Real Options Approach for Innovation Implementation Strategies[1]

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Abstract

Many interventions that are effective in one setting may be ineffective or even harmful in other settings. This poses a problem for organizations and communities engaged in planning efforts seeking to improve outcomes. This paper introduces the use of managerial real options combined with system dynamics models to design strategies for implementing community interventions when their effectiveness may be uncertain. A new notation for representing implementation strategies using real options is introduced. The approach is illustrated with an example of domestic violence community interventions. Results show that there are potential benefits to using a real options approach.

Keywords: public policy, real options, implementation science, domestic violence

Implementing innovations in complex social systems is fraught with uncertainty and risk. What works in one organization or community may be ineffective or even harmful in another—something we might not know until we have tried implementing the innovation. The inherent path dependence of complex systems means that the effects can frequently not be undone. This raises the stakes for decision makers when considering high risk or controversial innovations. While one may prefer to err on the side of caution, the need or pressure to act often trumps reason and deliberative action. If we have the time and resources, we may opt for more empirical research to decide which course of action is best, but this presupposes an underlying stable

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phenomenon that can be researched and yield generalizable knowledge and corresponding theories of action (Schön 1983). In complex social systems, both are limited and decision makers often operate under conditions of bounded rationality (Kahneman, Slovic, and Tversky 1982) in deciding what, when, and how to implement innovations. Is there a better way to manage the uncertainty and risk involved with implementing innovations in complex social systems?

This paper takes up this question by exploring the use of real options analysis (e.g., Dixit and Pindyck 1994) to develop strategies for implementing innovations. The idea of real options comes from corporate finance and provides a way to think more rationally about capital investment decisions when there is significant uncertainty about the potential benefits. A real option is the right to change some specific course of action without the obligation to exercise that right (Dixit and Pindyck 1994). For example, a company might purchase land next to an existing manufacturing facility. In purchasing the land, the company has created an option to expand, but it is not obligated to do so if market conditions do not warrant such investments. Purchasing the land gives the company flexibility and a means to manage the uncertainty of future expansion needs. The main idea behind real options analysis is that this flexibility has a value not captured by a cost/benefit analysis.

While real options analysis in corporate finance generally focuses on the valuation of investment strategies in terms of monetary outcomes, Ford and Sobek (2005) have extended the approach to include non-monetary outcomes in a comparison of two product development strategies, and then used the approach help explain Toyota's industry leading product development process. To avoid confusion with traditional corporate finance, Ford refers to this use of real options analysis as *managerial real options* to emphasize the decision making and non-monetary aspects of a real options approach. Hence, for the remainder of the paper, by 'real options' we mean managerial real options and will be explicit when distinguishing managerial real options from other uses of options.

In this paper, we develop an approach for real options to developing implementation strategies. We illustrate the approach using a system dynamics model of the implementation of a controversial mandatory arrest policy innovation in domestic violence and its unintended consequences on victim arrests (Hovmand and Ford in press; Hovmand et al. 2007; Hovmand et al. in press). The policy innovation, which requires law enforcement officers to make an arrest if there is evidence of domestic violence, has led to the unintended result of victims getting arrested for domestic violence. This is a good example of the kind of complexity, uncertainty and risk that we are interested in addressed because it represents a situation where (a) the intended benefits of the innovation were established empirically as much as one could hope for through large scale social research, (b) the outcomes on communities depended on complex interactions that could not have been adequately foreseen prior to implementation, and (c) there was not a "risk neutral" option in the sense that both action and inaction could lead to harming victims. The combination of these characteristics meant that communities had to make a decision about mandatory arrest policies and deal with the ensuing controversy stemming from such policies, motivating the question of whether there might be a better way to approach similar situations in developing an implementation strategy for a new practice or policy in an organization or community.

Background

To set the stage for the remainder of the paper, which spans diverse disciplines, we provide a brief overview on the background necessary for both understanding the basic approach we are proposing and its application to domestic violence mandatory arrest policies. In implementation science, there is often a distinction drawn between the diffusion, dissemination, adoption, and implementation of innovations. *Diffusion* is often characterized as the natural unsystematic process by which awareness of the innovation spreads from one actor to another actor, *dissemination* as the systematic efforts for getting information about the innovation to potential adopters and users, *adoption* as the decision to implement an innovation, and *implementation* as the actual use of the innovation as intended. These distinctions have become important in implementation science, especially in health care and social interventions, where there are often long delays between when a proven intervention is known and its routine use in some system.

An *implementation strategy* is fundamentally a theory of action (Schön 1983; Argyris and Schön 1978) about how to put an innovation of known dimensions into practice (Fixsen et al, 2005; Proctor et al., 2009). In contrast to tactics, which involve prescribed responses to well defined situations and objectives, strategies must address the problem that the environment is complex and changing, and therefore require actors to learn and adapt from experience in order to achieve their goals. A good implementation strategy is therefore one that provides both a set of general actions to pursue in order to implement an innovation *and* sufficient flexibility to handle changing conditions. The inherent tension in implementation strategies is therefore between the need to develop a disciplined approach to decision making while maintaining flexibility. The argument put forth in this paper is that this is exactly what a real options approach to implementation strategies can do, which we will illustrate through the application of real options to the problem of mandatory arrest in domestic violence.

1.1. Managerial Real Options

A managerial real options approach is a way to manage uncertainty in the environment. The uncertainty can be some unknown parameter (e.g., effectiveness of an intervention) or a stochastic process (e.g., changing characteristics of a population). Real options are defined by specifying the option or choice, reference strategy, alternative strategy, exercise signal, exercise condition, exercise rule, and action required to obtain the or retain flexibility.

An *option* is the ability to change from one strategy to another strategy. In financial options, these include the option to buy or sell a stock at a certain price. A call option is the right without the obligation to buy a stock at a certain price, whereas the put option is the right without the obligation to purchase a stock at a specified price. In corporate finance, options include the ability to stop or abandon an investment, change inputs in production process, change the products or services provided, scale up or down, temporarily shut down an operation, and defer activity. For implementation strategies, we need to think of what some of the equivalent options might be. For example, we might think of an option to change from implementing one kind of treatment to implementing another kind of treatment. Table A1 in the Appendix provides a crosswalk of examples from corporate finance to implementation strategies.

We define the option as the ability to change between two or more strategies. The *reference strategy* is the strategy we would do if we had no flexibility. The *alternative strategy* is the other inflexible strategy that we would like to do if we had the flexibility. In the case of the

stock call option, for example, the reference strategy would be not buying the stock, and the alternative strategy would be buying the stock. Both the reference and alternative strategy are inflexible, and reflect the dilemma that we try to resolve with the option. Specifically, the option gives us the right without the obligation to change strategies from the reference to the alternative strategy at some later date. In the case of the stock call option, we have the right to purchase the stock at a later date if we choose to do so.

The decision to exercise the option, i.e., to change from the reference to the alternative strategy, is based on an *exercise signal*, which is an observable variable in the system. We define when we change the course of action by defining an *exercise condition* based on the exercise signal. How we change the course of action is defined through an *exercise rule* that relates the exercise condition to some action, which can be formulated in an if-then-else statement in the form of,

IF <exercise condition> THEN <exercise option> ELSE < do not exercise option>.

Managerial real options become interesting when the option "costs" something. If the option were free, then we would always have the option. However, options become more complicated to evaluate when we give up something in exchange for having the option. This "cost" is reflects some action that we must take to acquire or maintain flexibility. In real options, the option cost might be the land purchase plus taxes and fees associated with the land purchase. In the managerial real options approach, we need to consider what the corresponding costs might be. In a community intervention, for example, the costs might include people who could have been helped with the other intervention or the training costs.

Evaluating the benefit of managerial option involves comparing the managerial real options strategy against the inflexible reference strategy. The difference between option strategy and reference strategy is the value of the option. The actual comparison must be made on some set of performance measures. In corporate finance, this would normally be the monetary return on investment. In the managerial real options approach, the *performance measure* needs to be defined with respect to the problem at hand. In the case of product development, for example, the performance measures could be the length of the development cycle and having the best technology. In the community intervention example, it might be the community level outcomes. For example, in a public health campaign to improve childhood vaccinations, it might be the proportion of school aged children who have been vaccinated in a given school district.

Each of these concepts must be formally defined for the managerial real options approach. In fact, one of the interesting aspects of this approach is that it forces one to more carefully consider the structure of decision making as it relates to the implementation strategy, and consider a variety of costs and performance measures when evaluating strategies.

1.2. Mandatory Arrest Policy

To illustrate the real options approach to implementing community interventions, we consider the introduction of a domestic violence arrest policy. A thorough discussion of the issues surrounding domestic violence arrests is beyond the scope of this paper and the reader is referred elsewhere (Avakame and Fyfe 2001; Bracher 1996; Eigenberg et al. 2003; Eitle 2005; Hirschel and Buzawa 2002; Hirschel and Hutchison 2003; Mignon and Holmes 1995; Mills 1998; Wanless 1996). However, a brief overview of the issue is will help set the stage for the

example in this paper and why this is good example for considering other types of social interventions.

Prior to the 1980's in the United States, the criminal justice response to domestic violence was characterized as a "laissez faire" approach. Sherman and Berk (1984) then published their results from their landmark Minneapolis experiment looking at the specific deterrent effects of arrest on domestic violence. They found that arrest did deter domestic violence recidivism. Based on these results combined with legal cases against police departments for failing to protect victims from their abusers, many communities began adopting and then implementing what became known as pro and mandatory arrest policies. In *pro arrest policies*, police officers are encouraged to make an arrest for domestic violence if they saw signs of domestic abuse (e.g., bruises on the victim, broken furniture). In *mandatory arrest policies*, they are required to make an arrest. By 2000, nearly 90% of police departments in the United States had written pro or mandatory arrest policies. However, an unintended consequence from the implementation of these policies was the increase in arrests of primary victims. Today approximately 20% of domestic violence arrests involve the arrests of the primary victim (Hirschel and Buzawa 2002; Durose et al. 2005). This has created considerable controversy about the effectiveness of criminal justice interventions for domestic violence, and raised major questions about how to implement community responses to domestic violence, and whether coordinated efforts should even be attempted given the potential for unintended consequences.

A system dynamics model was developed to understand the dynamics generating the increase in victim arrests (Hovmand et al. 2007). Analysis of the model showed how different feedback mechanisms contributed to increase and decline in primary victim arrests (Hovmand et al. in press), and how the relationships between the sequence and timing of multiple community interventions affected on outcomes (Hovmand and Ford in press). Follow-up analyses suggested that multiple interventions were needed to achieve the best outcomes, but simultaneous implementations of multiple interventions were less effective than a sequenced implementation strategy. Results showed a complex interaction between the sequence and timing of intervention strategies including the presence of local minima and maxima in outcomes that would be difficult for a coordinating council to navigate effectively. For example under some conditions, it would be better to wait to implement an intervention while other conditions would favor a implementing the intervention as soon as possible. Such interactions introduce significant uncertainty into the implementation of interventions since decision makers often do not know what state the system is in prior to implementation, if the interventions will work with a specific population, and delays in the implementation process can be hard to control.

The problem of victim arrests from implementing mandatory arrest policies represents a good model for considering the application of a real options approach. First, it highlights a real world example where the purported benefits of an empirically tested intervention had unintended consequences and created significant controversy across many communities in the United States. One might wonder if this is an exceptional case and whether one might not simply test the intervention more thoroughly, but alas most community interventions are tested much less thoroughly because they tend to be prohibitively expensive social experiments. Second, it highlights how the difference between effective and ineffective is not just between positive benefits and neutral benefits, but between positive benefits and harmful consequences. The tendency in social experiments is consider a failed implementation as neutral or ineffective, and ignore that it might also be quite harmful to communities and therefore requiring more rigorous understanding and assessment of the uncertainties involved and how to handle them. Third, it

illustrates a case where there are multiple outcomes that need to be considered over time (victim safety and assailant accountability) for the community intervention to be effective overall. Thus the problem here illustrates a case where one must act to respond to the issue, but there are significant uncertainties and risks that cannot be eliminated prior to implementation.

Model

This section provides a brief overview of the model, including the structure of domestic violence caseflows through the criminal justice system and the implementation process of multiple community interventions. The reader is referred elsewhere for a more detailed discussion of the model and its validation (Hovmand et al. 2007; Hovmand et al. in press). The full model is available in the supplemental materials for this paper.

Figure 1 Victim Arrests Model

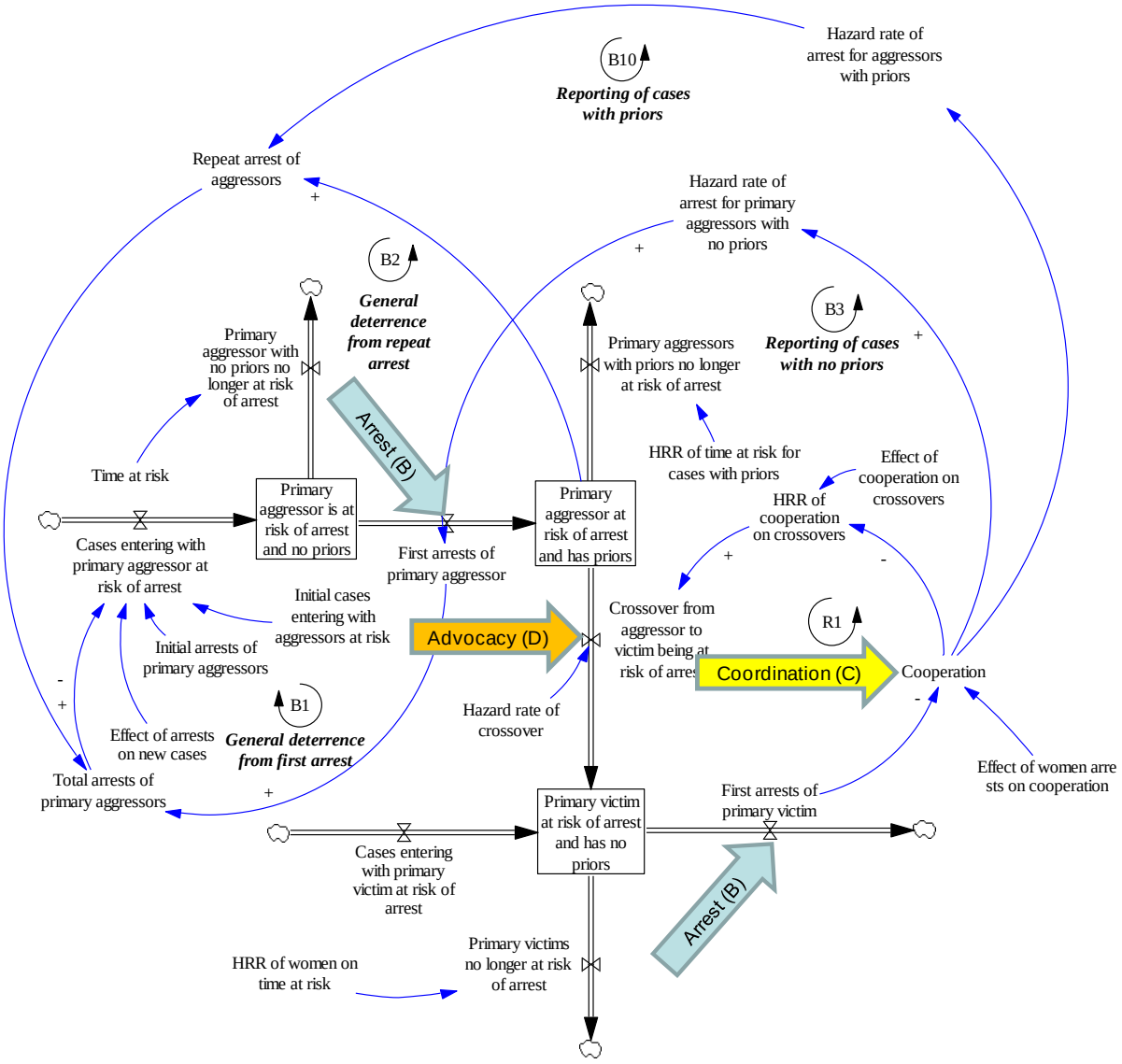


Figure 1 shows the basic stock-flow structure and feedback mechanisms for the victim arrests model considered in this paper, along with three main community intervention points: mandatory arrests, coordination, and advocacy. Briefly, cases represent intimate partner relationships where there is domestic violence, and what changes the status of a case in this system is who in the relationship is at risk of arrest. Thus, cases enter the system from the left when either the primary aggressor is at risk of arrest or the primary victim is at risk of arrest. Cases then transition through the stock-flow structure at rates influenced by a number of feedback mechanisms as well as the influence of the three main interventions. A key flow in this structure is the crossover mechanism where cases move from *Primary aggressor at risk of arrest and has priors* to *Primary victim at risk of arrest and has no priors*. This happens when primary aggressors, for example, learn how to manipulate the system to put the primary victim at risk of arrest.

The arrest intervention (B) is the mandatory arrest intervention. In this paper, it is assumed that the community has decided to implement the mandatory arrest intervention. This will have two effects. One effect is to move more cases from *Primary aggressors at risk of arrest and no priors* into the stock *Primary aggressor at risk of arrest and has priors*, and the second effect is to move cases out of the *Primary victim at risk of arrest and has no priors*. The coordination intervention (C) represents training of multiple providers in domestic violence response with the goal of improving coordination between providers, in this case, specifically between victim advocates, prosecutors, and law enforcement. When effective, this improves the coordination and reduces the crossover rates. The third intervention is the advocacy intervention (D) where specialized training is provided to the victim advocates and prosecutor's office for working with victims of domestic violence. When effective, this also slows the crossover rate.

Figure 2 Victim Arrests

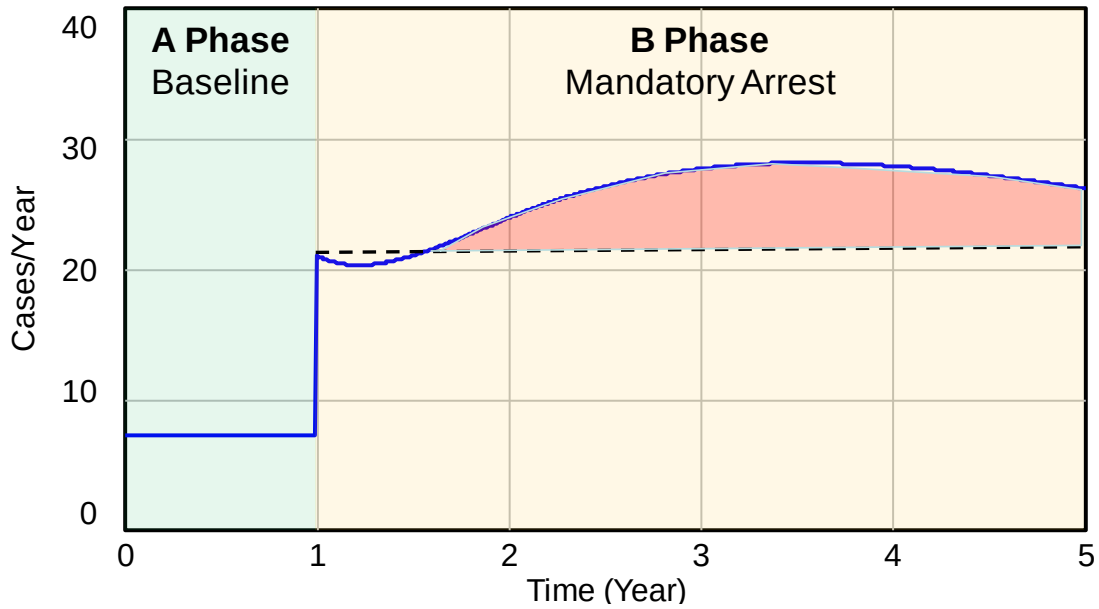
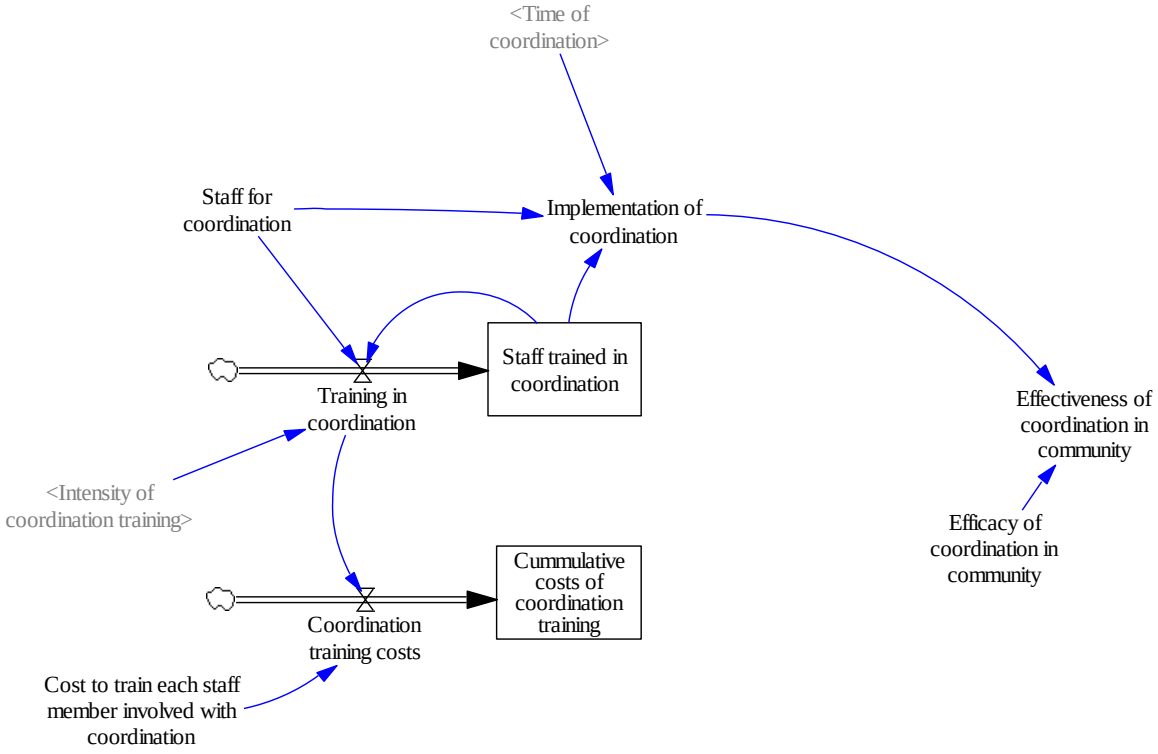


Figure 2 shows the simulated time series in primary victim arrests after the implementation of a mandatory arrest policy. The simulated time series is generated by the basic stock-flow structure shown in Figure 1. For this set of simulations, we consider two initial

phases of behavior. The A phase represents the baseline behavior when the model is a dynamic equilibrium. At year 1, the mandatory arrest policy is introduced starting the B phase. Figure 2 shows the transient response of the system to the mandatory arrest policy, with an initial and brief decline in victim arrests and then an increase above the initial spike in arrests. The problem behavior of increasing primary victim arrests is the increase above the initial spike, that is, the region in Figure 2 above the dashed line and shaded in red. The goal then is to then to develop a strategy for implementing the coordination and advocacy interventions that addresses the problem of increasing victim arrests while also managing the uncertainties in their effectiveness and the initial conditions for the community.

The model assumes that the mandatory arrest policy has been implemented in year 1, and that the implementation processes being modeled involve the coordination intervention and advocacy intervention. Both of these processes are essentially represented the same way, with a training component, costs associated with the training, actual implementation, and effectiveness determined by both the extent of implementation and the efficacy of the intervention. The model structure for the advocacy intervention is same as the structure for the coordination intervention shown in Figure 3.

Figure 3 Implementtion of Coordination



To keep things simple, we focused on modeling the situation where to implement an intervention, one must first train staff. The coordination training requires staff from multiple agencies to be trained in order to work together. The advocacy intervention only requires a small set of professionals to be trained in specific skills for working with victims of domestic violence. A key assumption in this model is that having been trained does not mean the intervention is implemented, or put differently, to put an intervention into practice presupposes that people have

already been trained. For example, a community cannot implement the advocacy training without first training advocates. The *Time of coordination* and *Time of victim advocacy* represent times for starting the implementation process for each intervention. Specifically, they are use in step functions. These times are manipulated endogenously in the model to allow for interventions to be implemented and then discontinued.

Implementation Strategies

Three implementation strategies are considered: a reference strategy and two alternative strategies using a managerial real options approach. To represent these strategies, we found it eventually necessary to develop a formal notation system because the actual implementation in Vensim was cumbersome and error prone. Thus we needed a formal notation system specifying the strategy and then comparing the implementation in Vensim against what should be happening according to our notation system.

The resulting system of notation is a modified version of a single subject research design notation where each condition is denoted with a capital letter beginning with the A phase for a baseline phase, and then subsequent intervention phases, i.e., B, C, D, etc. The strategy A—B then represents a baseline phase with the mandatory arrest phase, A—B—C represents the baseline phase followed by the mandatory arrest phase, which is then followed by the coordination intervention phase C. We denote different sub-phases of interventions using numeric subscripts, so the intervention phase C can be broken into different phases, C_1 and C_2 so that A—B—C_1C_2 is the same as A—B—C. Being able to break interventions into subcomponents is useful for identifying and constructing the options. For example, if C_1 represents the training component and C_2 the implementation of the intervention, we can separate these two activities into distinct phases (A—B—C_1—C_2) or partially implement them in one phase and fully implement them in a second phase (A—B—C_1—C_1C_2). To represent the option, we introduce a left-angle-bracket notation to reflect a branch in the implementation strategy conditional on the exercise condition:

$$S \equiv A - B \left\langle \begin{matrix} BC & \text{if arrests increase} \\ B & \text{if arrests decrease} \end{matrix} \right.$$

This means that we if primary victim arrests decrease (exercise signal), then we do not exercise our option and stay with B, but if primary victim arrests increase (exercise signal), then we do exercise our option by implementing the coordination intervention (exercise decision). In doing this, we have switched from the strategy A—B—B = A—B to A—B—BC if arrests increase. We now move on to formally describe the three strategies considered in this evaluation.

The reference strategy (S_0) involves implementing the mandatory arrest strategy (B) followed by the coordination strategy (C) where the coordination intervention is divided into two phases, C_1 for training and C_2 for the actual implementation of the coordination intervention. Using our notation, we represent this as:

$$S_0 \equiv A - BC_1C_2$$

Our first options strategy using the real options approach (S_1) begins with a steady state phase (A), implementation of the mandatory arrest phase (B) and then introduces an option by training practitioners in the coordination intervention (C_1) without implementing the coordination intervention. This purchases us the option to implement the coordination intervention immediately if the number of victim arrests increases. We represent this as:

$$S_1 \equiv A - BC_1 \begin{cases} B & if\ arrests\ decrease \\ BC_1C_2 & if\ arrests\ increase \end{cases}$$

The second options strategy (S_2) is similar except now we also consider the uncertainty that the coordination intervention may actually make matters worse. To guard against this, we introduce a second option to switch from the coordination intervention to the advocacy intervention if the numbers of crossovers begins to increase with the coordination intervention. This is represented as:

$$S_2 \equiv A - BC_1 \begin{cases} B & if\ arrests\ decrease \\ BC_1C_2D_1 & if\ arrests\ increase \begin{cases} BC_1C_2 & if\ crossovers\ decrease \\ BD_1D_2 & if\ crossovers\ increase \end{cases} \end{cases}$$

These strategies were modeled in R as functions using a set of custom functions using a custom R package called VensimR developed by the first author. R is an open-source statistical and graphical programming environment available at www.r-project.org based on the AT&T Bell Lab's S language. The main advantage of modeling the strategies in R is that it is easier to represent the procedural logic of the strategies. Earlier efforts implemented the same strategies in complicated set of nested Vensim IF THEN ELSE functions that lacked transparency and there also difficult to check.

Using this approach, strategies were modeled as functions, *Y=f(X)*, where *X* is a vector representing all the variables in the Vensim simulation model and their values at the current simulation time, and *Y* is a vector of model variables that should be set to the values of *Y* at the current simulation time. Table A2 in the Appendix shows the R functions representing the reference strategy and two options strategies. These functions were then used as arguments for custom function to run a sensitivity analysis for each strategy over a specified set of parameters. We did this by varying the effectiveness of the coordination intervention varying from harmful to helpful (represented as a range from -0.8 to +0.8 effect size) over two different communities, one with low crime and another with high crime.

Results

Table 1 shows the results from the simulating the three strategies over the two types of communities where there is variation in the effectiveness of the coordination intervention. These results are meant to be illustrative of the overall approach and only used to evaluate the potential of the method for further development of the real options approach to implementation strategies.

The results show values for the reduction in victim arrests where positive values larger reductions (and negative values reflect *increases* in victim arrests) along with the total cost of

implementing the intervention. The reduction in victim arrest is represented both in terms of the number of cases and as a percentage of the initial increase. The costs associated with these interventions are essentially training costs. The costs of implementation are based on the training costs. Since the coordination intervention requires professionals from multiple agencies to be trained, this is the most expensive intervention to implement. Costs in this case are calculated by the dollar value of professional time attending these interventions. Such costs are real in the sense that they impact organizations, but rarely directly supported a grant. The advocacy interventions are less expensive because fewer professionals need be trained.

The reference strategy (S_0) is the most expensive approach since the coordination intervention is fully implemented in all cases. For low crime communities, the average change in the victim arrests is an increase while high crime communities experience a decrease. The reference strategy provides a basis for comparing the relative benefits of the two other implementation strategies using a real options approach.

The results from the first options strategy (S_1) show no real differences from the reference strategy for the low crime communities, but better performance for the high crime communities. For high crime communities, there is a comparable reduction in the number of victim arrests, but the strategy is on average likely to cost significantly less. This is because the coordination intervention is only fully implemented if there is an increase in victim arrests. In high crime communities, there will already be a declining trend in victim arrests. As a consequence, the option is not exercised and this essentially saves the community resources.

The results from the second options strategy (S_2) are more interesting. Here the overall reduction in victim arrests is equal to or better than the reference strategy for both the low and high crime communities, but tends to be on average less expensive for both low and high crime communities.

Table 1 Results from Simulations of Strategies

MEANS	Low crime	High crime
Reference strategy S0		
Cumulative victim arrests	112	208
Total costs	$777K	$777K
Options strategy S1		
Cumulative victim arrests	112	208
Total costs	$777K	$259K
Options strategy S2		
Cumulative victim arrests	93	199
Total costs	$368K	$34K

Discussion and Conclusion

The primary goal of this paper was to evaluate the potential application of managerial real options to development of implementation strategies. The paper built on prior efforts in product development, and extended the approach to considering social interventions with an application in community responses to domestic violence focusing on mandatory arrest policies. Overall, the results show the feasibility of using managerial real options approaches for

developing strategies for implementing community interventions. Specifically, using the model to guide the development of options, new strategies were developed that helped mitigate the unintended consequences of the mandatory arrest policy or reduced the total costs of interventions. In particular, we found that we were much more disciplined in developing our implementation strategies and considering where the risks existed in the system, how these risks impacted the outcomes, and began looking much more carefully at how to understand them in terms of the system dynamics model.

The approach also illustrated how combining a managerial real options approach with system dynamics modeling provides a means for thinking through implementation strategies more formally and managing the uncertainty. For example, studying simulations related to the first options strategy lead to new ideas about how to design the second options strategy. We also gained insights into how we might consider restructuring the intervention to better address high crime communities. Overall, the victim advocacy intervention was found to be the more robust intervention in addition to also being the least costly.

A major limitation of real options analysis is decision makers not having a sufficient understanding of the underlying system or the option (Dixit and Pindyck 1994). This has been a problem with convention real options approach because underlying systems are rarely modeled; only predictions about the projected costs and benefits under varying conditions. Combining the system dynamics modeling, which is an explicit model of the underlying system, with the real options approach makes it much easier to discover flawed assumptions or missing elements in the implementation process. For example, one could look at Figure 3 and quickly arrive at a number of extensions to these structures that would need to be included in a more realistic model. For example, while coordination might have mainly the initial training costs, advocacy is more likely to also involve ongoing salary cost. Some might also question to what extent that having partially implemented a coordination intervention one might be able to discontinue the intervention. We see the explication of such models as a good and necessary step to any planning process involving complex social interventions.

Additionally, we might draw on group model building (e.g., Andersen and Richardson 1997; Vennix 1996; Richardson and Andersen 1995) techniques to help decision makers develop a better understanding of the implementation dynamics and more disciplined strategy for managing the uncertainties in their communities. This could lead to better solutions and consensus among stakeholders about how to respond to social problems, but it might also introduce some additional issues. For example, some might argue that specifying the decisions prior to implementation may actually create incentives or more it possible for individual stakeholders to sabotage interventions for political reasons. While this is certainly possible and should be considered openly among stakeholders, it is also important to realize that this kind of situation goes beyond mere uncertainty and involves a prior level of political conflict that makes any coordinated action difficult. The real options approach developed here is intended as an improved approach to a specific kind of problem, namely, a situation where a community is uncertain about how to proceed with implementing interventions when there might be significant uncertainty about their benefits relative to their risks.

Ultimately, it is important to realize that any effort to improve our decision making when we are dealing with dynamic complexity and uncertainty will find itself with a tension between developed disciplined strategies and overly prescriptive approaches that are unjustified given the uncertainty of the system. For example, the very nature of the dynamic complexity in these systems means that it is unlikely that we will be able to use decision rules similar to treatment

protocols in medicine or mental health. But, that does not mean that we should not try to develop more disciplined strategies that take into account some of the problems that stakeholders face when managing the implementation of complex social interventions. Perhaps more than ever before, it is important for us to leverage all the tools we have to address the more challenging problems of our day. The real options approach developed here represents one step toward that effort. Such efforts will become increasingly important as practitioners, policy makers, governments, private organizations, and community leaders come to see both the interdependencies of multiple issues and the need to implement multiple interventions to address complex social problems such as domestic violence.

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Appendix A

Table A1: Examples of real options in corporate finance and possible examples in innovation implementation in public health

Type	**Examples of real options in corporate finance**		**Possible examples of real options in innovation implementation**	
	Finance option	*Finance example*	*Implementation option*	*Implementation example*
Expansion	Being able to increase production if demand increases	Surplus production capacity	Being able to scale up implementation	Surplus of trainers and supervisors
Initiation or deferment	Being able to choose when to develop and extract a natural resource	Mining rights	Being able to choose when to implement an innovation	Training and continued certification of staff
Growth	Being able to expand into new market	Purchase competitor in adjacent geographic market	Being able to introduce innovations in new programs and services	Training staff in innovations that can be used to start programs with new populations
Abandonment or termination	Being able to abandon construction	Contract to transfer project to another party	Being able to terminate implementation process	Cancelling meetings needed to implement intervention
Contraction	Being able to reduce a project	Modularized project with well-defined requirements	Being able to subcontract training or supervision	Using interventions with standardized protocols and certified trainers
Sequencing	Being able to sequence the introduction of one product after another	Planned product development	Being able implement one innovation after another	Staggering implementation of multiple innovations
Temporary stop or shutdown	Being able to halt extraction of a oil if price drops	Equipment that can be mothballed	Being able to halt an implementation process	Developing training stages where the time between stages can vary
Switch	Being able to switch manufacturing from one facility to another facility	Identical manufacturing facilities	Being able to switch implementation from one intervention to another	Training staff in multiple interventions
Flexible manufacturing	Being able to switch vehicle production from one model to another model	Reprogrammable and reconfigurable assembly line equipment	Being able to switch from implementing one treatment or service to another innovation	Committee that can coordinate implementation of all innovations
Input mix or process flexibility	Being able to switch between oil and natural gas fueled power generation	A duel fuel gas turbine for electricity generation	Being able to switch between different roles and professional backgrounds	Standard volunteer/staff training for all professional backgrounds

Table A2: Real option implementation strategies

Dimension	S1—coordination	S2—coordination + victim advocacy
Uncertain performance measure	Victim arrests	Victim arrests
Driver of performance uncertainty	Impact of mandatory arrest policy, effectiveness of coordination intervention	Impact of mandatory arrest policy, effectiveness of coordination intervention
Reference strategy	Implement mandatory arrest + coordination intervention	Implement mandatory arrest + coordination intervention
Alternative strategy	Implement mandatory arrest	Implement mandatory arrest + victim advocacy intervention
Signal for changing strategy	Cumulative reduction in victim arrests	Cumulative reduction in victim arrests Observed crossovers
Conditions for strategy change	Cumulative reduction in victim arrests < 0	Cumulative reduction in victim arrests < 0, Observed crossovers > observed crossovers.ref
Actions required to obtain or retain flexibility	Train staff from multiple agencies in coordinated response to domestic violence	Train staff from multiple agencies in coordinated response to domestic violence Train staff in prosecutor's office in victim advocacy
Decision rule for changing strategy	IF cumulative reduction in victim arrests < 0, THEN implement coordination	IF cumulative reduction in victim arrests < 0, THEN implement coordination IF observed crossovers > observed crossovers.ref, THEN switch to implementing advocacy training

R code for reference strategy[1]	`S0<-function(X) {`
	`  Y<-NULL`
	`  if (X["Time"] > 1) {`
	`  Y["Intensity of coordination training"]<-20`
	`  Y["Implement coordination"]<-1`
	`  }`
	`  Y`
	`}`
		`S0<-function(X) {`
		`  Y<-NULL`
		`  if (X["Time"] > 1) {`
		`  Y["Intensity of coordination training"]<-20`
		`  Y["Implement coordination"]<-1`
		`  }`
		`  Y`
		`}`

R code for options strategy[1]

```
S1<-function(X) {
  Y<-NULL
  if (X["Time"] > 1 & X["Time"] < 2 ) {
    Y["Intensity of coordination training"]<-20
    }
  if (X["Time"] >= 2) {
    if (X["Cumulative reduction in primary victim
          arrests"] < 0) {
      Y["Intensity of coordination training"]<-20
      Y["Implement coordination"]<-1
      }
    else {
    Y["Intensity of coordination training"]<-0
    }
  }
  Y
}
```

```
S2<-function(X) {
  Y<-NULL
  if (X["Time"] > 1 & X["Time"] < 1.25 ) {
    Y["Intensity of coordination training"]<-20
    }
  if (X["Time"] >= 2 & X["Time"] < 2.25) {
    Crossovers.ref<<-X["Observed crossovers"]
    if (X["Cumulative reduction in primary victim
          arrests"] < 0) {
      Y["Intensity of coordination training"]<-20
      Y["Implement coordination"]<-1
      Y["Intensity of victim advocacy
        training"]<-10
      }
    else {
    Y["Intensity of coordination training"]<-0
    }
  }
  if (X["Time"] >= 3 & X["Observed crossovers"] >
  Crossovers.ref) {
      Y["Intensity of coordination training"]<-0
      Y["Implement coordination"]<-0
      Y["Intensity of victim advocacy
        training"]<-10
      Y["Implement advocacy"]<-1
  }
  Y
}
```

Notes: [1.] In the R programming language, `X<-Y` means assign the value of the variable Y to the variable X within the scope of the current workspace, and `Z<<-Y` means assign the value of the variable Y to the variable Z within the scope of the global workspace.