System Dynamics or Agent-Based Models?
Wrong question! Seek the right level of aggregation.

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Many novice modelers sense a need to choose between "System Dynamics" and "agent-based" approaches in their modeling projects. This is a false choice rooted in a confusion about what System Dynamics is.

The goal of System Dynamics models is to explain important dynamic phenomena, sometimes to build theoretical understanding, sometimes to implement policies for improvement, and often both. To do so System Dynamics modelers seek to include a broad model boundary that captures important feedbacks among the actors and entities in the system, to use decision rules for the actors and entities based on realistic behavioral decision making principles, often grounded in first-hand study of the organizations and people you are modeling, to represent important accumulation and state-transition processes, and to use the widest range of empirical data to specify the model, estimate parameters, and build confidence in the conclusions of the analysis.

System Dynamics models can therefore be implemented using a variety of different simulation architectures that vary in their representation of time (continuous or discrete), state variables (continuous or discrete), and uncertainty (stochastic or deterministic). Ordinary differential equations, stochastic differential equations, discrete event simulations, and agent-based models are common computational architectures offering different choices on these dimensions. Many software programs are available to implement these architectures, and some allow hybrid models that combine elements of the different simulation methods, for example, models that have compartments (aggregated stocks) for some state variables and individual-based structures (individual agents) for others.

Depending on the features of a problem, a good system dynamicist may choose one architecture or another, and this decision usually depends largely on the purpose of the model and the level of aggregation appropriate for that purpose. Any mechanism can be specified at various levels of aggregation. For example, in modeling the dynamics of obesity at the population level, one could use a single stock representing the obese population, multiple stock variables for people in different weight groups, or many individuals (agents), each with their own weight and BMI (Body Mass Index). In principle, we could further disaggregate such model to capture various body organs of individuals, the cells, molecules, and so on. The choice of aggregation level then informs the choice of simulation architecture. Typically, aggregate models are easier to represent in differential equation frameworks (compartment models, either deterministic or stochastic) while disaggregation to capture important degrees of heterogeneity across members of the population may call for an agent-based architecture.

Multiple considerations inform the choice of aggregation level. Modelers should seek an aggregation level that captures the dynamics of interest and strikes a balance between simplicity and realistic depiction of the underlying mechanisms. Creating this balance is complex and there are no simple rules, but a few considerations include:

(1) the level of aggregation in available data: if the model disaggregates far below the data sources, model formulations will require many auxiliary assumptions that are hard to justify, and many parameters that cannot be reliably estimated from available data. On the other hand, aggregating above the level of data may discard useful information, but may be warranted if those details are not relevant for the problem at hand.

(2) Internal consistency is easier to maintain when the level of aggregation for different model components and mechanisms are similar. That allows for seamless integration of model components.

(3) Given limited time and budget (and who has unlimited amounts of either?), modelers should focus on the components that add the most value to their project. Modelers must always make tradeoffs among disaggregating, collecting data, adding new mechanisms, conducting comprehensive analysis, communicating with stakeholders, and so on. Moreover, disaggregation typically increases computational costs, so that sensitivity and policy analysis become more costly. To maximize the overall value from the analysis the level of aggregation should be chosen so that the marginal return to dissaggregation is in balance with the returns to spending time on other aspects of modeling.

In some settings the appropriate level of aggregation is easily determined, while others may offer a complex choice with multiple pros and cons for different architectures. In the latter settings exploratory comparative studies that better identify the similarities and differences across levels of aggregation would be informative. An example of such comparative analysis can be found in: Rahmandad & Sterman (2008) Heterogeneity and Network Structure in the Dynamics of Diffusion: Comparing Agent-based and Differential Equation Models, Management Science, 54(5):998-1014.

To summarize, asking "should I used System Dynamics or an agent-based model?" is a category mistake. System Dynamics models can be implemented using a wide range of specific simulation methods, including differential equations, difference equations or discrete event simulation; aggregated compartment models or individual-based (agent-based) models; deterministic or stochastic models; and so on. Asking "System Dynamics or agent-based?" is like going to a restaurant for dinner and having the waiter ask "would you prefer a meal or the fish?" You came to the restaurant for a good meal. You choose not between a meal and a particular item on the menu, but among the different dishes on the menu.

A good System Dynamics modeler will choose the particular simulation method that best meets the purpose of the study, taking account of the availability of data, the audience for the work, and tradeoffs among computational burden, ability to carry out sensitivity analysis, the ability to understand the behavior of the model and the ability to communicate the results and reasons for them to the people you hope to influence.

In short, choose your model's level of aggregation judiciously, and let the computational architecture follow that choice.