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Cost Distribution Analysis of Remote Monitoring System Use in the Treatment of Chronic Diseases

Adeola Yusuf
University of Arkansas, Fayetteville

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Department of Industrial Engineering
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Adeola Yusuf

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Thesis Advisor:

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Thesis Committee:

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Abstract

The cost of the treatment of chronic diseases is very high and this has a huge impact on the health-care system. Several factors contribute to this high cost. Some of these include the direct costs of treatment and the costs of several potential complications that arise as a result of the presence of other diseases. The goal of this study is to evaluate a cost-effective way of managing some of the common chronic diseases by analyzing the potential cost savings of utilizing remote monitoring systems (RMS) as opposed to the use of the traditional bundle (which includes regular visits to clinics for various procedures and treatments).

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1. Background/Motivation

It has been reported that almost half of the adult population in the United States is diagnosed with at least one chronic disease and there is an expected increase in the number of diagnosed patients [1]. The treatment of chronic diseases is very costly and with the high number of patients, there is a high impact on the health-care system. Studies show that 75% of the healthcare spending in the United States is allocated to the treatment of chronic conditions [1]. Several factors contribute to this high cost, ranging from the direct costs of treatments of the diseases to the costs of the several potential complications that could arise as a result of the presence of these diseases. This paper aims at evaluating a cost-effective way of managing some of the common chronic diseases by analyzing the potential cost savings of utilizing remote monitoring systems (RMS) as opposed to the traditional method of treatment.

The traditional treatment method includes the receipt of medications, visits to medical care specialists, health screenings and other disease monitoring procedures. As such, the costs associated with the traditional treatment include the direct costs of the previously mentioned components and the costs related to complications that result in hospitalizations and emergency room visits. Further, there are the indirect costs related to the loss of productivity due to the previously mentioned treatments and procedures (e.g., the time spent visiting health centers).

RMS are described as “laptop-like units that have the capability to connect to wired and wireless medical devices such as blood pressure monitors, glucose meters, pulse oximeters, scales and peak flow meters. They can be configured to collect vital signs and transmit results to healthcare providers for monitoring. They include communication tools such as video conferencing and email notification, and can also send patient reminders and facilitate patient education. Patients interact with the systems according to scripted content based on specific patient diagnoses" [2]. To eliminate the need for a stationary laptop-like unit, medical devices that communicate with mobile phones, and applications that support their use, are also being developed.

With the traditional treatment of chronic diseases, there is less support for patients as they engage in daily disease management (e.g., diet and behavior modifications) as a way of avoiding complications such as heart attacks, strokes, kidney failure, and so on. On the other hand, the use of remote monitoring systems facilitates continuous monitoring of patients and focuses on preventive measures, consequently leading to an effective way of minimizing the costs incurred by emergency situations and admissions into health facilities. Although there is no guarantee that complications would not occur, the use of remote monitoring systems reduces the chances of occurrence of complications because they enable more frequent screening and more frequent patient education and thus, when screening tests indicate an impending complication, early intervention can occur.

This research aims at analyzing the distribution of annual savings incurred when introducing remote monitoring systems (RMS) instead of the traditional treatment system for patients of the following five common chronic disease population classes: Prediabetes (PD), Type I diabetes (T1D), Type II diabetes (T2D), Heart failure (HF) and Hypertension (HYP).

2. Literature Review

In order to fully understand the motivation behind this paper, it is important to truly know what remote monitoring systems are and to fully grasp their applications. Literature review on the topic revealed that remote monitoring systems are described as devices that facilitate telemedicine, which is a service that uses electronic and telecommunications technologies to monitor patient care over a geographic distance [3]. The terms "telemedicine", "telehealth" and "home telehealth" are among the terms used interchangeably to refer to these services. By definition, "*Home Telehealth* is a service that gives the clinician the ability to monitor and measure patient health data and information over geographical, social and cultural distances" via the use of video and non-video technologies [3, 4].

Remote monitoring devices aid in accomplishing the ultimate goal of telemedicine to "increase patient access to health services, improve disease management including self-care management and drive earlier and proactive interventions for positive outcomes" [3]. Systems currently on the market include the Intel Health Guide PHS6000 and Bosch T400 Telehealth System [5, 6]. Features of the latter include blood glucose meters, blood pressure monitors, pulse oximeters, peak flow meters and weight scales [6].

There have been several published articles highlighting the use of telemedicine and the benefits of the use of telemedicine in healthcare. The justification for this paper lies in the fact that among the numerous related articles, not many provide concrete evidence of the cost effectiveness of using remote monitoring systems as is the case with the study conducted in this paper. It is stated that "a comprehensive literature search of cost related articles on telemedicine identified more than 600 articles, but only 9% contained any cost benefit data" and "only 4% of these articles met quality criteria justifying inclusion in a formalized quality review…" [7]. This paper provides details of in-depth analysis conducted and results obtained utilizing data acquired from previous related studies.

One such previous study was conducted to analyze the value of (RMS) for the treatment of chronic disease from the perspective of a healthcare provider or payer. It was assumed that such analysis could facilitate reimbursement policies for health insurance providers [2]. Milburn et al [2] suggest that with the technological advancement of RMS, utilizing such systems fosters a more cost-effective and less labor-intensive way of managing the health care of patients with chronic illnesses by "focusing on preventive measures and continuous monitoring instead of emergency care and hospital admissions" [2].

In an effort to evaluate the total savings potential of RMS, Milburn et al (2011) approximated the annual expected cost for each population class (PD, T1D, T2D, HF, HYP) using each bundle (traditional bundle, RMS bundle). Input parameters assumed to be known with certainty were the number of people in each population class, the cost of providing the treatment included in each bundle, and the cost of complications, should they occur. Input parameters not known with certainty were the probabilities of complication occurrence. The occurrence of a complication for a member of a population class was treated as a random variable with a known probability distribution derived from data taken from the literature. This information was used to populate discrete optimization models that made allocation decisions for RMS considering three scenarios.

The first was a basic model in which there was no capacity limit on the devices available, and in the second model there was a capacity limit. In the third model, the number of devices was limited and equitability was considered by requiring that the difference in savings per patient between any pair of population classes benefitting from RMS is no greater than a permissible threshold [2]. With the results of their computational study, Milburn et al [2] concluded that cost savings would be realized for patients of the HF, T1D and T2D population classes if RMS were widely utilized to foster efficient health care.

In addition, a look was taken at a study that aimed at analyzing the cost-effectiveness of colorectal-cancer screening strategies in France [8]. This study utilized a simulation model, for a ten-year duration, to analyze the distribution of costs for three potential screening strategies and to obtain the most effective and cost-effective strategy. Another study, aimed at estimating the future number of end stage renal disease patients for the period 2009-2020 in Greece and analyzing the cost-effectiveness of reducing hemodialysis patients and consequently increasing the transplantation number by 2020 [9] was examined. In this study, a simulation model was used to predict the number of patients and to show the net savings realized.

3. RMS Analysis Overview

In this study, there are two paths of analysis of RMS costs and savings. These two paths will be broken into two parts as follows:

Part 1 – Using the models presented in [2] sensitivity analysis is performed for parameter values that impact the costs and savings associated with RMS.

Part 2 – Instead of relying on the expected cost per patient using each bundle as in Part 1, the full distribution of annual cost per patient is determined. This provides better insight into the actual costs experienced by each patient, as some patients encounter complications while others do not. Using Monte Carlo simulation, the distribution of annual cost per patient is approximated.

4. Data

Tables 11 through 15 in Appendix A provide the data required in this study. These values were taken from [2].

It is reported that monitoring procedures include fasting plasma glucose (FPG), hemoglobin (A1C), capillary blood glucose (CBG) and blood pressure (BP). In addition, follow-up office visits are encouraged and are thus considered as part of procedures. Table 11 provides a summary of the direct costs of each procedure per year for each population class and treatment bundle. Procedure frequency per year is accounted for in the values reported in Table 11. For example, a patient in the HYP population class is recommended one office visit per year and the cost is $160. A patient in the T2D population class is recommended four office visits per year, thus the cost reported is $640.

The authors in [2] provided estimates of the annual purchase price, transmission and monitoring costs for RMS, also provided in Appendix A. It should be noted that the purchase price is $600, assumed to be paid once during the one year planning horizon, and the transmission cost of $180 is comprised of twelve monthly transmission charges of $15. Additionally, a monitoring cost of $600 per year is assumed for each RMS system. This value was obtained by dividing the average nurse salary, $60,000 by the number of patients a nurse is assumed to monitor, 100.

It is important to note that for the RMS bundle, there is an optimistic situation in which the complication risk reduction associated with RMS use is assumed to be high and there is a moderate situation in which the risk reduction is lower. These scenarios are considered in order to provide sensitivity analysis for the risk reduction associated with RMS use. Table 13 summarizes the probability risks associated with each complication encountered by patients belonging to a certain population class and using a certain treatment bundle.

Table 4 lists the estimated costs associated with the complications that patients may encounter. These values were obtained directly from [2]. The cost of healthcare utilization is estimated as the total average of costs incurred as a result of trips to the doctor, hospital and emergency room that occur in the event of the occurrence of acute symptoms of HF.

5. Part 1 - AMPL Model Formulation, Solutions and Sensitivity Analyses

For this part, AMPL was used to compute the cost of RMS bundle per patient (CDev) and cost of traditional bundle per patient (CTrad) of each population class, fraction of population class to assign either RMS or traditional bundles, total cost of RMS bundles and total cost of traditional bundles per population class, total cost of RMS and traditional bundles, cost savings per population class and the total cost savings. The following models were used in conducting this analysis: basic model without RMS device capacity constraint; a capacitated model and a capacitated model with equitability. These are found in Appendix B.

5.1. Basic Model without RMS Device Capacity Constraint

In this case, there is an assumption that there is no limit on the availability of RMS devices. In other words, if every patient in all population classes were to require an RMS device, there would be enough to go around. The model, given in Appendix B, simply computes the expected annual cost of treatment for each population class using the traditional bundle and the RMS bundle, and assigns the more cost effective bundle to each class. The data values in Appendix A were used and the results were obtained for the high risk and low risk cases.

For the traditional bundle the purchase price, monitoring and transmission costs of bundle will be equal to zero for all population classes because these costs are exclusive to RMS devices. The total annual expected cost of treatment for a patient using a particular bundle is the sum of the purchase and monitoring costs, direct and indirect cot of procedures, and expected cost of complications. This cost is represented in Appendix B.

The savings to a patient in a particular population class using RMS was calculated by computing the difference between the cost of using a traditional bundle and the cost of using

RMS. If using a traditional treatment bundle is more cost-effective, there would be no savings computed. The total savings realized by using RMS across all population classes is therefore the sum of the product of savings per patient of each population class and the number of patients in the class. These savings were computed as shown in Appendix B.

The results of the computations are provided in the following sections.

5.1.1. RMS Analysis for High Risk of Complications

For the high risk case, the AMPL results, provided in Table 1 below, indicate that using RMS devices is cost-effective for all persons with T1D, T2D and HF but not for PD and HYP.

Table 1: Expected Costs for Basic Model with High Risk Probability

		Population Class				
		PD	T1D	T2D	HF	HYP
Base Mfg. Cost = $600	CDev	$1,489.70	$4,881.20	$6,244.56	$9,078.40	$2,773.98
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10
	Savings	0.00%	13.92%	10.21%	11.54%	0.00%

The results provide details of the decrease in the annual cost of treatment per T1D patient if the RMS bundle is used as opposed to the traditional bundle.

<u>Sensitivity Analysis for High Risk Probability</u>

In order to see if different results would be obtained, changes were made to the value of the base manufacturing cost of RMS devices. Arbitrarily, $300 and $0 were used to conduct this analysis and the following results were obtained.

Table 2: Sensitivity Analysis Results for Basic Model with High Risk Probability

		Population Class				
		PD	T1D	T2D	HF	HYP
Base Mfg. Cost = $300	CDev	$1,189.70	$4,581.20	$5,944.56	$8,778.40	$2,473.98
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10
	Savings	0.00%	19.21%	14.52%	14.47%	0.00%
Base Mfg. Cost = $0	CDev	$889.70	$4,281.20	$5,644.56	$8,478.40	$2,173.89
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10
	Savings	0.00%	24.49%	18.83%	17.39%	0.10%

As with the case when the base manufacturing cost of the device is $600, the results for it being $300 indicate that the RMS is cost-effective for all persons with T1D, T2D and HF but not for PD and HYP. However, when this cost is $0, the results show that in addition to being cost effective for persons with T1D, T2D and HF, the RMS treatment is cost-effective for HYP patients, with a 0.10% decrease in treatment cost, but still not for PD patients. To understand why these different results were obtained, the break-even price of a device was calculated using the equation below. The results in Table 3 were obtained.

$$Break\ even\ = CTrad - (CDev - 600)$$

Table 3: Break Even Price of RMS Device in High Risk Case

Population Class	Break-Even Price of RMS Device
PD	-$317.392
T1D	$1389.14
T2D	$1309.78
HF	$1784.6
HYP	$3.1

The values in the table provide a view of how the results change if the base manufacturing cost of a device is changed. From these results it can be seen that as long as the cost of a device is less than or equal to $3.1, the RMS bundle is more cost effective for HYP patients. This explains the differences in the results in Tables 7 through 9. The negative break-even price of -$317.392 indicate that the RMS bundle is never the best option for PD patients, suggesting that the base manufacturing cost of an RMS device has no impact for PD patients.

5.1.2. RMS Analysis for Low Risk of Complications

The same analyses conducted in section 5.1.1. was carried out in this instance. However, the values for the risk for complications were those of the optimistic RMS scenario. Table 4 below provides details of the obtained results.

Table 4: Expected Costs for Basic Model with Low Risk Probability

		Population Class				
		PD	T1D	T2D	HF	HYP
Base Mfg. Cost = $600	CDev	$1,641.40	$4,410.23	$5,297.43	$8,116.10	$2,274.70
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10
	Savings	0.00%	22.22%	23.83%	20.92%	0.00%
Base Mfg. Cost = $0	CDev	$1,341.40	$4,110.23	$4,997.43	$7,816.10	$1,974.70
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10
	Savings	0.00%	27.51%	28.14%	23.84%	9.255%
Base Mfg. Cost = $0	CDev	$1,041.40	$3,810.23	$4,697.43	$7,516.10	$1,674.70
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10
	Savings	0.00%	32.80%	32.45%	26.77%	23.04%

Table 5: Break-Even Price of RMS Device in Low Risk Case

Population Class	Break-Even Price of RMS Device
PD	-$469.092
T1D	$1860.11
T2D	$2256.91
HF	$2746.9
HYP	$501.4

The results obtained were similar to the results obtained in the previous section. The difference is that with the break-even device price of $501.4 for HYP patients, RMS devices are also assigned to HYP patients when the base manufacturing cost is $300, which is not the case in the previous section.

5.2. Capacitated Model

Based on the realization that it is somewhat impractical to assume that there will be enough or more than enough RMS devices to go around [2], a limit is placed on the RMS device capacity subject to the number of nurses available [2]. Modifications were made to the basic model in Section 5.1. Here, there are two cases: a low capacity case with only 3.8 million devices available and a high capacity case with only 8.45 million devices available.

In addition, the shadow price of a device was computed. This shadow price lets us know how much the objective function will change if an additional device is made available. Again, results were also obtained for the high risk and low risk situations.

5.2.1. Low Capacity

The results for the high risk, low capacity case in Table 6 show that with 3.8 million devices available, only 76% of the 5 million HF patients would receive RMS devices. HF patients receive devices because they have the highest risk for complications as is shown in Table 3. The cost of treatment reduces by 8.77%. All other patients receive the traditional treatment bundle. The shadow price suggests that if an additional RMS device is made available, the total cost would reduce by $1,184.60. To see which population class would be given the device, the base manufacturing cost of $600 was subtracted from each of the break-even prices in Table 10 and the results were compared to the shadow price below. As the break-even for HF is $1784.60, resulting in subtraction value of $600, it was concluded that an additional RMS device would be given to a HF patient. The results for the low risk case and all sensitivity analyses are provided in Appendix A.

Table 6: Expected Costs for Capacitated Model with High Risk Probability and Low Device Capacity

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,489.70	$4,881.20	$6,244.56	$9,078.40	$2,773.98	Shadow Price = $1,184.60
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0	0.76	0	
	Savings	0.00%	0.00%	0.00%	8.77%	0.00%	
Base Mfg. Cost = $300	CDev	$1,189.70	$4,581.20	$5,944.56	$8,478.40	$2,473.98	Shadow Price = $1,484.60
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0	0.76	0	
	Savings	0.00%	0.00%	0.00%	10.99%	0.00%	
Base Mfg. Cost = $0	CDev	$889.70	$4,281.20	$5,644.56	$8,178.40	$2,173.98	Shadow Price = $1,784.60
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0	0.76	0	
	Savings	0.00%	0.00%	0.00%	13.22%	0.00%	

Where “Fraction” represents the fraction of the patient population allocated a device. A fraction of 0 indicates that all patients of the population class are allocated a traditional treatment bundle.

5.2.2. High Capacity

The results in Table 7 show that for the high risk situation in this case, the availability of 8.45 million devices provides for all HF and T1D patients and about 0.13% of T2D patients. With only a small percentage utilizing RMS bundles, the annual treatment cost reduces only by 1.37%. The shadow price for a device here is $709.78 and like in the previous section, computations were obtained to show that any additional device would be given to a T2D patient.

Table 7: Expected Costs for Capacitated Model with High Risk Probability and High Device Capacity

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,489.70	$4,881.20	$6,244.56	$9,078.40	$2,773.98	Shadow Price = $709.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	1	0.13438	1	0	
	Savings	0.00%	13.92%	1.37%	11.54%	0.00%	
Base Mfg. Cost = $300	CDev	$1,189.70	$4,581.20	$5,944.56	$8,478.40	$2,473.98	Shadow Price = $1,009.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	1	0.13438	1	0	
	Savings	0.00%	19.21%	1.95%	14.47%	0.00%	
Base Mfg. Cost = $0	CDev	$889.70	$4,281.20	$5,644.56	$8,178.40	$2,173.98	Shadow Price = $1,309.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	1	0.13438	1	0	
	Savings	0.00%	24.50%	2.53%	17.39%	0.00%	

Results for the low risk situation are provided in Appendix C.

5.3. Capacitated Model with Equitability

Unlike in Section 5.2., the model used here reduces the expected annual cost in consideration of all population classes and not just the population class that the RMS device capacity can cover. Also, there is a requirement that between any 2 population classes that would potentially benefit from RMS, the difference in savings per patient is no greater than an allowable threshold.

5.3.1. Ten Percent (10%) Maximum Percent Savings Allowed

Table 8 below provides the result for the high risk, low capacity case when the maximum percent savings allowed (denoted as α) is 10%. The addition of the threshold evens out the distribution of RMS devices. Unlike in Section 5.2.1., where all the available devices are given to HF patients, some devices are given to T1D patients as well. In other words, about 69% of HF patients receive devices and about 26% of T1D patients receive devices. It should be noted that the savings realized for HF and T1D patients, when there is a device base manufacturing cost of zero, is 10%, which is the largest percentage savings any population class receives, subject to $\boldsymbol{\alpha}$, which is also 10%. Because $\boldsymbol{\alpha}$ is defined as the difference between the largest and smallest percent savings realized by any population class, and population classes that do not benefit from remote monitoring systems see zero savings, the largest percent savings are limited to $\boldsymbol{\alpha}$=10%.

Table 8: Expected Costs for Capacitated Model with High Risk Probability, Low Device Capacity and Maximum Allowed Savings of 10%

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,489.70	$4,881.20	$6,244.56	$9,078.40	$2,773.98	Shadow Price = $1,184.6
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0	0.76	0	
	Savings	0.00%	0.00%	0.00%	8.77%	0.00%	
Base Mfg. Cost = $300	CDev	$1,189.70	$4,581.20	$5,944.56	$8,478.40	$2,473.98	Shadow Price = $1,089.14
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.26424	0	0.6913	0	
	Savings	0.00%	5.08%	0.00%	10.00%	0.00%	
Base Mfg. Cost = $0	CDev	$889.70	$4,281.20	$5,644.56	$8,178.40	$2,173.98	Shadow Price = $1,309.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.40819	0.02462	0.57509	0	
	Savings	0.00%	10.00%	0.46%	10.00%	0.00%	

5.3.2. Five Percent (5%) Percent Savings Allowed

Table 9 below provides the result for a base manufacturing cost of $600 for the high risk, low capacity case when the maximum percent savings allowed (α) is 5%. With a smaller threshold than in the previous section, about 7% of T2D patients also receive RMS devices and the shadow price of $709.78 indicates that an additional device would be given to a T2D patient.

Table 9: Expected Costs for Capacitated Model with High Risk Probability, Low Device Capacity and Maximum Allowed Savings of 5%

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,489.70	$4,881.20	$6,244.56	$9,078.40	$2,773.98	Shadow Price = $709.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.35927	0.07294	0.43318	0	
	Savings	0.00%	5.00%	0.01%	5.00%	0.00%	
Base Mfg. Cost = $300	CDev	$1,189.70	$4,581.20	$5,944.56	$8,478.40	$2,473.98	Shadow Price = $1,009.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.26031	0.10833	0.34565	0	
	Savings	0.00%	5.00%	1.56%	5.00%	0.00%	
Base Mfg. Cost = $0	CDev	$889.70	$4,281.20	$5,644.56	$8,178.40	$2,173.98	Shadow Price = $1,309.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.2041	0.13106	0.28754	0	
	Savings	0.00%	5.00%	2.47%	5.00%	0.00%	

Again, the maximum savings realized is 5% as is the value of α.

6. Part 2 – Distribution of Annual Cost per Patient

In order to estimate the distribution of annual cost per patient for both the traditional and RMS bundles for each population class, a Monte Carlo Simulation was performed using @RISK software. To minimize simulation run time, only 1 simulation with 1000 iterations was used. Further, a fixed seed of “1” was used in order to ensure that the simulation run process was uniform across all cases.

For each population class there were values for:

- Known inputs – purchase, monitoring, transmission and procedure costs for both bundles, modeled as constant values; costs associated with complications, should they occur, also modeled as constant values

- Uncertain inputs – risk of complications experienced by a patient using a given bundle, for both bundles; these are modeled using probability distributions
- Output – distribution of annual cost per patient per year

The values for known inputs and parameter values for risk complication distributions were obtained from the data provided [2]. The distribution of annual cost of complications per patient per year was determined by considering the complication risk distributions and the cost of complications. For each bundle, the distribution of annual cost per patient was determined by adding purchase, monitoring, transmission and annual procedure costs to the distribution of annual cost of complications per patient per year as can be seen in the equation below:

$$A = M + \sum_{t \in T} P_t + \sum_{j \in J} C_j p_j$$

Where:

A: annual cost per patient

M: purchase price, monitoring and transmission costs of bundle

T: set of procedures

J: set of complications

P_t: cost of procedure t

C_j: cost of complication j

p_j: probability of occurrence of complication j

To account for uncertainty in the available data regarding complication risk, we experimented using several alternative probability distributions to model complication risk. Specifically, we considered binomial, triangular, and truncated normal distributions to model patient risk for each complication. Parameters for these distributions were chosen so that the expected values were equal to the expected risk values used in the previous study. Following analyses for several scenarios, it was evident that it was most accurate to use a triangular distribution for complication risk probabilities and a binomial distribution for costs incurred. This will be explained in further detail in the following analysis.

Cost estimations were evaluated for both the traditional bundle treatment option and the RMS treatment option.

Triangular Distributions for Complication Risk Probabilities and Binomial Distributions for Costs Incurred

To begin this analysis, a triangular distribution was used to model complication risks. In a Triangular distribution, there is an upper limit, a lower limit and a mode. On the assumption that complication risk follows this type of distribution, it means that at the very least, a patient experiences a complication with a certain probability, say p; at most, a patient experiences a complication with probability, say q; and there is a most likely case in which a patient experiences complication with probability, say m. For this analysis, the annual cost was computed for the RMS for T2D patients in two different cases as follows:

- Traditional Bundle: The values in Table 12 were used as the most likely values and 90% and 110% of these values were used as the minimum and maximum values respectively. For example, the cell value for the risk for kidney failure was "=RiskTriang(0.9*0.4, 0.4,1.1*0.4)"
- RMS bundle: The values for the optimistic situation in Table 12 were used as the most likely values and 90% of these values were used as the minimum values. For the maximum values, 110% of the values for the traditional bundle were used. The cell value for the risk for kidney failure in this instance was "=RiskTriang(0.9*0.24,0.24, 1.1*0.4)".

Moreover, a Bernoulli distribution was used to simulate the occurrence of the complication for a patient with the specified risk value. In other words, while a given patient's risk for a complication is the value sampled from the triangular distribution, whether or not the complication occurs depends on the outcome of a Bernoulli trial where the probability of success is equal to the stated risk. In a Bernoulli trial, two outcomes are possible: success and failure. A success occurs with probability *p*, and a failure occurs with probability 1-*p*. If we assume that complication risk follows a Bernoulli distribution, then either a patient experiences a complication (with probability *p*) or they do not (with probability 1-*p*). Let p_{ijk} be the risk for complication *k* experienced by a patient in population class *i* using bundle *j*. The parameter values selected for the Bernoulli distribution associated with each population class and treatment bundle are given in Table 13 which specifies p_{ijk} for all *i*,*j*,*k*.

Thus, two distributions of expected annual cost per patient of each population class are developed: one for the traditional bundle and one for the RMS bundle. The parameter values selected are provided in Table 12 and the results of this analysis are provided in Table 10 below.

Table 10: Expected Annual Cost/Patient/Year ($) using Distributions for Risk Probabilities and Costs Incurred

Class	Traditional				RMS			
	Min	Max	Mean	StDev	Min	Max	Mean	StDev
T2D	1,345.2	35,865.2	6,939.86	6,365.61	1,491.2	26,091.2	5,702.06	5,756.22
T1D	1,053.2	35,573.2	5,645.94	6,302.37	1,199.2	25,799.2	4,484.68	5,380.39
PD	160.4	17,180.4	570.50	1,940.38	786.4	13,086.4	975.86	1,345.53
HYP	160	37,460	2,154.66	5,215.94	786	38,086	2,135.48	4,373.57
HF	640	10,263	9,839.59	1,975.61	786	10,409	8,488.46	3,848.18

The results indicate the distribution of expected annual costs that patients belonging to a certain population class would have to pay. The "Mean" values represent the average expected costs that would be realized based on procedure costs and the binomial distributions of the probability that a patient encounters complications. The "Min" values represent the total expected costs that would be realized if a patient encounters none of the complications (i.e. only procedure costs would be realized). The “Max” values represent the total expected costs realized if a patient encounters all complications (i.e. procedure costs and all complication costs would be realized).

For example, the minimum annual cost for T2D patients using the traditional bundle is $1,345.20, which is the sum of the costs of FPG, A1C, CBG and office visits; numerically, the sum of $1.6, $119.6, $540 and $640 respectively. If all complications associated with T2D (with the exception of retinopathy) are encountered, the sum of the complications as well as procedure costs would lead to a maximum of $35,865.20. This is the sum of $1.6, $119.6, $540, $640, $9920, $4720, $12300 and $12300. It appeared that the cost of retinopathy was not considered because it has the slimmest chance of occurrence. The values of the risk probabilities provided in Table 3 come into play in the estimation of the mean annual cost per patient. The expected annual cost is obtained by adding the procedure costs to the expected value of each complication cost based on the probable outcomes.

The following figures provide views of the distribution of the cost for T2D patients for the traditional bundle and the RMS bundle. Cost distributions for other patients are provided in Appendix D.

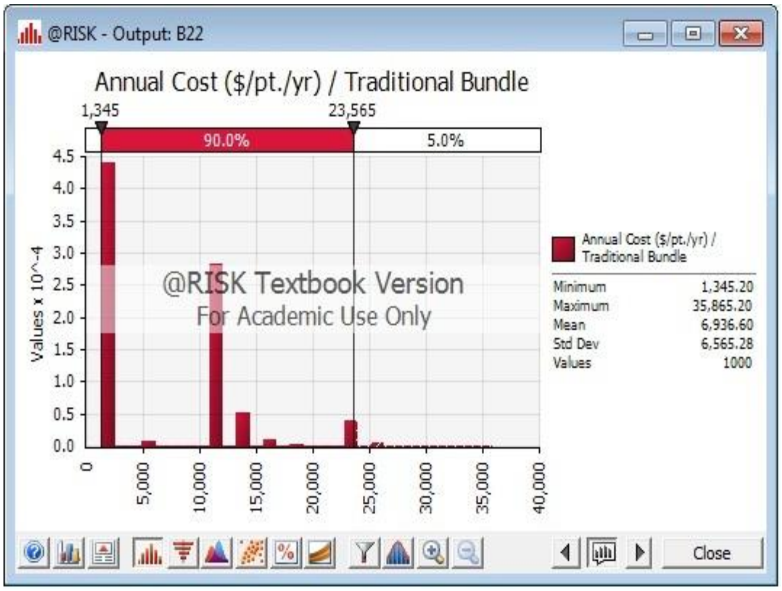

Figure 1: Expected Annual Cost of Traditional Bundle for T2D Patients

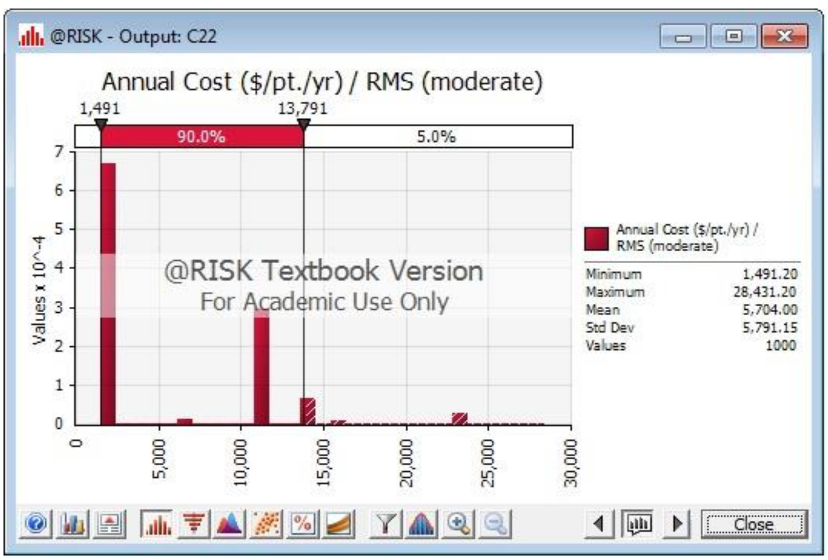

Figure 2: Expected Annual Cost of RMS Bundle for T2D Patients

7. Discussion of Results and Recommendations for Future Work

It is evident that for some chronic diseases and problem parameters, using remote monitoring systems is the more cost-effective route to the treatment of chronic diseases as can be seen in the results which show that the RMS option costs less. For some other diseases and parameters, such is not the case. In Section 5, with the exception of PD patients, it was seen that the RMS option is more cost-effective than the traditional bundle depending on what the situation might be (i.e. high risk, low capacity, variation in α, and so on).

With respect to Section 6, although the minimum and maximum values of the costs obtained provide insight as to what the expected annual cost under certain circumstances will be, these values are not an integral part of the analysis. This is because they represent situations in which patients either encounter no complication or encounter all complications and it is assumed that such situations are unlikely. As a result, analysis is based on the mean values of the estimated annual cost per patient.

In the analysis, with a triangular distribution used for the risk probabilities, a binomial distribution for the complication costs incurred and the optimistic and moderate situations for the RMS combined into one, the results indicate that the RMS is more cost-effective for all population classes except PD.

It is significant to note that essentially, the values for the expected cost savings realized for remote monitoring systems are the greatest for HF patients, next, for T2D patients, followed by values for T1D patients and then values for HYP patients being the least. The knowledge of this would be useful in a situation in which there is a limit on the number of RMS devices available. As was somewhat highlighted in Section 5, It would be more economical to allocate devices to HF patients first and then to T2D, T1D and HYP patients correspondingly.

In effect, this paper provides substantial evidence, based on the data that was available for populating the models, to demonstrate the cost effective benefits of remote monitoring systems for patients of the chronic diseases mentioned. In addition, such systems are also advantageous for hospitals, clinics and other healthcare providing facilities in that they help to alleviate emergency room overcrowding [10]. Forecasts indicate that the market for such systems in the US is expected to double by 2016 [10].

A beneficial area of future study would be to conduct analysis for additional model parameters, other than the base manufacturing cost of RMS devices and the complication risk reductions associated with their use. This analysis may reveal whether RMS systems are ever cost effective for PD patients. Moreover, the approaches used in this study can be used to analyze the benefits for patients of other diseases such as chronic obstructive pulmonary disease (COPD).

Appendix A Data Used to Populate Optimization Models

This data was obtained from [2].

Table 11: Procedure costs

Known Inputs	Procedure Costs ($/pt./yr.)									
	Treatment Bundle					RMS				
Procedure	T2D	T1D	PD	HYP	HF	T2D	T1D	PD	HYP	HF
FPG	1.6	1.6	0	0	0	1.6	1.6	0	0	0
A1C	119.6	119.6	0	0	0	119.6	119.6	0	0	0
CBG	584	292	0.4	0	0	584	292	0.4	0	0
BP	0	0	0	0	0	0	0	0	0	0
Office Visit	640	640	160	160	640	0	0	0	0	0

Table 12: Purchase, Transmission and Monitoring Costs

Known Inputs	Traditional Bundle	RMS
Purchase Price	-	600
Transmission Cost	-	180
Monitoring Cost	-	600

Table 13: Complication Risk Probabilities

Complication	Risk for Complications (%)														
	Traditional Bundle					RMS (moderate)					RMS (optimistic)				
	T2D	T1D	PD	HYP	HF	T2D	T1D	PD	HYP	HF	T2D	T1D	PD	HYP	HF
Kidney Failure	40	30	2.5	3.81	-	30.80	20	0.81	2.63	-	24	18	24	1.63	-
Retinopathy	2.30	2.30	1.44	-	-	1.50	1.50	0.04	-	-	1.38	1.38	0.036	-	-
Heart Disease	6.23	6.23	0.39	4.31	-	4.20	4.20	0.11	2.97	-	3.115	3.115	0.08	1.9	-
Stroke	6.23	6.23	0.39	5.64	-	4.20	4.20	0.11	3.89	-	3.115	3.115	0.08	2.48	-
Heart Attack	-	-	-	1.6	-	-	-	-	1.1	-	-	-	-	0.7	-
Healthcare Utilization	-	-	-	-	100	-	-	-	-	80	-	-	-	-	70

Table 14: Cost of Complications

Complication	Cost ($/yr.)
Kidney Failure	9920
Retinopathy	4720
Heart Disease	12300
Stroke	12300
Heart Attack	25000
Healthcare Utilization	9623

Table 15: Number of Persons per Population Class

Population Class	Number in Class
PD	22,200,000
T1D	1,300,000
T2D	16,000,000
HF	5,000,000
HYP	50,000,000

Appendix B Optimization Models

The following optimization models were also obtained from [2].

<u>Section 5.1 (Basic Model)</u>

I: set of population classes

n_i: number of patients in population class $i \in I$

B_i: set of available treatment bundles for class $i \in I$

B: set of all treatment bundles, $B = \cup_{i \in I} B_i$

m_b: purchase price, monitoring and transmission costs of bundle b

T_b: set of procedures in bundle $b \in B$

T: set of all procedures, $T = \cup_{b \in B} T_b$

d_t: direct cost of procedure $t \in T$

l_t: indirect cost of procedure $t \in T$

f_t: frequency of procedure $t \in T$

J_b: set of all complications associated with bundle $b \in B$

J: set of all complications, $J = \cup_{b \in B} J_b$

C_j: cost of complication $j \in J$

p_j: probability of occurrence of complication $j \in J$

S_i: savings per patient in population class $i \in I$ using RMS

S: total savings across all population classes using RMS

$$b = \begin{cases} 0, & \text{corresponding to the traditional bundle} \\ 1, & \text{corresponding to the remote monitoring system} \end{cases}$$

$$C_i^b = m_b + \sum_{t \in T_b} f_t(d_t + l_t) + \sum_{j \in J_b} c_j p_j$$

$$S_i = \min\{0, C_i^0 - C_i^1\}$$

$$S = \sum_{i \in I} n_i S_i$$

<u>Section 5.2 (Capacitated Model)</u>

Data elements:

r_k: amount available of resource k

u_k^b: amount of resource k used in a single patient assignment of treatment bundle b

Decision variables:

y_i^b: fraction of i^{th} population class served by monitoring bundle b

Objective function:

$$minimize \sum_{i \in I} \sum_{b \in B_i} n_i C_i^b y_i^b$$

Constraints:

$\sum_{b \in B_i} y_i^b = 1 \quad \forall\, i \in I$ (this ensure that all patients are either served by the traditional bundle or RMS bundle)

$\sum_{i \in I} \sum_{b \in B_i} n_i u_k^b y_i^b \leq r_k \quad \forall\, k$ (this ensure that the limit on available devices is respected)

$0 \leq y_i^b \leq 1 \ \forall\, i \in I, b \in B_i$.

Section 5.3 (Capacitated Model with Equitability)

Data elements:

α: maximum difference in percent savings allowed between the population classes

Decision variables:

A_i: total annual expected cost per patient for patients in population class i

v: the smallest percentage savings any population class receives

w: the largest percentage savings any population class receives

Objective function:

$$minimize \sum_{i \in I} n_i A_i$$

Constraints

$\sum_{b \in B_i} y_i^b = 1 \quad \forall\, i \in I$

$A_i = \sum_{b \in B_i} C_i^b y_i^b \;\; \forall\, i \in I$ (the total cost per patient per population class)

$$\sum_{i \in I} \sum_{b \in B_i} n_i u_k^b y_i^b \leq r_k \;\; \forall\, k$$

$v \leq \frac{C_i^0 - A_i}{C_i^0} \;\; \forall\, i \in I^{RMS}$ and $w \geq \frac{C_i^0 - A_i}{C_i^0} \;\; \forall\, i \in I^{RMS}$ (these compute the smallest and largest percentage savings over all classes that can benefit from RMS)

$w - v \leq \alpha$, (this ensures that the difference between the largest percentage saving and smallest percentage savings is less than the given bound)

$0 \leq y_i^b \leq 1 \;\; \forall\, i \in I, b \in B_i$.

Appendix C Results for Optimization Models Used in Part 1

Table 16: Sensitivity Analysis Results for Capacitated Model with High Risk Probability and Low Device Capacity

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $300	CDev	$1,489.70	$4,881.20	$6,244.56	$8,778.40	$2,773.98	Shadow Price = $1,484.60
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0	0.76	0	
	Savings	0.00%	0.00%	0.00%	10.99%	0.00%	
Base Mfg. Cost = $0	CDev	$1,489.70	$4,881.20	$6,244.56	$8,478.40	$2,773.98	Shadow Price = $1,784.60
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Savings	0.00%	0.00%	0.00%	13.22%	0.00%	
	Fraction	0	0	0	0.76	0	

Table 17: Expected Costs for Capacitated Model with Low Risk Probability and Low Device Capacity

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,641.40	$4,410.23	$5,297.43	$8,116.10	$2,274.70	Shadow Price = $2,146.90
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	1	1	1	0.76	1	
	Savings	0.00%	0.00%	0.00%	15.90%	0.00%	
Base Mfg. Cost = $300	CDev	$1,341.40	$4,110.23	$4,997.43	$7,816.10	$1,974.70	Shadow Price = $2,446.90
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0	0.76	0	
	Savings	0.00%	0.00%	0.00%	18,12%	0.00%	
Base Mfg. Cost = $0	CDev	$1,041.40	$3,810.23	$4,697.43	$7,516.10	$1,674.70	Shadow Price = $2,746.90
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0	0.76	0	
	Savings	0.00%	0.00%	0.00%	20.34%	0.00%	

Table 18: Expected Costs for Capacitated Model with Low Risk Probability and High Device Capacity

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,641.40	$4,410.23	$5,297.43	$8,116.10	$2,274.70	Shadow Price = $1,656.91
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0.215625	1	0	
	Savings	0.00%	0.00%	5.14%	20.92%	0.00%	
Base Mfg. Cost = $300	CDev	$1,341.40	$4,110.23	$4,997.43	$7,816.10	$1,974.70	Shadow Price = $1,956.91
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0.215625	1	0	
	Savings	0.00%	0.00%	6.07%	23.84%	0.00%	
Base Mfg. Cost = $0	CDev	$1,041.40	$3,810.23	$4,697.43	$7,516.10	$1,674.70	Shadow Price = $2,256.91
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0.215625	1	0	
	Savings	0.00%	0.00%	7.00%	26.77%	0.00%	

Table 19: Expected Costs for Capacitated Model with Low Risk Probability and Low Device Capacity

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,641.40	$4,410.23	$5,297.43	$8,116.10	$2,274.70	Shadow Price = $1,656.91
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0.0881131	0.478038	0	
	Savings	0.00%	0.00%	2.10%	10.00%	0.00%	
Base Mfg. Cost = $300	CDev	$1,341.40	$4,110.23	$4,997.43	$7,816.10	$1,974.70	Shadow Price = $1,956.91
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0.106429	0.419429	0	
	Savings	0.00%	0.00%	2.99%	10.00%	0.00%	
Base Mfg. Cost = $0	CDev	$1,041.40	$3,810.23	$4,697.43	$7,516.10	$1,674.70	Shadow Price = $2,256.91
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0.120743	0.37361	0	
	Savings	0.00%	0.00%	3.92%	10.00%	0.00%	

Table 20: Expected Costs for Capacitated Model with Low Risk Probability, Low Device Capacity and Maximum Allowed Savings of 5%

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,641.40	$4,410.23	$5,297.43	$8,116.10	$2,274.70	Shadow Price = $1,656.91
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0.162807	0.239019	0	
	Savings	0.00%	0.00%	3.88%	5.00%	0.00%	
Base Mfg. Cost = $300	CDev	$1,341.40	$4,110.23	$4,997.43	$7,816.10	$1,974.70	Shadow Price = $1,956.91
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0.171964	0.209714	0	
	Savings	0.00%	0.00%	4.84%	5.00%	0.00%	
Base Mfg. Cost = $0	CDev	$1,041.40	$3,810.23	$4,697.43	$7,516.10	$1,674.70	Shadow Price = $964.75
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.154558	0.156229	0.189432	0.003045	
	Savings	0.00%	5.00%	5.00%	5.00%	0.07%	

Table 21: Expected Costs for Capacitated Model with High Risk Probability, High Device Capacity and Maximum Allowed Savings of 10%

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,489.70	$4,881.20	$6,244.56	$9,078.40	$2,773.98	Shadow Price = $709.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.718547	0.199003	0.866368	0	
	Savings	0.00%	10.00%	2.03%	10.00%	0.00%	
Base Mfg. Cost = $300	CDev	$1,189.70	$4,581.20	$5,944.56	$8,778.40	$2,473.98	Shadow Price = $1,009.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.520625	0.269794	0.69127	0	
	Savings	0.00%	10.00%	3.92%	10.00%	0.00%	
Base Mfg. Cost = $0	CDev	$889.70	$4,281.20	$5,644.56	$8,478.40	$2,173.98	Shadow Price = $1,309.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.408191	0.315245	0.575087	0	
	Savings	0.00%	5.00%	5.00%	5.00%	0.00%	

Table 22: Expected Costs for Capacitated Model with Low Risk Probability, High Device Capacity and Maximum Allowed Savings of 10%

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,641.40	$4,410.23	$5,297.43	$8,116.10	$2,274.70	Shadow Price = $1,656.91
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0	0.378738	0.478038	0	
	Savings	0.00%	0.00%	9.02%	10.00%	0.00%	
Base Mfg. Cost = $300	CDev	$1,341.40	$4,110.23	$4,997.43	$7,816.10	$1,974.70	Shadow Price = $447.61
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.364591	0.356482	0.420738	0.003373	
	Savings	0.00%	10.00%	10.00%	10.00%	0.03%	
Base Mfg. Cost = $0	CDev	$1,041.40	$3,810.23	$4,697.43	$7,516.10	$1,674.70	Shadow Price = $964.75
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.318083	0.321523	0.389855	0.018857	
	Savings	0.00%	10.00%	10.00%	10.00%	0.43%	

Table 23: Expected Costs for Capacitated Model with High Risk Probability, High Device Capacity and Maximum Allowed Savings of 5%

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,489.70	$4,881.20	$6,244.56	$9,078.40	$2,773.98	Shadow Price = $709.78
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.359273	0.363564	0.433184	0	
	Savings	0.00%	5.00%	3.71%	5.00%	0.00%	
Base Mfg. Cost = $300	CDev	$1,189.70	$4,581.20	$5,944.56	$8,778.40	$2,473.98	Shadow Price = $0
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.260313	0.344349	0.345649	0	
	Savings	0.00%	5.00%	5.00%	5.00%	0.00%	
Base Mfg. Cost = $0	CDev	$889.70	$4,281.20	$5,644.56	$8,478.40	$2,173.98	Shadow Price = $0
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.204095	0.265736	0.287824	0.04987	
	Savings	0.00%	5.00%	5.00%	5.00%	0.01%	

Table 24: Expected Costs for Capacitated Model with Low Risk Probability, High Device Capacity and Maximum Allowed Savings of 5%

		Population Class					
		PD	T1D	T2D	HF	HYP	
Base Mfg. Cost = $600	CDev	$1,641.40	$4,410.23	$5,297.43	$8,116.10	$2,274.70	Shadow Price = $0
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.224993	0.209858	0.239019	0	
	Savings	0.00%	5.00%	5.00%	5.00%	0.00%	
Base Mfg. Cost = $300	CDev	$1,341.40	$4,110.23	$4,997.43	$7,816.10	$1,974.70	Shadow Price = $447.61
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.206953	0.20235	0.238823	0.074985	
	Savings	0.00%	5.00%	5.00%	5.00%	0.01%	
Base Mfg. Cost = $0	CDev	$1,041.40	$3,810.23	$4,697.43	$7,516.10	$1,674.70	Shadow Price = $964.75
	CTrad	$572.31	$5,670.34	$6,954.34	$10,263.00	$2,176.10	
	Fraction	0	0.203616	0.205817	0.249559	0.072889	
	Savings	0.00%	5.00%	5.00%	5.00%	1.68%	

Appendix D Results for Monte Carlo Simulation Models Used in Part 2

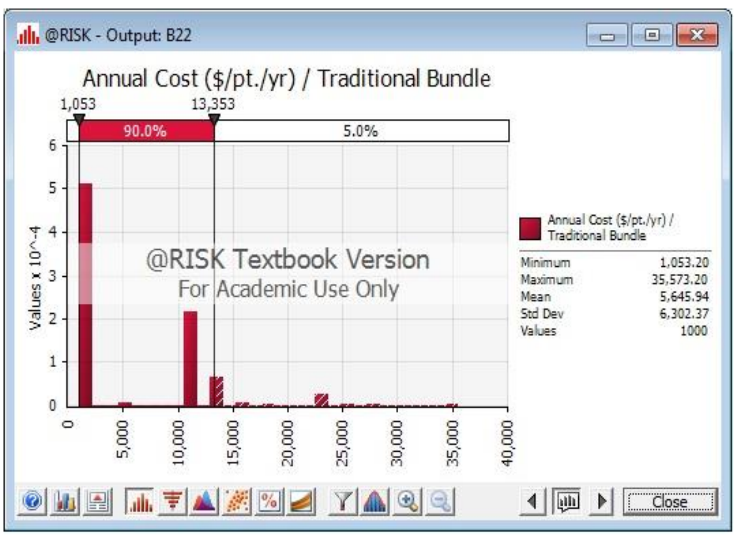

Figure 3: Expected Annual Cost of Traditional Bundle for T1D Patients

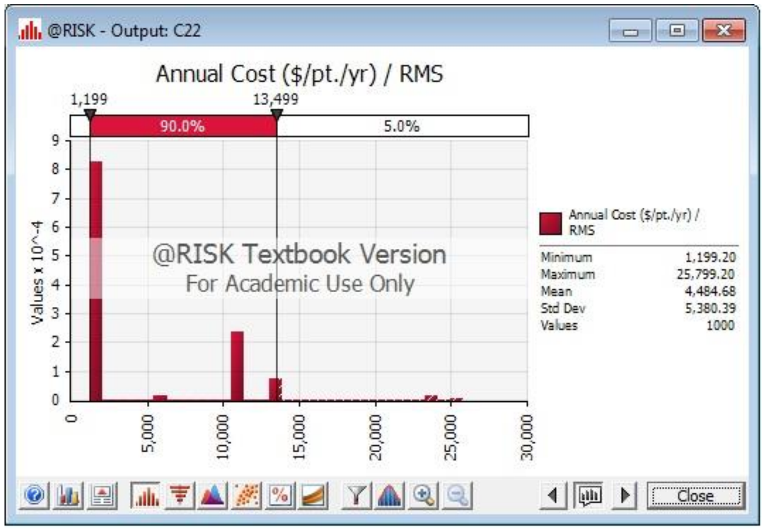

Figure 4: Expected Annual Cost of RMS Bundle for T1D Patients

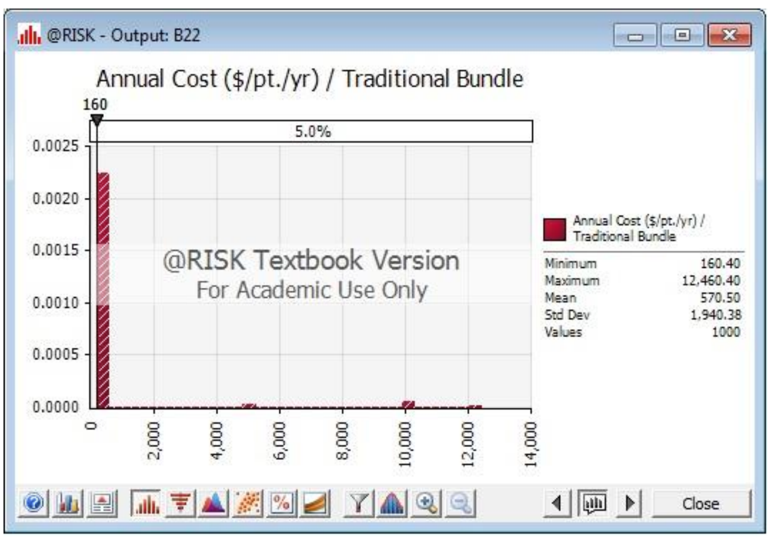

Figure 5: Expected Annual Cost of Traditional Bundle for PD Patients

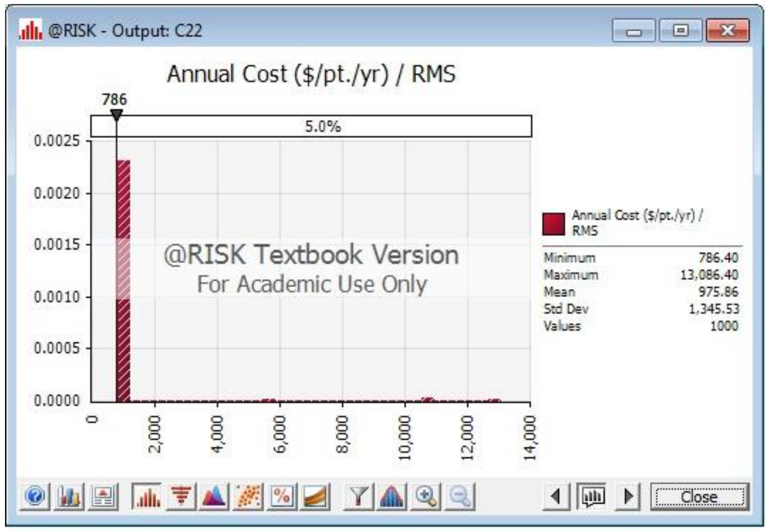

Figure 6: Expected Annual Cost of RMS Bundle for PD Patients

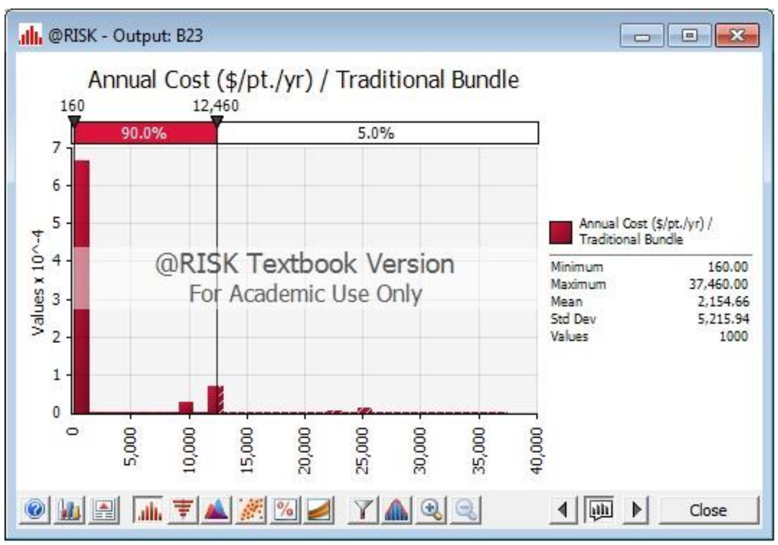

Figure 7: Expected Annual Cost of Traditional Bundle for HYP Patients

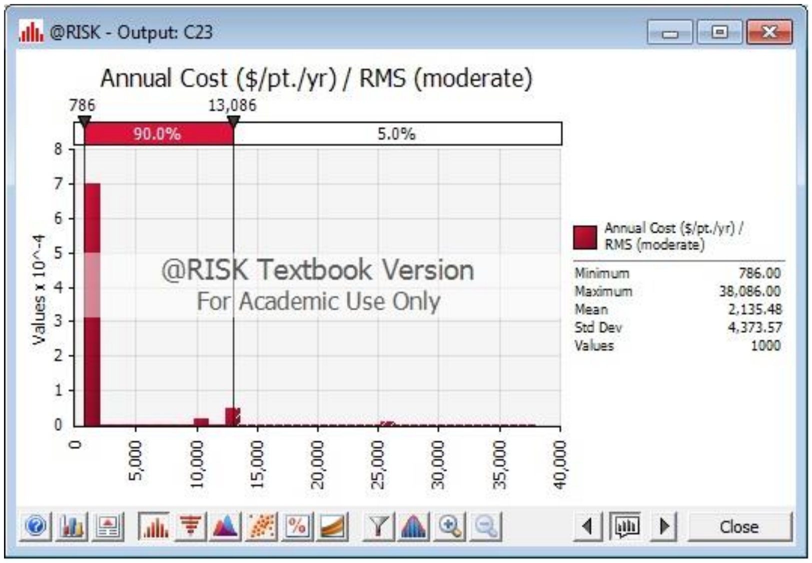

Figure 8: Expected Annual Cost of RMS Bundle for HYP Patients

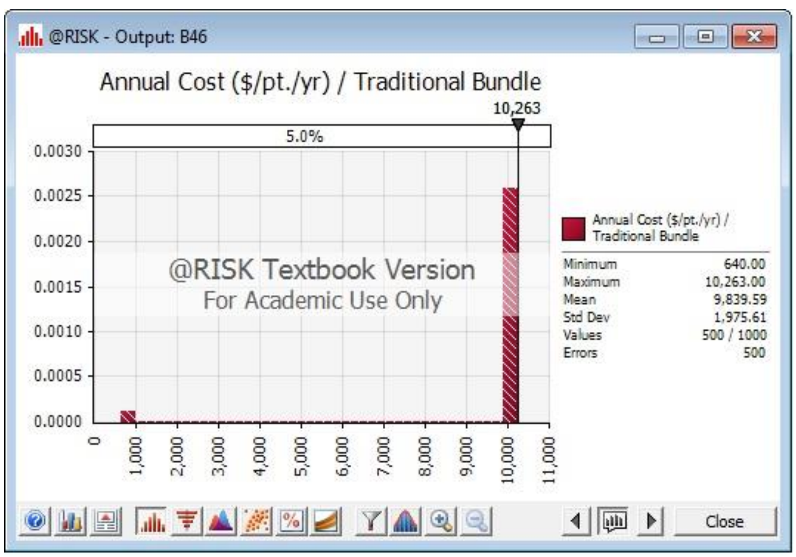

Figure 9: Expected Annual Cost of Traditional Bundle for HF Patients

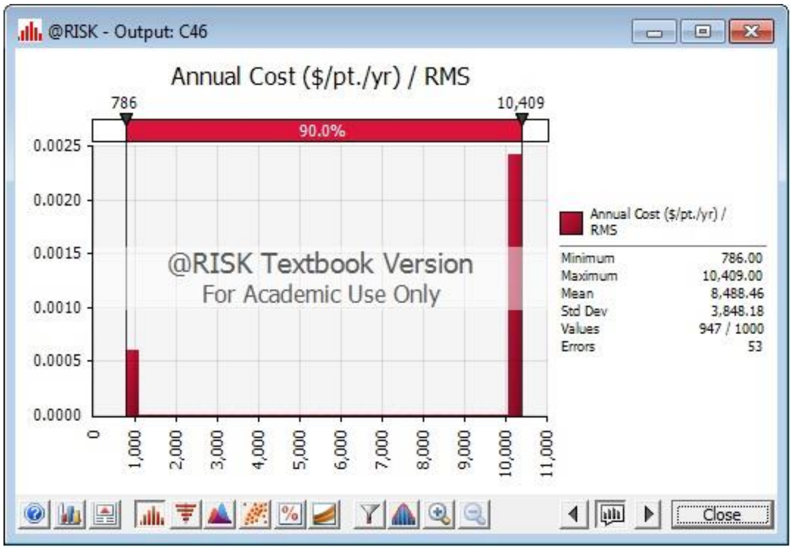

Figure 10: Expected Annual Cost of RMS Bundle for HF Patients

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