigns to supplementing the baseline *Intent* and *Behavior* of a population. The scenario analysis provided and understanding of the foundational behavior of each population. The treatment analysis offers methods and points of intervention based on the scenario.

If there are no physical barriers to recycling, then moral-based or process-based education is an effective strategy for increasing the recycling behavior in a community. In scenario 1, when there is a well-established recycling program, treatments 1 and 2 each increased the number of people always intending to recycle by about 60 and the number of people always recycling by about 30. In scenario 2, when there is a new recycling program, treatments 1 and 2 each increased the number of people always intending to recycle by about 60 and the number of people always recycling by about 30. As discussed in the scenario analysis, the difference between scenario 1 and scenario 2 parameters of *Attitude, Subjective Norm,* and *Perceived Behavioral Control* are not different enough to generate significantly distinct steady states for scenario 1 and 2. The results to the treatment analysis indicate that the same high levels of recycle *Behavior* can be achieved in both scenario 1 and 2 by using treatment 1 or 2. This means that the age of a recycling program is not important in the effectiveness of educational campaigns.

STELLA and System Dynamics as a way to address PEB

STELLA proved to be a very useful tool for modeling recycling behavior at an individual and population level. This method allowed for the complete structural equation model work that Taylor and Todd published to be modeled. Although the level of detail that was included was perhaps not necessary, this method allowed every factor and connection to be included. The operationalization of latent variables is very hard and very rare, but STELLA allowed me to do it. Informed by the structure and path coefficients of structural equation model work, system dynamics is a powerful tool that can be applied to make complex behavioral motivation problems.

A major benefit of using STELLA in this work is that ease with which it allows treatment testing and parameter design. By designing a used interface, this model is accessible to everyone. An interface was built to allow policy makers, researchers, students, or activists to interact with the model. They can choose the starting scenario, define their population characteristics and test the impact of different treatments. STELLA allows this model to be simultaneously complex and comprehensive.

Future Work

The next step in this project is to expand the possible factors that influence intent and behavior. I propose integrating socioeconomic factors into the next iteration of this model. Considering heterogeneity within the studied population would add another layer or reality. This feature would also allow the model to come to a bimodal equilibrium—when the model comes to a steady state with two distinct factions within the population. It would also be very interesting to explore the impact of demographic factors on a population's recycling intent and behavior. There are empirical studies on the impacts of race, age, and gender on Pro-Environmental Behavior, but the integration of these studies into a STELLA model would allow researchers to design and examine customized educational or marketing strategies. The model presented in this project provides a basic framework for studying how attitudes, norms, and perceptions effect recycling intent and behavior. Continued work could extend this framework to include a plethora of social, economic, ecological, or political factors that impact how people behave.

Researchers will continue to study why people act the way they do. Understanding human nature is a core motivator for many academics, especially those who look at environmental behavior. System dynamics is a very practical way of combining theoretical work on moral behavior and empirical studies of Pro-Environmental Behavior. In the future, I would opt for a higher-level STELLA model to supplement empirical work. For example, rather than include every survey question in the STELLA model, simplify it to the seven sub-sub factors. I think that the detail that was included in this model, while it had value in proving the method of using system dynamics methods on structural equation models, was ultimately more cumbersome than effective. System dynamics and STELLA are best at integrating different types of systems, so future work should seek to integrate ecological, economic, political, and social systems using STELLA as a tool to examine Pro-Environmental Behavior.

The application of system dynamics modeling and simulation is a powerful tool and should continue to be used to understand Pro-Environmental Behavior. The problems addressed in Pro-Environmental Behavior research are extremely complicated and system dynamics offers a helpful framework for breaking down problems and testing out potential solutions. STELLA allows one to understand complex human environmental behaviors while simultaneously exploring points and methods of intervention.

References

Ajzen, I. 1991. The theory of planned behavior. Organ. Behav. Hum. Dec. 50: 179–211.

Ajzen, I., & Fishbein, M. 1980. *Understanding attitudes and predicting social behavior.* Englewood Cliffs, NJ: Prentice-Hall.

Anderson, M. W. 2012. New Ecological Paradigm (NEP) Scale. *The Berkshire Encyclopedia of Sustainability: Measurements, Indicators, and Research Methods for Sustainability*. 260-262.

Bamberg, S. & Moser G. 2006. Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behavior. Journal of Environmental Psychology. 27: 14-25.

Black, J.S., P.C. Stern & J.T. Elworth. 1985. Personal and contextual influences on household energy adaptations. J. Appl. Psychol. 70: 3–21.

Carrier, J. G. 2004. Anderson, David G., and Berglund, Eeva (eds). 2003. Ethnographies of Conservation. Environmentalism and the Distribution of Privilege. Oxford: Berghahn. Social Anthropology, 12(3), 373-374.

Dunlap, R.E. & K.D. Van Liere. 1978. The new environmental paradigm. J. Environ. Educ. 9: 10–19.

Guagnano, G.A., P.C. Stern & T. Dietz. 1995. Influences on attitude-behavior relationships: a natural experiment with curbside recycling. Environ. Behav. 27: 699–718.

Hines, J. M., Hungerford. H. R., & Tomera, A. N. 1986. Analysis and Synthesis of Research on Responsible Environmental Behavior: A Meta-Analysis. Journal of Environmental Education. 18(2):1-8.

Isee System, The World Leader in System Thinking Software. 2015. http://www.iseesystems.com (accessed 15 December 2015).

Kollmuss, A. & Agyeman, J. 2002. Mind the Gap: why do people act environmentally and what are the barriers to pro-environmental behavior? Environmental Education Research. 8(3): 239-260.

Oni, S. K., Dillon, P. J., Metcalfe, R.A., & Futter, M.N. 2012. Dynamic Modeling of the Impact of Climate Change and Power Flow Management Options using STELLA: Application to the Steephill Falls Reservoir, Ontario, Canada. Canadian Water Resources Journal. 37(2): 125-148.

Ouyang, Y., Zhang, J., Leininger, T. D., & Frey, B. 2015. A STELLA Model to Estimate Water and Nitrogen Dynamics in a Short-Rotation Woody Crop Plantation. Journal of Environmental Quality. 44(1).

Ouyang, Y. 2008. Modeling the mechanisms for uptake and translocation of dioxane in a soil-plant ecosystem with STELLA. *Journal of Contaminant Hydrology,95*(1), 17-29.

Park, J., & Ha, S. 2012. Understanding pro-environmental behavior. International Journal of Retail & Distribution Management. 40(5): 388-403.

Schwartz, S.H. 1970. Elicitation of moral obligation and self-sacrificing behavior: an experimental study of volunteering to be a bone marrow donor. J. Pers. Soc. Psychol. 15: 283–293.

Schwartz, S. 1973. Normative explanations of helping behavior: A critique, proposal, and empirical test1. *Journal of Experimental Social Psychology, 9*(4), 349-364.

Schwartz, S.H. 1977. Normative influences on altruism. Adv. Exp. Soc. Psychol. 10: 221–279.

Schwartz, S.H. 1994. Are there universal aspects in the structure and contents of human values? J. Soc. Issues. 50: 19–45.

Semeniuk, C., Haider, W., Cooper, A., & Rothley, K. 2010. A linked model of animal ecology and human behavior for the management of wildlife tourism. Ecological Modelling. 221(22): 2699-2713

Stern, P.C., T. Dietz & L. Kalof. 1993. Value orientations, gender, and environmental concern. Environ. Behav. 25: 322–348.

Stern, P.C. et al. 1999. A value-belief-norm theory of support for social movements: the case of environmentalism. Hum. Ecol. Rev. 6: 81–97.

Taylor, S., & Todd, P. 1995. An integrated model of waste management behavior: A test of household recycling and composting intentions. *Environment and Behavior, 27*(5), 603-630.

Turaga, R., Howarth, R., & Borsuk, M. 2010. Pro-environmental behavior: Rational choice meets moral motivation. Annals of the New York Academy of Sciences. 1185: 211-224.

Van Liere, K.D. & R.E. Dunlap. 1978. Moral norms and environmental behavior: an application of Schwartz's norm-activation model to yard burning. J. Appl. Soc. Psychol. 8: 174–188.

Weller, F., Cecchini, L., Shannon, L., Sherley, R.B., Crawford, R., Altwegg, R., Scott, L., Stewart, T., & Jarre A. 2014. A system dynamics approach to modelling multiple drivers of the African penguin population on Robben Island, South Africa. Ecological Modelling. 277:38-56.

Appendix A

Questionnaire from Taylor and Todd study (1995)

Relative Advantages

b_1 I will help to protect the environment by recycling (strongly disagree/strongly agree).

e_1 Helping to protect the environment is an (extremely unimportant/extremely important) part of my decision whether to recycle.

b_2 I will help to reduce our landfill waste by recycling (strongly disagree/strongly agree).

e_2 Helping to reduce our landfill waste is an (extremely unimportant/extremely important) part of my decision whether to recycle.

Complexity

b_3 Recycling is difficult (strongly disagree/strongly agree).

e_3 Whether or not recycling is difficult is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.

b_4 Recycling is easy (strongly disagree/strongly agree).

e_4 Whether or not recycling is easy is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.

Internal Normative Beliefs

nb_1 My family thinks that I should recycle (strongly disagree/strongly agree).

mc_1 With respect to waste management behaviors, I want to do what my family thinks I should do (strongly disagree/strongly agree).

nb_2 People in my household think that I should recycle (strongly disagree/strongly agree).

mc_2 With respect to waste management behaviors, I want to do what the people in my household think I should do (strongly disagree/strongly agree).

External Normative Beliefs

nb_3 My friends think that I should recycle (strongly disagree/strongly agree).

mc_3 With respect to waste management behaviors, I want to do what my friends thinks I should do (strongly disagree/strongly agree).

nb_4 My neighbors think that I should recycle (strongly disagree/strongly agree).

mc_4 With respect to waste management behaviors, I want to do what my neighbors thinks I should do (strongly disagree/strongly agree).

Self-Efficacy

cb_1 I cannot figure out what is and what is not to be recycled (strongly disagree/strongly agree).

pf_1 Being able to figure out what is to be recycled is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.

cb_2 I do not what know what should be recycled (strongly disagree/strongly agree).

pf_2 Knowing what should be recycled is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.

cb_3 I cannot figure out how to recycle effectively (strongly disagree/strongly agree).

pf_3 Figuring out how to recycle effectively is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.

Resource-Facilitating Conditions

cb_4 I have convenient access to a blue box (strongly disagree/strongly agree).

pf_4 Having convenient access to a blue box is an (extremely unimportant/extremely important) part of my decision whether to recycle.

Compatibility

cb_5 Recycling does not fit with my lifestyle (strongly disagree/strongly agree).

pf_5 Whether or not recycling fits with my lifestyle is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.

cb_6 Recycling is inconvenient (strongly disagree/strongly agree).

pf_6 Whether or not recycling is inconvenient is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.

cb_7 I do not have time to recycle (strongly disagree/strongly agree).

pf_7 Having the time to recycle is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.

cb_8 Recycling does not fit with my daily routine (strongly disagree/strongly agree).

pf_8 Whether or not recycling fits with my daily routine is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.

cb_9 For me, recycling take too much effort (strongly disagree/strongly agree).

pf_9 Whether or not recycling takes too much effort is an (extremely unimportant/extremely important) part of my decision whether to engage in this behavior.

Appendix B

Full equation list of baseline model:

Stocks, Flows, and Conveyers:

Always_recycles[Small_Pop](t) = Always_recycles[Small_Pop](t - dt) + (sometimes_to_always_behavior[Small_Pop] - always_to_sometimes_behavior[Small_Pop]) * dt

INIT Always_recycles[Small_Pop] = 0
INFLOWS: sometimes_to_always_behavior[Small_Pop] = IF (.75<percent_recycling) THEN 1 ELSE IF behavior_pulse_up_switch=1 THEN behavior_pulse_up ELSE 0
OUTFLOWS: always_to_sometimes_behavior[Small_Pop] = IF (percent_recycling<.75) THEN 1 ELSE IF behavior_pulse_down_switch=1 THEN behavior_pulse_down ELSE 0

Intent:_always[Small_Pop](t) = Intent:_always[Small_Pop](t - dt) + (sometimes_to_always[Small_Pop] - always_to_sometimes[Small_Pop]) * dt

INIT Intent:_always[Small_Pop] = 0
INFLOWS: sometimes_to_always[Small_Pop] = IF (1 < Intent) OR (Always_convayer_intent=10) THEN Intent:_sometimes ELSE IF intent_pulse_up_swtich=1 THEN intent_pulse_up ELSE 0
OUTFLOWS: always_to_sometimes[Small_Pop] = IF (sometimes_convayer_intent=10) OR (never_convayer_intent=10) THEN Intent:_always ELSE IF intent_pulse_down_switch=1 THEN intent_pulse_down ELSE 0

Intent:_never[Small_Pop](t) = Intent:_never[Small_Pop](t - dt) + (sometimes__to_never[Small_Pop] - never_to_sometimes[Small_Pop]) * dt

INIT Intent:_never[Small_Pop] = 0
INFLOWS: sometimes__to_never[Small_Pop] = IF(Intent<-1) OR (never_convayer_intent=10) THEN Intent:_sometimes ELSE IF intent_pulse_down_switch=1 THEN intent_pulse_down ELSE 0
OUTFLOWS: never_to_sometimes[Small_Pop] = IF (sometimes_convayer_intent=10) OR (Always_convayer_intent=10) THEN Intent:_never ELSE IF intent_pulse_up_swtich=1 THEN intent_pulse_up ELSE 0

Intent:_sometimes[Small_Pop](t) = Intent:_sometimes[Small_Pop](t - dt) + (never_to_sometimes[Small_Pop] + always_to_sometimes[Small_Pop] - sometimes_to_always[Small_Pop] - sometimes__to_never[Small_Pop]) * dt

INIT Intent:_sometimes[Small_Pop] = 1
INFLOWS: never_to_sometimes[Small_Pop] = IF (sometimes_convayer_intent=10) OR (Always_convayer_intent=10) THEN Intent:_never ELSE IF intent_pulse_up_swtich=1 THEN intent_pulse_up ELSE 0
always_to_sometimes[Small_Pop] = IF (sometimes_convayer_intent=10) OR (never_convayer_intent=10) THEN Intent:_always ELSE IF intent_pulse_down_switch=1 THEN intent_pulse_down ELSE 0

OUTFLOWS: sometimes_to_always[Small_Pop] = IF (1 < Intent) OR (Always_convayer_intent=10) THEN Intent:_sometimes ELSE IF intent_pulse_up_swtich=1 THEN intent_pulse_up ELSE 0
sometimes__to_never[Small_Pop] = IF(Intent<-1) OR (never_convayer_intent=10) THEN Intent:_sometimes ELSE IF intent_pulse_down_switch=1 THEN intent_pulse_down ELSE 0

Never_Recycles[Small_Pop](t) = Never_Recycles[Small_Pop](t - dt) + (sometimes_to__never_behavior[Small_Pop] - never_to_sometimes_behavior[Small_Pop]) * dt

INIT Never_Recycles[Small_Pop] = 0
INFLOWS: sometimes_to__never_behavior[Small_Pop] = IF (percent_recycling<.25) THEN 1 ELSE IF behavior_pulse_down_switch=1 THEN behavior_pulse_down ELSE 0
OUTFLOWS: never_to_sometimes_behavior[Small_Pop] = IF (.25 < percent_recycling) THEN 1 ELSE IF behavior_pulse_up_switch=1 THEN behavior_pulse_up ELSE 0

Not_Recycling[Small_Pop](t) = Not_Recycling[Small_Pop](t - dt) + (behavior:_not_recycling[Small_Pop] - decaying_mem_not_recycling[Small_Pop]) * dt

INIT Not_Recycling[Small_Pop] = 1-Recycling
INFLOWS: behavior:_not_recycling[Small_Pop] = IF(Monte_Carlo_Recycling=0) THEN 1 ELSE 0
OUTFLOWS: decaying_mem_not_recycling[Small_Pop] = Not_Recycling/Salience

Recycling[Small_Pop](t) = Recycling[Small_Pop](t - dt) + (behavior:_recycling[Small_Pop] - decaying_mem_recycling[Small_Pop]) * dt

INIT Recycling[Small_Pop] = Monte_Carlo_Recycling
INFLOWS: behavior:_recycling[Small_Pop] = IF(Monte_Carlo_Recycling=1) THEN 1 ELSE 0
OUTFLOWS: decaying_mem_recycling[Small_Pop] = Recycling/Salience

Sometimes_recycles[Small_Pop](t) = Sometimes_recycles[Small_Pop](t - dt) + (never_to_sometimes_behavior[Small_Pop] + always_to_sometimes_behavior[Small_Pop] - sometimes_to_always_behavior[Small_Pop] - sometimes_to__never_behavior[Small_Pop]) * dt

INIT Sometimes_recycles[Small_Pop] = 1
INFLOWS: never_to_sometimes_behavior[Small_Pop] = IF (.25 < percent_recycling) THEN 1 ELSE IF behavior_pulse_up_switch=1 THEN behavior_pulse_up ELSE 0
always_to_sometimes_behavior[Small_Pop] = IF (percent_recycling<.75) THEN 1 ELSE IF behavior_pulse_down_switch=1 THEN behavior_pulse_down ELSE 0
OUTFLOWS: sometimes_to_always_behavior[Small_Pop] = IF (.75<percent_recycling) THEN 1 ELSE IF behavior_pulse_up_switch=1 THEN behavior_pulse_up ELSE 0
sometimes_to__never_behavior[Small_Pop] = IF (percent_recycling<.25) THEN 1 ELSE IF behavior_pulse_down_switch=1 THEN behavior_pulse_down ELSE 0

Always_convayer_intent[Small_Pop](t) = Always_convayer_intent[Small_Pop](t - dt) + (always_inflow[Small_Pop] - always_outflow[Small_Pop]) * dt

INIT Always_convayer_intent[Small_Pop] = 0
TRANSIT TIME = 10
CAPACITY = INF
INFLOW LIMIT = INF
INFLOWS: always_inflow[Small_Pop] = Always_recycles
OUTFLOWS: always_outflow[Small_Pop] = CONVEYOR OUTFLOW

Negative_Int_Change[Small_Pop](t) = Negative_Int_Change[Small_Pop](t - dt) + (neg_int_change[Small_Pop] - neg_int_outflow[Small_Pop]) * dt
INIT Negative_Int_Change[Small_Pop] = 0
TRANSIT TIME = 1
CAPACITY = INF
INFLOW LIMIT = INF
INFLOWS: neg_int_change[Small_Pop] = IF (Always_convayer_intent=10) AND (Intent:_sometimes=1) OR (Intent:_never=1) THEN 1 ELSE IF (sometimes_convayer_intent=10) AND (Intent:_never=1) THEN 1 ELSE 0
OUTFLOWS: neg_int_outflow[Small_Pop] = CONVEYOR OUTFLOW

never_convayer_intent[Small_Pop](t) = never_convayer_intent[Small_Pop](t - dt) + (never_inflow[Small_Pop] - never_outflow[Small_Pop]) * dt
INIT never_convayer_intent[Small_Pop] = 0
TRANSIT TIME = 10
CAPACITY = INF
INFLOW LIMIT = INF
INFLOWS: never_inflow[Small_Pop] = Never_Recycles
OUTFLOWS: never_outflow[Small_Pop] = CONVEYOR OUTFLOW

Positive_intent_change[Small_Pop](t) = Positive_intent_change[Small_Pop](t - dt) + (pos_intent_change[Small_Pop] - pos_int__outflow[Small_Pop]) * dt
INIT Positive_intent_change[Small_Pop] = 0
TRANSIT TIME = 1
CAPACITY = INF
INFLOW LIMIT = INF
INFLOWS: pos_intent_change[Small_Pop] = IF (never_convayer_intent=10) AND (Intent:_sometimes=1) OR (Intent:_always=1) THEN 1 ELSE IF (sometimes_convayer_intent=10) AND (Intent:_always=1) THEN 1 ELSE 0
OUTFLOWS: pos_int__outflow[Small_Pop] = CONVEYOR OUTFLOW

sometimes_convayer_intent[Small_Pop](t) = sometimes_convayer_intent[Small_Pop](t - dt) + (sometimes__inflow[Small_Pop] - sometimes__outflow[Small_Pop]) * dt
INIT sometimes_convayer_intent[Small_Pop] = 0
TRANSIT TIME = 10
CAPACITY = INF
INFLOW LIMIT = INF
INFLOWS: sometimes__inflow[Small_Pop] = Sometimes_recycles
OUTFLOWS: sometimes__outflow[Small_Pop] = CONVEYOR OUTFLOW

Converters:
accessibility_of__recycling_bins = 1
attitude:_RA_and_C[Small_Pop] = compexity+relative_advantage+RA_A__change
average_A = MEAN(attitude:_RA_and_C)
average_PBC = MEAN(PBC:__E_RFC_and_Co)
average_SN = MEAN(subjective_norms:_INB_and_ENB)
ave_intent = MEAN(Intent)
A_I_change[Small_Pop] = A_prop_change*Wa*.98
A_normalized[Small_Pop] = (attitude:_RA_and_C+A_I_change)/(4*9)
A_prop_change[Small_Pop] = delta_A/SD_A
b1_x_e1[Small_Pop] = input:_e1_norm*(input:_b1)
b2_x_e2[Small_Pop] = input:_e2_norm*(input:_b2)
b3_x_e3[Small_Pop] = (input:_b3*accessibility_of__recycling_bins)*input:_e3_norm
b4_x_e4[Small_Pop] = input:_e4_norm*(input:_b4*accessibility_of__recycling_bins)
behavior_pulse_down = GRAPH(TIME)
(0.00, 0.00), (1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.00), (26.0, 0.00), (27.0, 0.00), (28.0, 0.00), (29.0, 0.00), (30.0, 0.00), (31.0, 0.00), (32.0, 0.00), (33.0, 0.00), (34.0, 0.00), (35.0, 0.00), (36.0, 0.00), (37.0, 0.00), (38.0, 0.00), (39.0, 0.00), (40.0, 0.00), (41.0, 0.00), (42.0, 0.00), (43.0, 0.00), (44.0, 0.00), (45.0, 0.00), (46.0, 0.00), (47.0, 0.00), (48.0, 0.00), (49.0, 0.00), (50.0, 1.00), (51.0, 1.00), (52.0, 1.00), (53.0, 1.00), (54.0, 1.00), (55.0, 1.00), (56.0, 1.00), (57.0, 1.00), (58.0, 1.00), (59.0, 1.00), (60.0, 1.00), (61.0, 1.00), (62.0, 1.00), (63.0, 1.00), (64.0, 1.00), (65.0, 1.00), (66.0, 0.00), (67.0, 0.00), (68.0, 0.00), (69.0, 0.00), (70.0, 0.00), (71.0, 0.00), (72.0, 0.00), (73.0, 0.00), (74.0, 0.00), (75.0, 0.00), (76.0, 0.00), (77.0, 0.00), (78.0, 0.00), (79.0, 0.00), (80.0, 0.00), (81.0, 0.00), (82.0, 0.00), (83.0, 0.00), (84.0, 0.00), (85.0, 0.00), (86.0, 0.00), (87.0, 0.00), (88.0, 0.00), (89.0, 0.00), (90.0, 0.00), (91.0, 0.00), (92.0, 0.00), (93.0, 0.00), (94.0, 0.00), (95.0, 0.00), (96.0, 0.00), (97.0, 0.00), (98.0, 0.00), (99.0, 0.00), (100, 0.00)
behavior_pulse_down_switch = 0
behavior_pulse_up = GRAPH(TIME)
(0.00, 0.00), (1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.00), (26.0, 0.00), (27.0, 0.00), (28.0, 0.00), (29.0, 0.00), (30.0, 0.00), (31.0, 0.00), (32.0, 0.00), (33.0, 0.00), (34.0, 0.00), (35.0, 0.00), (36.0, 0.00), (37.0, 0.00), (38.0, 0.00), (39.0, 0.00), (40.0, 0.00), (41.0, 0.00), (42.0, 0.00), (43.0, 0.00), (44.0, 0.00), (45.0, 0.00), (46.0, 0.00), (47.0, 0.00), (48.0, 0.00), (49.0, 0.00), (50.0, 1.00), (51.0, 1.00), (52.0, 1.00), (53.0, 1.00), (54.0, 1.00), (55.0, 1.00), (56.0, 1.00), (57.0, 1.00), (58.0, 1.00), (59.0, 1.00), (60.0, 1.00), (61.0, 1.00), (62.0, 1.00), (63.0, 1.00), (64.0, 1.00), (65.0, 1.00), (66.0, 0.00), (67.0, 0.00), (68.0, 0.00), (69.0, 0.00), (70.0, 0.00), (71.0, 0.00), (72.0, 0.00), (73.0, 0.00), (74.0, 0.00), (75.0, 0.00), (76.0, 0.00), (77.0, 0.00), (78.0, 0.00), (79.0, 0.00), (80.0, 0.00), (81.0, 0.00), (82.0, 0.00), (83.0, 0.00), (84.0, 0.00), (85.0, 0.00), (86.0, 0.00), (87.0, 0.00), (88.0, 0.00), (89.0, 0.00), (90.0, 0.00), (91.0, 0.00), (92.0, 0.00), (93.0, 0.00), (94.0, 0.00), (95.0, 0.00), (96.0, 0.00), (97.0, 0.00), (98.0, 0.00), (99.0, 0.00), (100, 0.00)
behavior_pulse_up_switch = 0

cb1_x_pf1[Small_Pop] = input:_cb1*input:_pf1__norm
cb2_x_pf2[Small_Pop] = input:_cb2*input:_pf2__norm
cb3_x_pf3[Small_Pop] = input:_cb3*input:_pf3__norm
cb4_x_pf4[Small_Pop] = input:_cb4*input:_pf4__norm
cb5_x_pf5[Small_Pop] = input:_cb5*input:_pf5__norm
cb6_x_pf6[Small_Pop] = input:_cb6*input:_pf6__norm
cb7_x_pf7[Small_Pop] = input:_cb7*input:_pf7__norm
cb8_x_pf8[Small_Pop] = input:_cb8*input:_pf8_norm
cb9_x_pf9[Small_Pop] = input:_cb9*input:_pf_norm
change_in_b1[Small_Pop] = IF (pos_intent_change=1) THEN 1 ELSE IF (neg_int_change=1) THEN -1 ELSE 0
change_in_b2[Small_Pop] = IF (pos_intent_change=1) THEN 1 ELSE IF (neg_int_change=1) THEN -1 ELSE 0
change_in_nb3[Small_Pop] = IF (Total_Pos_change=5) THEN 1 ELSE IF (Total_Neg_change=5) THEN -1 ELSE 0
change_in_nb4[Small_Pop] = IF (Total_Pos_change=5) THEN 1 ELSE IF (Total_Neg_change=5) THEN -1 ELSE 0
Compatibility[Small_Pop] = cb5_x_pf5+cb6_x_pf6+cb7_x_pf7+cb8_x_pf8+cb9_x_pf9
compexity[Small_Pop] = b3_x_e3+b4_x_e4
Co_PBC_change[Small_Pop] = Co_prop_change*W_Co*1.36
Co_prop_change[Small_Pop] = delta_Co/SD_Co
delta_A[Small_Pop] = attitude:_RA_and_C-previous_A
delta_Co[Small_Pop] = Compatibility-prev_Co
delta_E[Small_Pop] = Efficacy-prev_E
delta_ENB[Small_Pop] = External_Norm_Beliefs-prev_ENB
delta_INB[Small_Pop] = Internal_Norm_Beliefs-prev_INB
delta_PBC[Small_Pop] = PBC:__E_RFC_and_Co-prev_PBC
delta_RA[Small_Pop] = relative_advantage-prev_rel_adv
delta_RFC[Small_Pop] = ResourceFacilitating_Conditions-prev_RFC
delta_SN[Small_Pop] = subjective_norms:_INB_and_ENB-prev_SN
Efficacy[Small_Pop] = cb1_x_pf1+cb2_x_pf2+cb3_x_pf3
ENB_prop_change[Small_Pop] = delta_ENB/SD_ENB
External_Norm_Beliefs[Small_Pop] = nb3_x_mc3+nb4_x_mc4
E_PBC__change[Small_Pop] = E_prop_change*W_E*1.38
E_prop_change[Small_Pop] = delta_E/SD_E
graphical_switch = 0
INB_prop_change[Small_Pop] = delta_INB/SD_INB
input:_b1[Small_Pop] = GRAPH(INIT(normal_b1) + change_in_b1)(-9.00, -9.00), (9.00, 9.00)
input:_b2[Small_Pop] = GRAPH(INIT(normal_b2) + change_in_b2)(-9.00, -9.00), (9.00, 9.00)
input:_b3[Small_Pop] = GRAPH(INIT(normal_b3)) (-9.00, -9.00), (9.00, 9.00)
input:_b4[Small_Pop] = GRAPH(INIT(normal_b4)) (-9.00, -9.00), (9.00, 10.0)
input:_cb1[Small_Pop] = GRAPH(INIT(normal_cb1)) (-9.00, 9.00), (9.00, -9.00)
input:_cb2[Small_Pop] = GRAPH(INIT(normal_cb2)) (-9.00, 9.00), (9.00, -9.00)
input:_cb3[Small_Pop] = GRAPH(INIT(normal_cb3)) (-9.00, 9.00), (9.00, -9.00)
input:_cb4[Small_Pop] = GRAPH(INIT(normal_cb4)*accessibility_of__recycling_bins) (-9.00, -9.00), (9.00, 9.00)

input:_cb5[Small_Pop] = GRAPH(INIT(normal_cb5)) (-9.00, 9.00), (9.00, -9.00)
input:_cb6[Small_Pop] = GRAPH(INIT(normal_cb6) * accessibility_of__recycling_bins) (-9.00, 9.00), (9.00, -9.00)
input:_cb7[Small_Pop] = GRAPH(INIT(normal_cb7)) (-9.00, 9.00), (9.00, -9.00)
input:_cb8[Small_Pop] = GRAPH(INIT(normal_cb8)) (-9.00, 9.00), (9.00, -9.00)
input:_cb9[Small_Pop] = GRAPH(INIT(normal_cb9)) (-9.00, 9.00), (9.00, -9.00)
input:_e1[Small_Pop] = GRAPH(INIT(normal_e1)) (-9.00, -9.00), (9.00, 9.00)
input:_e1_norm[Small_Pop] = GRAPH(input:_e1) (-9.00, 0.00), (9.00, 1.00)
input:_e2[Small_Pop] = GRAPH(INIT(normal_e2)) (-9.00, -9.00), (9.00, 9.00)
input:_e2_norm[Small_Pop] = GRAPH(input:_e2) (-9.00, 0.00), (9.00, 1.00)
input:_e3[Small_Pop] = GRAPH(INIT(normal_e3)) (-9.00, -9.00), (9.00, 9.00)
input:_e3_norm[Small_Pop] = GRAPH(input:_e3) (-9.00, 0.00), (9.00, 1.00)
input:_e4[Small_Pop] = GRAPH(INIT(normal_e4)) (-9.00, -9.00), (9.00, 9.00)
input:_e4_norm[Small_Pop] = GRAPH(input:_e4) (-9.00, 0.00), (9.00, 1.00)
input:_mc1[Small_Pop] = GRAPH(INIT(normal_mc1)) (-21.0, 0.00), (21.0, 0.00)
input:_mc1__norm[Small_Pop] = GRAPH(input:_mc1) (-21.0, 0.00), (21.0, 1.00)
input:_mc2[Small_Pop] = GRAPH(INIT(normal_mc2)) (-21.0, -21.0), (21.0, 21.0)
input:_mc2__norm[Small_Pop] = GRAPH(input:_mc2) (-21.0, 0.00), (21.0, 1.00)
input:_mc3[Small_Pop] = GRAPH(INIT(normal_mc3)) (-21.0, -21.0), (21.0, 21.0)
input:_mc3__norm[Small_Pop] = GRAPH(input:_mc3) (-21.0, 0.00), (21.0, 1.00)
input:_mc4[Small_Pop] = GRAPH(INIT(normal_mc4)) (-21.0, -21.0), (21.0, 21.0)
input:_mc4_norm[Small_Pop] = GRAPH(input:_mc4) (-21.0, 0.00), (21.0, 1.00)
input:_nb1[Small_Pop] = GRAPH(INIT(normal_nb1)) (-21.0, -21.0), (21.0, 21.0)
input:_nb2[Small_Pop] = GRAPH(INIT(normal_nb2)) (-21.0, -21.0), (21.0, 21.0)
input:_nb3[Small_Pop] = GRAPH(INIT(normal_nb3) + change_in_nb3) (-21.0, -21.0), (21.0, 21.0)
input:_nb4[Small_Pop] = GRAPH(INIT(normal_nb4) + change_in_nb4) (-21.0, -21.0), (21.0, 21.0)
input:_pf1[Small_Pop] = GRAPH(INIT(normal_pf1)) (-9.00, -9.00), (9.00, 9.00)
input:_pf1__norm[Small_Pop] = GRAPH(input:_pf1) (-9.00, 0.00), (9.00, 1.00)
input:_pf2[Small_Pop] = GRAPH(INIT(normal_pf2)) (-9.00, -9.00), (9.00, 9.00)
input:_pf2__norm[Small_Pop] = GRAPH(input:_pf2) (-9.00, 0.00), (9.00, 1.00)
input:_pf3[Small_Pop] = GRAPH(INIT(normal_pf3)) (-9.00, -9.00), (9.00, 9.00)
input:_pf3__norm[Small_Pop] = GRAPH(input:_pf3) (-9.00, 0.00), (9.00, 1.00)
input:_pf4[Small_Pop] = GRAPH(INIT(normal_pf4)) (-9.00, -9.00), (9.00, 9.00)
input:_pf4__norm[Small_Pop] = GRAPH(input:_pf4) (-9.00, 0.00), (9.00, 1.00)
input:_pf5[Small_Pop] = GRAPH(INIT(normal_pf5)) (-9.00, -9.00), (9.00, 9.00)
input:_pf5__norm[Small_Pop] = GRAPH(input:_pf5) (-9.00, 0.00), (9.00, 1.00)
input:_pf6[Small_Pop] = GRAPH(INIT(normal_pf6)) (-9.00, -9.00), (9.00, 9.00)
input:_pf6__norm[Small_Pop] = GRAPH(input:_pf6) (-9.00, 0.00), (9.00, 1.00)
input:_pf7[Small_Pop] = GRAPH(INIT(normal_pf7)) (-9.00, -9.00), (9.00, 9.00)
input:_pf7__norm[Small_Pop] = GRAPH(input:_pf7) (-9.00, 0.00), (9.00, 1.00)
input:_pf8[Small_Pop] = GRAPH(INIT(normal_pf8)) (-9.00, -9.00), (9.00, 9.00)
input:_pf8_norm[Small_Pop] = GRAPH(input:_pf8) (-9.00, 0.00), (9.00, 1.00)
input:_pf9[Small_Pop] = GRAPH(INIT(normal_pf9)) (-9.00, -9.00), (9.00, 9.00)
input:_pf_norm[Small_Pop] = GRAPH(input:_pf9) (-9.00, 0.00), (9.00, 1.00)

Intent[Small_Pop] = A_normalized+SN_normalized+PBC_normalized
intent_pulse_down = GRAPH(TIME)
(0.00, 0.00), (1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.00), (26.0, 0.00), (27.0, 0.00), (28.0, 0.00), (29.0, 0.00), (30.0, 0.00), (31.0, 0.00), (32.0, 0.00), (33.0, 0.00), (34.0, 0.00), (35.0, 0.00), (36.0, 0.00), (37.0, 0.00), (38.0, 0.00), (39.0, 0.00), (40.0, 0.00), (41.0, 0.00), (42.0, 0.00), (43.0, 0.00), (44.0, 0.00), (45.0, 0.00), (46.0, 0.00), (47.0, 0.00), (48.0, 0.00), (49.0, 0.00), (50.0, 1.00), (51.0, 1.00), (52.0, 1.00), (53.0, 1.00), (54.0, 1.00), (55.0, 1.00), (56.0, 1.00), (57.0, 1.00), (58.0, 1.00), (59.0, 1.00), (60.0, 1.00), (61.0, 1.00), (62.0, 1.00), (63.0, 1.00), (64.0, 1.00), (65.0, 1.00), (66.0, 0.00), (67.0, 0.00), (68.0, 0.00), (69.0, 0.00), (70.0, 0.00), (71.0, 0.00), (72.0, 0.00), (73.0, 0.00), (74.0, 0.00), (75.0, 0.00), (76.0, 0.00), (77.0, 0.00), (78.0, 0.00), (79.0, 0.00), (80.0, 0.00), (81.0, 0.00), (82.0, 0.00), (83.0, 0.00), (84.0, 0.00), (85.0, 0.00), (86.0, 0.00), (87.0, 0.00), (88.0, 0.00), (89.0, 0.00), (90.0, 0.00), (91.0, 0.00), (92.0, 0.00), (93.0, 0.00), (94.0, 0.00), (95.0, 0.00), (96.0, 0.00), (97.0, 0.00), (98.0, 0.00), (99.0, 0.00), (100, 0.00)
intent_pulse_down_switch = 0
intent_pulse_up = GRAPH(TIME)
(0.00, 0.00), (1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.00), (26.0, 0.00), (27.0, 0.00), (28.0, 0.00), (29.0, 0.00), (30.0, 0.00), (31.0, 0.00), (32.0, 0.00), (33.0, 0.00), (34.0, 0.00), (35.0, 0.00), (36.0, 0.00), (37.0, 0.00), (38.0, 0.00), (39.0, 0.00), (40.0, 0.00), (41.0, 0.00), (42.0, 0.00), (43.0, 0.00), (44.0, 0.00), (45.0, 0.00), (46.0, 0.00), (47.0, 0.00), (48.0, 0.00), (49.0, 0.00), (50.0, 1.00), (51.0, 1.00), (52.0, 1.00), (53.0, 1.00), (54.0, 1.00), (55.0, 1.00), (56.0, 1.00), (57.0, 1.00), (58.0, 1.00), (59.0, 1.00), (60.0, 1.00), (61.0, 1.00), (62.0, 1.00), (63.0, 1.00), (64.0, 1.00), (65.0, 1.00), (66.0, 0.00), (67.0, 0.00), (68.0, 0.00), (69.0, 0.00), (70.0, 0.00), (71.0, 0.00), (72.0, 0.00), (73.0, 0.00), (74.0, 0.00), (75.0, 0.00), (76.0, 0.00), (77.0, 0.00), (78.0, 0.00), (79.0, 0.00), (80.0, 0.00), (81.0, 0.00), (82.0, 0.00), (83.0, 0.00), (84.0, 0.00), (85.0, 0.00), (86.0, 0.00), (87.0, 0.00), (88.0, 0.00), (89.0, 0.00), (90.0, 0.00), (91.0, 0.00), (92.0, 0.00), (93.0, 0.00), (94.0, 0.00), (95.0, 0.00), (96.0, 0.00), (97.0, 0.00), (98.0, 0.00), (99.0, 0.00), (100, 0.00)
intent_pulse_up_swtich = 0
Internal_Norm_Beliefs[Small_Pop] = nb1_x_mc1+nb2_x_mc2
max_intent = MAX(Intent[*])
min_intent = MIN(Intent[*])
Monte_Carlo_Recycling[Small_Pop] = IF (rand_num<= recycling_bin__adjusted_prob) THEN 1 ELSE 0
nb1_x_mc1[Small_Pop] = input:_mc1__norm*input:_nb1
nb2_x_mc2[Small_Pop] = input:_mc2__norm*input:_nb2
nb3_x_mc3[Small_Pop] = input:_mc3__norm*(input:_nb3)
nb4_x_mc4[Small_Pop] = input:_mc4_norm*input:_nb4
normal_b1[Small_Pop] = NORMAL(raw_emp_mean_b1,raw_emp__sd_b1)
normal_b2[Small_Pop] = NORMAL(raw_emp_mean_b2,raw_emp__sd_b2)
normal_b3[Small_Pop] = NORMAL(raw_emp_mean_b3,raw_emp__sd_b3)
normal_b4[Small_Pop] = NORMAL(raw_emp_mean_b4,raw_emp__sd_b4)

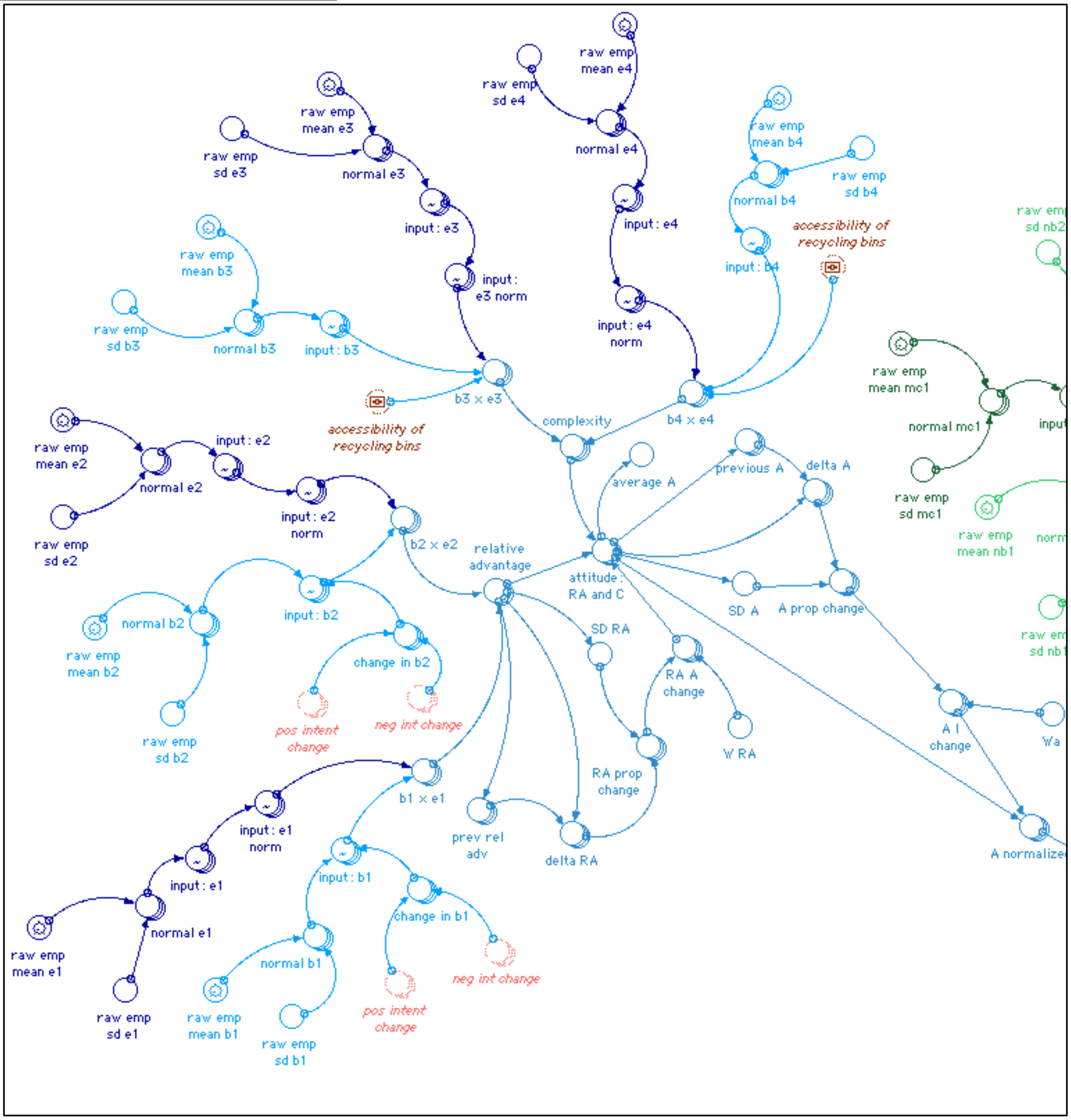
normal_cb1[Small_Pop] = NORMAL(raw_emp_mean_cb1,raw_emp_sd_cb1)
normal_cb2[Small_Pop] = NORMAL(raw_emp_mean_cb2,raw_emp_sd_cb2)
normal_cb3[Small_Pop] = NORMAL(raw_emp_mean_cb3,raw_emp_sd_cb3)
normal_cb4[Small_Pop] = NORMAL(raw_emp_mean_cb4,raw_emp_sd_cb4)
normal_cb5[Small_Pop] = NORMAL(raw_emp_mean_cb5,raw_emp_sd_cb5)
normal_cb6[Small_Pop] = NORMAL(raw_emp_mean_cb6,raw_emp_sd_cb6)
normal_cb7[Small_Pop] = NORMAL(raw_emp_mean_cb7,raw_emp_sd_cb7)
normal_cb8[Small_Pop] = NORMAL(raw_emp_mean_cb8,raw_emp_sd_cb8)
normal_cb9[Small_Pop] = NORMAL(raw_emp_mean_cb9,raw_emp_sd_cb9)
normal_e1[Small_Pop] = NORMAL(raw_emp_mean_e1,raw_emp_sd_e1)
normal_e2[Small_Pop] = NORMAL(raw_emp_mean_e2,raw_emp_sd_e2)
normal_e3[Small_Pop] = NORMAL(raw_emp_mean_e3,raw_emp_sd_e3)
normal_e4[Small_Pop] = NORMAL(raw_emp_mean_e4,raw_emp_sd_e4)
normal_mc1[Small_Pop] = NORMAL(raw_emp_mean_mc1,raw_emp_sd_mc1)
normal_mc2[Small_Pop] = NORMAL(raw_emp_mean_mc2,raw_emp_sd_mc2)
normal_mc3[Small_Pop] = NORMAL(raw_emp_mean_mc3,raw_emp_sd_mc3)
normal_mc4[Small_Pop] = NORMAL(raw_emp_mean_mc4,raw_emp_sd_mc4)
normal_nb1[Small_Pop] = NORMAL(raw_emp_mean_nb1,raw_emp__sd_nb1)
normal_nb2[Small_Pop] = NORMAL(raw_emp_mean_nb2,raw_emp__sd_nb2)
normal_nb3[Small_Pop] = NORMAL(raw_emp_mean_nb3,raw_emp__sd_nb3)
normal_nb4[Small_Pop] = NORMAL(raw_emp_mean_nb4,raw_emp__sd_nb4)
normal_pf1[Small_Pop] = NORMAL(raw_emp_mean_pf1,raw_emp_sd_pf1)
normal_pf2[Small_Pop] = NORMAL(raw_emp_mean_pf2,raw_emp_sd_pf2)
normal_pf3[Small_Pop] = NORMAL(raw_emp_mean_pf3,raw_emp_sd_pf3)
normal_pf4[Small_Pop] = NORMAL(raw_emp_mean_pf4,raw_emp_sd_pf4)
normal_pf5[Small_Pop] = NORMAL(raw_emp_mean_pf5,raw_emp_sd_pf5)
normal_pf6[Small_Pop] = NORMAL(raw_emp_mean_pf6,raw_emp_sd_pf6)
normal_pf7[Small_Pop] = NORMAL(raw_emp_mean_pf7,raw_emp_sd_pf7)
normal_pf8[Small_Pop] = NORMAL(raw_emp_mean_pf8,raw_emp_sd_pf8)
normal_pf9[Small_Pop] = NORMAL(raw_emp_mean_pf9,raw_emp_sd_pf9)
PBC:__E_RFC_and_Co[Small_Pop] =
Efficacy+E_PBC__change+ResourceFacilitating_Conditions+RFC_PBC_change+Compatibility
+Co_PBC_change
PBC_I_change[Small_Pop] = PBC_prop_change*Wpbc*.98
PBC_normalized[Small_Pop] = (PBC:__E_RFC_and_Co+PBC_I_change)/(9*9)
PBC_prop_change[Small_Pop] = delta_PBC/SD_PBC
percent_recycling[Small_Pop] = Recycling/(Recycling+Not_Recycling)
population_total_behavior:_always_recycles = SUM(Always_recycles)
population_total_behavior:_never_recycles = SUM(Never_Recycles)
population_total_behavior:_sometimes_recycles = SUM(Sometimes_recycles)
population_total_intent:_never = SUM(Intent:_never)
population_total_intent:__always = SUM(Intent:_always)
population_total_intent:__sometimes = SUM(Intent:_sometimes)
previous_A[Small_Pop] = PREVIOUS(attitude:_RA_and_C, INIT(attitude:_RA_and_C))
prev_Co[Small_Pop] = PREVIOUS(Compatibility, INIT(Compatibility))
prev_E[Small_Pop] = PREVIOUS(Efficacy, INIT(Efficacy))

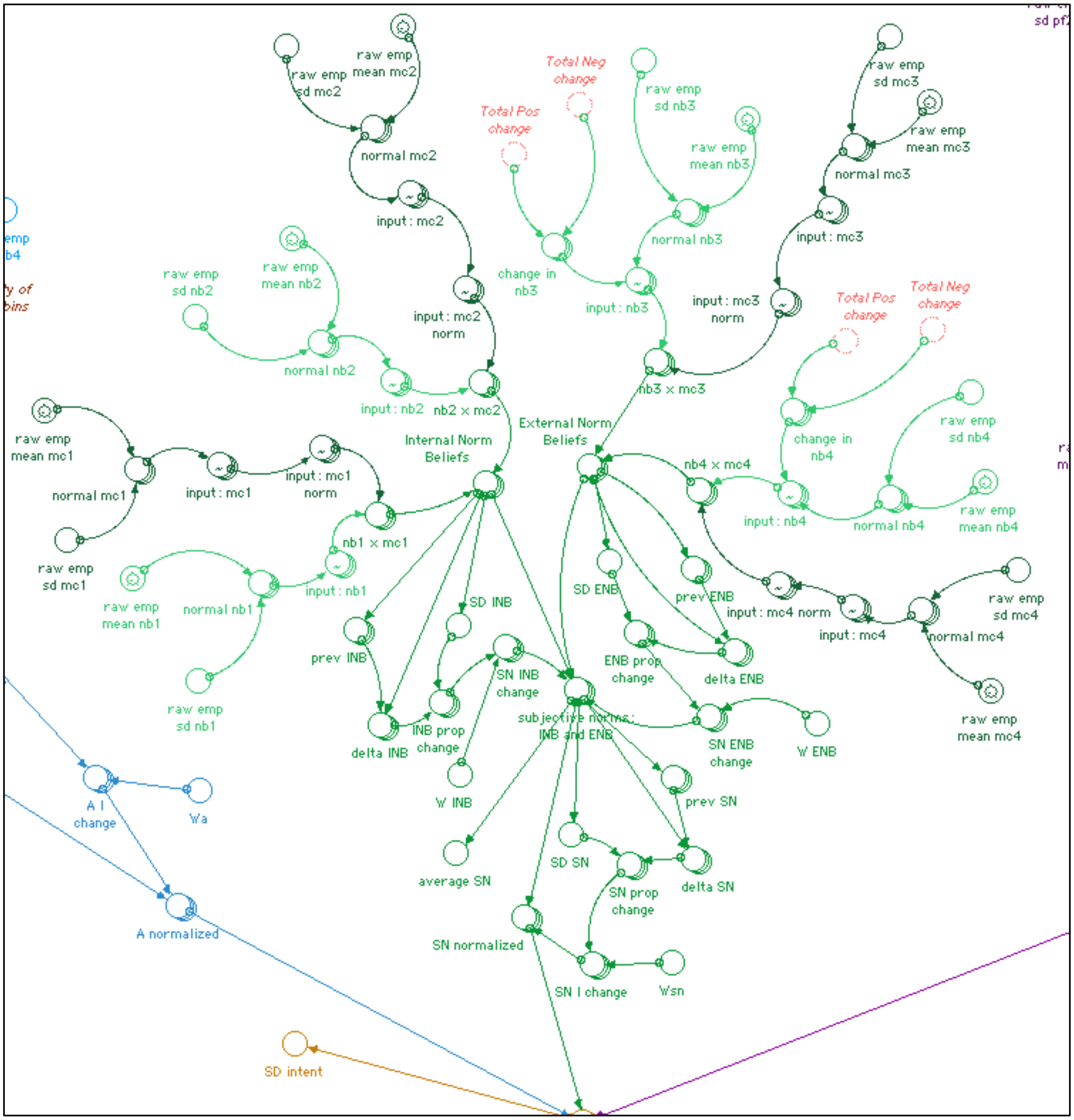
prev_ENB[Small_Pop] = PREVIOUS(External_Norm_Beliefs, INIT(External_Norm_Beliefs))
prev_INB[Small_Pop] = PREVIOUS(Internal_Norm_Beliefs, INIT(Internal_Norm_Beliefs))
prev_PBC[Small_Pop] = PREVIOUS(PBC:__E_RFC_and_Co, INIT(PBC:__E_RFC_and_Co))
prev_rel_adv[Small_Pop] = PREVIOUS(relative_advantage,INIT(relative_advantage))
prev_RFC[Small_Pop] = PREVIOUS(ResourceFacilitating_Conditions, INIT(ResourceFacilitating_Conditions))
prev_SN[Small_Pop] = PREVIOUS(subjective_norms:_INB_and_ENB, INIT(subjective_norms:_INB_and_ENB))
prob_of_recycling[Small_Pop] = IF(Intent:_never=1) THEN prob_of_recycling:_never ELSE IF (Intent:_sometimes=1) THEN prob_of_recycling:_sometimes ELSE IF (Intent:_always=1) THEN prob_of_recycling:_always ELSE 0
prob_of_recycling:_always = 0.75
prob_of_recycling:_never = 0.25
prob_of_recycling:_sometimes = 0.5
rand_num[Small_Pop] = RANDOM(0,1)
raw_emp_mean_b1 = 6.99
raw_emp_mean_b2 = 6.99
raw_emp_mean_b3 = 1.51
raw_emp_mean_b4 = 1.51
raw_emp_mean_cb1 = -0.01
raw_emp_mean_cb2 = -0.01
raw_emp_mean_cb3 = -0.01
raw_emp_mean_cb4 = -1.99
raw_emp_mean_cb5 = 3.18
raw_emp_mean_cb6 = 3.18
raw_emp_mean_cb7 = 3.18
raw_emp_mean_cb8 = 3.18
raw_emp_mean_cb9 = 3.18
raw_emp_mean_e1 = 6.99
raw_emp_mean_e2 = 6.99
raw_emp_mean_e3 = 1.51
raw_emp_mean_e4 = 1.51
raw_emp_mean_mc1 = 9.66
raw_emp_mean_mc2 = 9.66
raw_emp_mean_mc3 = 4.67
raw_emp_mean_mc4 = 4.67
raw_emp_mean_nb1 = 9.66
raw_emp_mean_nb2 = 9.66
raw_emp_mean_nb3 = 4.67
raw_emp_mean_nb4 = 4.67
raw_emp_mean_pf1 = -0.01
raw_emp_mean_pf2 = -0.01
raw_emp_mean_pf3 = -0.01
raw_emp_mean_pf4 = -1.99
raw_emp_mean_pf5 = 3.86
raw_emp_mean_pf6 = 3.86

raw_emp_mean_pf7 = 3.86
raw_emp_mean_pf8 = 3.86
raw_emp_mean_pf9 = 3.86
raw_emp_sd_cb1 = 5.29
raw_emp_sd_cb2 = 5.29
raw_emp_sd_cb3 = 5.29
raw_emp_sd_cb4 = 4.32
raw_emp_sd_cb5 = 1.38
raw_emp_sd_cb6 = 1.38
raw_emp_sd_cb7 = 1.38
raw_emp_sd_cb8 = 1.38
raw_emp_sd_cb9 = 1.38
raw_emp_sd_e1 = 2.92
raw_emp_sd_e2 = 2.92
raw_emp_sd_e3 = 5.38
raw_emp_sd_e4 = 5.38
raw_emp_sd_mc1 = 8.17
raw_emp_sd_mc2 = 8.17
raw_emp_sd_mc3 = 6.61
raw_emp_sd_mc4 = 6.61
raw_emp_sd_pf1 = 5.29
raw_emp_sd_pf2 = 5.29
raw_emp_sd_pf3 = 5.29
raw_emp_sd_pf4 = 4.32
raw_emp_sd_pf5 = 1.38
raw_emp_sd_pf6 = 1.38
raw_emp_sd_pf7 = 1.38
raw_emp_sd_pf8 = 1.38
raw_emp_sd_pf9 = 1.38
raw_emp__sd_b1 = 2.92
raw_emp__sd_b2 = 2.92
raw_emp__sd_b3 = 5.38
raw_emp__sd_b4 = 5.38
raw_emp__sd_nb1 = 8.17
raw_emp__sd_nb2 = 8.17
raw_emp__sd_nb3 = 6.61
raw_emp__sd_nb4 = 6.61
RA_A__change[Small_Pop] = .69*RA_prop__change*W_RA
RA_prop__change[Small_Pop] = delta_RA/SD_RA
recycling_bins_graphical__input = GRAPH(TIME)
(0.00, 0.521), (1.00, 0.521), (2.00, 0.521), (3.00, 0.521), (4.00, 0.521), (5.00, 0.521), (6.00, 0.521), (7.00, 0.521), (8.00, 0.521), (9.00, 0.521), (10.0, 0.521), (11.0, 0.521), (12.0, 0.518), (13.0, 0.518), (14.0, 0.518), (15.0, 0.695), (16.0, 0.727), (17.0, 0.736), (18.0, 0.746), (19.0, 0.746), (20.0, 0.752), (21.0, 0.762), (22.0, 0.765), (23.0, 0.772), (24.0, 0.778), (25.0, 0.781), (26.0, 0.785), (27.0, 0.788), (28.0, 0.791), (29.0, 0.801), (30.0, 0.807), (31.0, 0.81), (32.0, 0.814), (33.0, 0.814), (34.0, 0.814), (35.0, 0.814), (36.0, 0.814), (37.0, 0.814), (38.0, 0.814), (39.0,

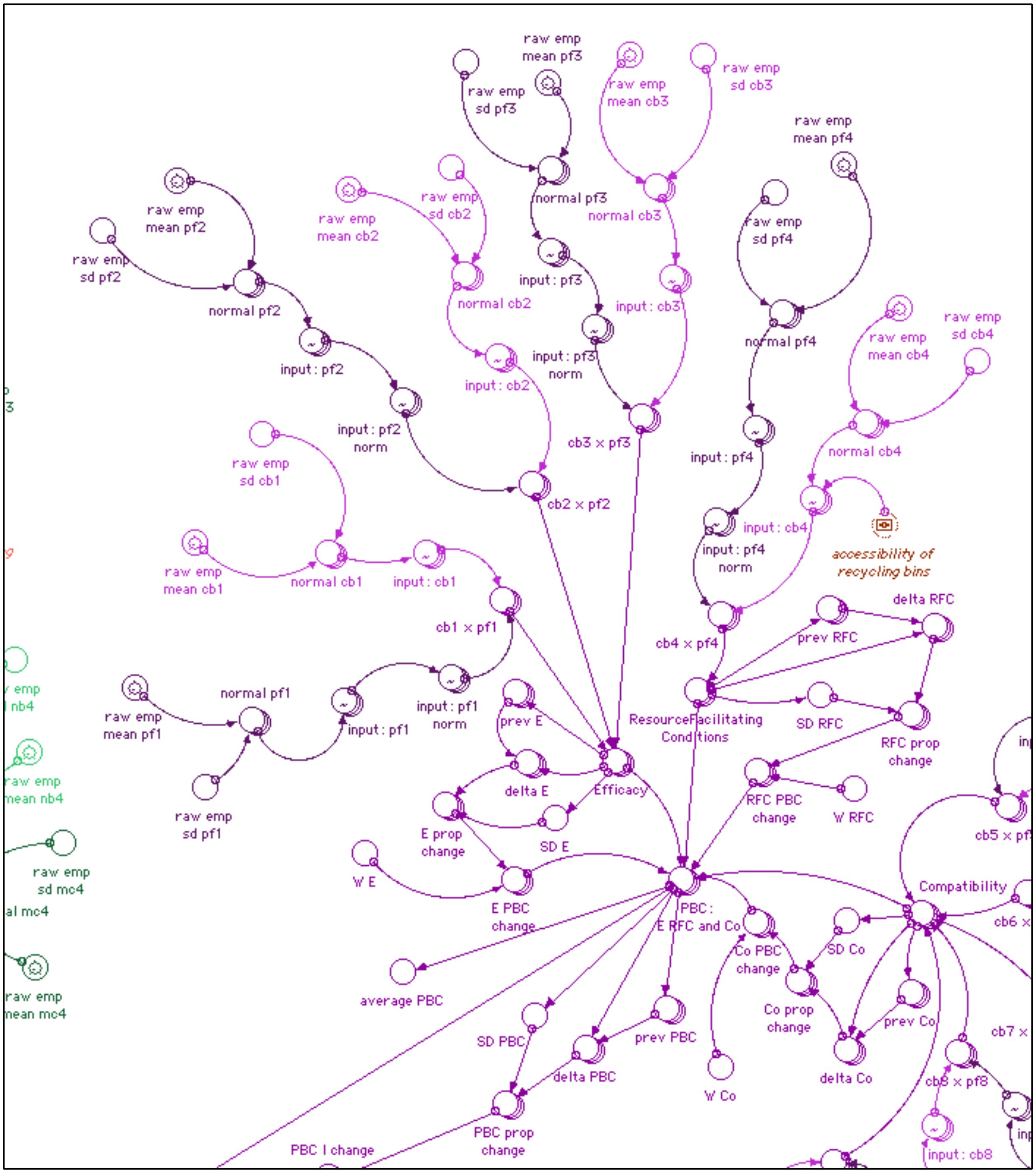
0.817), (40.0, 0.817), (41.0, 0.82), (42.0, 0.82), (43.0, 0.82), (44.0, 0.82), (45.0, 0.82), (46.0, 0.82), (47.0, 0.82), (48.0, 0.817), (49.0, 0.814), (50.0, 0.81), (51.0, 0.807), (52.0, 0.807), (53.0, 0.807), (54.0, 0.807), (55.0, 0.807), (56.0, 0.807), (57.0, 0.807), (58.0, 0.807), (59.0, 0.807), (60.0, 0.807), (61.0, 0.804), (62.0, 0.797), (63.0, 0.791), (64.0, 0.778), (65.0, 0.772), (66.0, 0.762), (67.0, 0.756), (68.0, 0.746), (69.0, 0.74), (70.0, 0.727), (71.0, 0.719), (72.0, 0.701), (73.0, 0.685), (74.0, 0.672), (75.0, 0.659), (76.0, 0.643), (77.0, 0.627), (78.0, 0.617), (79.0, 0.595), (80.0, 0.588), (81.0, 0.585), (82.0, 0.572), (83.0, 0.563), (84.0, 0.559), (85.0, 0.553), (86.0, 0.55), (87.0, 0.54), (88.0, 0.572), (89.0, 0.608), (90.0, 0.669), (91.0, 0.72), (92.0, 0.765), (93.0, 0.839), (94.0, 0.91), (95.0, 0.949), (96.0, 0.958), (97.0, 0.961), (98.0, 0.971), (99.0, 0.971), (100, 0.974)
recycling_bin__adjusted_prob[Small_Pop] = IF (graphical_switch=0) THEN accessibility_of__recycling_bins*prob_of_recycling ELSE prob_of_recycling*recycling_bins_graphical__input
relative_advantage[Small_Pop] = b1_x_e1+b2_x_e2
ResourceFacilitating_Conditions[Small_Pop] = cb4_x_pf4
RFC_PBC_change[Small_Pop] = RFC_prop_change*W_RFC*1.38
RFC_prop_change[Small_Pop] = delta_RFC/SD_RFC
Salience = 10
SD_A = STDDEV(attitude:_RA_and_C)
SD_Co = STDDEV(Compatibility)
SD_E = STDDEV(Efficacy)
SD_ENB = STDDEV(External_Norm_Beliefs)
SD_INB = STDDEV(Internal_Norm_Beliefs)
SD_intent = STDDEV(Intent)
SD_PBC = STDDEV(PBC:__E_RFC_and_Co)
SD_RA = STDDEV(relative_advantage[*])
SD_RFC = STDDEV(ResourceFacilitating_Conditions)
SD_SN = STDDEV(subjective_norms:_INB_and_ENB)
Sensi_Param = 1
SN_ENB_change[Small_Pop] = W_ENB*ENB_prop_change*1.51
SN_INB_change[Small_Pop] = INB_prop_change*W_INB*1.51
SN_I_change[Small_Pop] = SN_prop_change*Wsn*.98
SN_normalized[Small_Pop] = (subjective_norms:_INB_and_ENB+SN_I_change)/(4*21)
SN_prop_change[Small_Pop] = delta_SN/SD_SN
subjective_norms:_INB_and_ENB[Small_Pop] = Internal_Norm_Beliefs+SN_INB_change+External_Norm_Beliefs+SN_ENB_change
Total_Neg_change = SUM(Negative_Int_Change)
Total_Pos_change = SUM(Positive_intent_change)
Wa = 1.92
Wpbc = 0.18
Wsn = -0.08
W_Co = -0.04
W_E = 0.06
W_ENB = 0.09
W_INB = 0.08
W_RA = 0.38
W_RFC = 0.29

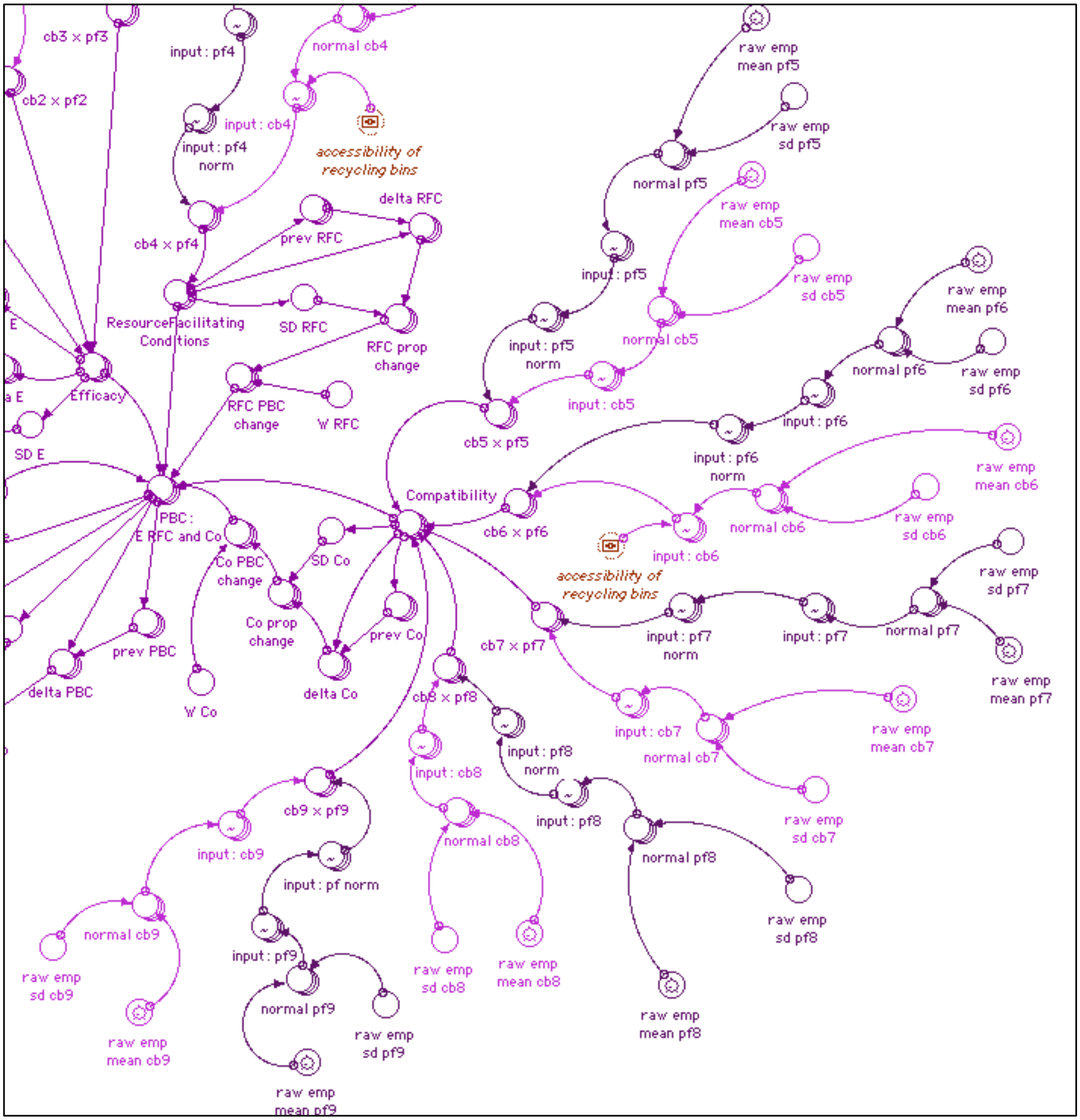
Full map of STELLA model:



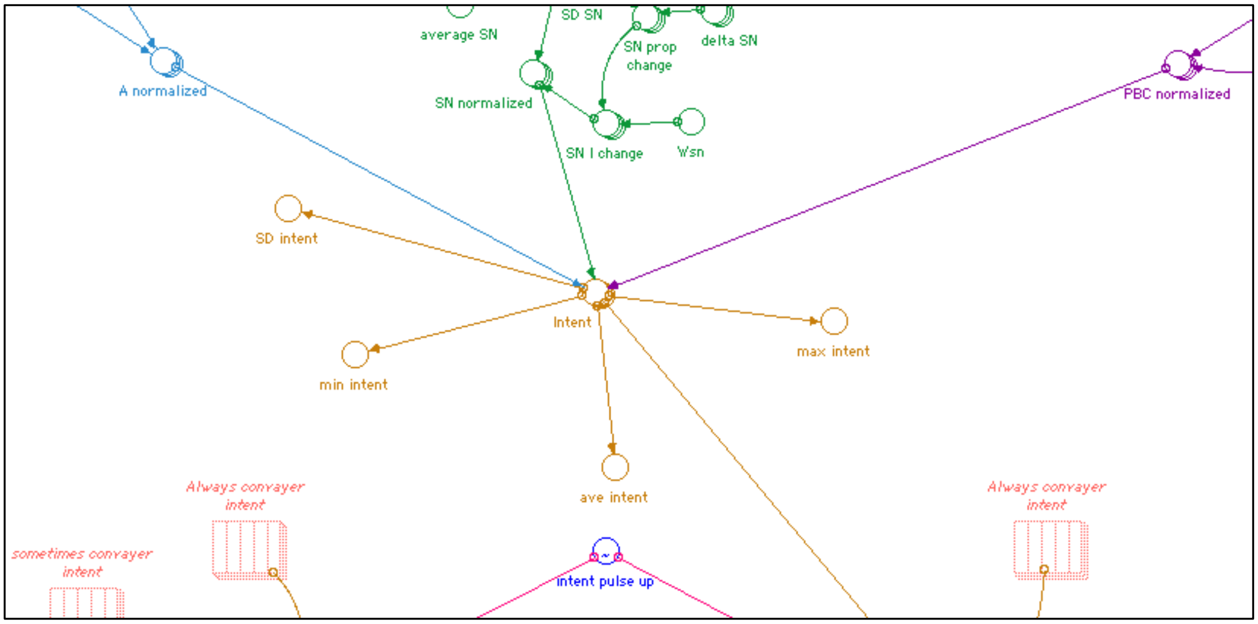


raw emp sd mc2
raw emp mean mc2
normal mc2
input : mc2
input : mc2 norm
Total Pos change
Total Neg change
change in nb3
raw emp sd nb3
raw emp mean nb3
normal nb3
input : nb3
raw emp sd mc3
raw emp mean mc3
normal mc3
input : mc3
input : mc3 norm
nb3 x mc3
raw emp sd nb2
raw emp mean nb2
normal nb2
input : nb2
nb2 x mc2
Internal Norm Beliefs
External Norm Beliefs
change in nb4
raw emp sd nb4
raw emp mean nb4
normal nb4
input : nb4
nb4 x mc4
raw emp mean mc1
normal mc1
input : mc1
input : mc1 norm
raw emp sd mc1
nb1 x mc1
raw emp mean nb1
normal nb1
input : nb1
raw emp sd nb1
prev INB
SD INB
delta INB
INB prop change
SN INB change
W INB
SD ENB
prev ENB
ENB prop change
delta ENB
input : mc4 norm
input : mc4
normal mc4
raw emp sd mc4
raw emp mean mc4
subjective norms: INB and ENB
SN ENB change
W ENB
prev SN
SD SN
SN prop change
delta SN
average SN
SN normalized
SN I change
Wsn
A I change
Wa
A normalized
SD intent

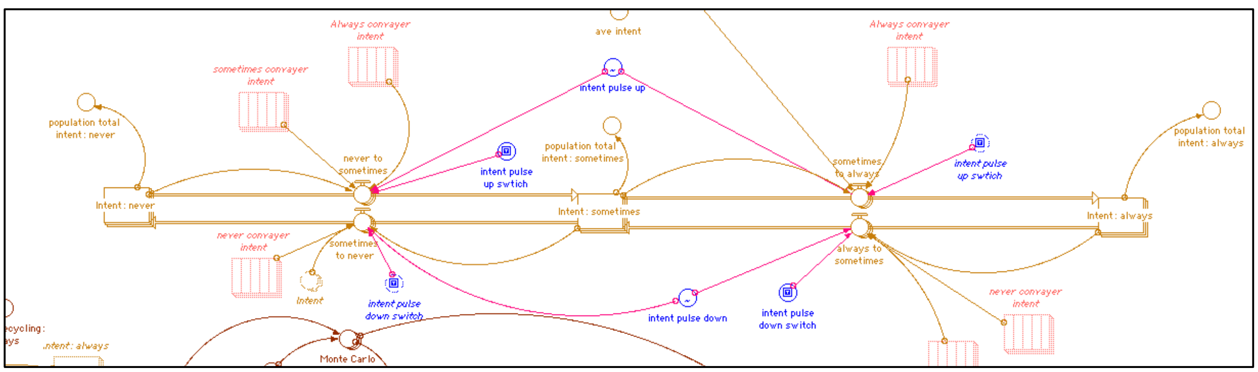

raw emp mean pf3
raw emp sd pf3
raw emp mean cb3
raw emp sd cb3
raw emp mean pf4
normal pf3
normal cb3
raw emp sd cb2
raw emp mean cb2
raw emp mean pf2
raw emp sd pf2
raw emp sd pf4
normal pf2
input : pf3
normal cb2
input : cb3
input : pf2
input : pf3 norm
normal pf4
raw emp mean cb4
raw emp sd cb4
input : cb2
input : pf2 norm
cb3 × pf3
input : pf4
normal cb4
raw emp sd cb1
cb2 × pf2
input : cb4
input : pf4 norm
accessibility of recycling bins
raw emp mean cb1
normal cb1
input : cb1
delta RFC
cb1 × pf1
cb4 × pf4
prev RFC
normal pf1
raw emp mean pf1
input : pf1 norm
input : pf1
prev E
ResourceFacilitating Conditions
SD RFC
RFC prop change
delta E
Efficacy
RFC PBC change
W RFC
raw emp sd pf1
E prop change
SD E
cb5 × pf
W E
E PBC change
Compatibility
PBC : E RFC and Co
cb6 ×
Co PBC change
SD Co
average PBC
Co prop change
prev Co
cb7 ×
SD PBC
prev PBC
delta PBC
delta Co
W Co
cb8 × pf8
PBC prop change
PBC I change
input : cb8
raw emp mean nb4
raw emp sd mc4
raw emp mean mc4



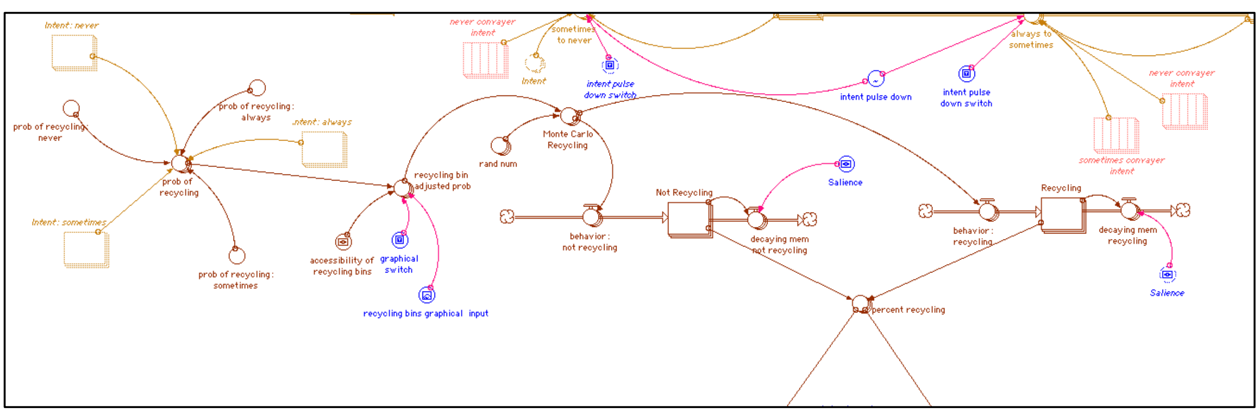
cb3 × pf3
input : pf4
normal cb4
raw emp mean pf5
cb2 × pf2
input : cb4
raw emp sd pf5
input : pf4 norm
accessibility of recycling bins
normal pf5
delta RFC
raw emp mean cb5
cb4 × pf4
prev RFC
input : pf5
raw emp sd cb5
raw emp mean pf6
ResourceFacilitating Conditions
SD RFC
normal cb5
input : pf5 norm
RFC prop change
normal pf6
raw emp sd pf6
Efficacy
RFC PBC change
W RFC
input : cb5
input : pf6
SD E
cb5 × pf5
input : pf6 norm
raw emp mean cb6
Compatibility
PBC : E RFC and Co
cb6 × pf6
normal cb6
raw emp sd cb6
Co PBC change
SD Co
input : cb6
accessibility of recycling bins
raw emp sd pf7
Co prop change
prev Co
input : pf7 norm
input : pf7
normal pf7
prev PBC
cb7 × pf7
raw emp mean pf7
delta PBC
W Co
delta Co
cb8 × pf8
input : cb7
raw emp mean cb7
normal cb7
input : pf8 norm
input : cb8
input : pf8
raw emp sd cb7
cb9 × pf9
normal cb8
normal pf8
input : cb9
input : pf norm
raw emp sd pf8
normal cb9
input : pf9
raw emp sd cb8
raw emp mean cb8
raw emp sd cb9
normal pf9
raw emp sd pf9
raw emp mean pf8
raw emp mean cb9
raw emp mean pf9



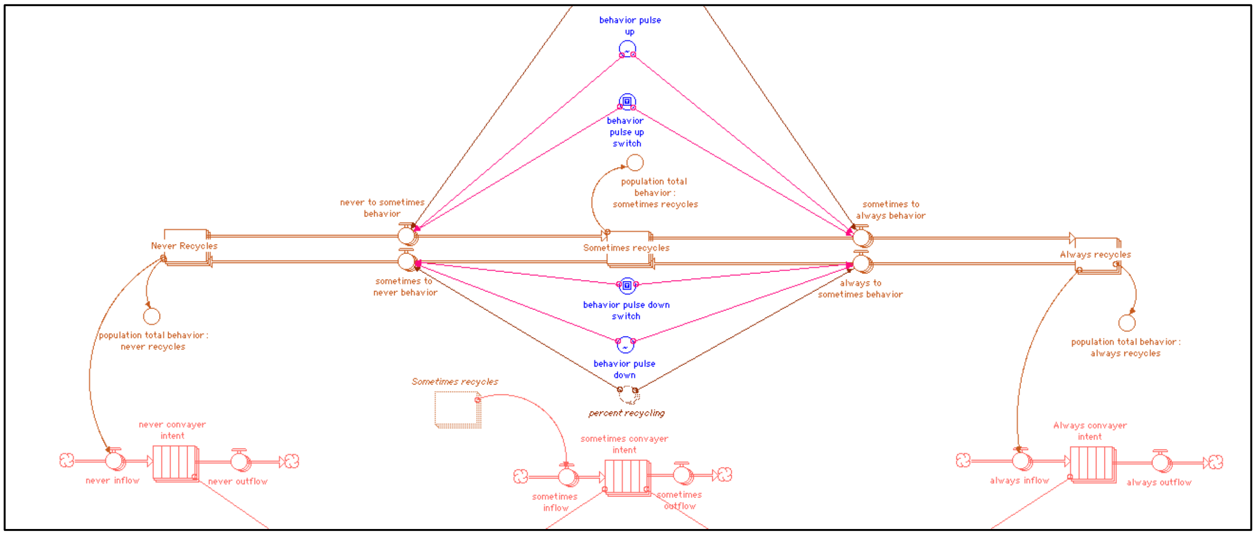
A normalized
average SN
SD SN
SN prop change
delta SN
SN normalized
SN I change
Wsn
PBC normalized
SD intent
Intent
max intent
min intent
ave intent
Always convayer intent
sometimes convayer intent
intent pulse up
Always convayer intent

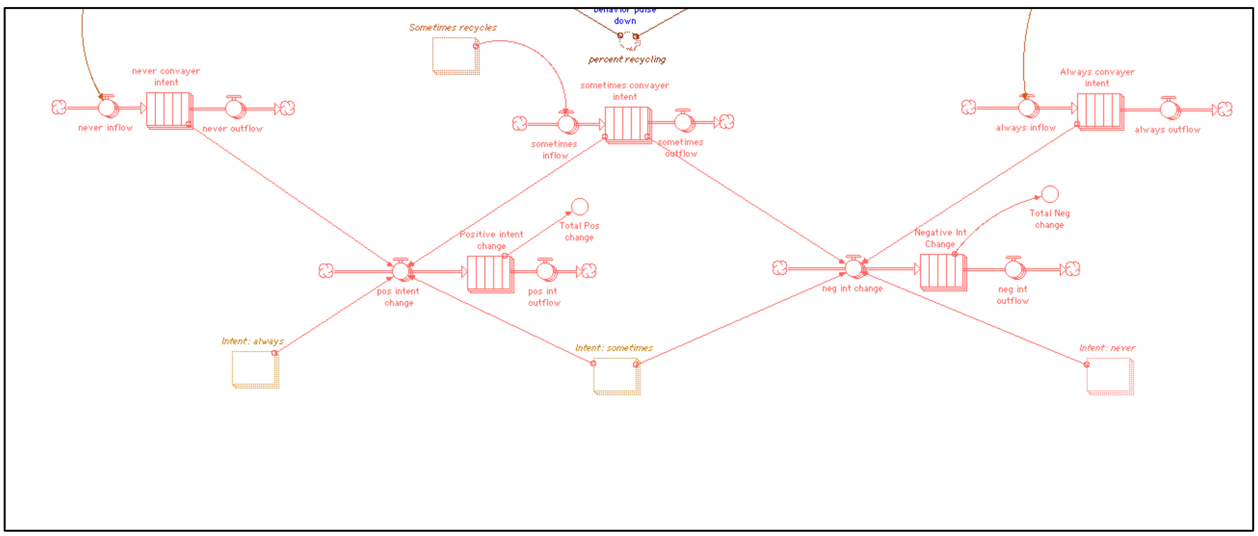


Always convayer intent
ave intent
Always convayer intent
sometimes convayer intent
intent pulse up
population total intent: never
never to sometimes
intent pulse up swtich
population total intent: sometimes
sometimes to always
intent pulse up swtich
population total intent: always
Intent: never
Intent: sometimes
Intent: always
never convayer intent
sometimes to never
always to sometimes
Intent
intent pulse down switch
intent pulse down
intent pulse down switch
never convayer intent
Monte Carlo



Intent: never
never convayer intent
sometimes to never
always to sometimes
never convayer intent
Intent
intent pulse down switch
intent pulse down
intent pulse down switch
prob of recycling: always
prob of recycling never
Intent: always
Monte Carlo Recycling
rand num
sometimes convayer intent
prob of recycling
recycling bin adjusted prob
Salience
Not Recycling
Recycling
Intent: sometimes
behavior : not recycling
decaying mem not recycling
behavior : recycling
decaying mem recycling
accessibility of recycling bins
graphical switch
prob of recycling: sometimes
Salience
recycling bins graphical input
percent recycling


behavior pulse up
behavior pulse up switch
population total behavior : sometimes recycles
never to sometimes behavior
sometimes to always behavior
Never Recycles
Sometimes recycles
Always recycles
sometimes to never behavior
always to sometimes behavior
behavior pulse down switch
behavior pulse down
population total behavior : never recycles
population total behavior : always recycles
Sometimes recycles
percent recycling
never convayer intent
sometimes convayer intent
Always convayer intent
never inflow
never outflow
sometimes inflow
sometimes outflow
always inflow
always outflow


behavior pulse down
Sometimes recycles
percent recycling
never convayer intent
sometimes convayer intent
Always convayer intent
never inflow
never outflow
sometimes inflow
sometimes outflow
always inflow
always outflow
Positive intent change
Total Pos change
Negative Int Change
Total Neg change
pos intent change
pos int outflow
neg int change
neg int outflow
Intent: always
Intent: sometimes
Intent: never

Appendix C

Raw Simulation Outputs

Scenario 1: Well-Established Recycling Program
Baseline behavior

<u>INPUTS</u>

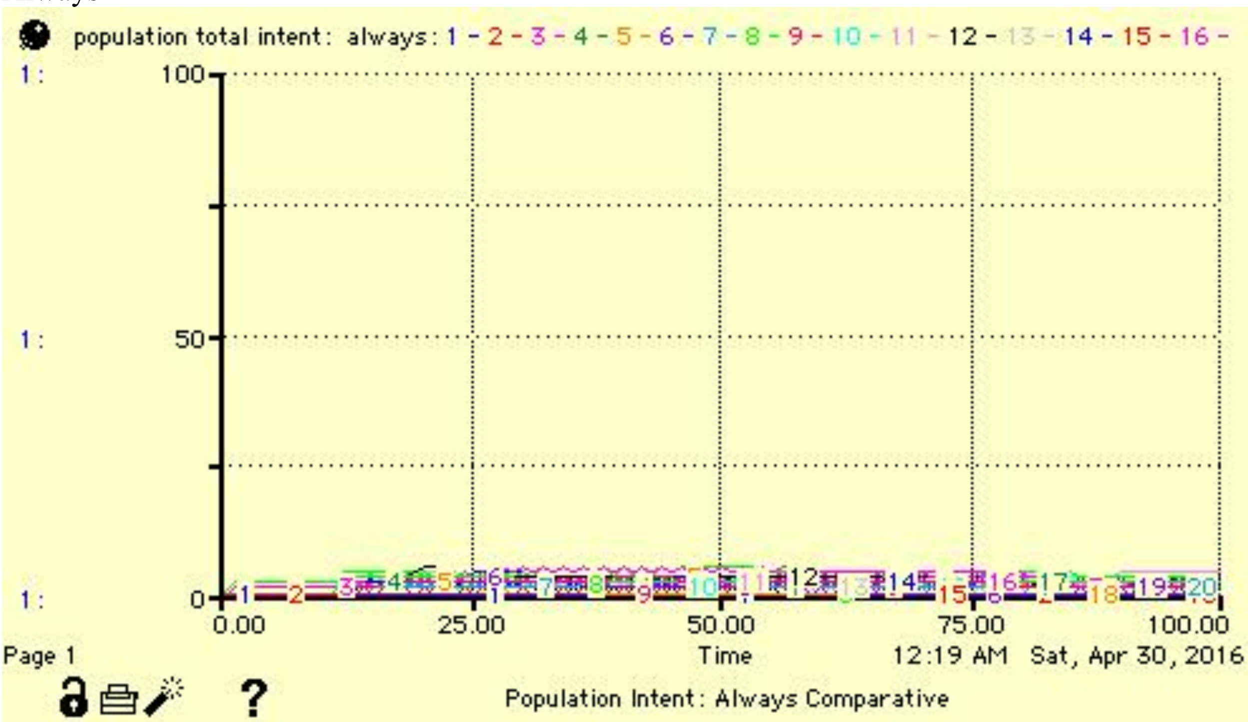
Factor	*Mean*	*Standard Deviation*
Relative Advantage	6.99[a]	2.92
Complexity	1.51[a]	5.38
Internal Normative Belief	9.66[b]	8.17
External Normative Belief	4.65[b]	6.61
Self-Efficacy	-0.01[a]	5.29
Compatibility	-1.99[a]	4.32
Resource-Facilitating Conditions	3.86[a]	1.38

a. Scaled from -9 to 9.
b. Scaled from -21 to 21.
Table 1: Baseline parameters for STELLA model of recycling behavior. Parameters are informed by the empirical work done by Taylor and Todd (1995).

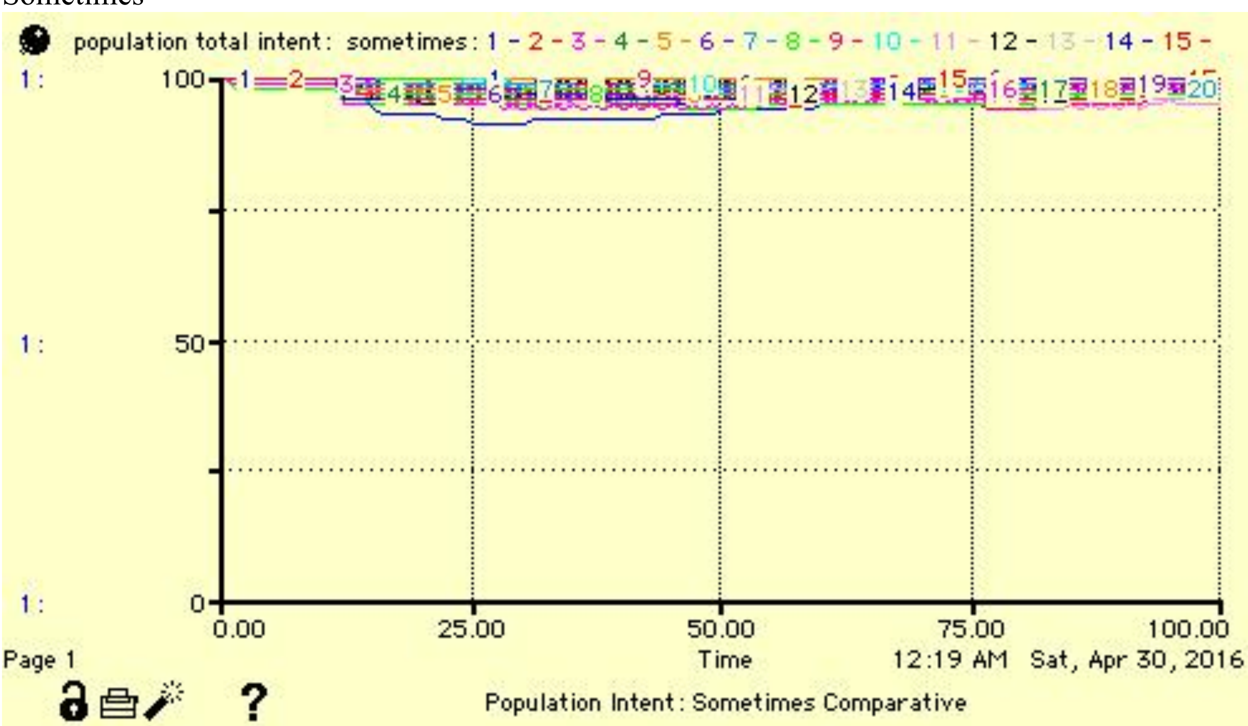
Factor (source)	*Factor (target)*	*Path Coefficient*
Relative Advantage	Attitude	*0.38***
Complexity	Attitude	*0.00**
Internal Normative Belief	Subjective Norm	*0.08***
External Normative Belief	Subjective Norm	*0.09***
Self-Efficacy	Perceived Behavioral Control	*0.06**
Compatibility	Perceived Behavioral Control	*-0.04**
Resource-Facilitating Conditions	Perceived Behavioral Control	*0.29***
Attitude	Intent	*1.92***
Subjective Norm	Intent	*-0.08**
Perceived Behavioral Control	Intent	*0.18***

**p* <.01; ***p*<.001.
Table 2: Path coefficients between factors in STELLA model, adapted from the structural equation model in Taylor and Todd's work (1995).

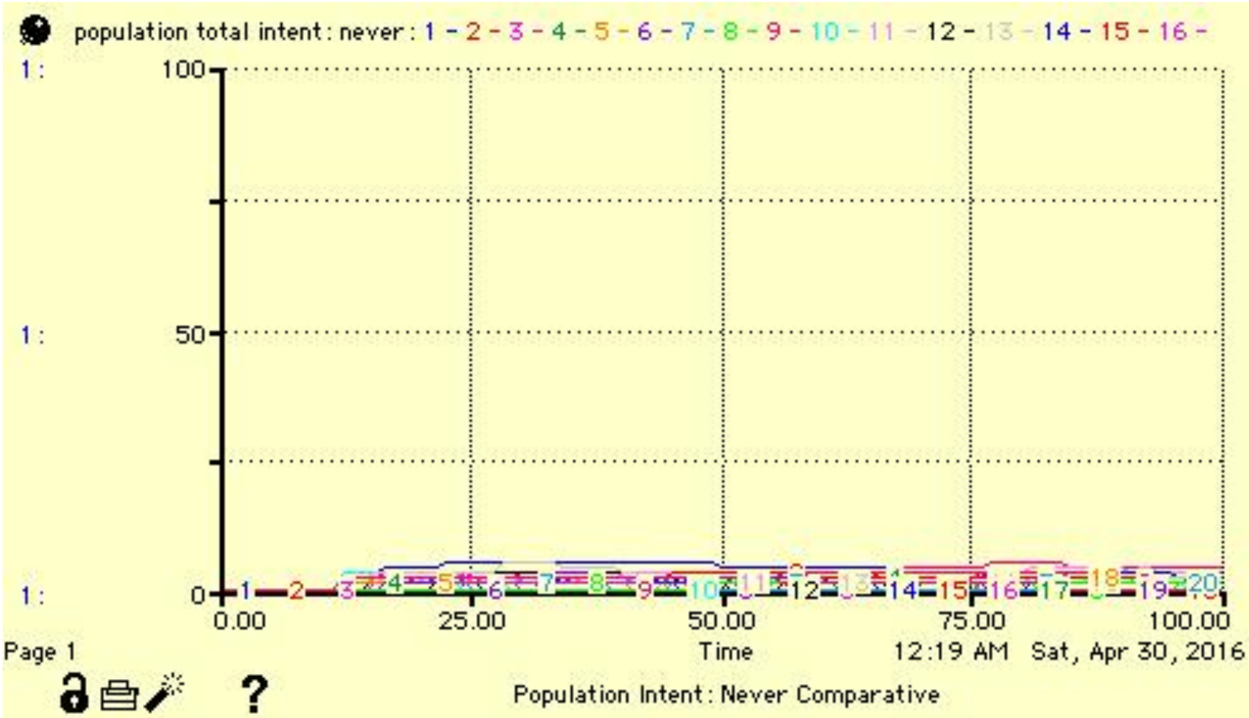
OUTPUTS
Intent:
Always



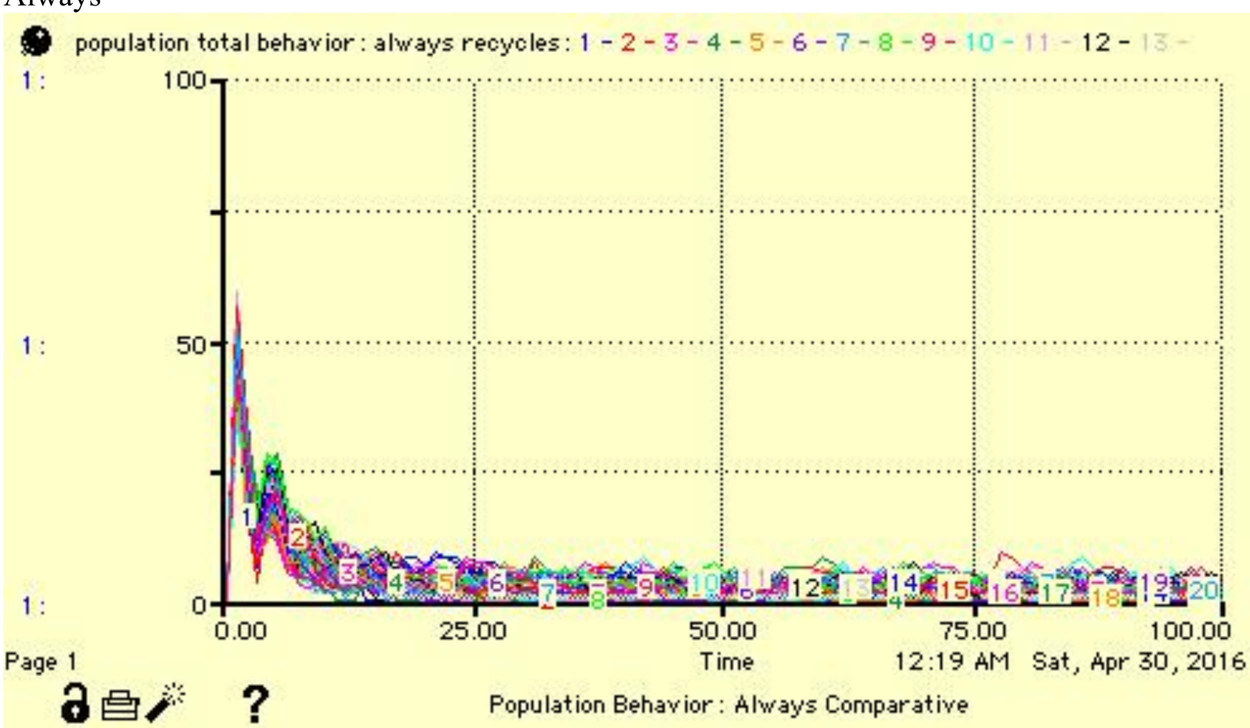
Sometimes



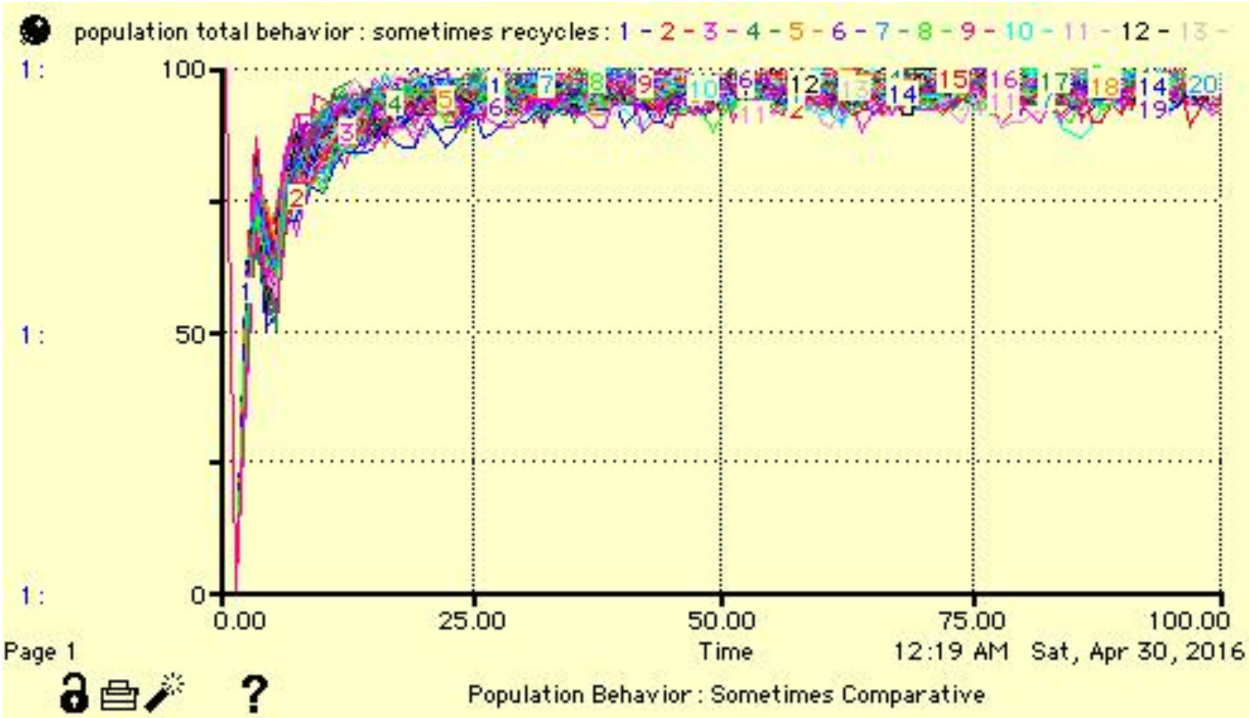
Never



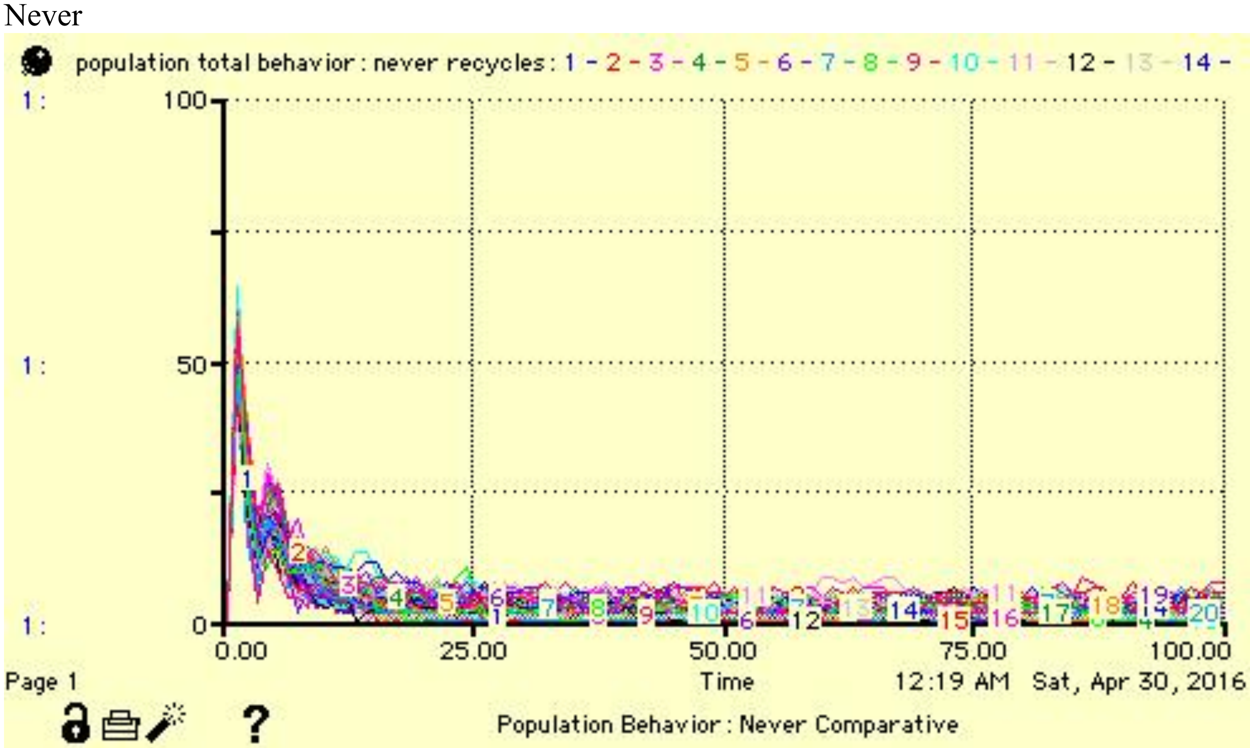
Behavior:
Always



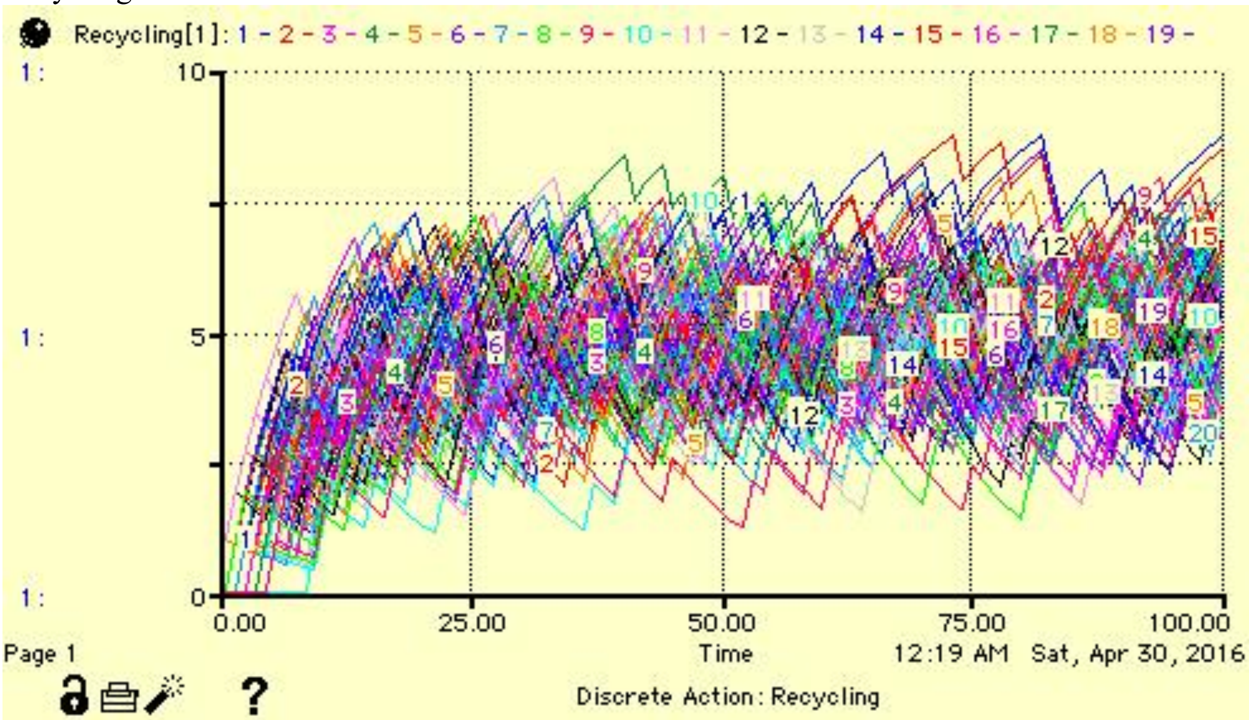
Sometimes



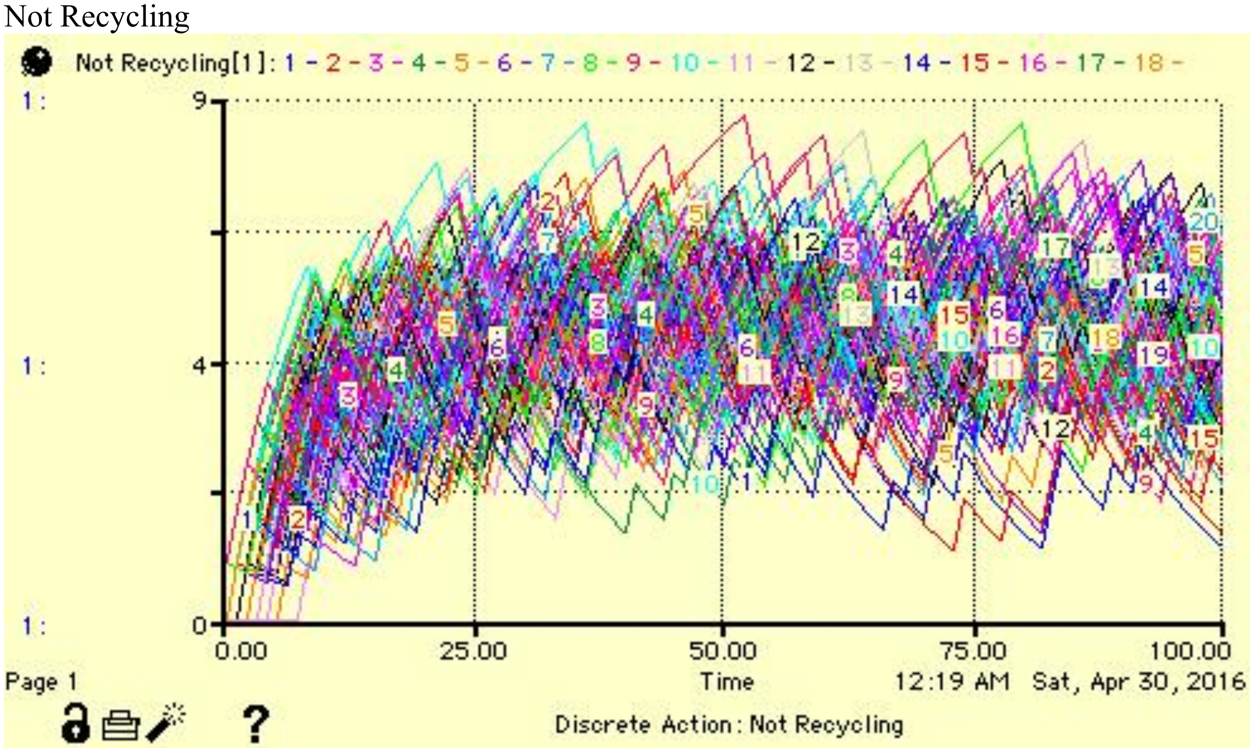
Never

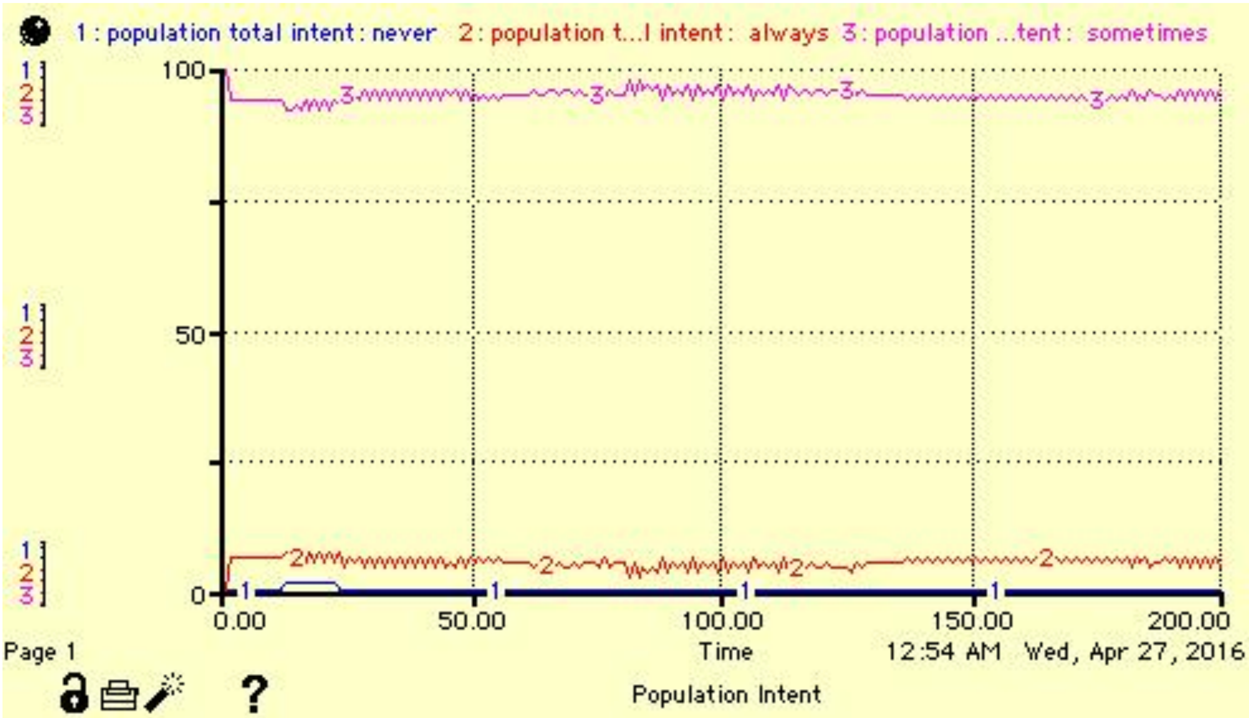


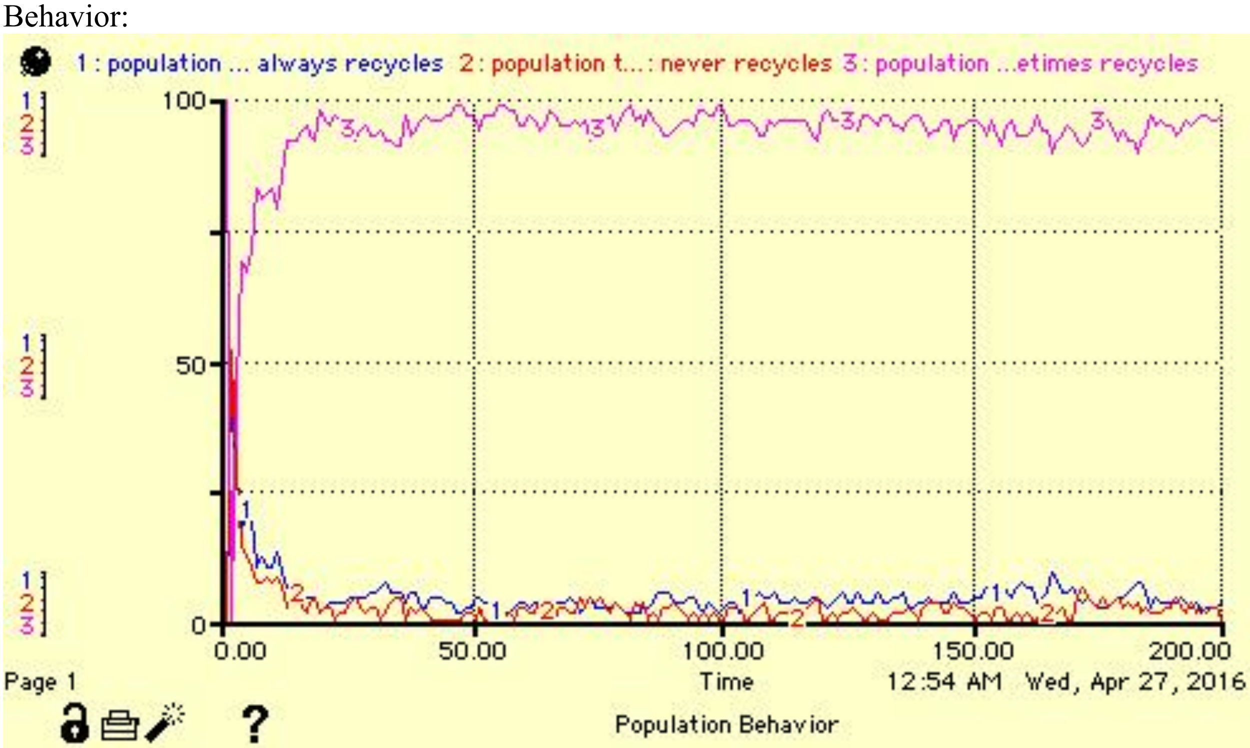
Discrete Action:
Recycling



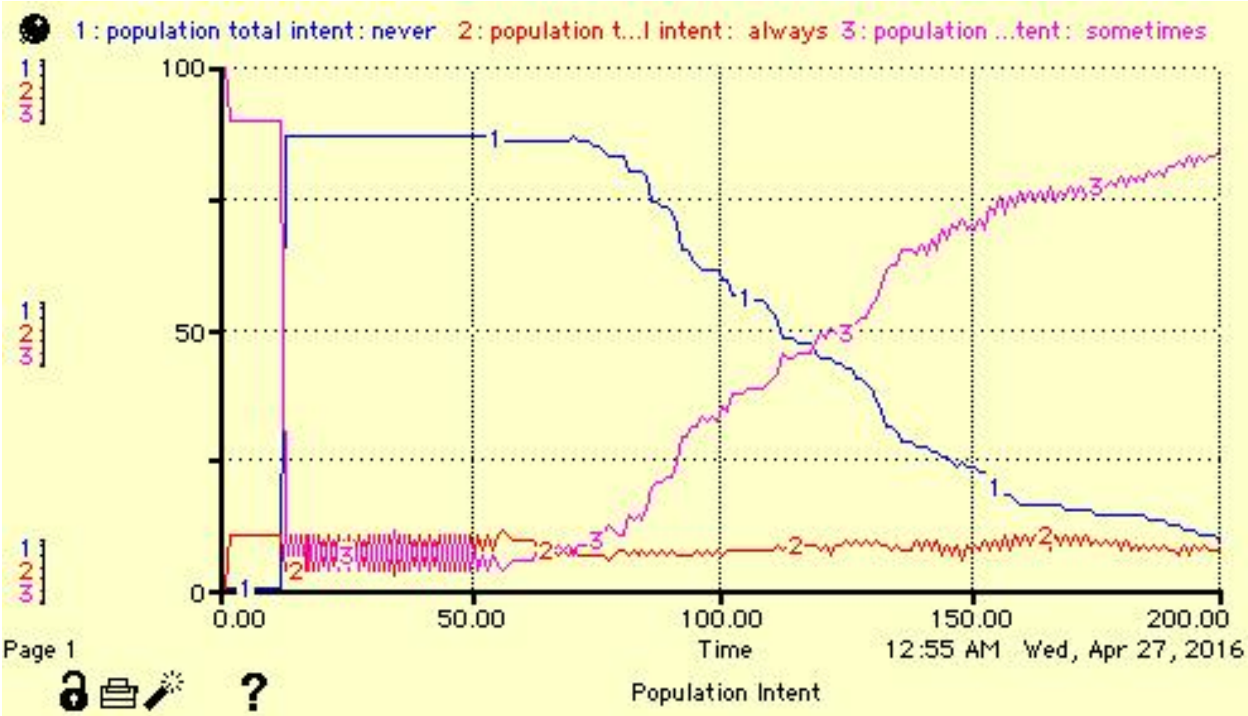
Not Recycling



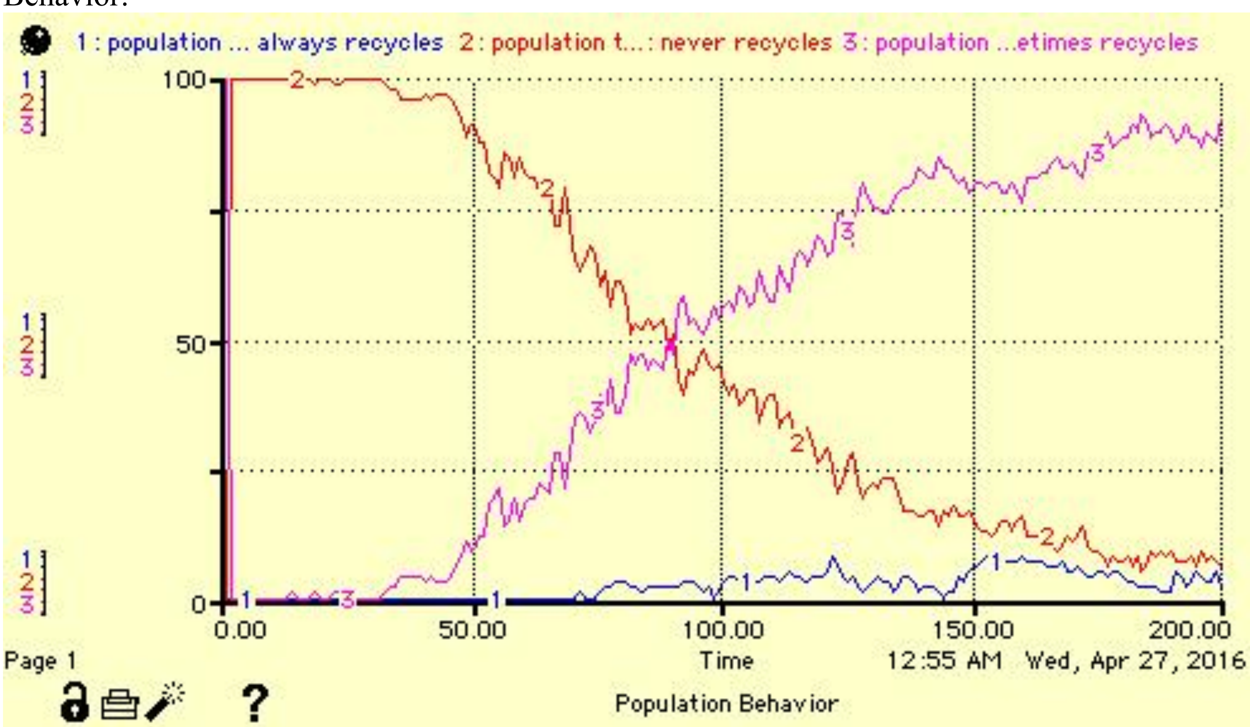
Step Tests
Compare to:
Intent:


Behavior:


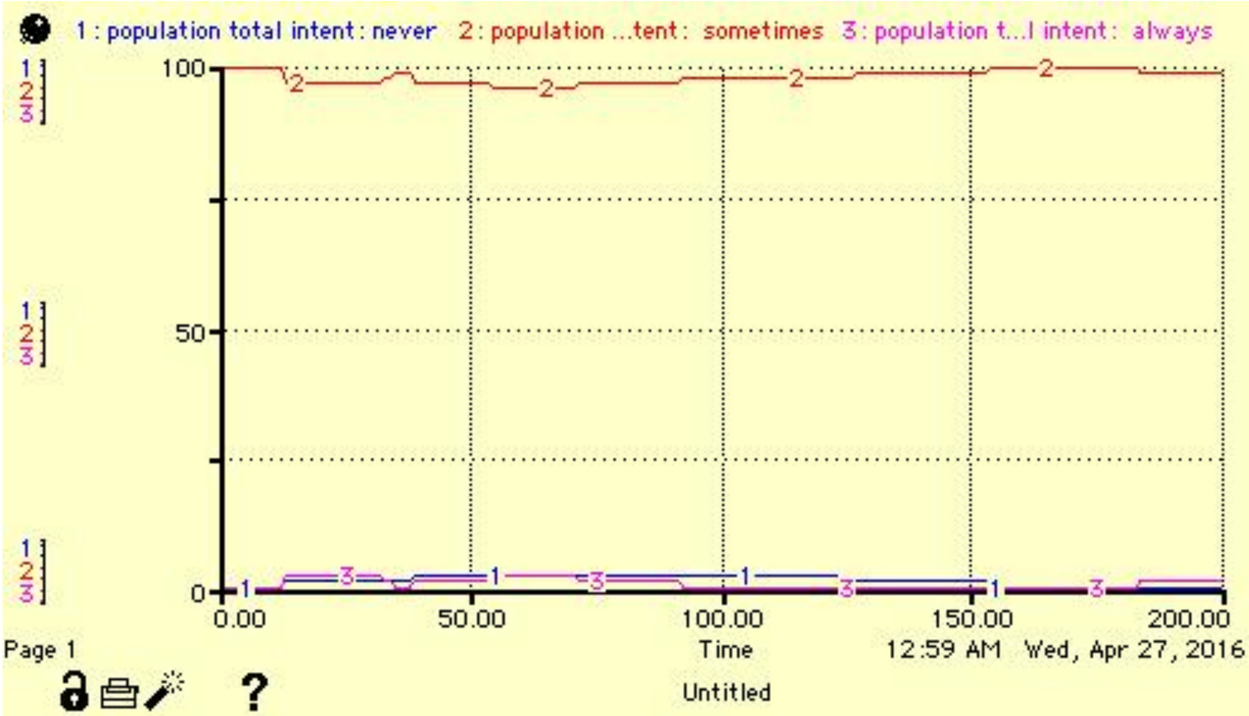
Accessibility
Intent:



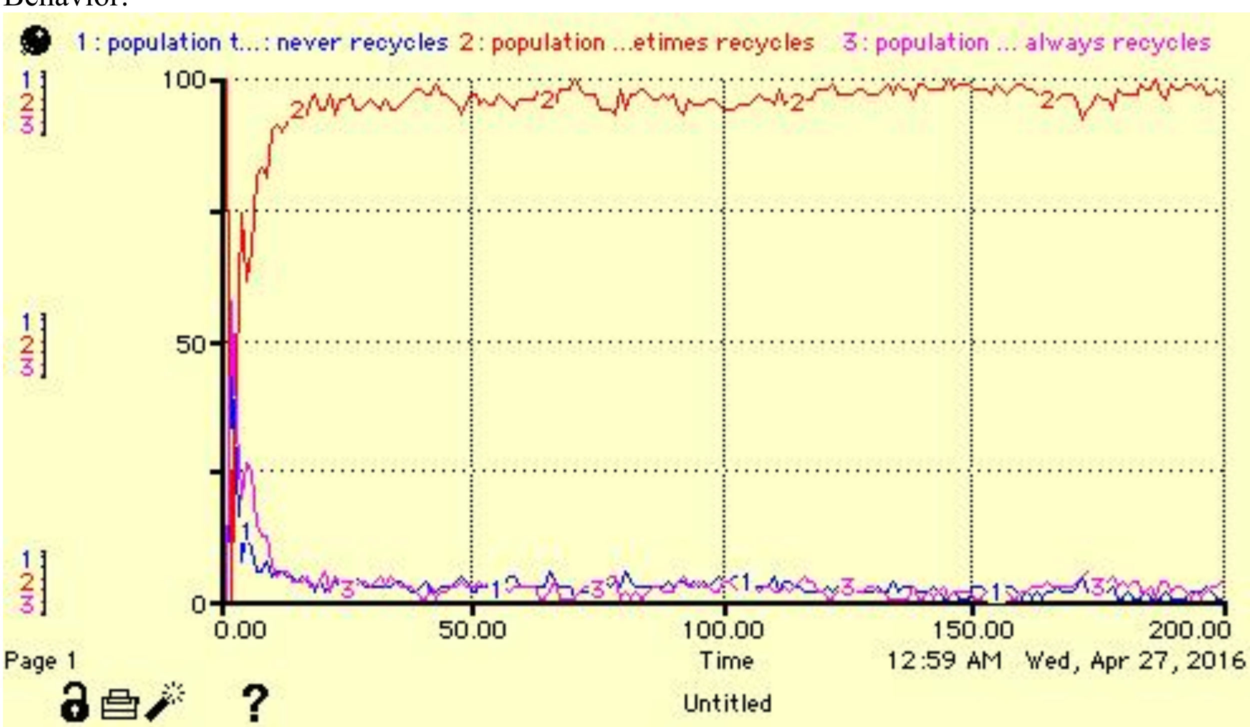
Behavior:



Relative Advantage:
Intent:

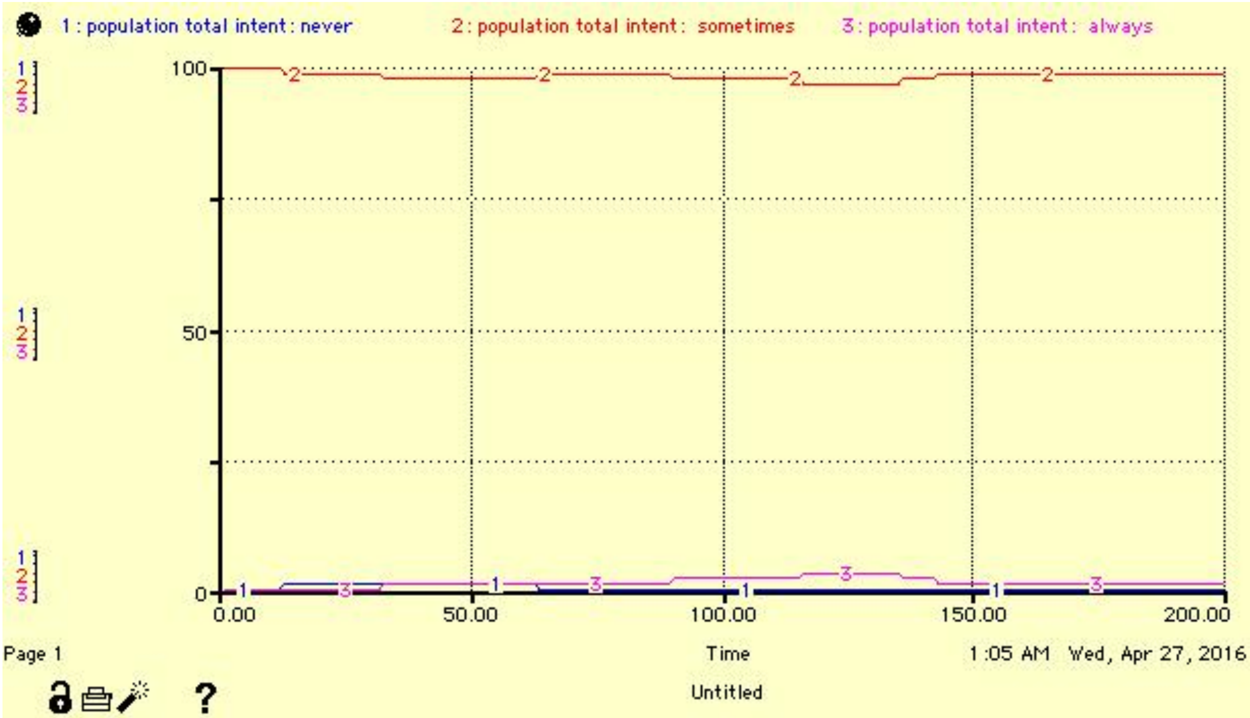


Behavior:

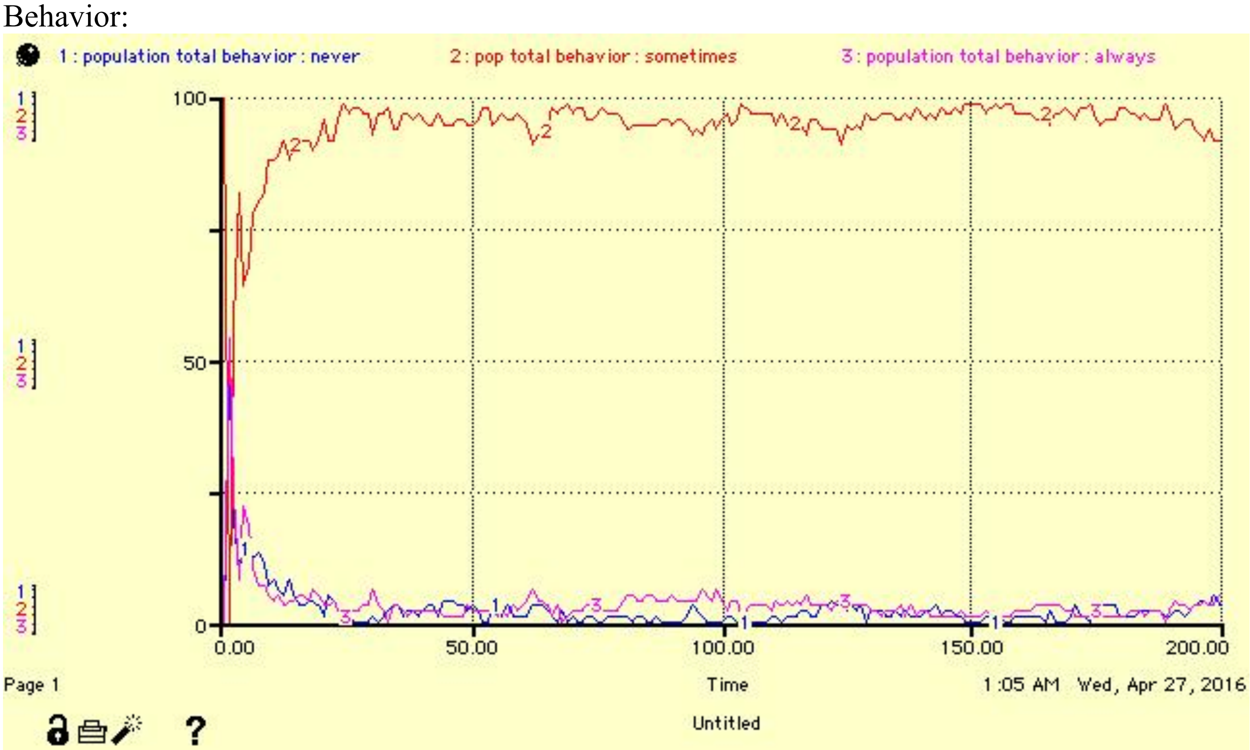


Complexity:

Intent:

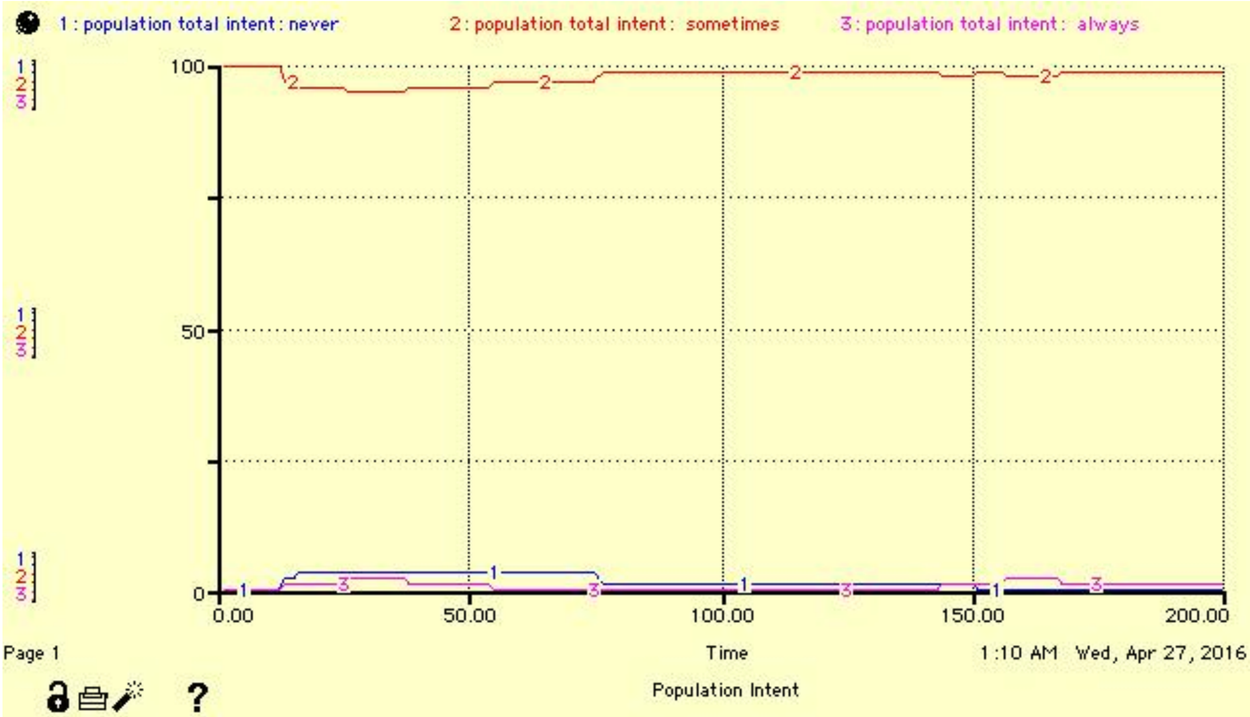


Behavior:

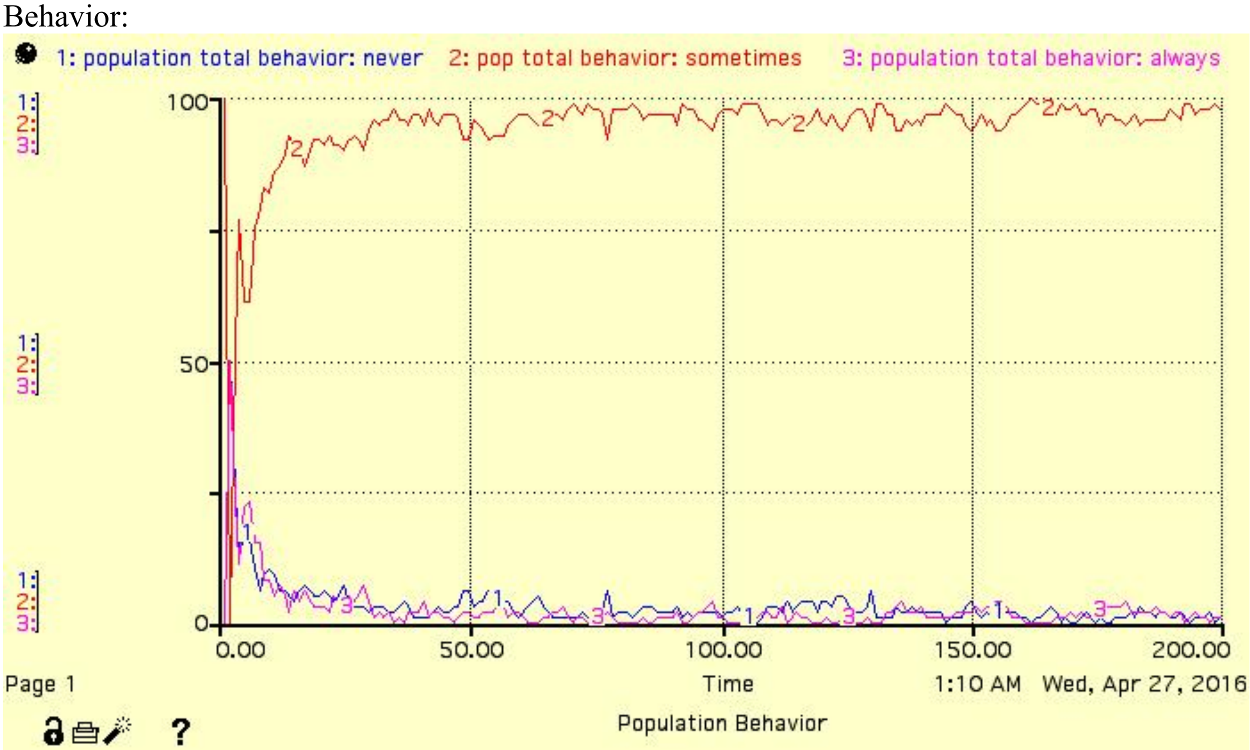


Internal Normative Beliefs:

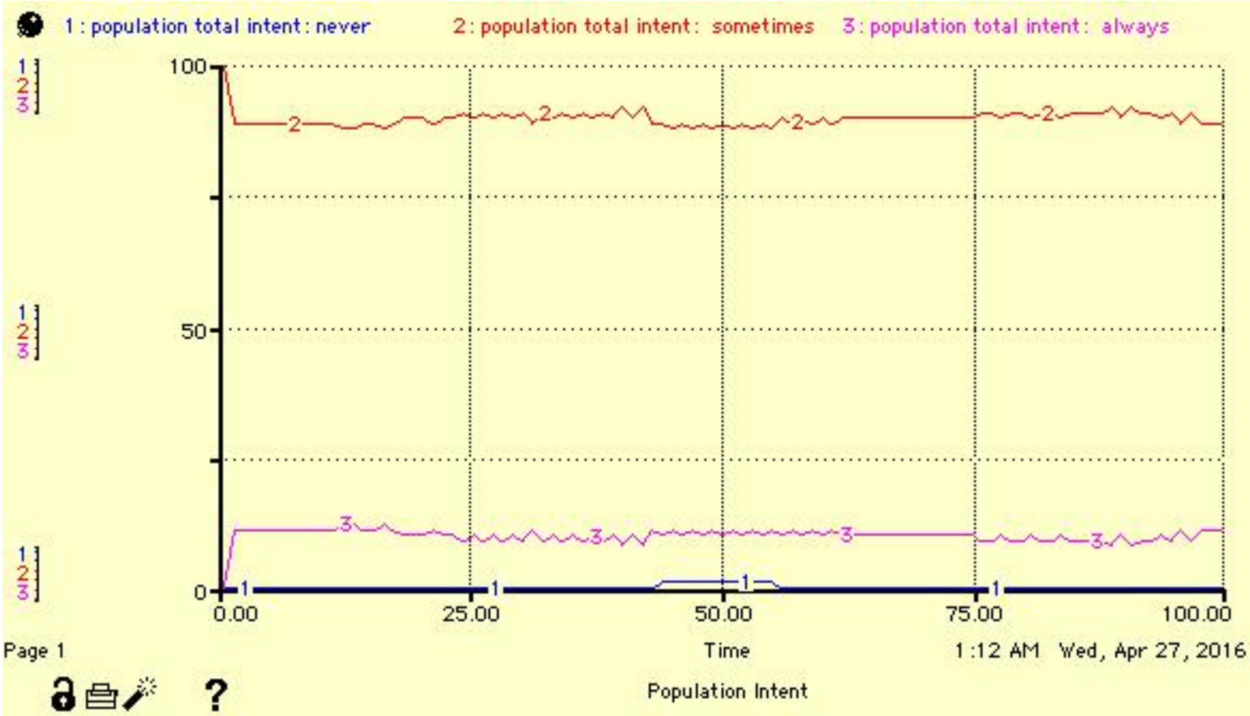
Intent:



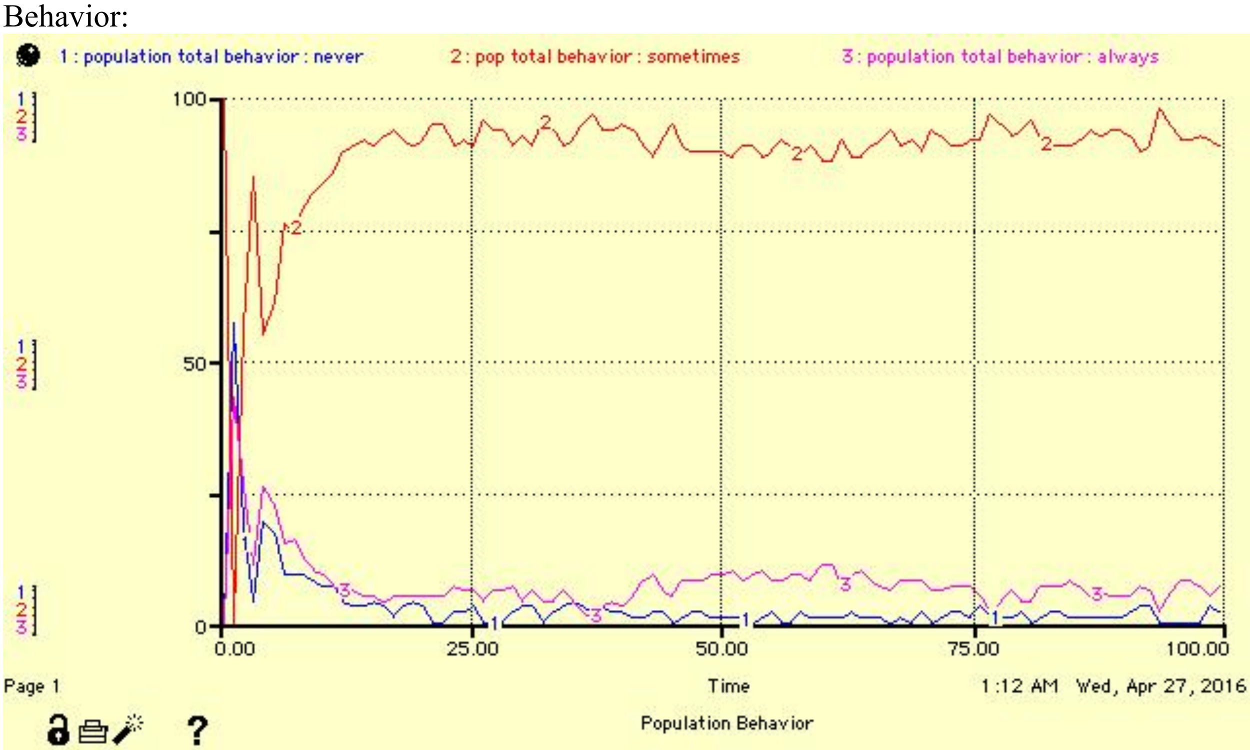
Behavior:



External Normative Beliefs:
Intent:

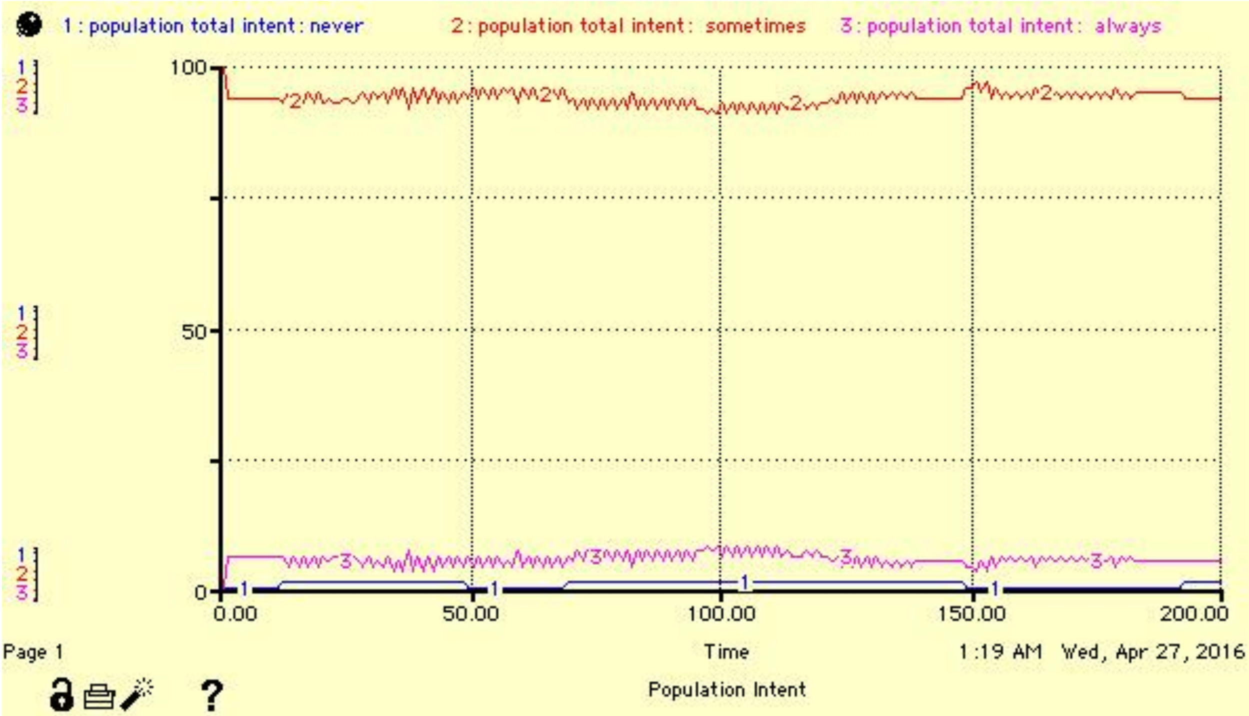


Behavior:

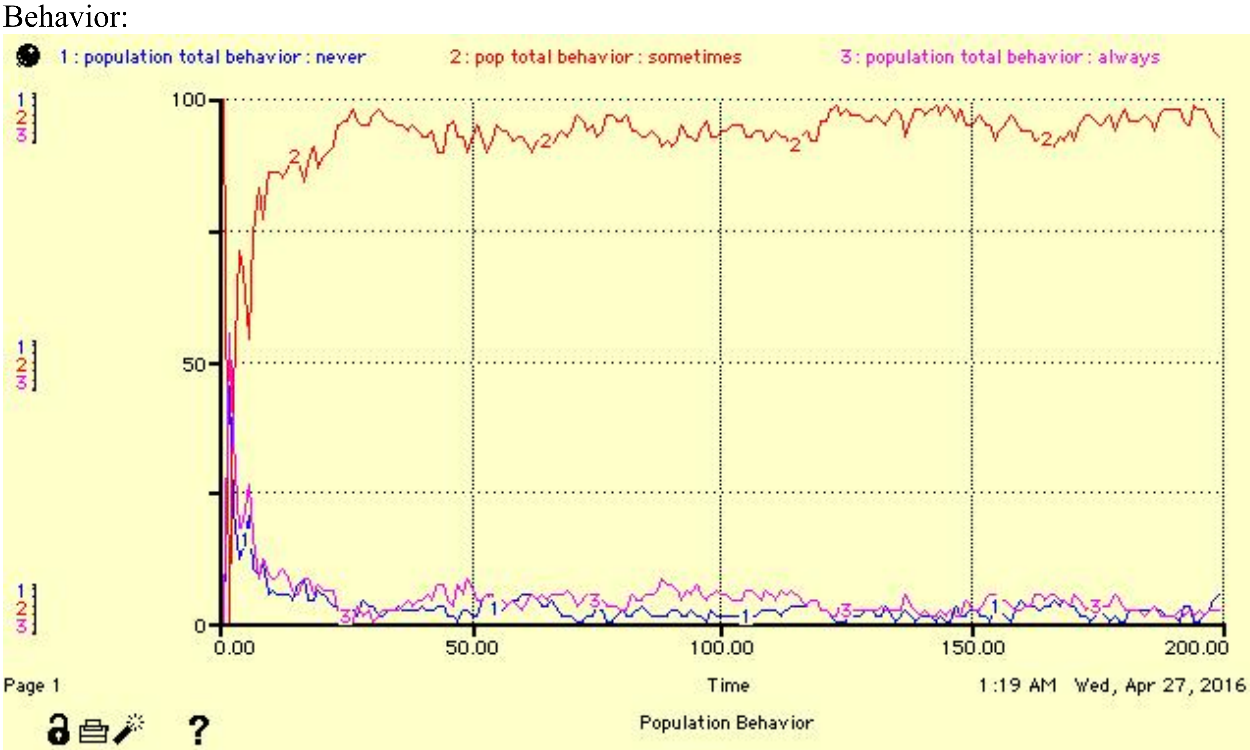


Efficacy:

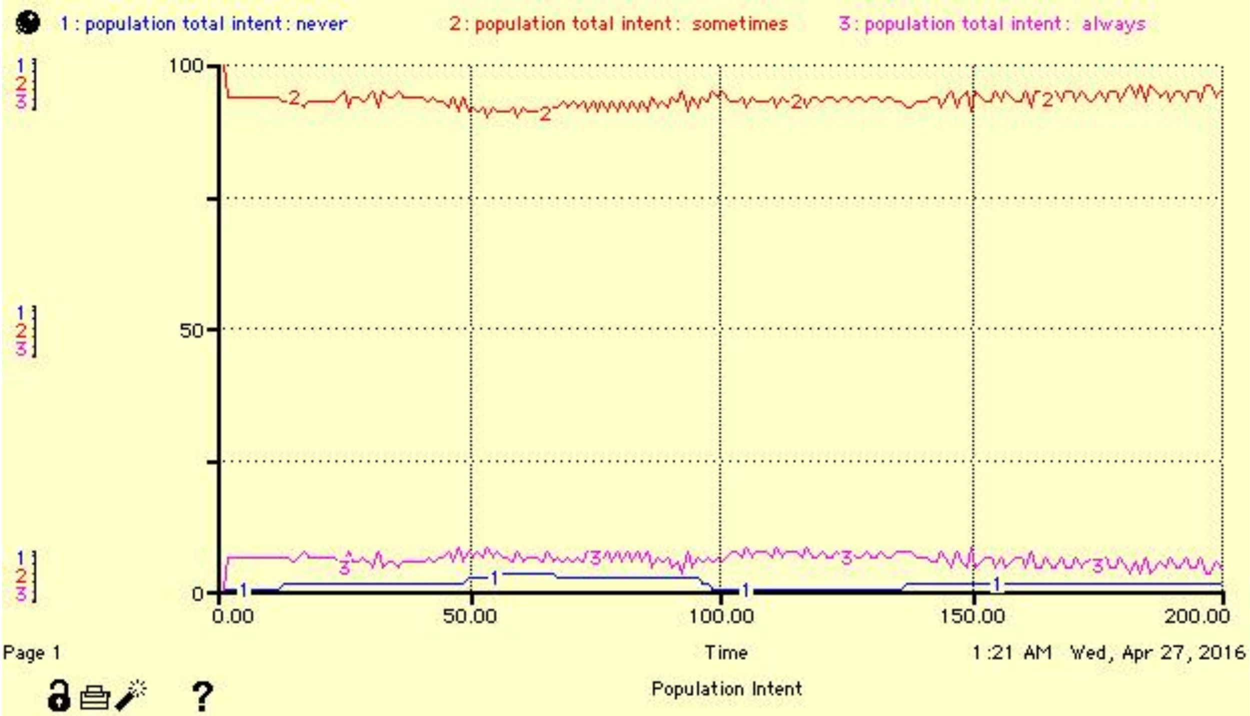
Intent:



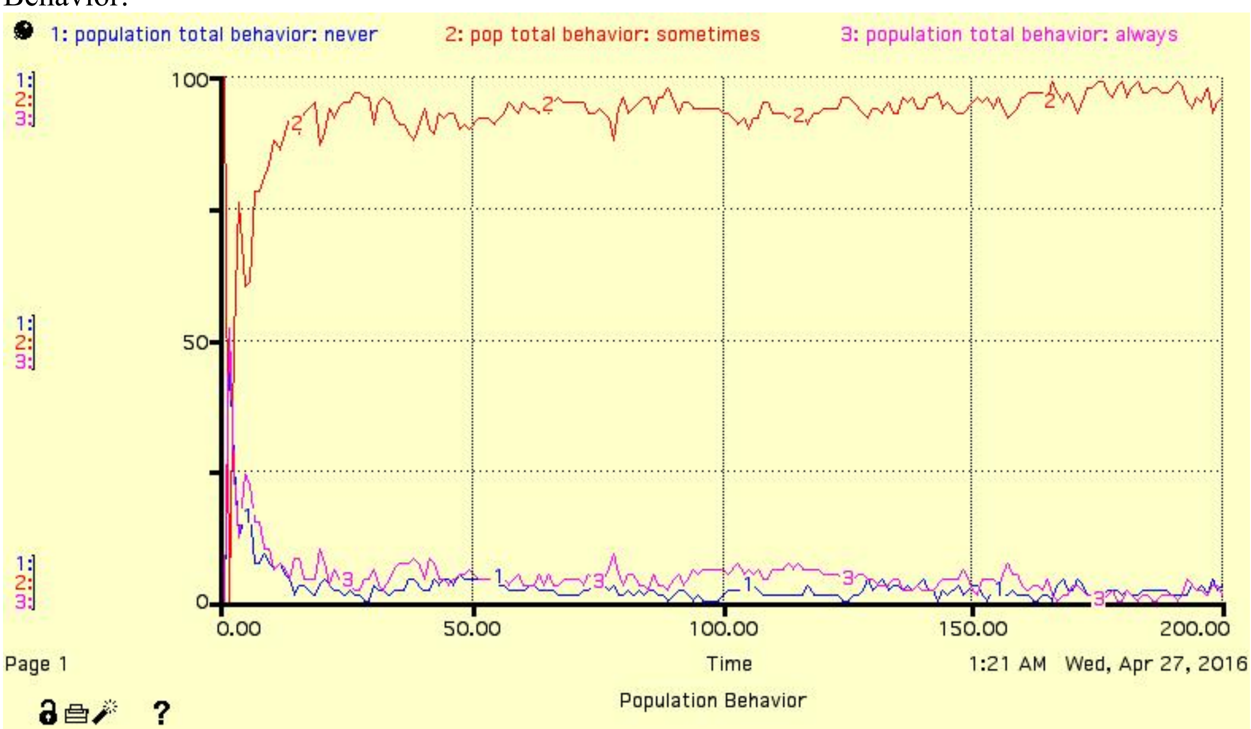
Behavior:



Resource Facilitating Conditions:
Intent:

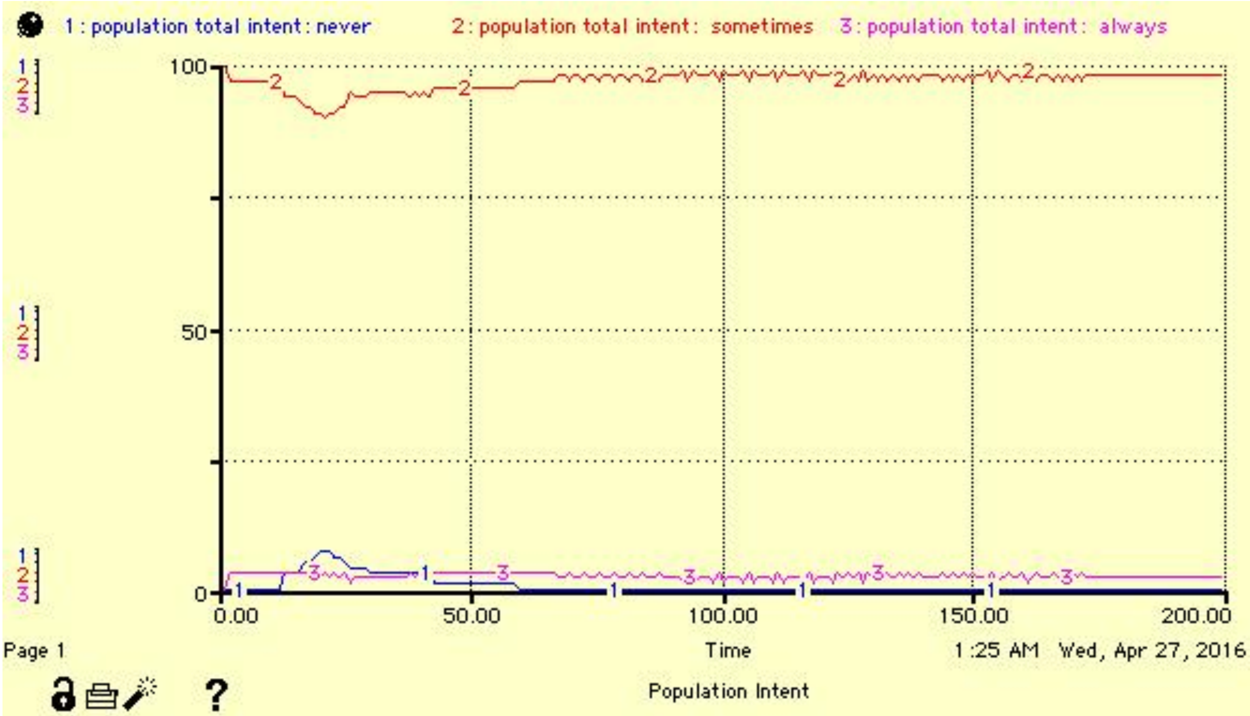


Behavior:

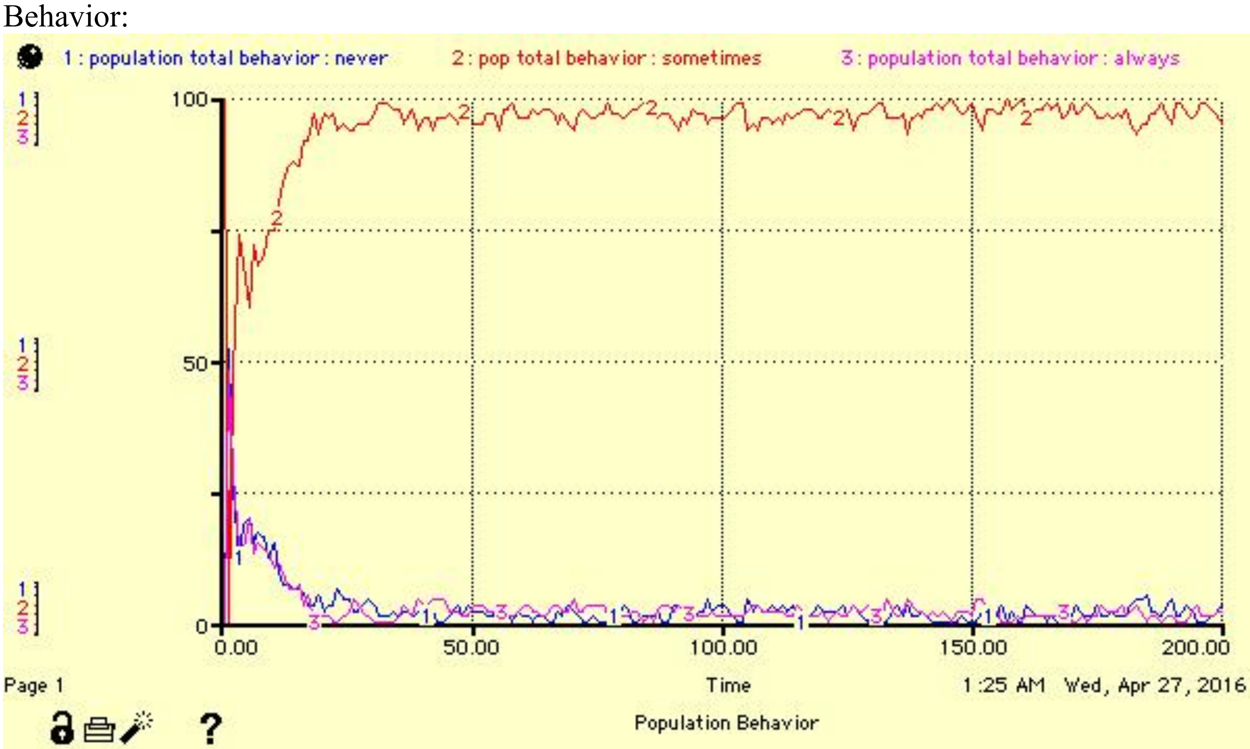


Compatibility:

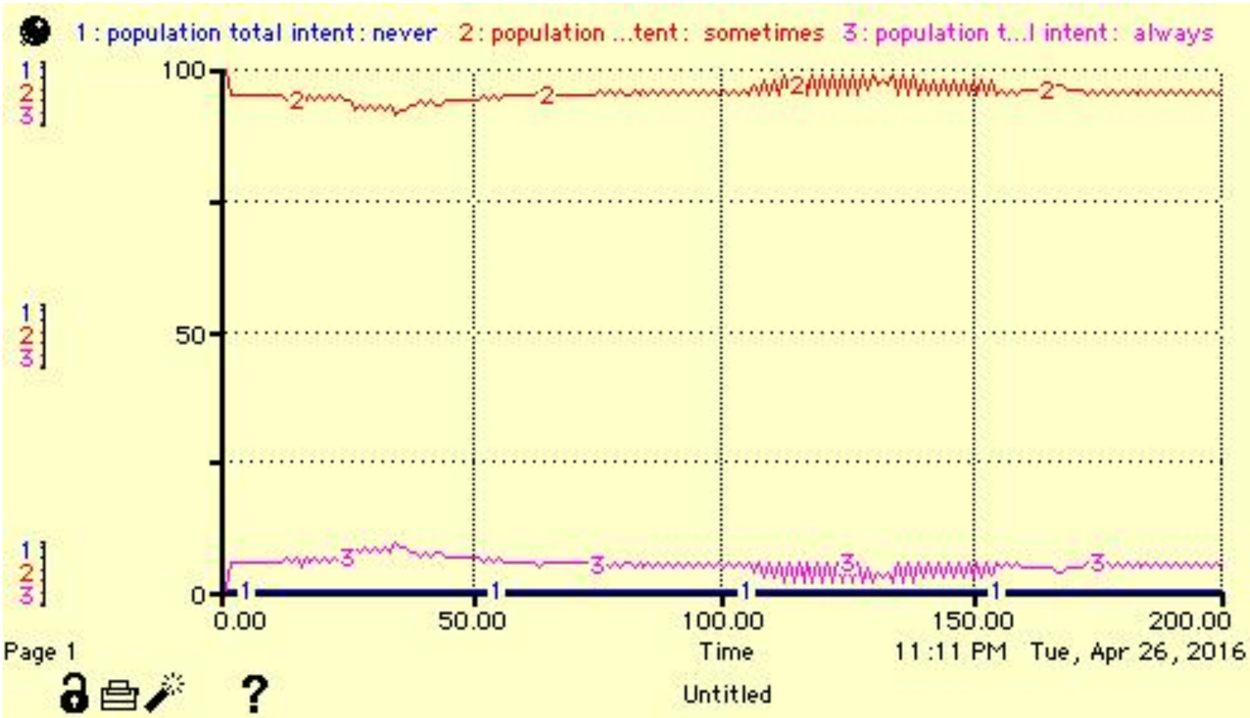
Intent:



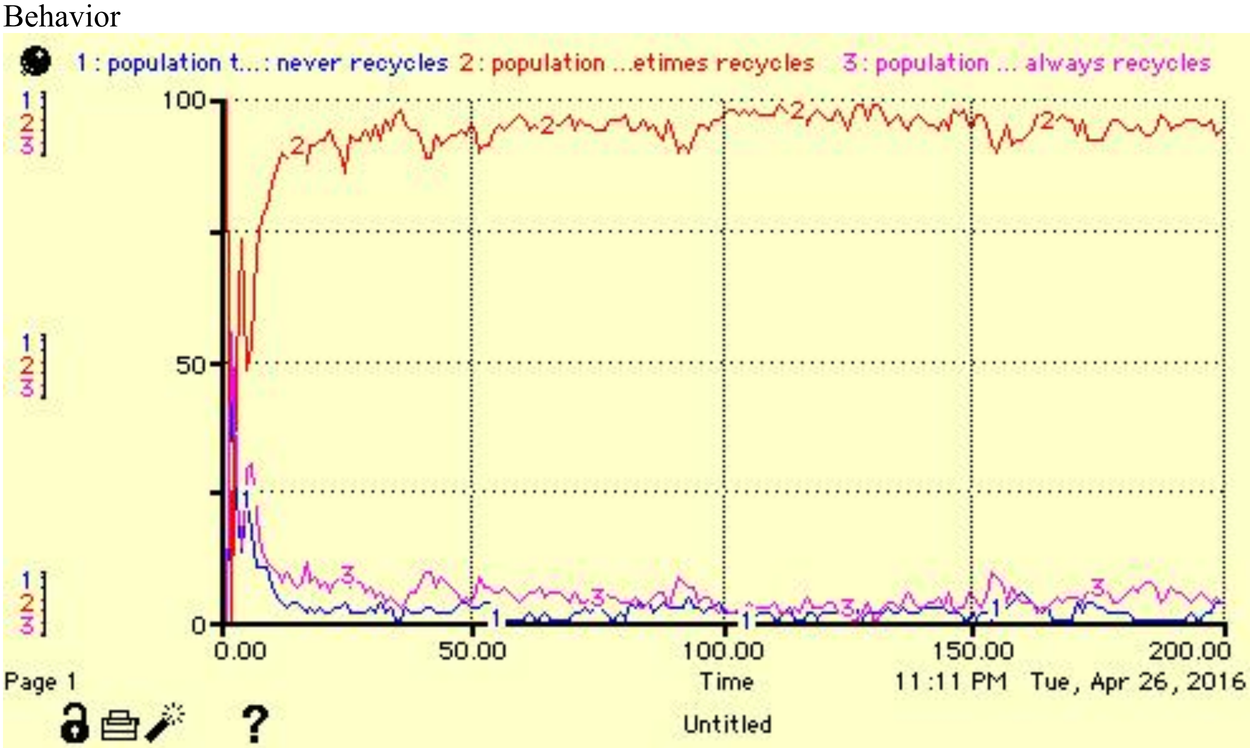
Behavior:



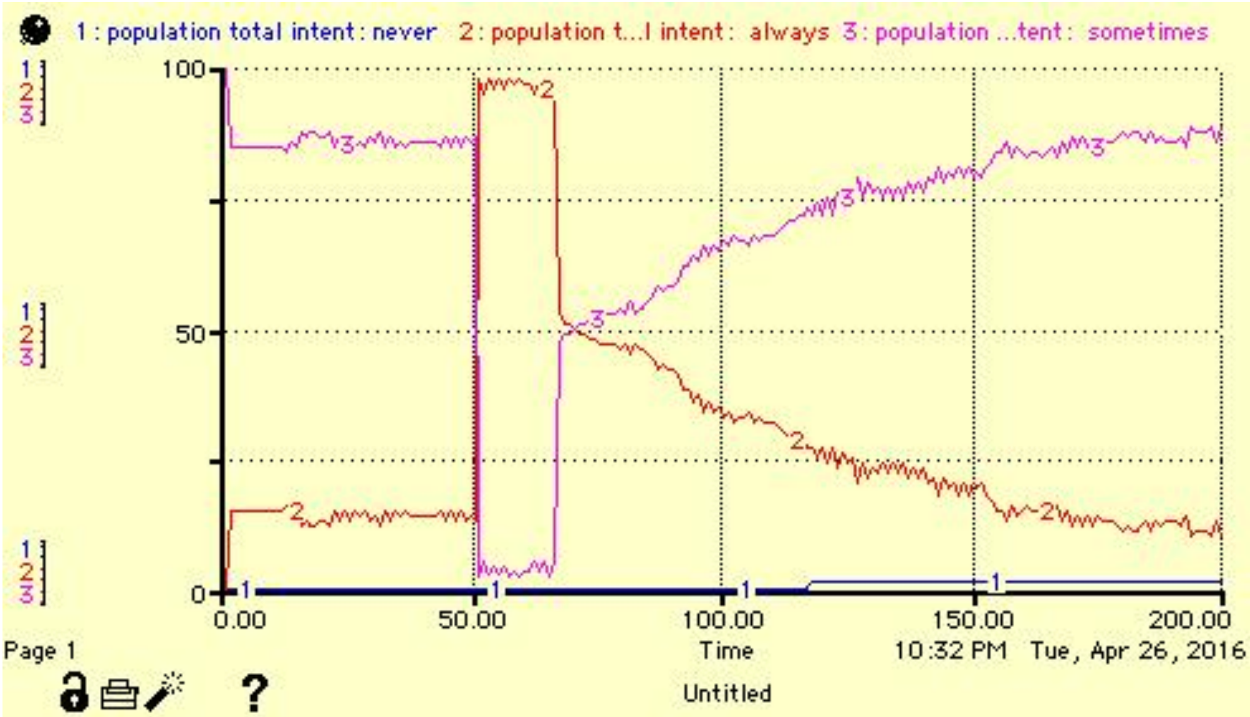
Pulse Tests
Compare to:
Intent:

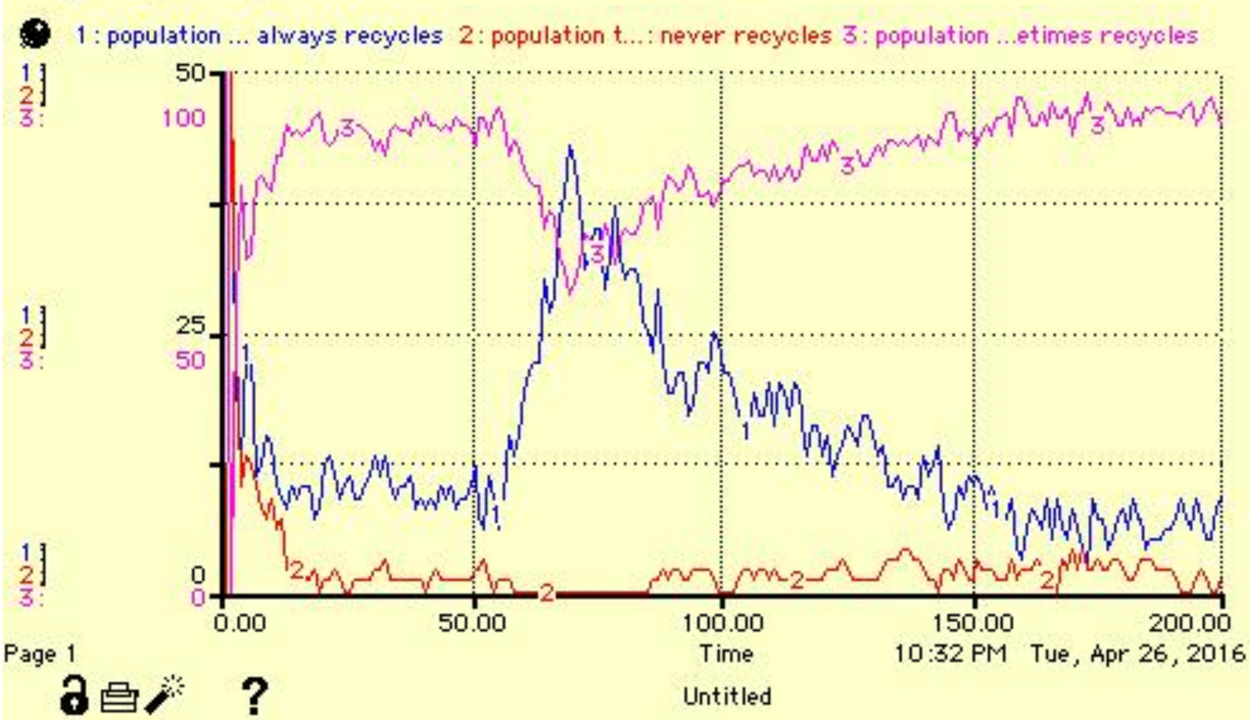


Behavior

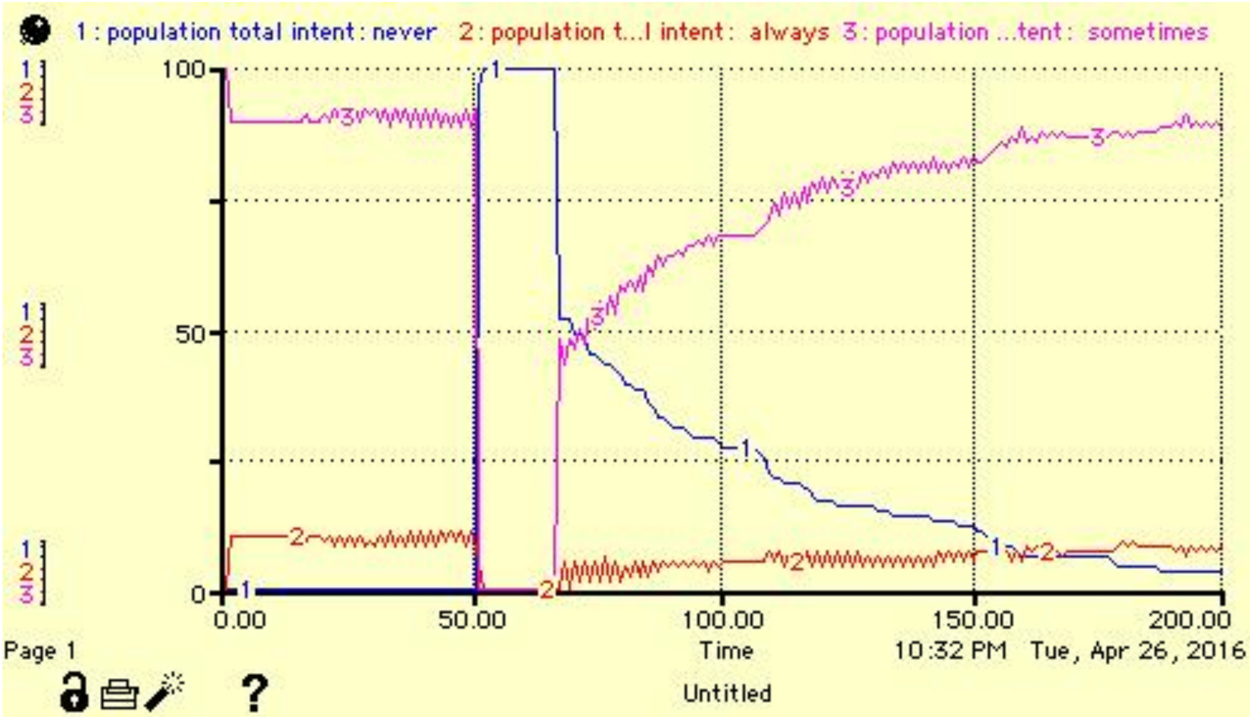


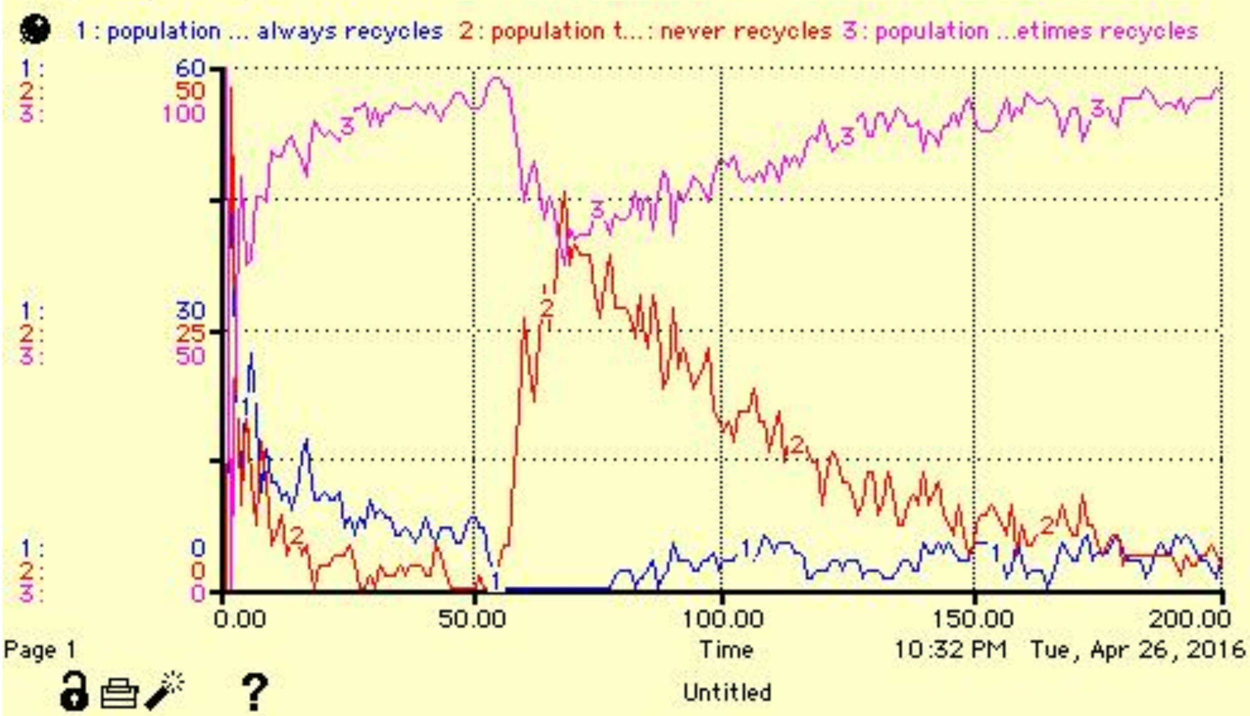
Pulse: Intent UP



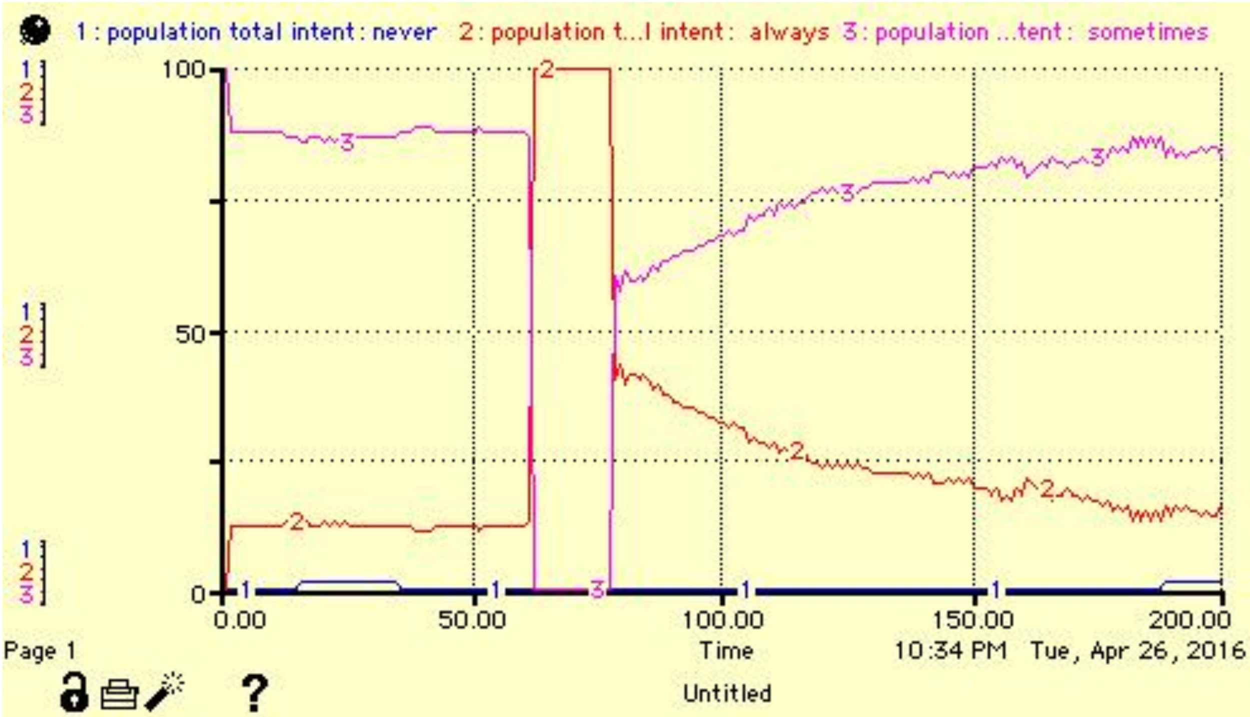


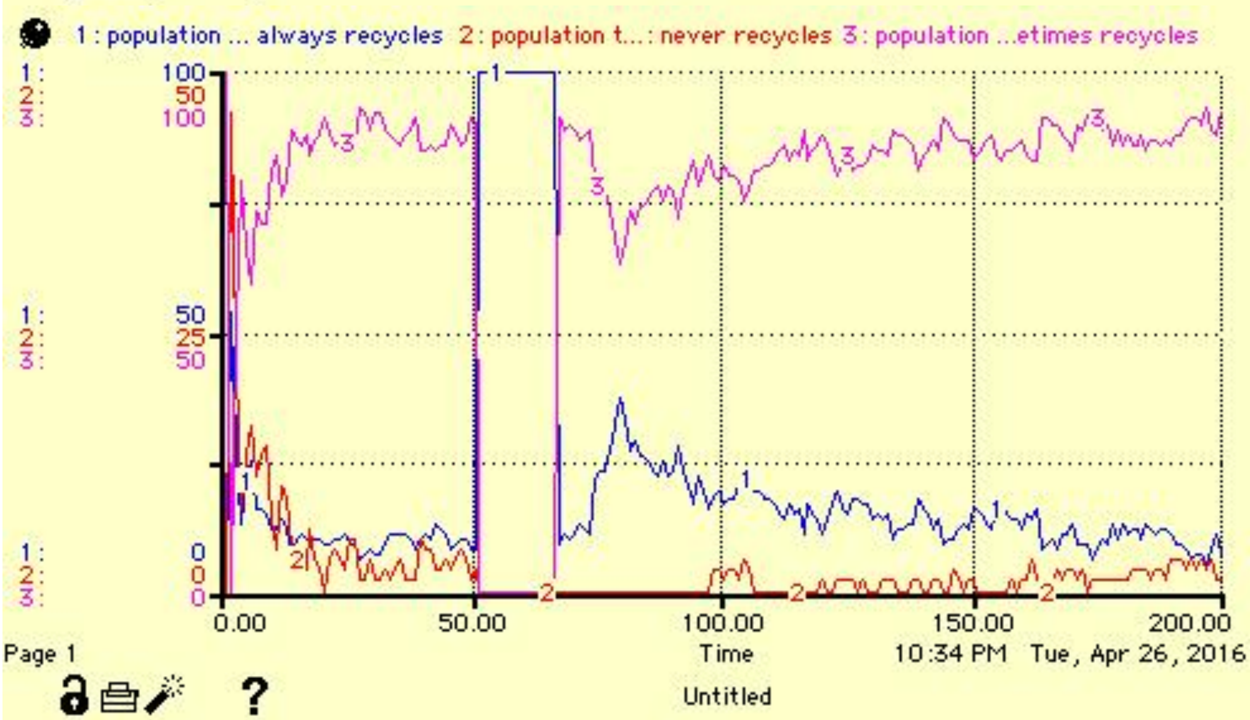
Pulse: Intent DOWN



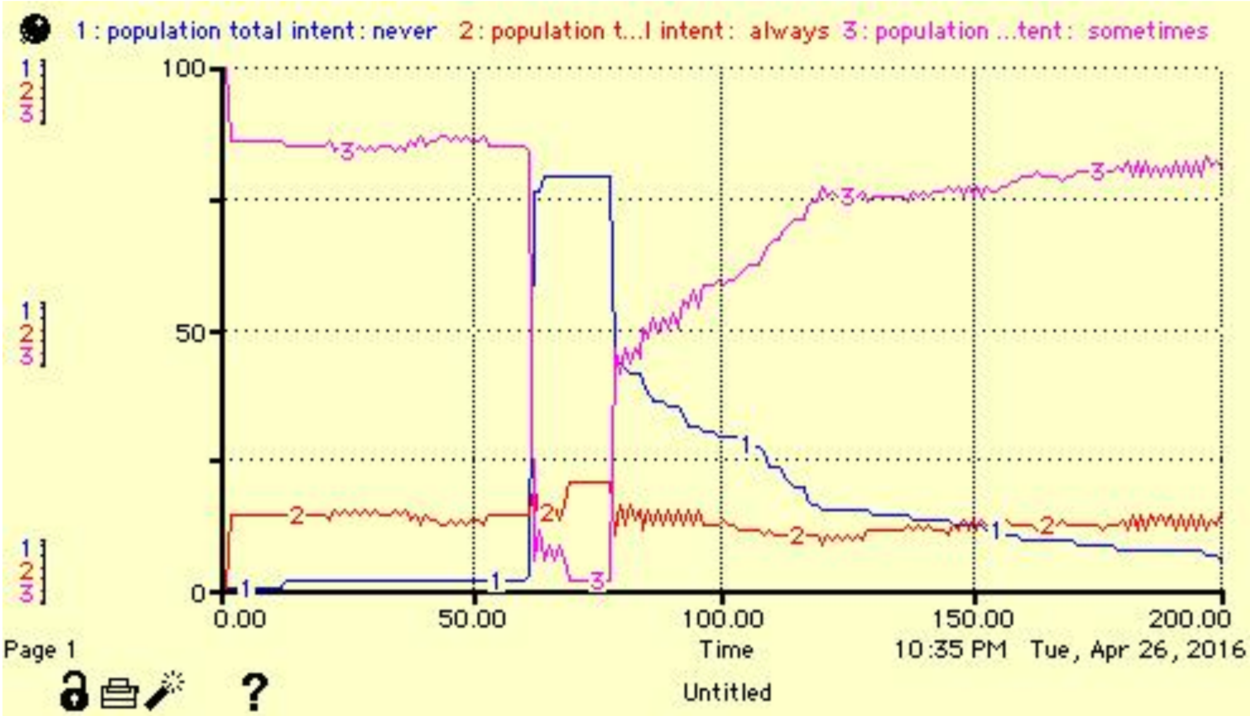


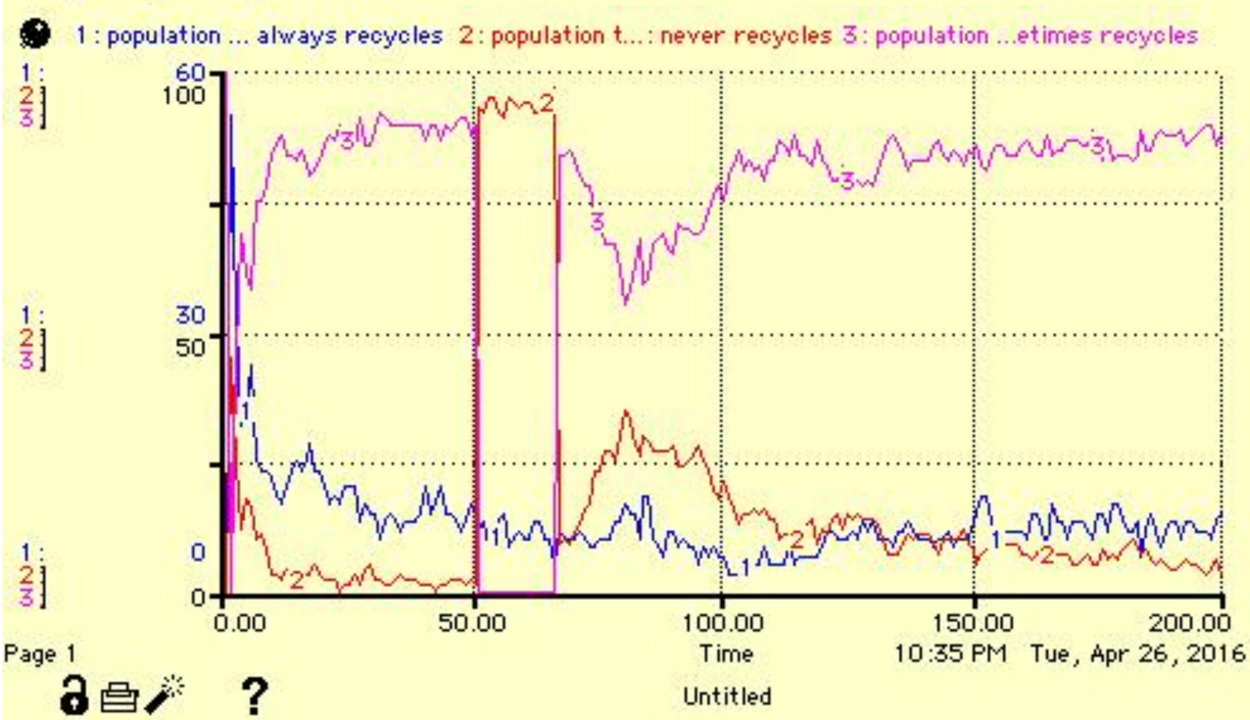
Pulse: Behavior UP



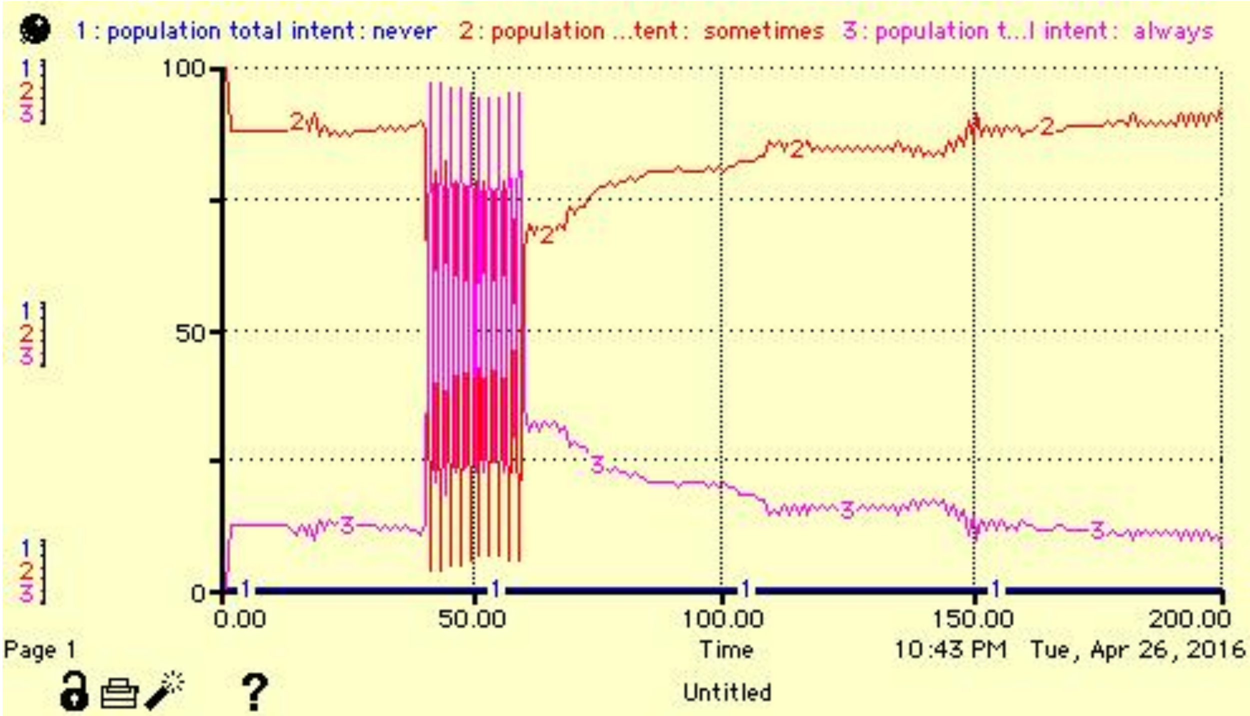


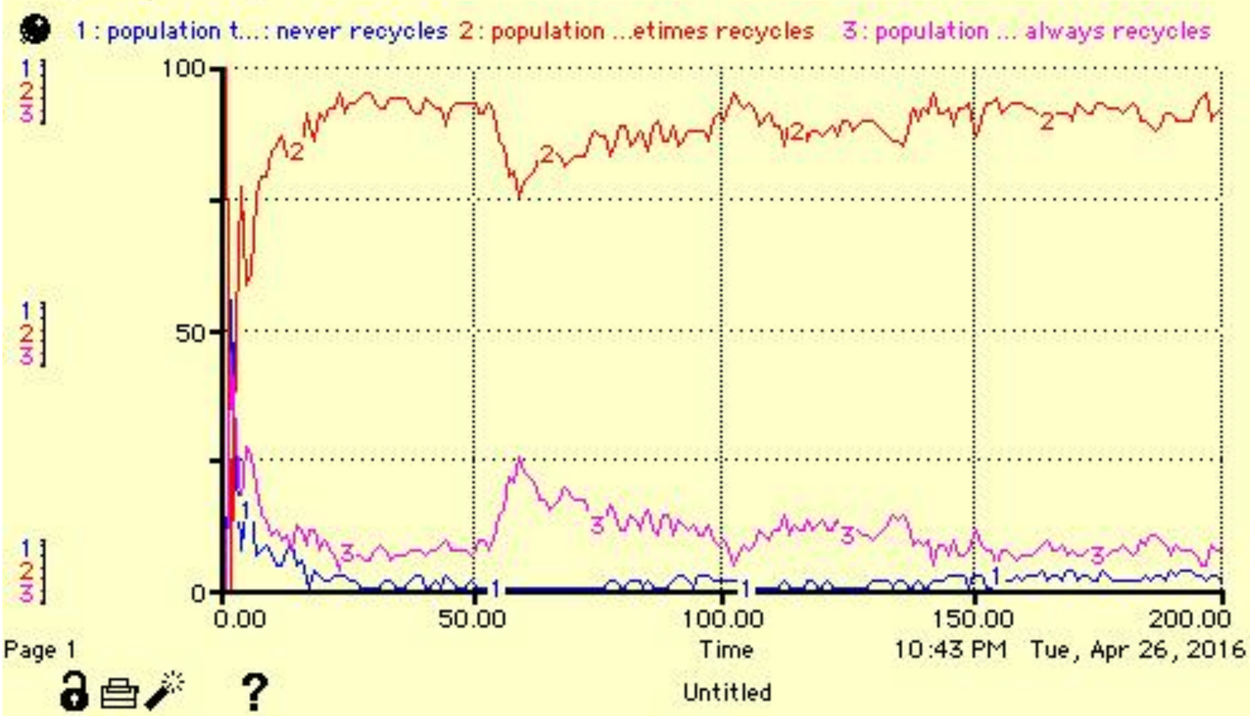
Pulse: Behavior DOWN



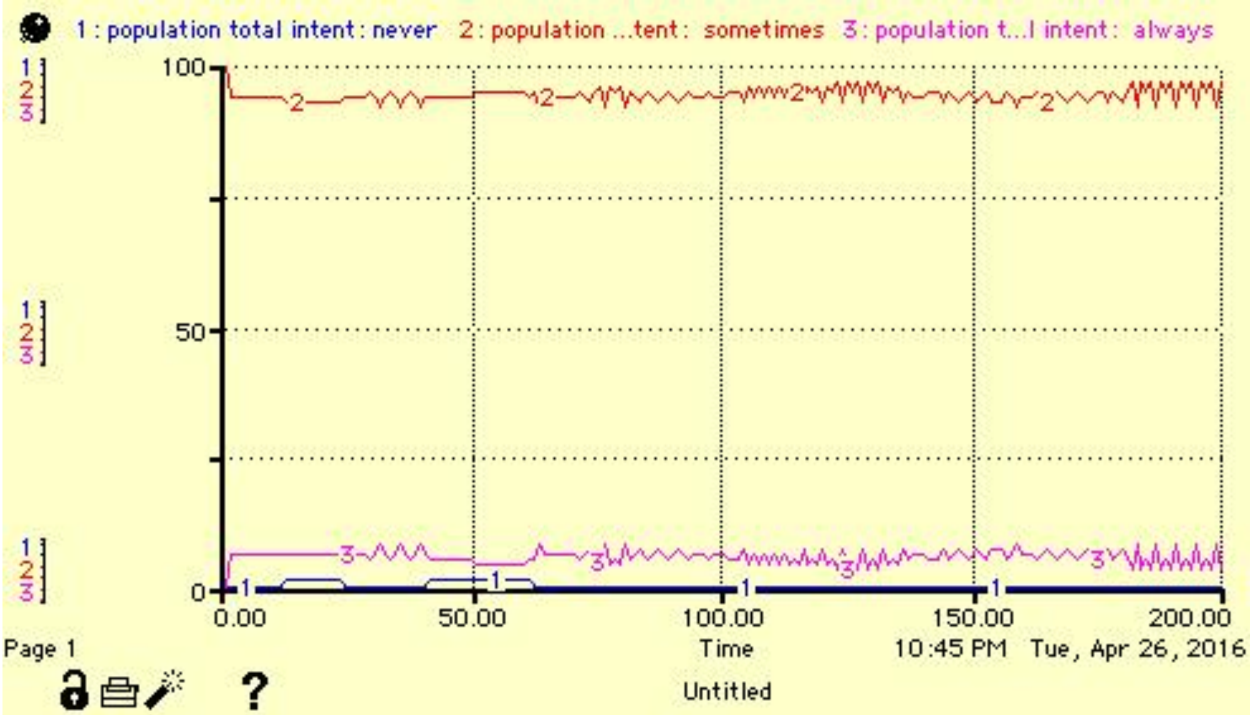


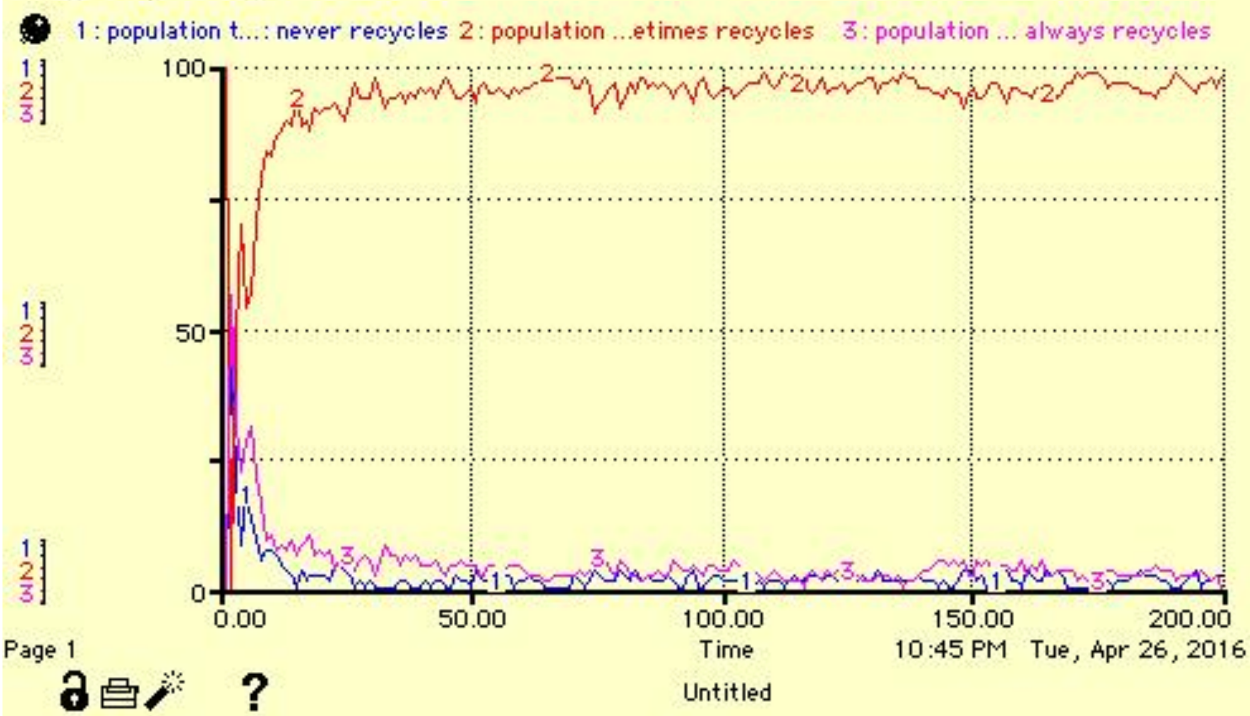
Pulse: Attitude UP



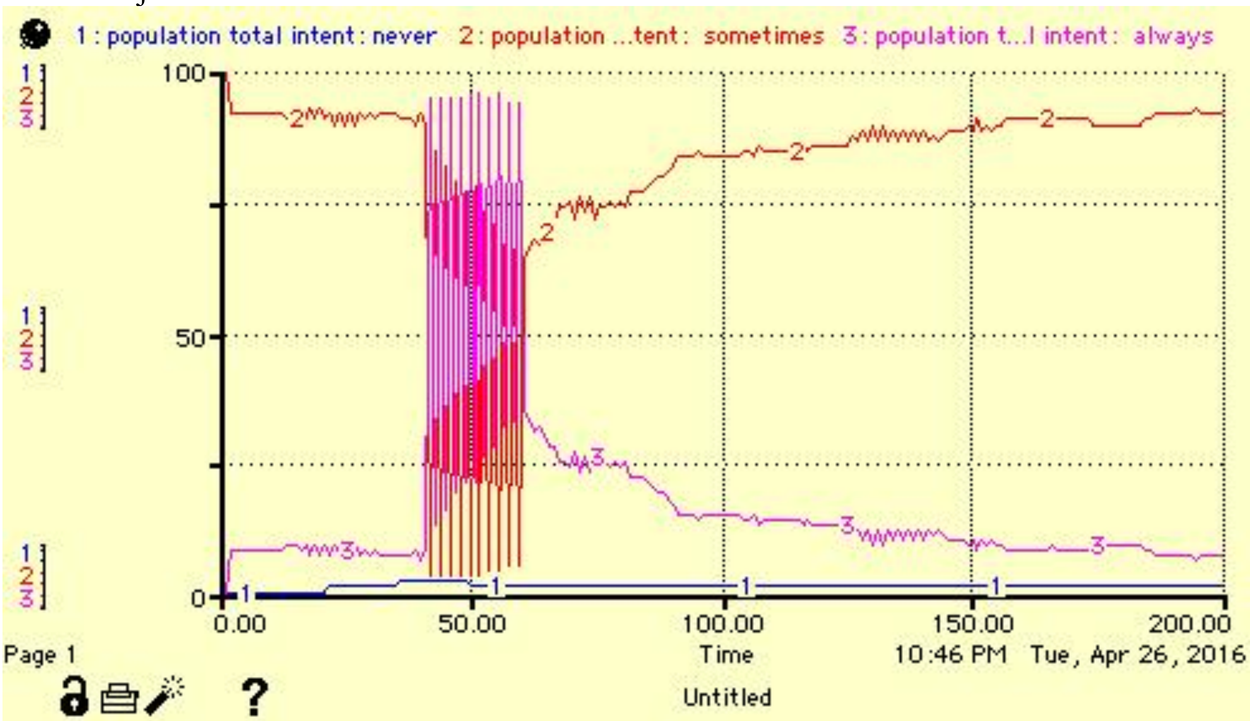


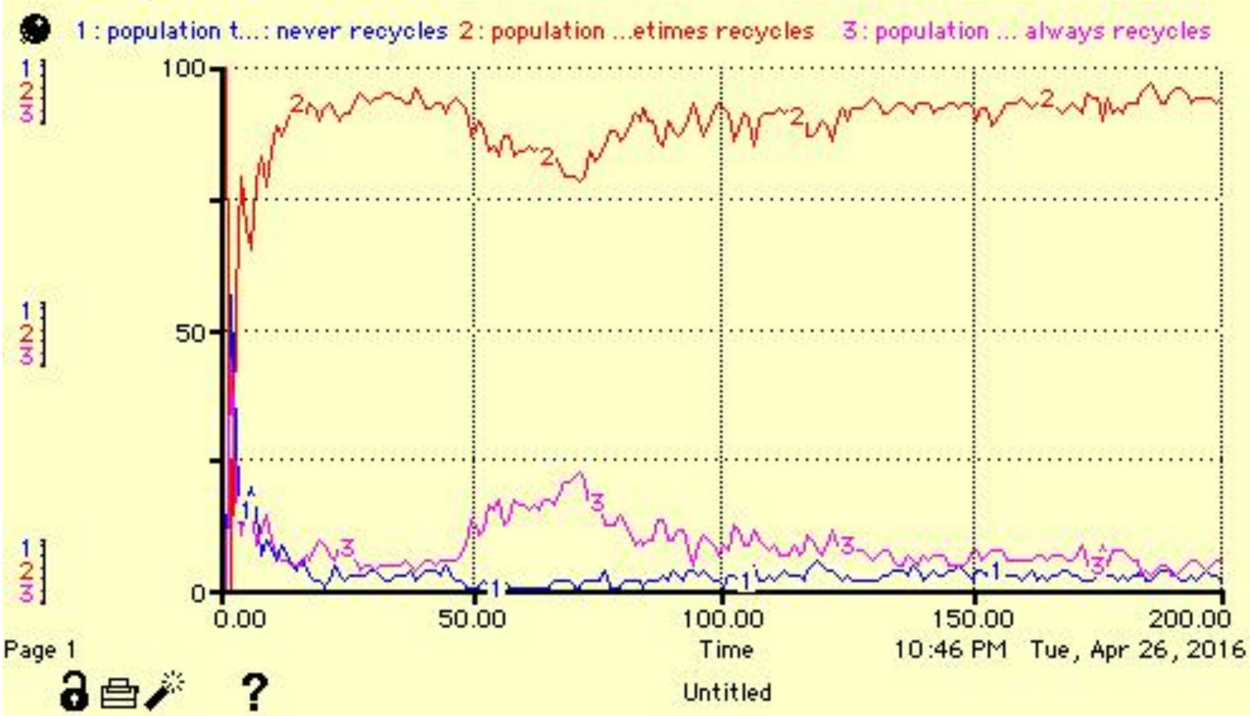
Pulse: Attitude DOWN



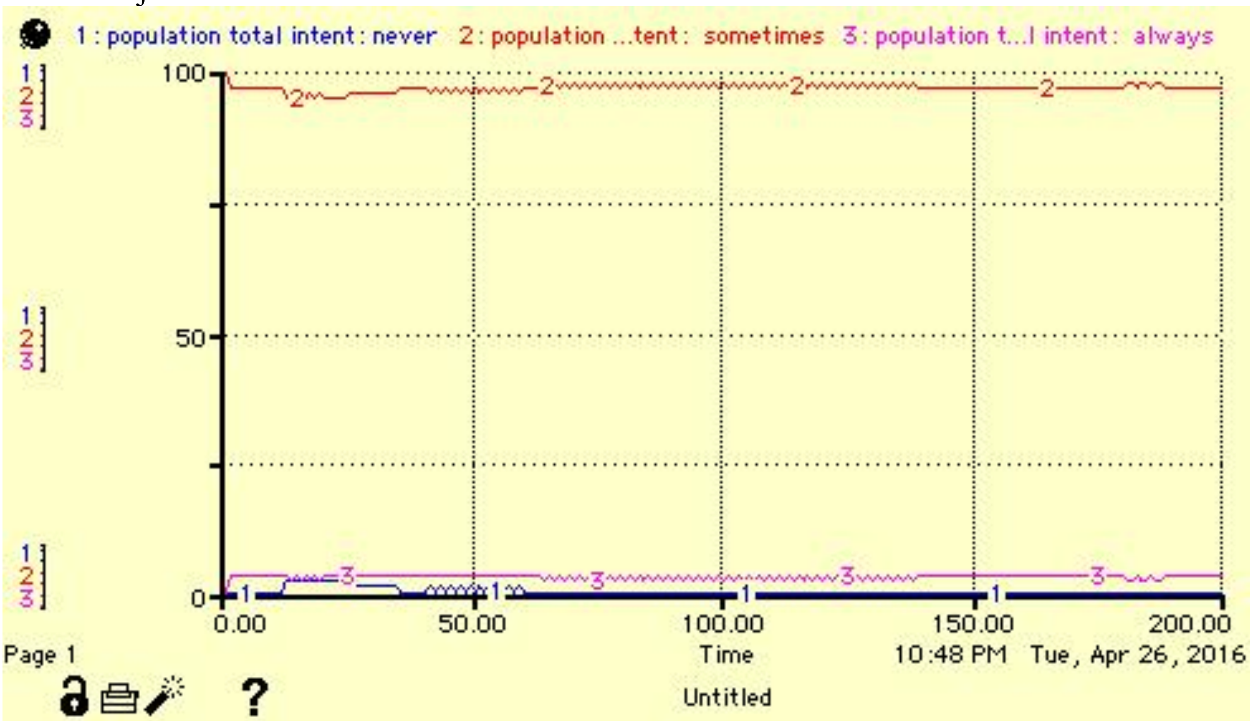


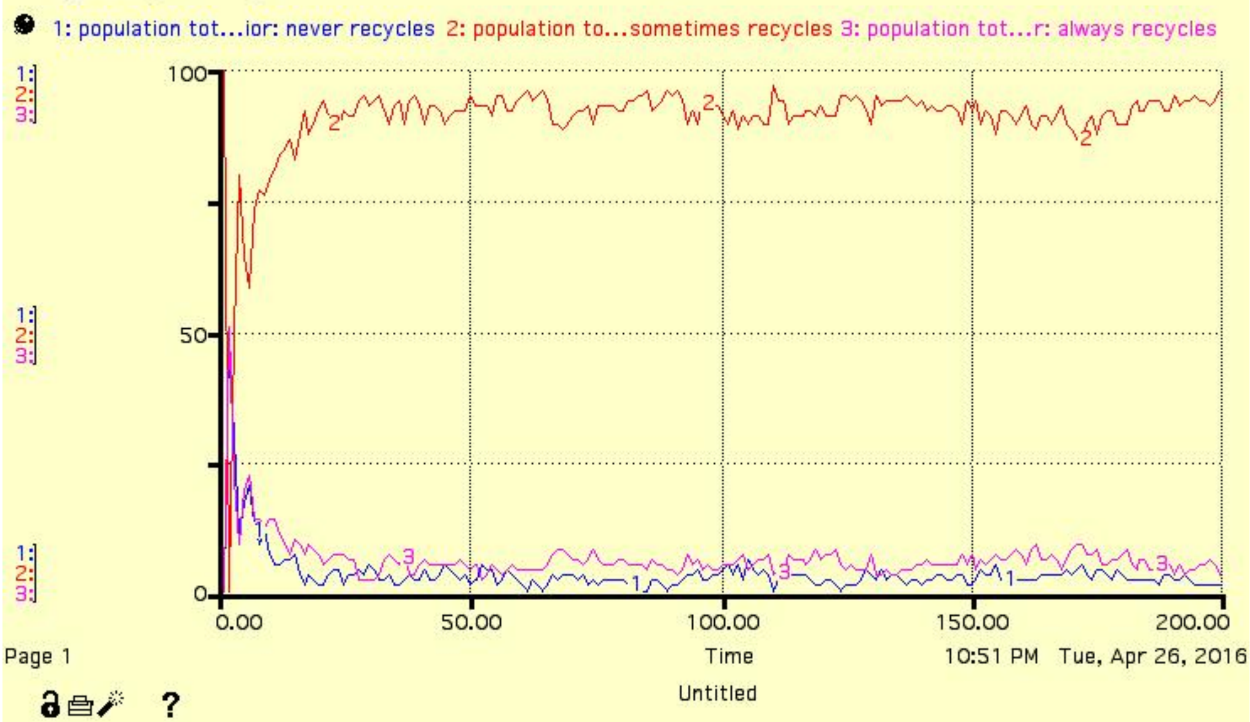
Pulse: Subjective Norm UP



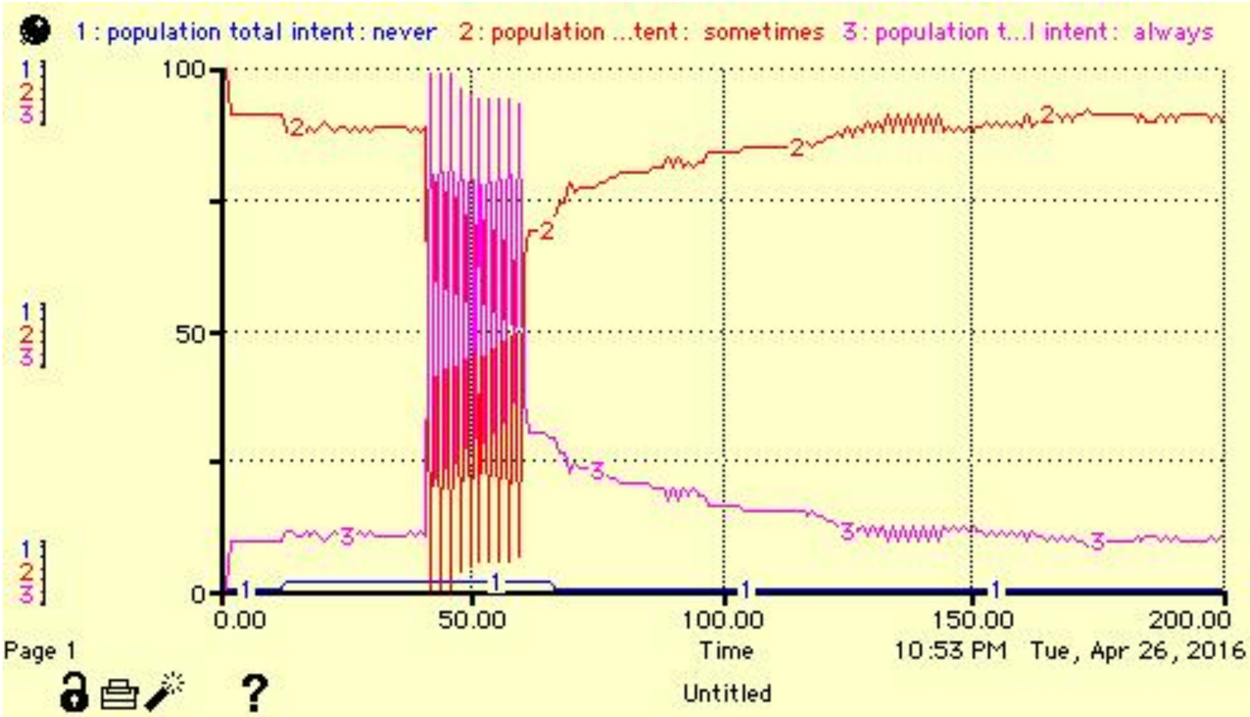


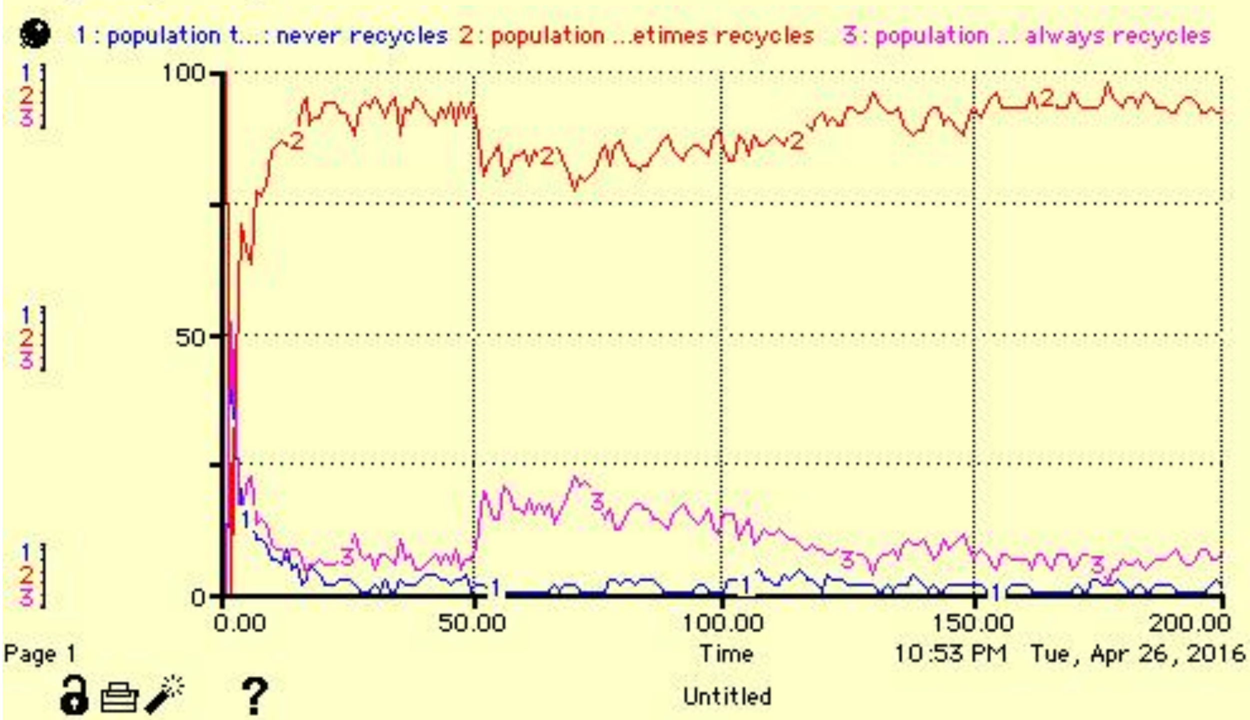
Pulse: Subjective Norm DOWN



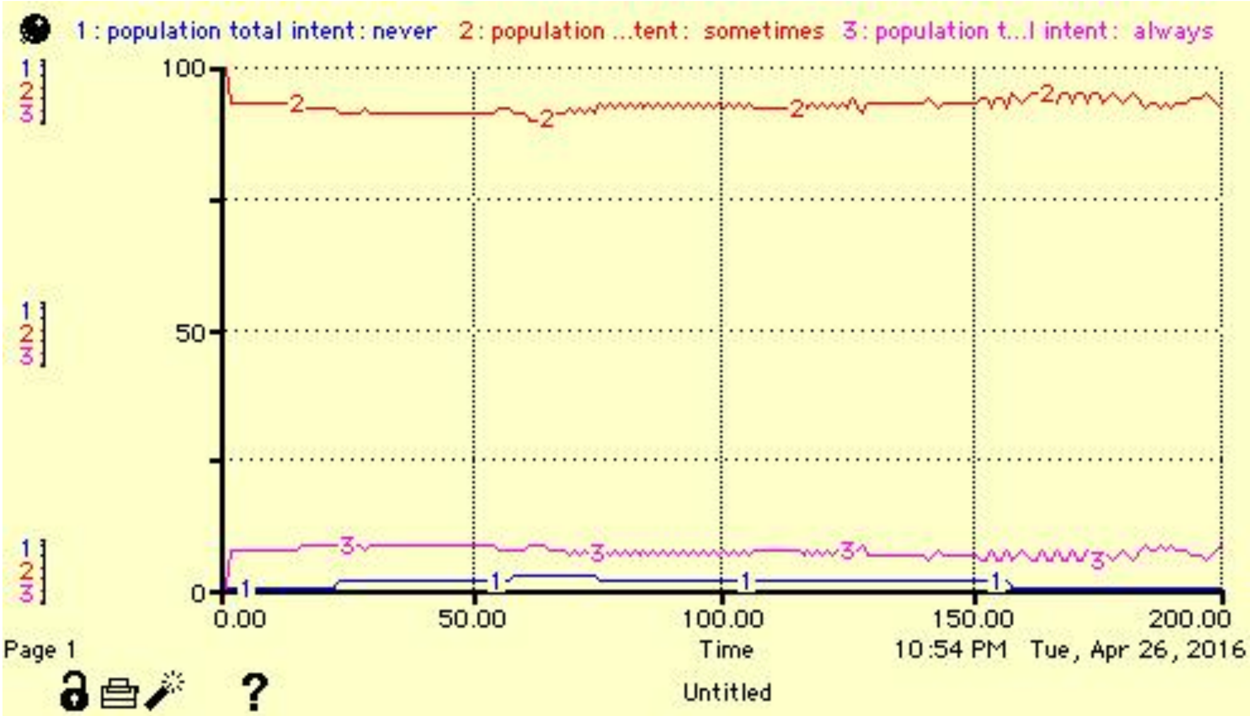


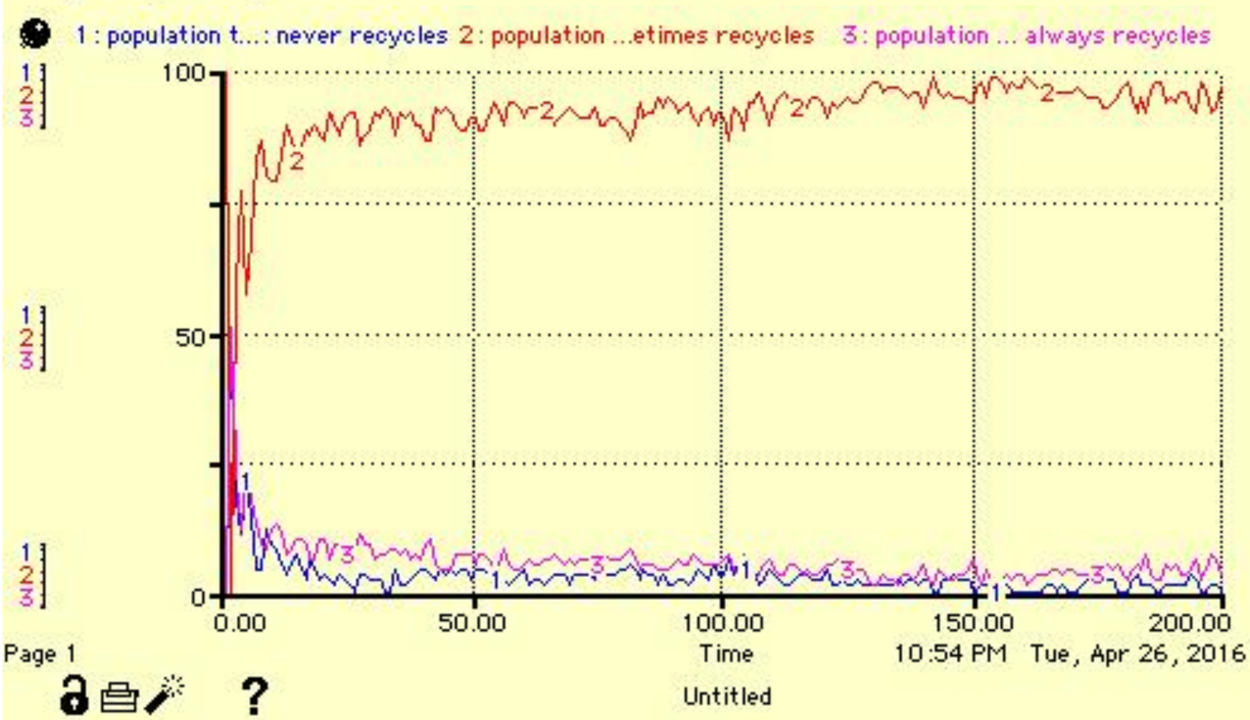
Pulse: Perceived Behavioral Control UP





Pulse: Perceived Behavioral Control DOWN





Scenario 2: New Recycling Program

INPUTS

Factor	*Mean*	*Standard Deviation*
Relative Advantage	6.17[a]	3.16
Complexity	1.39[a]	4.64
Internal Normative Belief	7.06[b]	9.00
External Normative Belief	3.67[b]	6.17
Self-Efficacy	-0.14[a]	5.12
Compatibility	-2.00[a]	3.85
Resource-Facilitating Conditions	3.57[a]	5.32

a. Scaled from -9 to 9.
b. Scaled from -21 to 21.

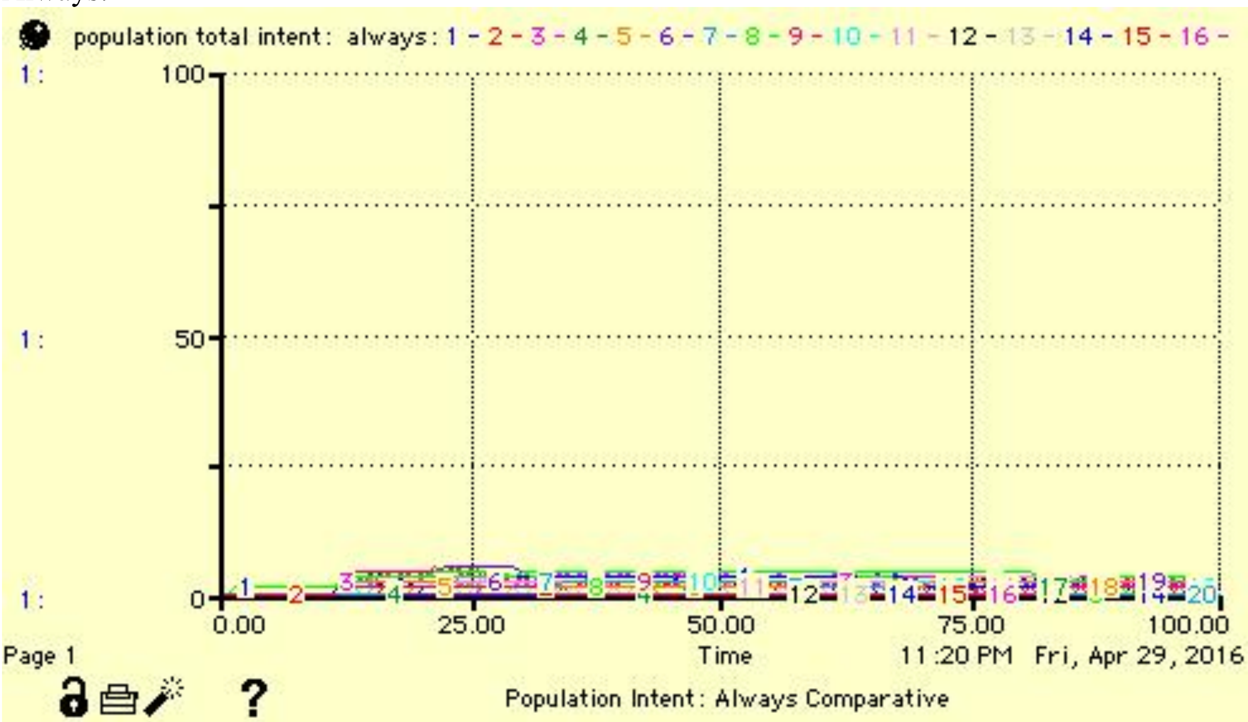
Table 6: Scenario 2 parameters for STELLA model of recycling behavior. Parameters are informed by the empirical work done by Taylor and Todd (1995).

Factor (source)	*Factor (target)*	*Path Coefficient*
Relative Advantage	Attitude	*0.35**
Complexity	Attitude	*-0.05**
Internal Normative Belief	Subjective Norm	*0.07***
External Normative Belief	Subjective Norm	*0.11***
Self-Efficacy	Perceived Behavioral Control	*0.64**
Compatibility	Perceived Behavioral Control	*-0.89**
Resource-Facilitating Conditions	Perceived Behavioral Control	*0.15***
Attitude	Intent	*1.38***
Subjective Norm	Intent	*0.20**
Perceived Behavioral Control	Intent	*0.33***

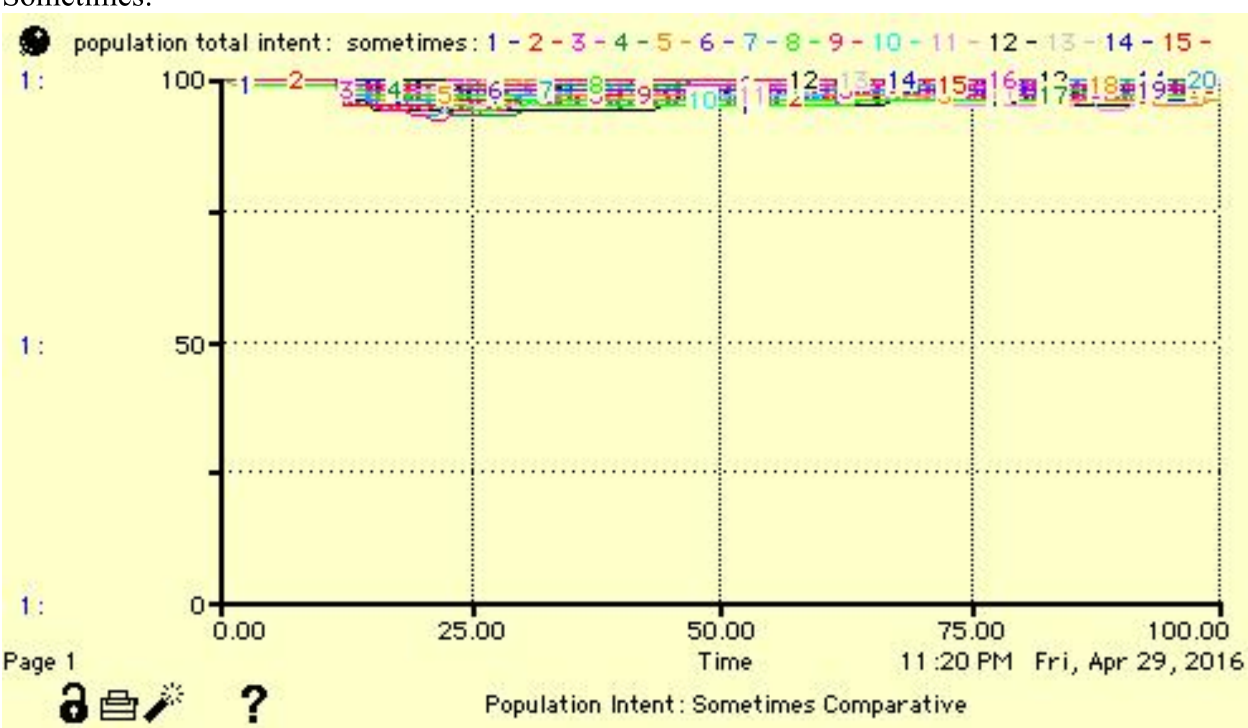
*p <.01; **p<.001.

Table 7: Path coefficients between factors in STELLA model, adapted from the structural equation model in Taylor and Todd's work (1995).

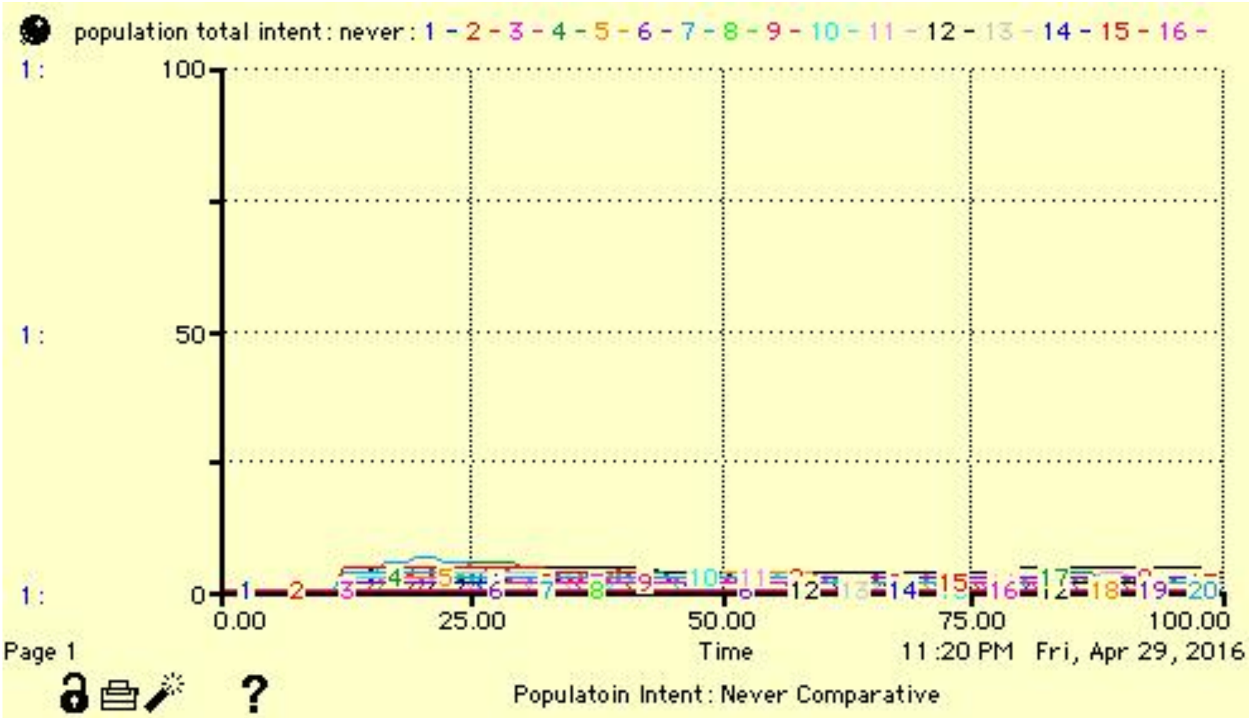
<u>OUTPUTS</u>
Intent:
Always:



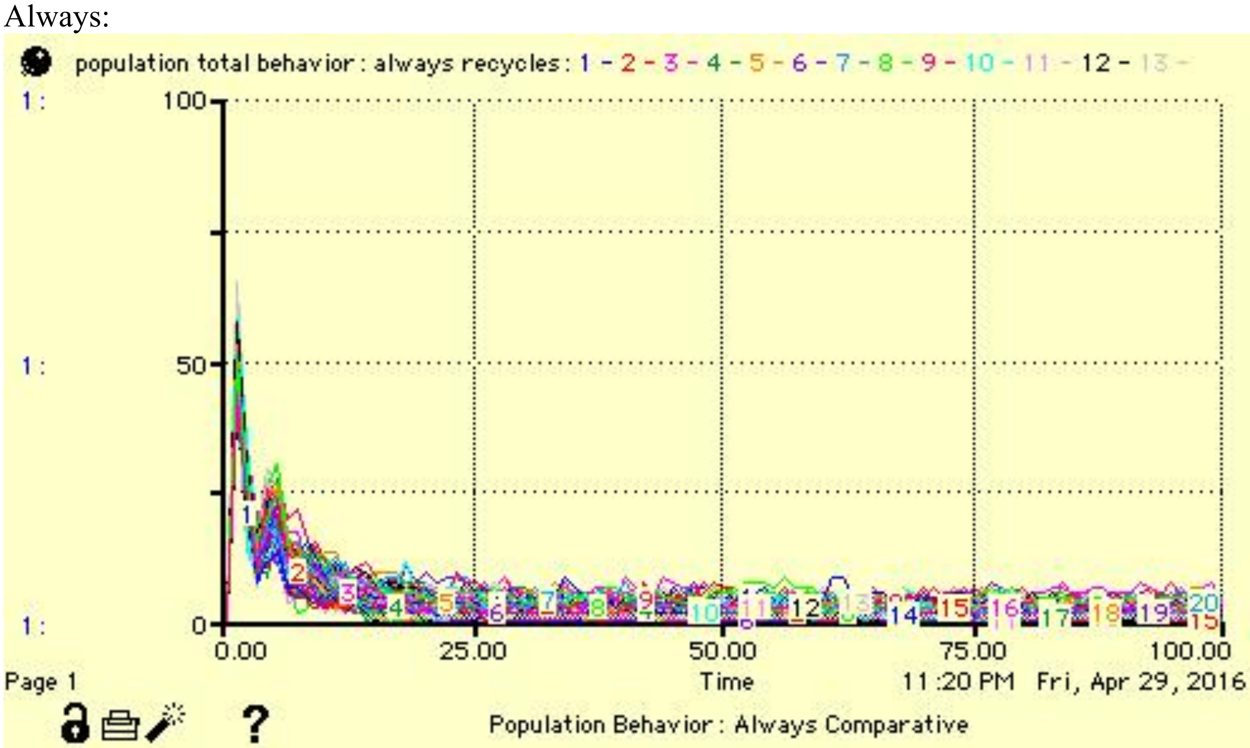
Sometimes:



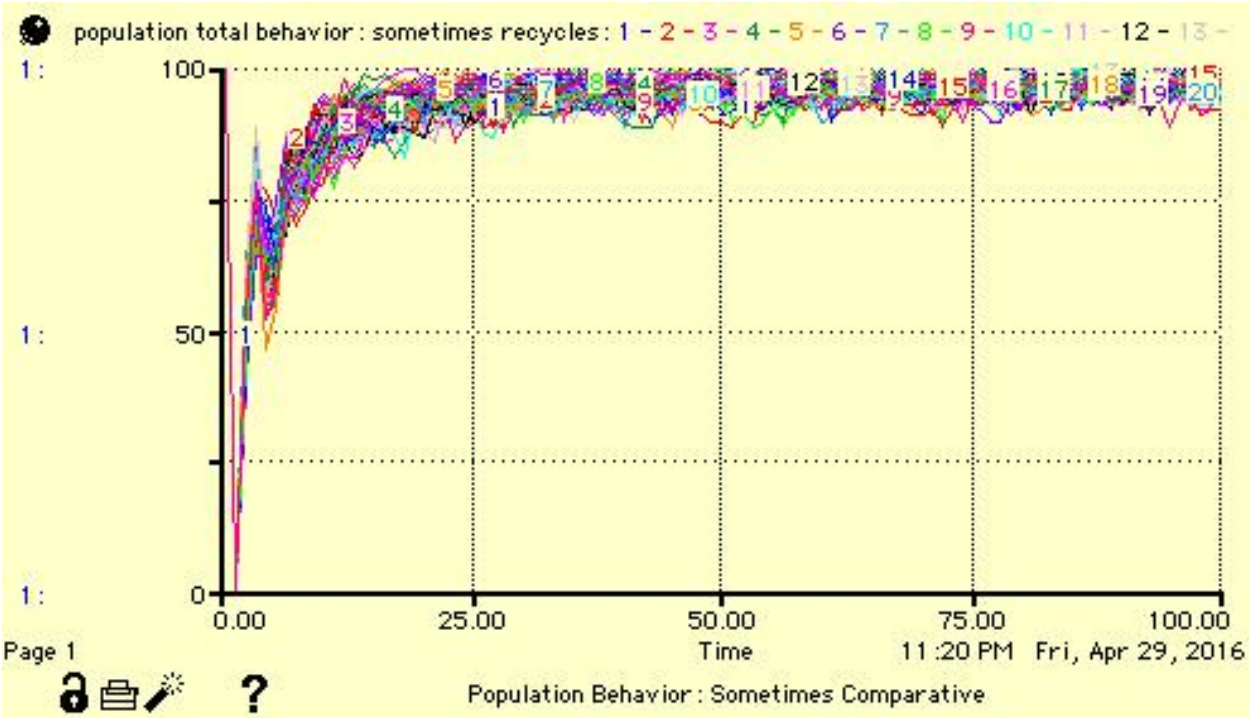
Never:



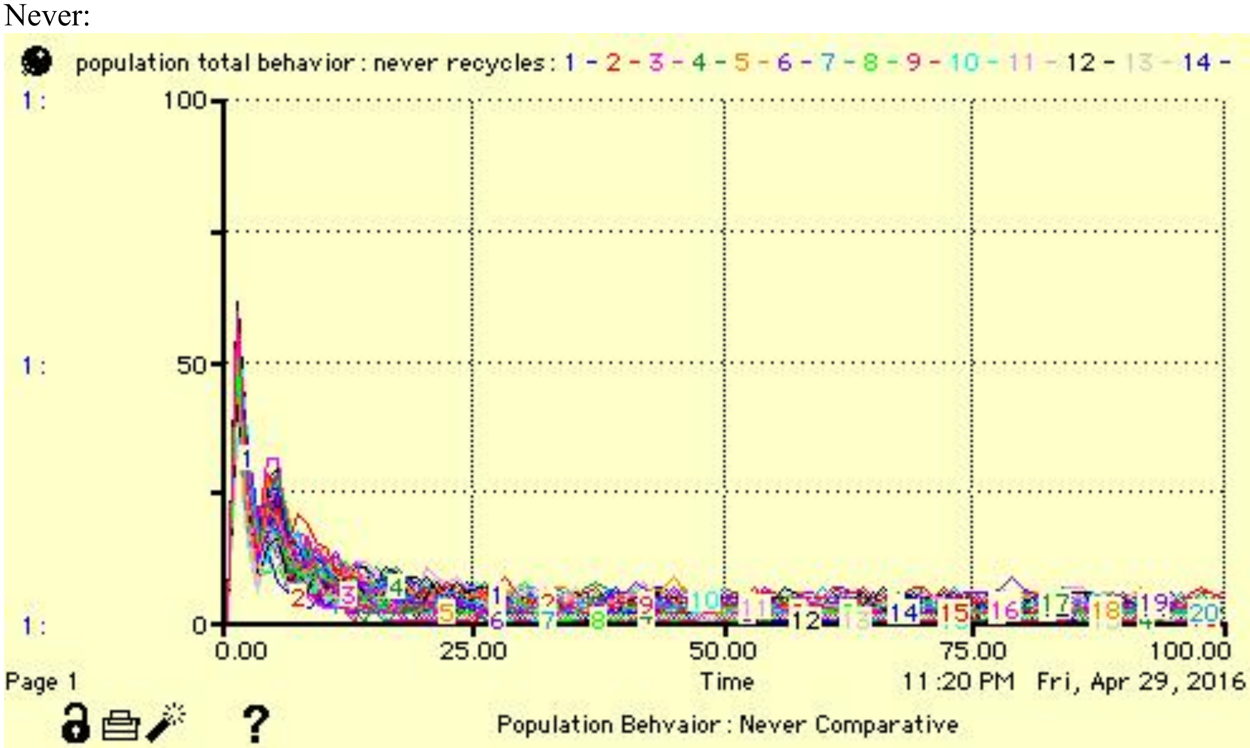
Behavior:
Always:



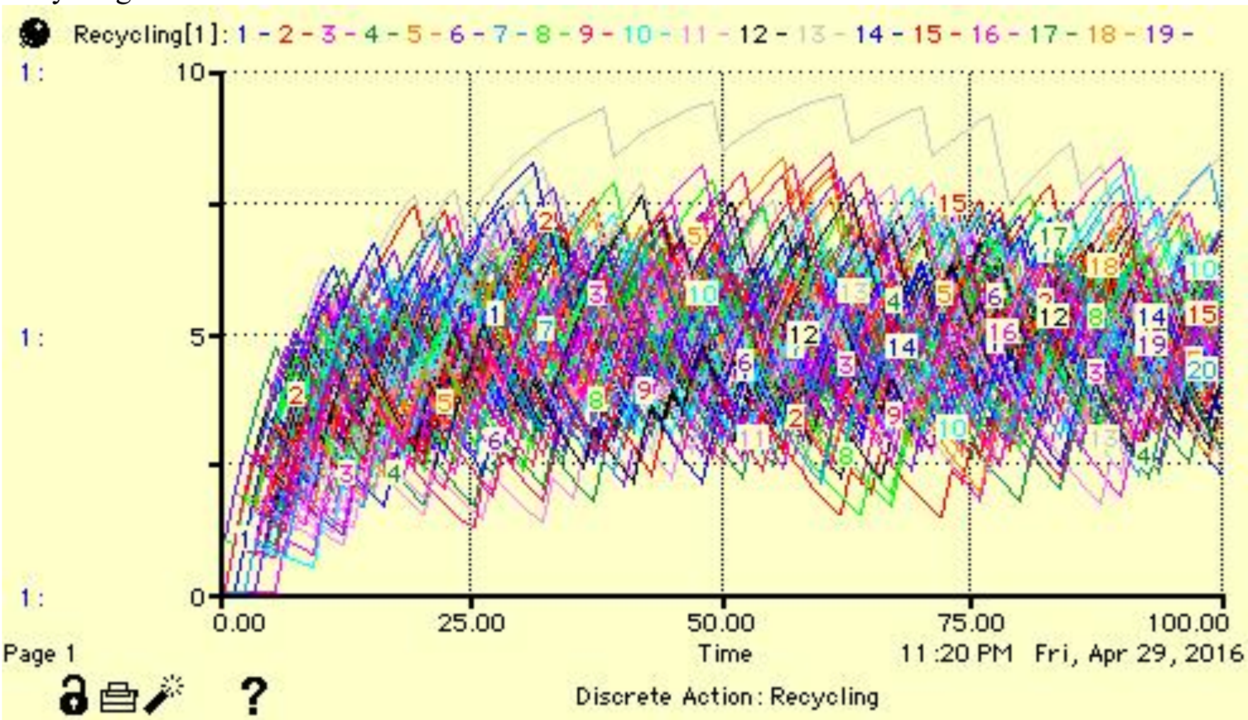
Sometimes:



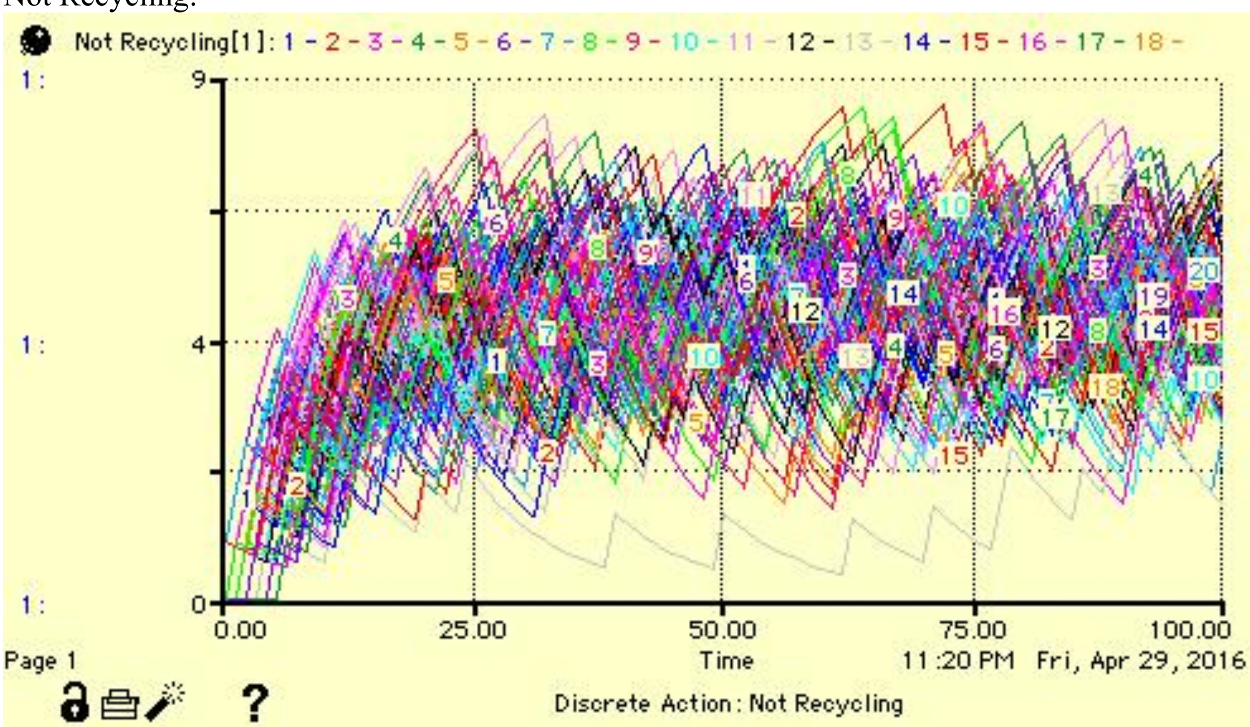
Never:



Discrete Action:
Recycling:



Not Recycling:



Scenario 3: No Recycling Program

INPUTS

Factor	*Mean*	*Standard Deviation*
Relative Advantage	3.01[a]	3.16
Complexity	-3.25[a]	4.64
Internal Normative Belief	-1.94[b]	9.00
External Normative Belief	-2.50[b]	6.17
Self-Efficacy	-5.26[a]	5.12
Compatibility	-3.85[a]	3.85
Resource-Facilitating Conditions	-1.75[a]	5.32

a. Scaled from -9 to 9.
b. Scaled from -21 to 21.
Table 10: Scenario 3 parameters for STELLA model of recycling behavior. Parameters are informed by the empirical work done by Taylor and Todd (1995).

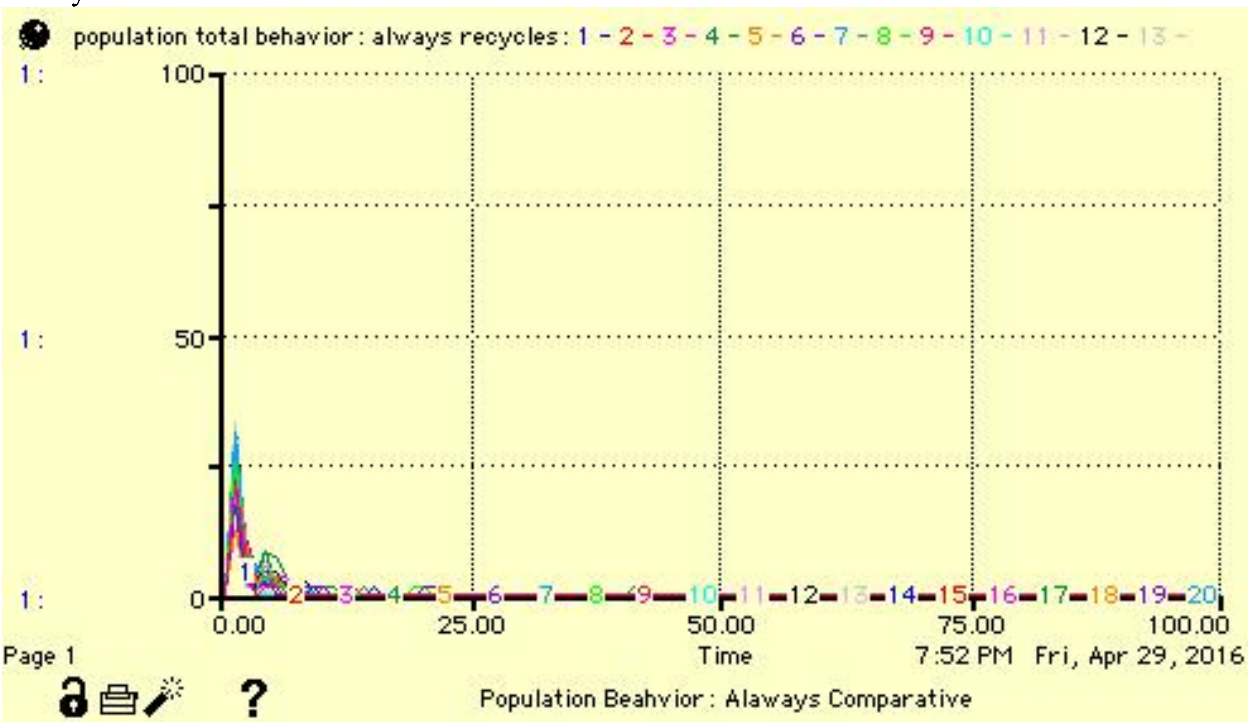
Factor (source)	*Factor (target)*	*Path Coefficient*
Relative Advantage	Attitude	*0.35**
Complexity	Attitude	*-0.05**
Internal Normative Belief	Subjective Norm	*0.07***
External Normative Belief	Subjective Norm	*0.11***
Self-Efficacy	Perceived Behavioral Control	*0.64**
Compatibility	Perceived Behavioral Control	*-0.89**
Resource-Facilitating Conditions	Perceived Behavioral Control	*0.15***
Attitude	Intent	*1.38***
Subjective Norm	Intent	*0.20**
Perceived Behavioral Control	Intent	*0.33***

**p <.01; **p<.001.*
Table 11: Path coefficients between factors in STELLA model, adapted from the structural equation model in Taylor and Todd's work (1995).

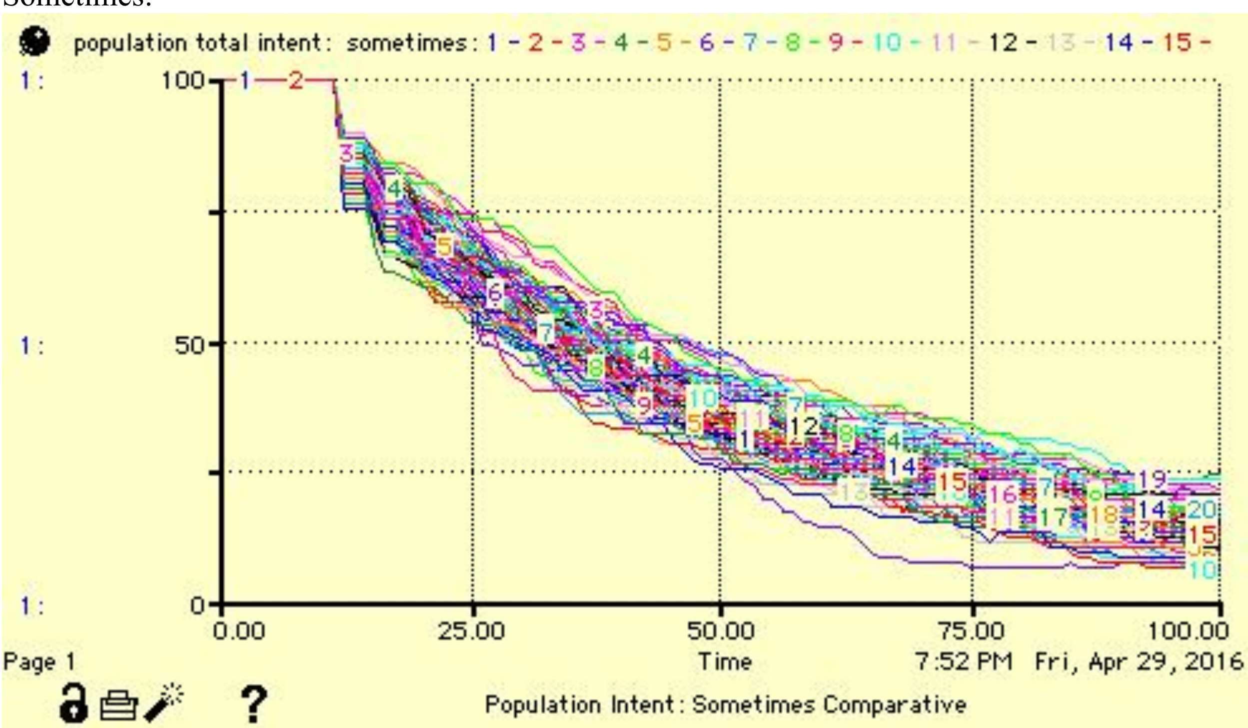
OUTPUTS

Intent:

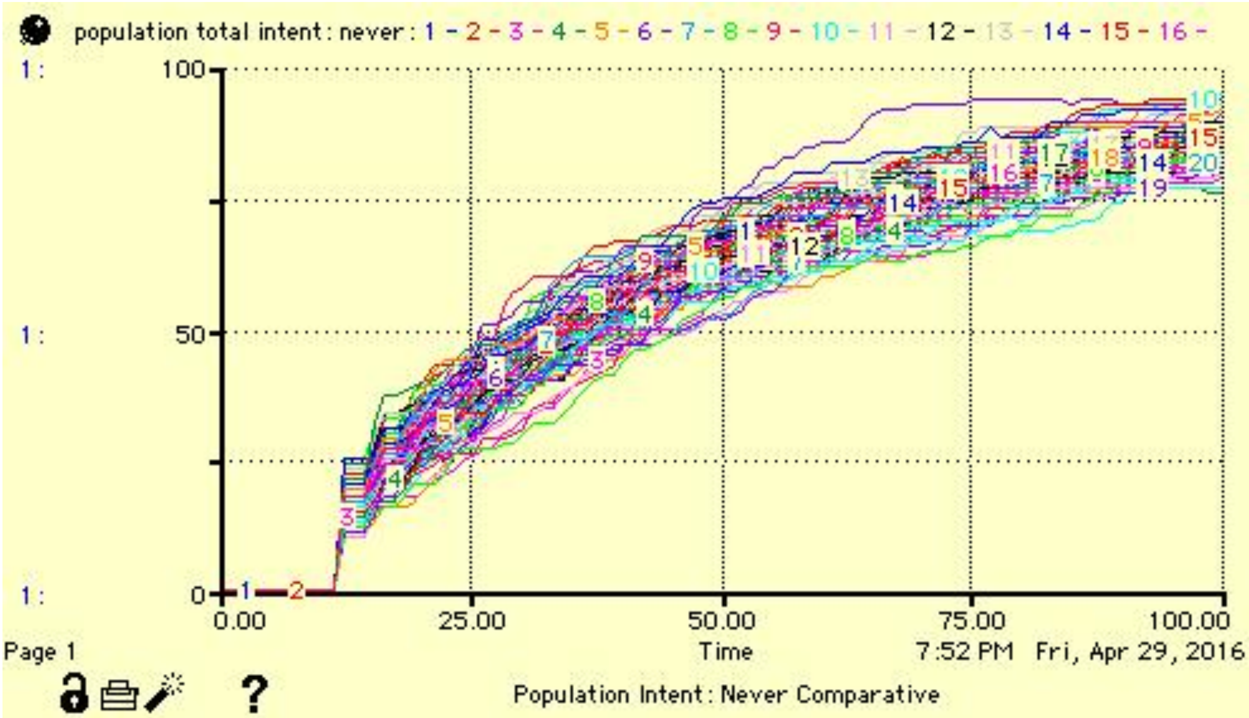
Always:



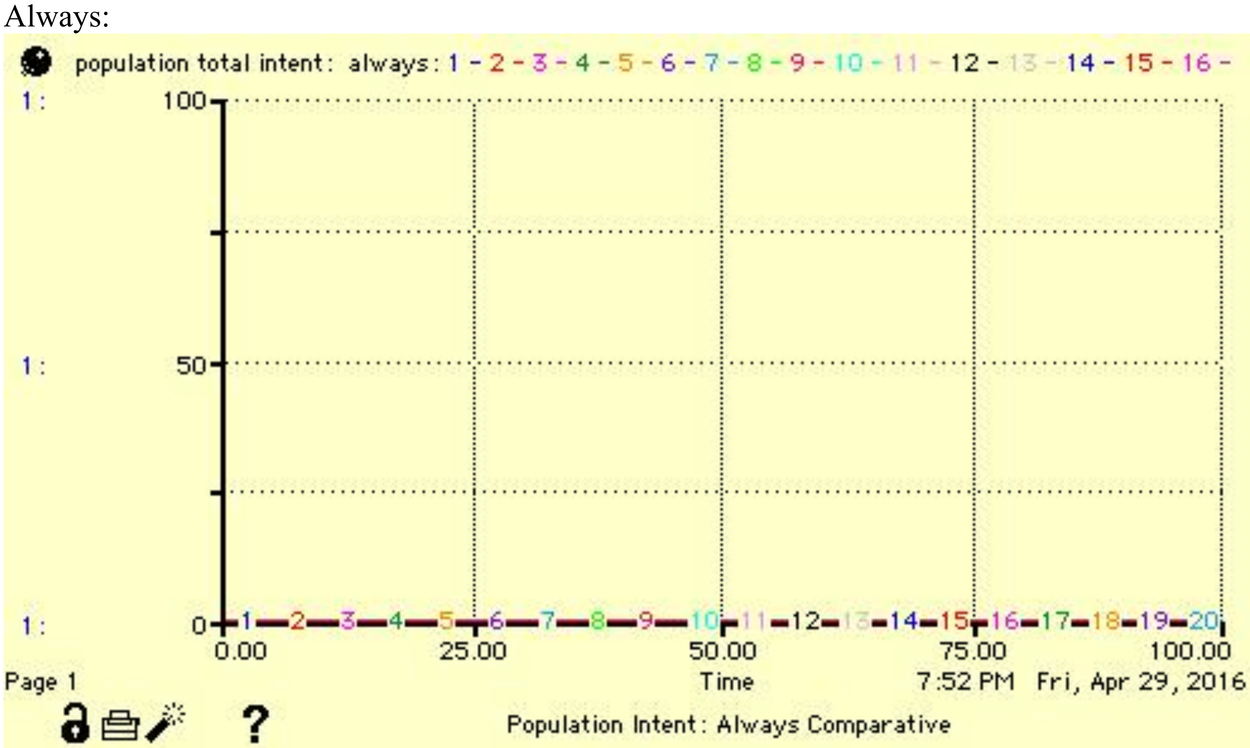
Sometimes:



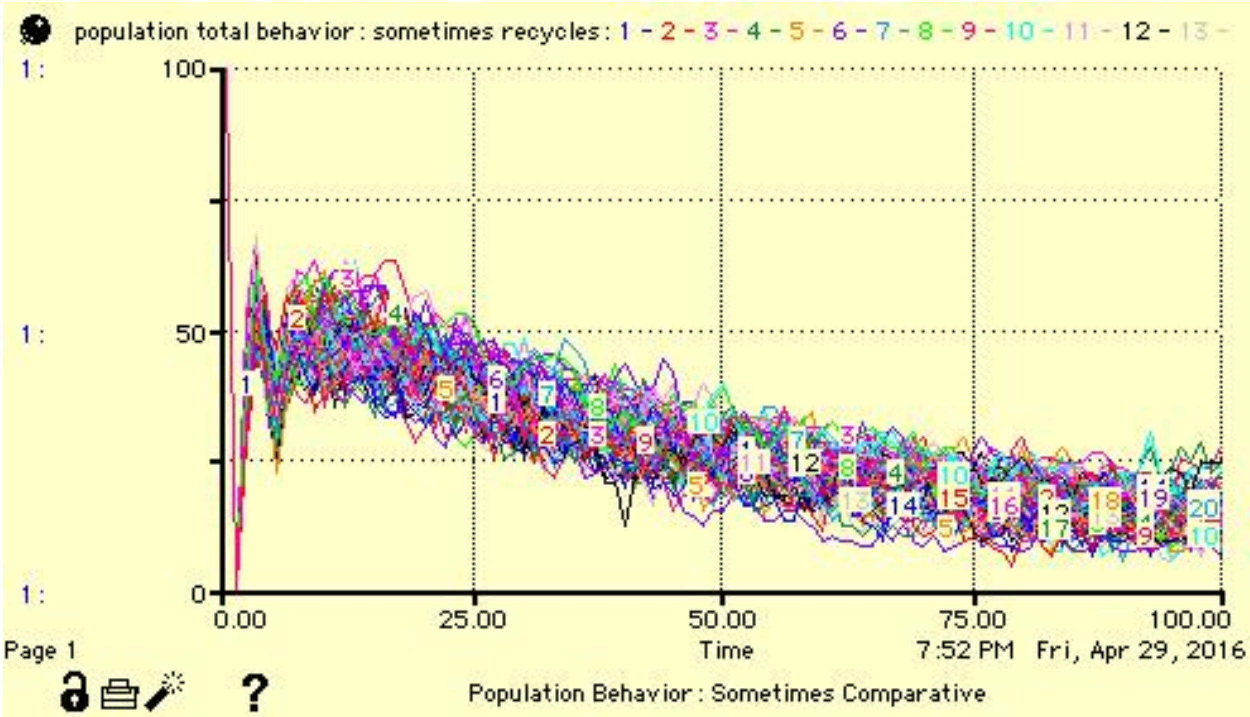
Never:



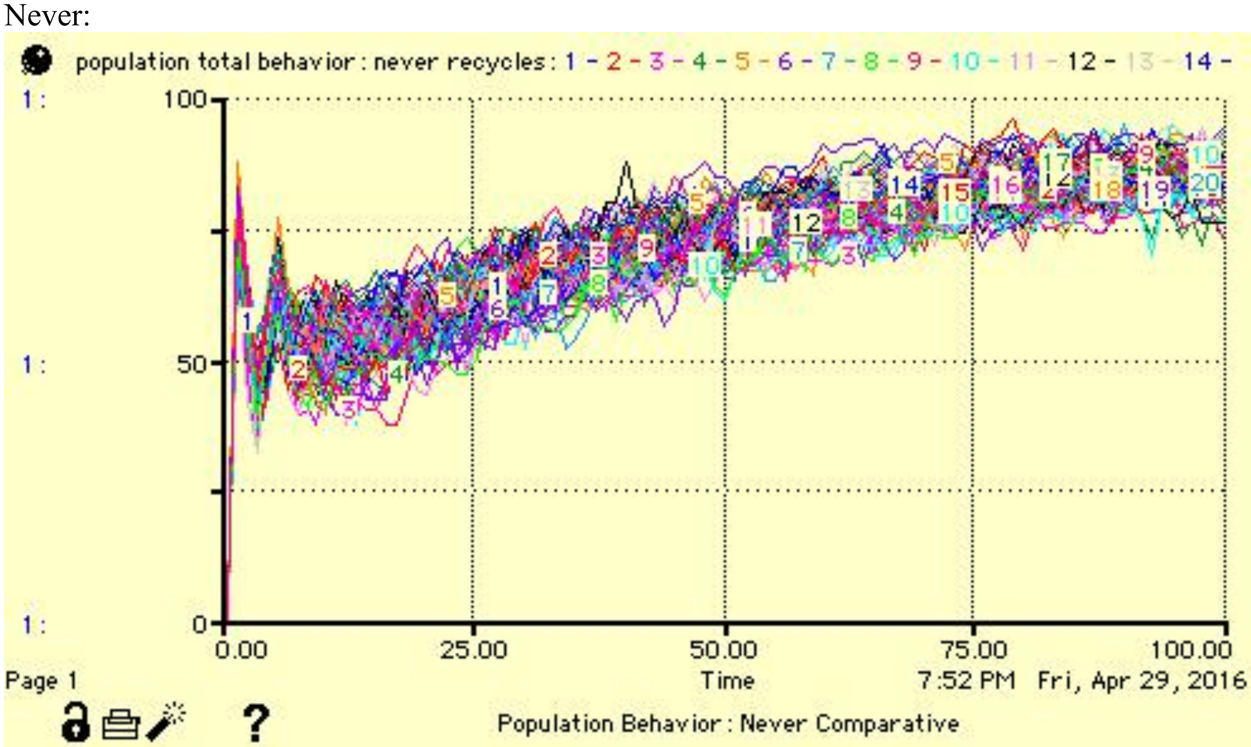
Behavior:
Always:



Sometimes:

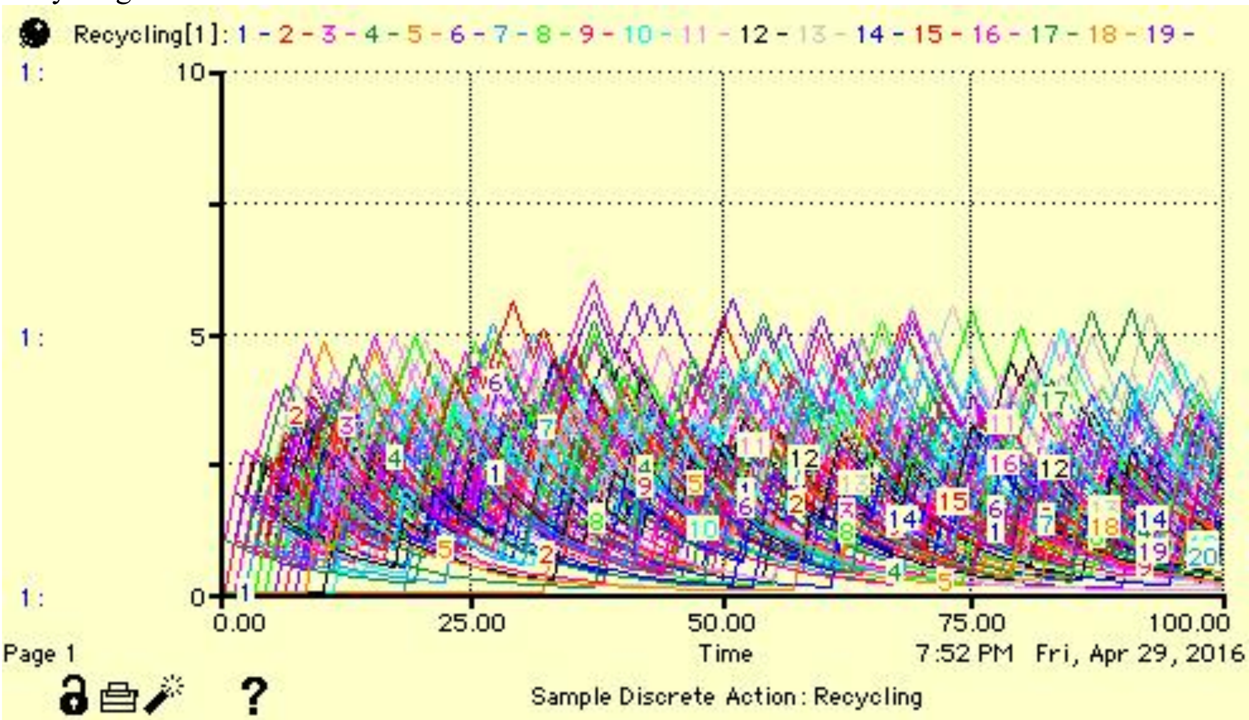


Never:



Discrete Action:

Recycling:



Not Recycling: