A SYSTEM DYNAMICS APPROACH TO MODELING THE COST ELEMENTS OF CHRONIC DISEASE MANAGEMENT INTERVENTIONS

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ABSTRACT

Medical treatment for chronic conditions forms a major portion of the US healthcare expenditure. Chronic diseases are generally associated with ailments without any permanent cure which significantly affect the health status, lifestyle, mobility and longevity of patients. A variety of chronic disease management interventions have been deployed to help patients better manage their medical condition. The main purpose of such interventions is to improve their health condition while achieving cost savings through a reduced healthcare utilization rate. While these interventions are desirable from the point of view of relevant clinical outcomes, the monetary outcomes in terms of costs and savings are uncertain. Further, most studies rely on short term savings and do not consider future healthcare costs. This study presents a system dynamics model representing the key cost factors involved in implementing a disease management intervention, and the dynamics associated with those factors. A simple goal seeking structure is embedded in the model as a simulation based optimization routine. The functionality of the model is demonstrated by means of hypothetical scenarios implemented via sensitivity analysis. The model provides useful insights into how the initial estimates of the cost of intervention and the resulting savings would change depending on the uncertainties, feedbacks and the targeted savings in the system. The model is designed to be used as a learning and decision support tool for implementing chronic disease management interventions.

Keywords: chronic disease management, ambulatory healthcare system, intervention modeling, support system

1. INTRODUCTION

Medical treatment for chronic conditions forms a major portion of the US healthcare expenditure. The increase in Medicare spending between 1987 and 2002 can be significantly attributed to patients treated for multiple chronic conditions (Thorpe & Howard, 2006). Nearly half of the US healthcare costs in 1996 accounted for five chronic conditions namely mood disorders, diabetes, heart disease, asthma and hypertension (Druss, Marcus, Olfson, Tanielian, Elinson, & Pincus, 2001). Half the female population and 40% of the male population had at least one chronic condition while 78% of the healthcare dollars were spent for treatment of chronic conditions in 1998 (Anderson & Horvath, 2004). Chronic diseases are a persistent and escalating problem with nearly 40% of adults between age of 18 to 64 years having at least one condition as compared to 34 % in 2003 (Tu & Cohen, 2009). In the same study 28% of the adults with chronic conditions reported financial problems in dealing with healthcare costs compared to 13 % with non chronic conditions.

Chronic diseases are associated with ailments without any permanent cure and which significantly affect the health status, lifestyle, mobility and longevity of the patients. Perrin, et al. (1993) suggests a two level approach that includes duration and impact when defining chronic conditions for children. Duration is referred to conditions lasting more than 3 months and classified as chronic. The impact of the condition on the child is considered in terms of healthcare utilization and any inabilities or restrictions on his/her lifestyle. O'Halloran, Miller, & Britt, 2004 provide a broader framework for defining chronic conditions wherein they identify duration, prognosis, pattern and sequelae are considered as relevant factors to be included in the definition of chronic conditions. Although no single definition of chronic conditions exits, a number of criteria are available that helps clinician a researchers classifying chronic versus non-chronic conditions. The term ‘Chronic’ is widely used in context of ailments such as Chronic obstructive pulmonary disease (COPD), Congestion Heart Failure (CHF), Asthma, Diabetes, and Cancer, though other conditions like arthritis, psychological disorders and HIV are referred to as ‘chronic’ as well.

To assist patients in managing their chronic condition, a variety of chronic disease management mechanisms have been developed. Chronic disease management is defined by Weingarten et al. (2002) as interventions designed to control or prevent chronic conditions by potentially using multiple treatment methods. These interventions include provider education, provider feedback, provider reminders, patient education, patient reminder and patient financial incentives (Weingarten, et al., 2002). Wagner, Austin, & Von Korff (1996) suggest organizing interventions within a framework called chronic care model (CCM). CCM defines a successful chronic disease healthcare system by being inclusive of six main components that include Delivery System Design, Self Management Support, Decision Support, Clinical Information Systems, Community Resources and Health Care Organization (Wagner E. H., Austin, Davis, Hindmarsh, Schaefer, & Bonomi, 2001). Interventions can be targeted at one or more of these components. Zwar (2006) shows that including few of these elements in the healthcare system leads to improvements in healthcare outcomes. The Innovative Care for Chronic Conditions (ICCC) presented in (World Health Organization, 2002) is a more universally applicable model based on the CCM. The ICCC takes a broader perspective as compared to the CCM by including the health policy at the macro level and the patients and their families at the micro level.

The literature in chronic disease management interventions targeted at various components of the healthcare system seen from this perspective is substantial and extensive. Evaluating the efficiency and effectiveness of intervention alternatives to a targeted population segment for a given condition is a relevant and remaining issue. This is essential since resources available for implementing such intervention are limited in most scenarios. This is also fundamental in achieving cost saving from launching interventions in addition to attaining improved clinical outcomes. Thus, it becomes imperative to perform a cost-benefit analysis to determine which intervention or set of interventions produce the targeted results in terms of health and monetary outcomes. Meyer & Smith (2008) suggest that the degree of success of the intervention depends on a number of factors like the particular chronic condition under consideration, patient characteristics, the type and frequency of the intervention chosen and the resultant impact on healthcare utilization patterns. Further, there seems to be no consensus on the cost elements to be considered in performing a cost-benefit or returns on investment analyses for the potentially applied interventions. For example, in the medical context the issue of whether to include future unrelated medical expenses seems open ended since most studies restrict themselves to consider only related costs (Meltzer, 1997). Unrelated future expenses are the expenses that would be incurred to treat the patient for conditions other than his original medical condition. These expenses are resultant from the extension of patient's life due to the medical intervention (Van Baal, Feenstra, Polder, Hoogenveen, & Brouwer, 2011). Thus, an intervention which may seem to be cost saving on a shorter term may prove to be otherwise in the long term. A long-term evaluation of intervention strategies is an intricate issue mired with multiple complexities and feedbacks.

This study presents a system dynamics model representing the key factors affecting the evaluation of an intervention and the dynamics associated with those factors. A simple goal-seeking structure from a system dynamics approach is embedded in the model as a simulation-based optimization routine. The functionality of the model is demonstrated with hypothetical scenarios implemented via sensitivity analysis. The model provides useful insights into how the initial estimates of the cost of intervention and the resulting saving changes depending on the uncertainties and feedbacks in the model. The model is designed to be used as a learning and decision support tool for evaluating the implementation of chronic disease management interventions.

The paper is organized as follows. In the next section a brief review of the relevant literature will be provided. This will be followed by the introduction and description of the said system dynamics model. The fourth section will present the model simulation based on theoretical scenarios and the outcomes of the same. The paper concludes with the discussion of the results and scope of future work.

2. LITERATURE REVIEW

A current issue of contention is the idea that chronic disease management interventions lead to quality improvement while achieving cost benefits. Fireman, Barlett, & Selby (2004) compare healthcare cost and quality trends among groups of adults having chronic diseases and under disease management and those not having chronic diseases. Results from this analysis suggest that although disease management interventions proved to be a useful tool, they do not produce any cost savings. Further, an increase in healthcare costs is observed at least in the shorter term. This analysis does not consider any long term related or unrelated costs, however. An extensive review of cost benefit studies in chronic disease management context was performed by Goetzel, Ozminkowski, Villagra, & Duffy (2005). They report positive savings for chronic conditions like CHF and other multiple disease conditions. Although interventions for diabetes, for example, are found to report positive savings, a need for more research is stressed. These authors assert that interventions targeted to certain chronic conditions such asthma produce mixed results while those targeted at depression report to produce negative results. Thus, it seems that interventions produce different results depending on which chronic condition they attempt to address. Meyer & Smith (2008) assert that depending on a number of factors such as the type of chronic condition, types and frequency of intervention, and the demography of the patients, it is possible to predict the success of the savings produced by the interventions. However, the numerous studies considered by Meyer & Smith (2008) assume that chronic disease management interventions deliver savings.

Fireman, Barlett, & Selby (2004) suggest that disease management interventions attain savings through the following means: first, improving quality of health through use of medications and self-care such that future complications are prevented; second, reducing overuse of healthcare by working with patients; and lastly, through productivity improvements by the way of allowing allocation of some tasks related to interventions from the physicians to other staff. However, in this suggested scheme the consideration of future related and unrelated costs due to increased life expectancy resulting from the implemented interventions is missing. The consideration of future costs has been generally limited to consideration of 'related' healthcare costs in cost effectiveness studies concerned with medical interventions (Meltzer, 1997).

Related healthcare costs refer to the costs directly concerned with the ailment at which the intervention is targeted. Van Baal, Feenstra, Polder, Hoogenveen, & Brouwer (2011) point out that if a medical intervention in the form of a heart surgery saves a patient's life, then future heart related healthcare costs for that patient is a 'related' healthcare costs. However, if the same patient is detected with diabetes after the heart surgery, then the cost of treating diabetes is an unrelated healthcare cost. The consideration of unrelated costs in evaluating intervention effectiveness studies is increasingly gaining support (Van Baal, Feenstra, Polder, Hoogenveen, & Brouwer, 2011).

Measures of performance that gauge the effects of chronic disease management interventions in certain contexts are rather limited. For example, conclusive evidence regarding the effect of chronic disease management interventions on mortality is unclear for all chronic conditions. However, a number of studies, especially in heart disease interventions, have reported an important reduction in mortality resulting from disease management interventions. Roccaforte, Demers, Baldassarre, Teo, & Yusuf (2005) report a significant reduction in mortality, among heart failure patients under disease management program as compared to those not under such a program. Garcia-Lizana & Sarria-Santamera (2007) report a reduction in mortality due to intervention for cardiovascular diseases while no improvement is reported for other chronic diseases. Hamalainen, Luurila, Kallio, & Knuts (1995) also report significant reduction in incidence of sudden deaths and mortality related to coronary disease resulting from disease management intervention. Miksch, et al. (2010) report a reduced mortality among patient enrolled under a disease management program for managing chronic diabetic conditions. Meigs, et al. (2003) conduct an analysis of web-based diabetes management interventions and claim that it has the potential to reduce patient mortality.

Due the impact of disease management interventions on mortality, the design and implementation of effective chronic diseases interventions is a need. To properly evaluate a given intervention from the cost-benefit perspective is necessary to consider future related and unrelated costs of healthcare. However, many studies seem to ignore such considerations. Few studies, such as Chan, Heidenreich, Weinstein, & Fonarow (2008) utilize a Markov model to consider such issues. The possibility that a patient will survive, hospitalize, or die is characterized by a transition probabilities matrix associated with the model. This study considers related and unrelated healthcare expenses while finding that the patients under disease management have a longer lifespan, and hence, producing higher costs to the system. The simulation of this model shows that disease management interventions for heart failures are likely to be cost-effective while incurring more cost than the base case scenario. Gohler, et al. (2008) and Miller, Randolph, Forkner, Smith, & Galbreath (2009) conducted similar studies and report comparable results. The Congressional Budget Office (2004) seems to be aligned with these suggestions when expressing that disease management programs may not be able to realize the anticipated cost savings, especially in the longer term.

Since potentially disease management programs can be cost-effective but prospectively not cost-saving, the extent of investment decisions in such programs can be controversial. Such decisions can be particularly difficult for healthcare programs in the public arena like the Medicare, wherein the administrators and the public are already weary of rising costs. Making appropriate decisions in this complex environment is possible when the stakeholders have correctly appreciated the complexities and the feedback structures within the system. The purpose of this paper is to develop a basic framework that supports such deliberations. The aforementioned complexities and feedbacks in this intricate context make system dynamics an ideal platform for such an effort. Further, system dynamics models are intuitive and can closely represent real-life factors and characteristics. Such a tool can serve as a useful scenario analysis and consensus building tool among stakeholders with conflicting viewpoints, and thus, facilitate the accomplishment of the most appropriate decisions.

3. MODEL DESCRIPTION

The objective of the model suggested in this paper is to establish the cost of intervention per patient per unit time and the cost of healthcare per visit, in such a manner that the targeted savings are achieved. The simulation model diagram is exhibited in Figure 1. The difference between the targeted savings and the actual savings denoted by 'savings pressure', drives the model towards adjusting the system parameters until the required savings are obtained and the system attains a steady state. To achieve the targeted savings the 'savings pressure' adjusts the 'cost of care pressure' and the 'cost of intervention pressure'. The magnitude of influence that the 'savings pressure' has on both of these pressures is defined by the elasticity associated with the each of these parameters. The elasticity determines the degree of change in the parameter in response to a unit change in the 'savings pressure'. The 'cost of intervention per patient' and the 'Actual cost of care per patient' are influenced by the 'cost of intervention pressure' and the 'cost of care pressure respectively'. The total cost of intervention is determined by the cost of intervention per patient, the total patient population, and the fraction of the patient population that is targeted for the intervention.

The intervention is assumed to produce a degree of improvement in the health status, which leads to a reduction in the net mortality rate. The mortality rate influences the patient population which further influences the total cost of intervention and the total cost of care. A certain pre- and post-intervention per capita healthcare utilization is assumed to estimate the total patient visits. The post intervention utilization has an aging amplification factor, 'Aging delay', associated with it. This occurs after a delay of certain time period. This factor is representative of the fact that after a reduction in per capita utilization in the short term, the per capita utilization will likely increase after certain period of time. This takes place as the patient population is further aged due to life extension resulting from the disease management intervention. Further, as the patients age they are likely to develop multiple chronic conditions which will result in further increase in utilization. Following the same logic a cost amplification factor is applied with a time delay, to compensate for the likely hike in the cost of care for treating multiple chronic conditions as compared to fewer chronic conditions at the onset.

Using the pre-intervention per capita utilization and the pre-intervention mortality rate, parameters for retrospective patient population and retrospective patient visit are determined. These parameters along with the retrospective cost of care per patient per unit time are used to estimate the total cost of healthcare in absence of the intervention. The difference between the pre- and the post-intervention healthcare costs determine the total savings in the healthcare costs as a result of the intervention. The final savings are obtained by taking the difference between the total savings in the healthcare cost and the total cost of administering the intervention. Parameters like the effectiveness of the intervention, the initial estimated cost of intervention, and cost of care or the effect of intervention on the per capita visits rate are represented by stochastic functions. These stochastic functions are embedded in the system to take into account uncertainties associated with estimating these parameters. Finally, the system stabilizes when the savings pressure is reduced to zero or to the possible extent reliant upon the values of the elasticity associated with the cost of intervention and the cost of healthcare. The trajectories of the cost of intervention and the cost of healthcare exhibit the actual resources that can be spent to achieve targeted savings.

4. SIMULATION AND RESULTS

The objective of this section is to simulate the model under different scenarios. The outcomes of these scenarios assist in developing useful insights from the system. To demonstrate its functionality, a simple hypothetical case is developed. Consider an initial population = 100, estimated cost of care post intervention=100, cost of care per visit pre intervention = 100, initial estimated cost of intervention = 10, cost of care elasticity = 0.5, cost of intervention elasticity = 0.01, health status pre-intervention = 2 (on 1-5 scale), pre-intervention per capita utilization = 3.5. Using these theoretical values, the model is simulated under specific scenarios such that its behavior can be described.

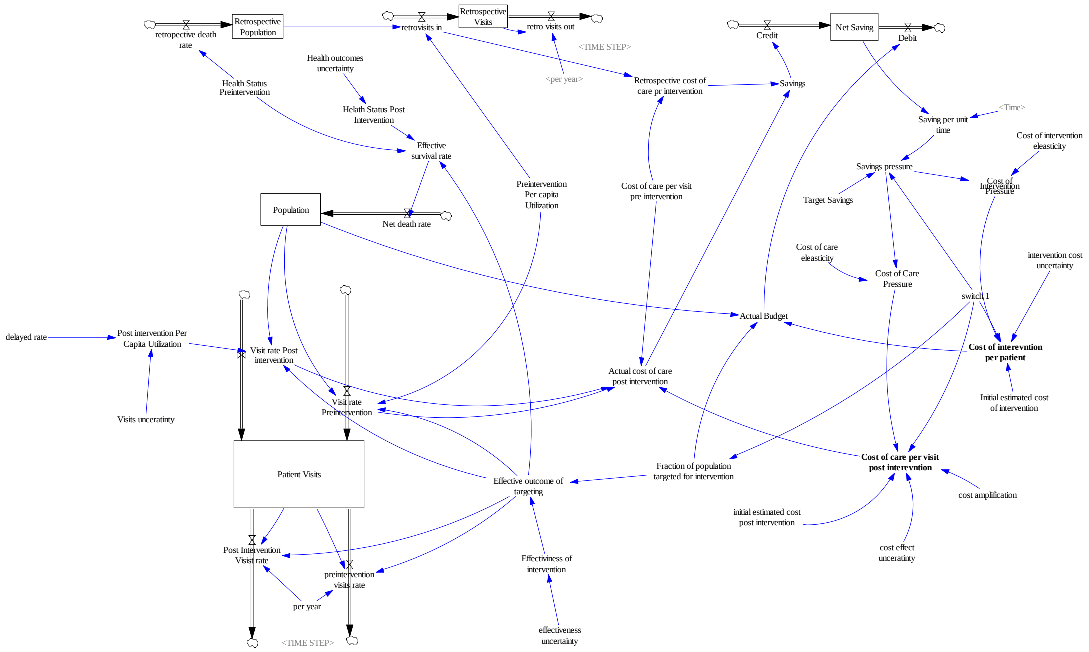

Figure 1. Simulation model for the proposed model

Scenario 1- To compare the model performance in 'intervention versus no intervention' scenario while setting the target savings to zero.

The purpose of this scenario is to see how the key system parameters behave under 'intervention' versus 'no intervention' i.e. the original system. As can be seen in Figure 2 the total visits by patients increase in both the scenarios due to increasing population. However, in the 'intervention' scenario the total visits, are initially less as compared to the 'no intervention' scenario due to the effects of the intervention. However, in the longer term the visits rate in the 'intervention' scenario exceed that of the 'no intervention' scenario as a result of aging and life extension and the increase per capita utilization at advanced age due to multiple chronic conditions.

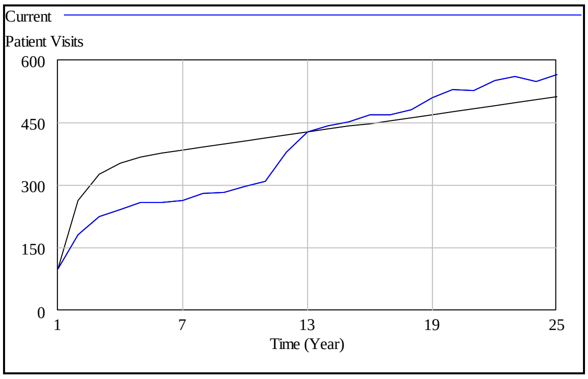

Figure 2- Total Patient Visits (blue line- intervention, black line- no intervention)

Figure 3 shows the savings accumulation in the 'intervention' versus 'no intervention' scenarios. It can be seen that 'interventions' produce higher net savings in the short term. However, the savings are eroded as the per capita utilization and the cost of utilization of the patients escalate due to aging. This result demonstrates the point of view seen earlier, that the disease management intervention may not be cost saving, especially in the longer term.

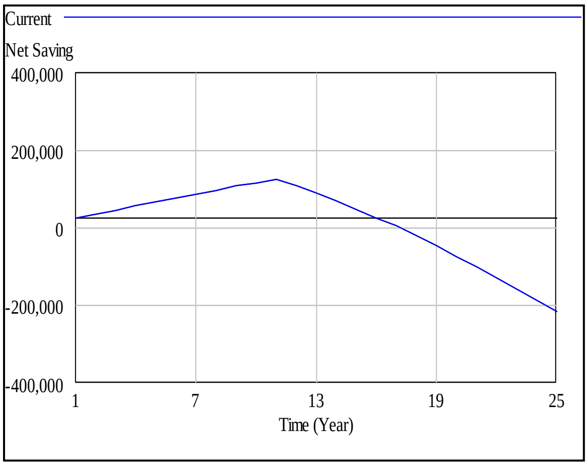

Figure 3- Net Savings (blue line- intervention, black line- no intervention)

Figure 4 shows the patient population growth in the 'intervention vs. no intervention' scenario. In the 'intervention' scenario, the population grows at a faster rate, due to decrease in the mortality rate resulting from better disease management, and therefore, increase in longevity.

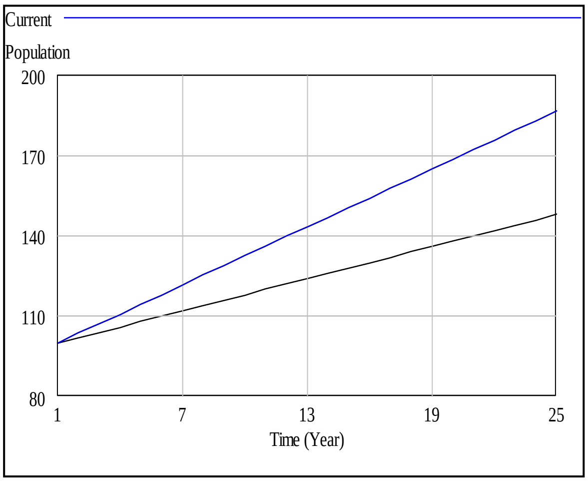

Figure 4- Population Growth (blue line- intervention, black line- no intervention)

4.1. Scenario 2- Model performance when the target savings is set versus zero target saving

This scenario serves as a demonstration of the goal seeking structure of the model. In the first case the target savings of the system are set at 25,000 dollars, while in the other case the target savings are set to zero. Figure 5 illustrates the resulting hypothetical net savings from both the cases within the scenario. When the target is set at 25,000, the goal seeking structure adjusts other components of the model to produce the higher net savings as compared to the case where no saving was targeted. However, as Figure 6 exhibits, to produce the higher savings a significant cut in the cost of care per patient is required.

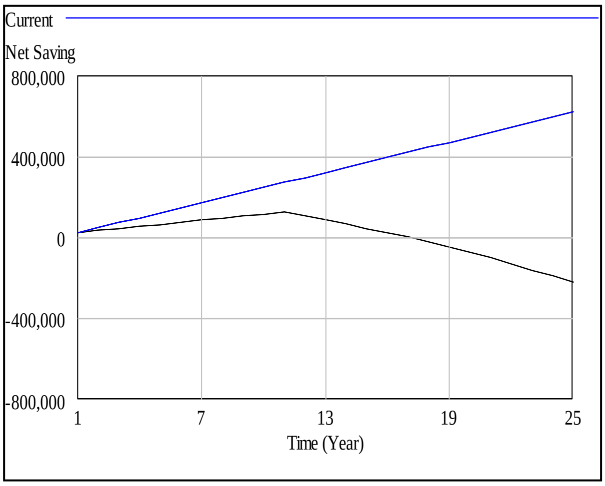

Figure 5- Net Savings (blue line- target saving, black line- no target saving)

The cost cut is not as severe in case of the cost of intervention per patient as seen in Figure 7. This is because of the low elasticity associated with the cost of intervention. Typically, the cost of intervention is found to be significantly lower than the cost of care. As a result, the net savings obtained from reducing the cost of intervention is far less than the net saving that can be obtained by reducing the cost of care. As a result the elasticity of intervention is set to be far lower than the elasticity of the cost of care.

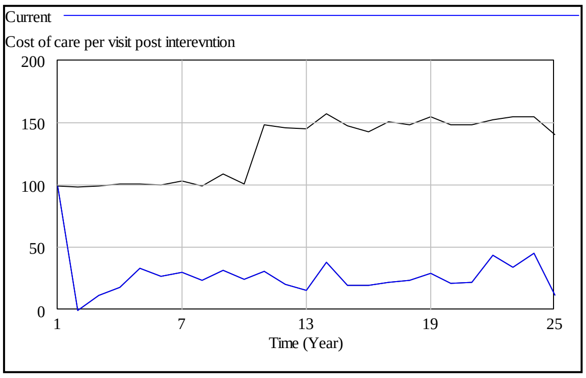

Figure 6- Cost of healthcare per visit (blue line- target saving, black line- no target saving)

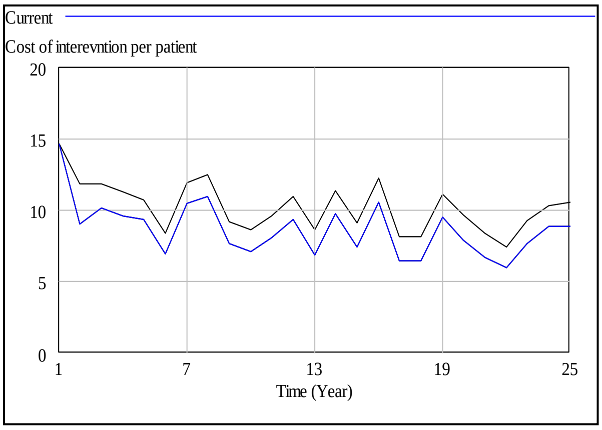

Figure 7- Cost of intervention per patient per unit time (blue line- target saving, black line- no target saving)

This scenario helps us to understand the consequences that the healthcare system would have to face if the targeted savings have to be achieved. In a more practical scene, this scenario helps us identifying the magnitude of cost efficiency that has be brought about in the healthcare system resulting of the intervention, if the targeted savings have to be realized.

5. CONCLUSIONS

The occurrence of chronic disease is widespread in the United States. Chronic diseases constitute a major portion of the healthcare expenditure which is projected to increase with the aging population. Chronic disease management has been a popular tool for mitigating some of the issues related to chronic diseases in a cost effective manner. The stress of this methodology is to create a partnership between the patients and the healthcare organization with the purpose of achieving better management of chronic conditions. This is achieved through the exercise of various disease management interventions primarily focused on patient and provider education and communication. Although the cost effectiveness of such interventions is widely acknowledged, the cost saving potential or at least the cost neutrality of such intervention is a matter of debate.

Cost evaluations of disease management interventions are complicated by a number of uncertainties in estimating the actual cost of delivering the intervention, impact of intervention of the actual utilization and the cost impact on the cost of healthcare. A number of factors like the type and the frequency of the intervention, type of chronic conditions, patient characteristics and so on determine the actual impact of the intervention on the cost and utilization of healthcare. Although inconclusive the literature suggests that certain disease management interventions can be cost saving in the short term. However, the cost saving potential of such interventions on a long term costs basis seems unfavorable. Longer term cost saving analysis based on Markov models, points to the fact that although disease management interventions are likely to be cost effective, they are unlikely to be cost saving in the long term. This is because disease management interventions lead to reduction in mortality and leads to future costs related to the disease and possibly unrelated costs of other chronic conditions that the patient may acquire as a result of acute aging.

While cost effectiveness is a welcome characteristic of such interventions, the excessive pressure of escalating healthcare costs on individuals and organization makes cost saving imperative. In such a situation the deliberating parties have to achieve a balance between harnessing the effectiveness of such interventions to produce better health outcomes while finding ways to make such efforts cost saving.

This paper has presented a system dynamics tool that takes into account the various complexities and the feedbacks comprising this system as mentioned earlier. This model presents an intuitive representation of the dynamics of the system, which would be of valuable help in analyzing various scenarios, associated with this system. Such a scenario analysis would be of value to the deliberation and decision making process mentioned earlier. The applicability of this model in such a scenario analysis was demonstrated using two hypothetical scenarios. The scenario analysis indicates that the application of intervention is likely to produce reduced utilization and savings only in the short term, which would be erased in the longer term. Also, population of aged patient is likely to increase due to reduced mortality rate as a result of the intervention. The goal seeking structure embedded in the model demonstrates the changes that the healthcare cost structure would have to undergo, to produce a certain targeted saving in healthcare cost. It is seen that a rapid reduction of healthcare costs per visit would be required to obtain the required long term savings in face of rapidly increasing utilization and escalating total costs in wake of the disease management intervention. In a practical sense, this demonstrates a positive feedback structure instigated by the intervention which increasingly makes it difficult to be cost saving in longer term. The results obtained from this scenario analysis provide useful insights and corroborate with the assertions made in the literature. This fact serves as the validation for the model behavior.

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