Utility Perception in System Dynamics Models

Saeed P. Langarudi[1] and Isa Bar-On[2]

[1]New Mexico State University
[2]Worcester Polytechnic Institute

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Abstract

Utility that individuals perceive is believed to be different from the utility that they actually experience. System dynamicists implicitly categorize this phenomenon as a form of bounded rationality and traditionally employ a simple smoothing function to capture it. We challenge this generalization by testing it against an alternative formulation of utility perception that is suggested by modern theories of behavioral economics. In particular, traditional smoothing formulation is compared with peak-end rule in a simple theoretical model as well as in a medium-size model of electronic health record implementation problem. Experimentation with the models reveals that the way utility perception is formulated is important and might affect behavior and policy implications of system dynamics models.

Decisions regarding preferences involve the utility derived from the preferred outcome. Utility in this context can be either experienced utility or decision utility, and there can be notable differences between the two (Kahneman et al., 1997; Kahneman, 2003; Kahneman, Thaler, 2006).

Experienced utility is the pleasure (or its opposite) that we gain from an action at any moment. Decision utility is revealed by the choices we make, and is also called revealed preference. Experienced utility can be summarized over time to obtain the total utility as determined by some valid measure. For decision utility it has been shown that it is frequently disproportionally affected by the peak and end values of an experience, while duration of experience seems to be less significant (Fredrickson, Kahneman, 1993; Kahneman et al., 1993).

System dynamics models represent utility-based decisions using the construct of perceived utility. Perceived utility (or perceived preference) is formulated as a first order smooth. One example is the reaction of customers to long delays in delivery. Customer satisfaction from delivery time (x) will be perceived ($\bar{x}$) with a delay (T):

$$\bar{x}_{t+dt} = \bar{x}_t + \frac{x_t - \bar{x}_t}{T} \cdot dt \tag{1}$$

This perception of utility, is usually symmetrical and uniformly smoothed over a particular time period. As such it is akin to the sum of experienced utilities. The representation of utilities used in system dynamics models is developed from the use of smooths in the formulation of perceived information. Perceived information includes an information delay (smooth) of the actual information to represent the discrepancy between actual information and what agents perceive as information. Decision utility is qualitatively different as it includes psychological factors. These may lead to a disregard of time duration and emphasis on extreme values and more recent experiences thus leading to the Peak-End rule.

The Peak-End rule had originally been documented for pain experienced during medical procedures (Redelmeier, Kahneman, 1996) where patients were asked during the procedure to rate the pain that they experienced during the procedure in fixed intervals. After the procedure the patients were asked to rate the total amount of pain that they had experienced during the procedure. The results indicated that this later measure was not reflective of the sum of the values during the procedure, but was better represented by the average of the peak and last values—thus the term Peak-End value. This Peak-End rule has since been documented for a range of situations (Stone et al., 2000; Clark, Georgellis, 2004; Langer et al., 2005). Implementation of a peak-end formulation for preferences gives the following:

$$U = \frac{P + E}{2} \tag{2}$$

U	-	Perceived (remembered) utility
P	-	Utility from most intense experience (PEAK)
E	-	Utility from most recent experience (END)

This formulation is substantially different from that of an averaged expression of utility. In this paper we pose the question that whether or not alternative formulations of utility functions for preference decisions will substantially alter the results of the modeling exercise.

In this paper we apply Kahneman's decision utility to two system dynamics models and compare the results to those obtained from traditional perceived utility formulations. Specifically, we use the peak-end rule for comparison with the traditional formulation. This rule, a result from behavioral economics, has been used successfully to describe preferences in a range of applications.

Experiments with a simple theoretical model that focuses on the different utility formulations indicate that there may be significant differences in model outcomes. The peak-end rule is then applied in a medium size model of electronic health record (EHR) implementation. The model has many (positive and negative) feedback loops and includes 7 utility perception equations and four different payment schemes. One thousand Monte Carlo simulation runs are performed for each formulation and for each of the four payment policies, yielding 8000 total runs. Comparison between simulation runs across different models and different scenarios reveals that discrepancy in outputs of different models is considerable. The extent of discrepancy, however, depends on the initial setup of the models. Results also show that it is very likely that the two models lead to diametrically opposed policy recommendations.

Based on these results we conclude that different utility formulations for preferences actually matter. The point of this investigation was not to prove that the peak-end rule is necessarily the better formulation for the EHR model. Rather, we were trying to show that the formulation of the decision utility for preferences may affect recommended policies. This situation is complicated as studies in behavioral economics seem to indicate that decision utility can, in addition, be influenced by time passed, repeated experiences and other psychological factors (Miron-Shatz, 2009) for which there are no accepted utility formulations to date.

Despite the lack of consensus in utility formulation, we argue that the possibility of alternative formulations such as the peak-end rule (or others) should be investigated in cases where there is a reason to assume that they might be the dominant decision utility description or as a matter of good practice. These different formulations should be investigated together with a wide parameter space in order to identify potential policy recommendations that differ from those obtained with the traditional information.

Much more work needs to be done to understand the effect of alternative utility formulations on the outcomes of system dynamics models, and a good starting point might be the investigation of generic structures and their sensitivity to such formulations.

Finally, we recommend that alternative formulations for utility perception be included in system dynamics software packages so that applications of theories such as peak-end value become readily available to modelers.

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