Medical Diagnosis & Treatment:

A Decision Analysis Study

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EXECUTIVE SUMMARY

The goal of this project was to provide a framework and analyze a medical decision of treating and diagnosing a disease. The decision maker was considered to be the doctor, and a utility assessment on a medical student was conducted to capture preferences and risk attitudes. The analysis also involved the development of an alternative systems and determination of appropriate attribute ranges.

A multiattribute utility analysis was conducted, which provided a framework for considering tradeoffs and revealed the best course of action. Sensitivity analysis was also performed to determine the sensitivity of the parameters and determine what would be the best alternative under different scenarios.

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1. INTRODUCTION

1.1 Background

A medical decision is an important decision that usually involves making a diagnosis and selecting an appropriate treatment for an illness. However, due to the direct involvement of humans, time constraint, catastrophic consequences and high uncertainty, the decision becomes very difficult. In addition, multiple alternatives and conflicting objectives that cannot be converted to a common metric make choosing the optimal course of action even harder for the decision maker.

1.2 Motivation

The decision maker considered in this analysis is the physician, who will be making a diagnosis that is not immediately clear and prescribing a treatment. This decision is currently being made poorly because is not systematic. The physician makes a decision after looking at evidence, relying on intuition and inappropriately considering the different tradeoffs. Research has shown that experts in decisions involving high stakes and pressure rely on intuition, following a recognition primed decision approach by matching the situation with experience to arrive at a course of action without weighing alternatives. Thus, the doctor is prone to decision biases such as anchoring, availability and representativeness. Medical surveys have revealed that misdiagnosis can be as high as 25%. Poor prognosis is common and high uncertainty in both the diagnosis and outcome of the treatment make the decision very complex.

Due to the uncertainty and tradeoff nature of the problem, a structured and formal approach is recommended to address the doctor's decision of prescribing the medical treatment. The suggested approach is to utilize multiattribute utility analysis (MAUA).

2. FORMULATION

A structured approach to address the decision problem involved a formulation phase, followed by an evaluation phase, and concluded with an appraisal phase. The flow chart of the decision analysis is show below in Figure 1.

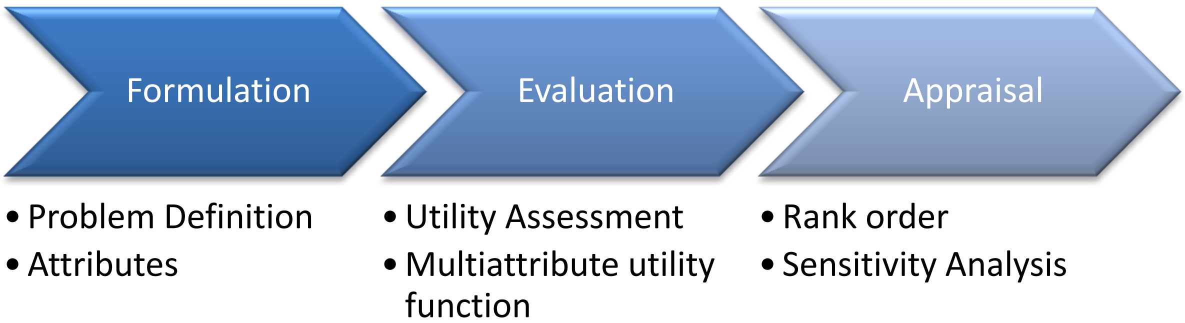


Figure 1. Decision analysis flow chart

2.1 Alternatives

The decision maker was a medical student acting as a doctor. After the initial meeting, he selected a decision problem form a clinical research case he was familiar with and had seen in his studies. The problem consisted in selecting a treatment for a patient that has been seriously injured in the leg and was shown high evidence of infection. The possible courses of action that were considered are described below in Figure 2. The option of conducting a test is not shown.

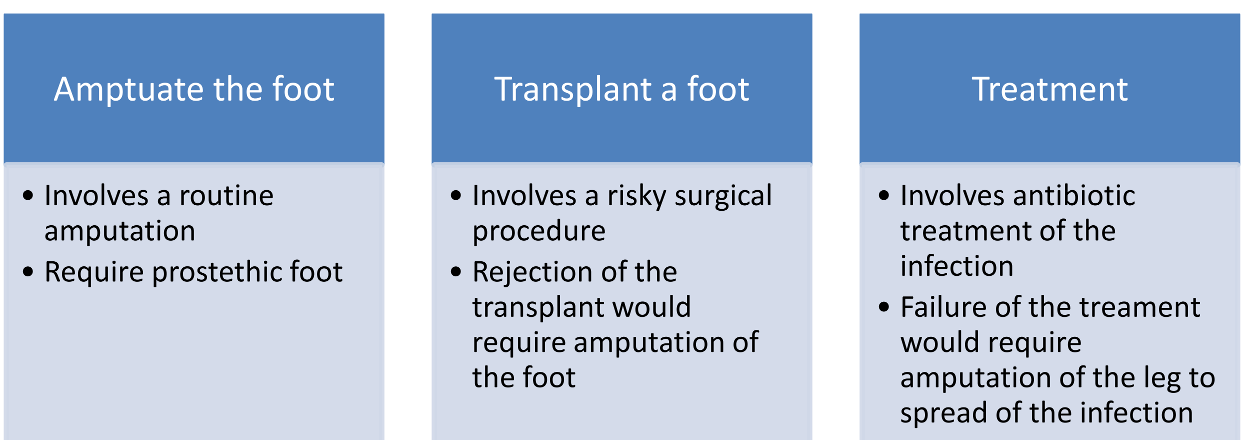


Figure 2. Alternatives

2.2 Attributes

The objective was to maximize total utility. However, there are unavoidable constraints and cause-effects relationships among the alternatives. After conducting a brainstorming session with the decision maker, the most important categories, or attributes, that the physician cared and was willing to make trade-offs were determined. The attributes are summarized in the objective hierarchy shown in Figure 3.

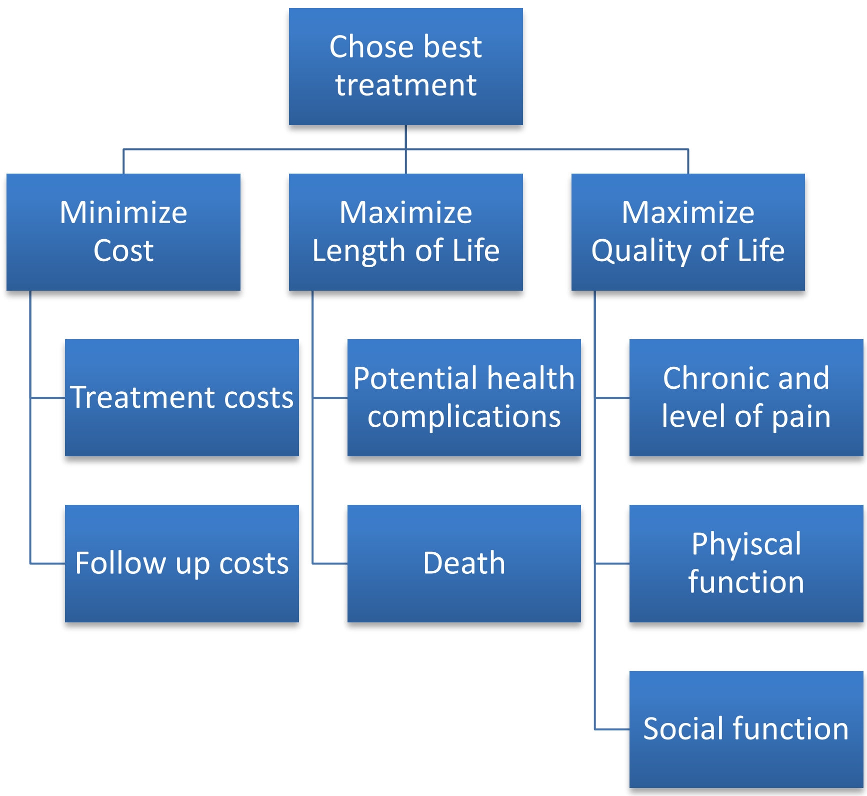


Figure 3. Objective Hierarchy

Cost refers to the total cost of the chosen alternative, which includes treatment cost and follow-up costs, such as doctor visits and drugs. Length of life refers to the percentage of the life expectancy at full health, while quality of life refers to the patient's general well-being. It is important to make a distinction between length of life and quality of life because the health state clearly is more than just being alive. For example, 1 years of life pain free might be preferred over 2 years of life with pain and chronic visits to the doctor. The attribute ranges are summarized in Table 1.

Table 1. Attribute Ranges

Attributes	Worst	Best
$x_1 =$ **Cost ($)**	-500	-100
$x_2 =$ **Length of Life (0%=Death, 100% = Full)**	0	1
$x_3 =$ **Quality of Life (0 = worst, 10 = best)**	0	10

2.3 Decision Diagram

As discussed above, the problem involves risk and uncertain events. For example, transplantation surgery can result in death, rejection of the transplanted foot or successful transplant. Similarly, the treatment can result in death, failure of the treatment of successful effect of the treatment. Further testing also involves uncertainties due to the imperfect nature of the source of information. A decision diagram (Figure 4**Error! Reference source not found.**) was constructed to capture the important decisions, uncertainties and values, which are represented at the distinction level, that were characterized in the previous sections.

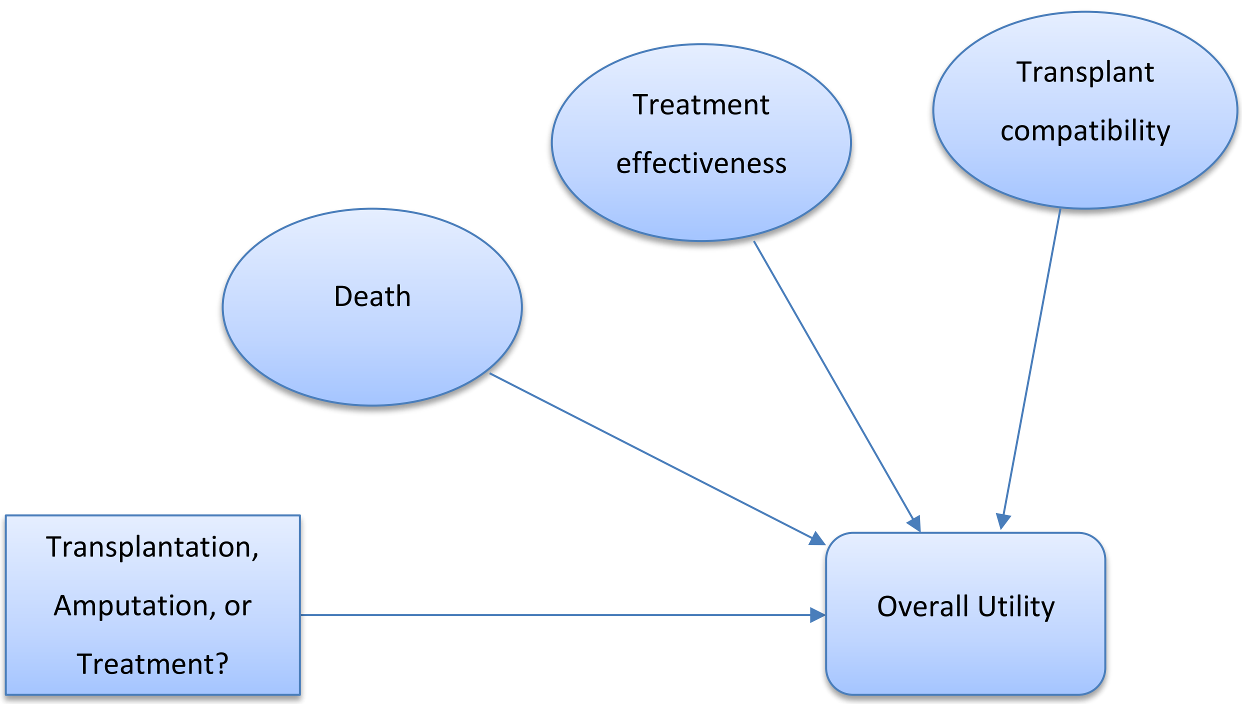


Figure 4. Decision Diagram

3. EVALUATION

3.1 Preferential Independence

After the formulation of the decision problem, a utility function assessment survey was developed and then the assessment was performed on the decision maker. The first step was to test preferential independence. A sample test is shown below.

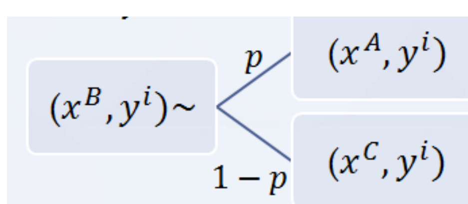
$$\left(x_1{}^A, x_2{}^i\right) > \left(x_1{}^B, x_2{}^i\right)$$

$$\left(x_1{}^i, x_2{}^A\right) > \left(x_1{}^i, x_2{}^B\right)$$

The first test asked the decision maker if he preferred attribute x_1 at level A over level B, regardless of the level of x_2. Then the second test asked the reverse for the preference in attribute x_2. Since both tests were true, these two attributes were mutually preferentially independent. The test was repeated for all two-pair attributes and also three attributes at the same time. The results indicated that preferential independence holds.

3.2 Utility Independence

Utility independence was tested by verifying that the decision maker's risk attitude in one attribute did not depend on the levels of the other attributes. This was tested by asking the decision maker the certain equivalent x_b that will make him indifferent with the lottery shown below (p was given):



The decision maker stated that the certain equivalent did not change over different levels of the other attribute (and combinations of the other two attributes). The test results were the same for the reverse and the other two attributes, indicating that mutual utility independence holds for the given attribute ranges. It is important to note that the assessment was done from the perspective of the doctor. The results of the lotteries are shown below in Figure 5.

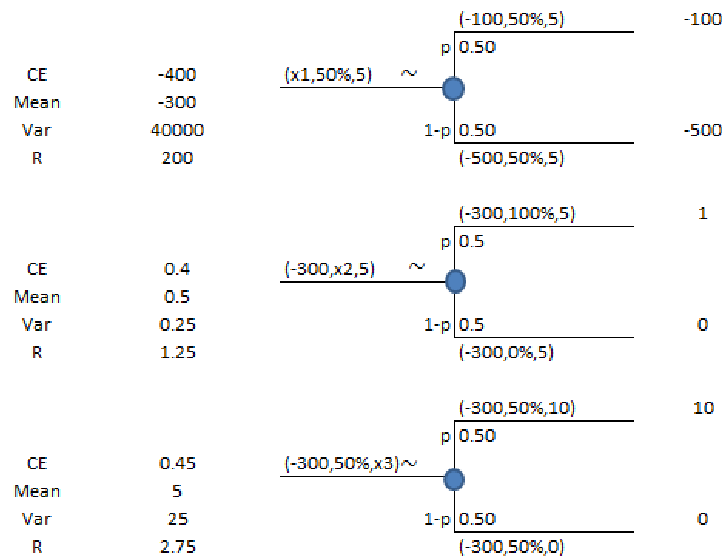


Figure 5. Utility independence assessment

3.3 Single attribute functions

An exponential form was chosen for the utility function due to its wide applicability, mathematical properties and easiness in assessing the risk tolerance (R). In order to avoid cognitive overload, the lottery assessments shown above were used to approximate the risk tolerance by using the following equation (Pratt 1964):

$$CE \approx \mu - \frac{0.5\sigma^2}{R}$$

The calculations of the risk tolerance coefficient (R) are shown above in Figure 5 next to the lottery assessments. The constants a and b were then determined by solving the following system of equations that scale the utility to range from 0 to 1:

$$U(x^-) = a + be^{-x/R} = 0$$

$$U(x^+) = a + be^{-x/R} = 1$$

The parameters that completely define the single attribute utility functions and the utility unction plots are shown below in Table 2 and Figure 6 respectively. The higher concavity of the plot for the quality of life attribute shows that the decision makers is more risk averse when it comes to this attribute.

Table 2. Single attribute utility function parameters

Single Attribute Utility	Risk Tolerance	a	b
Cost	200	1.157	-0.095
Length of Life	1.25	1.816	-1.816
Quality of Life	2.75	1.027	-1.027

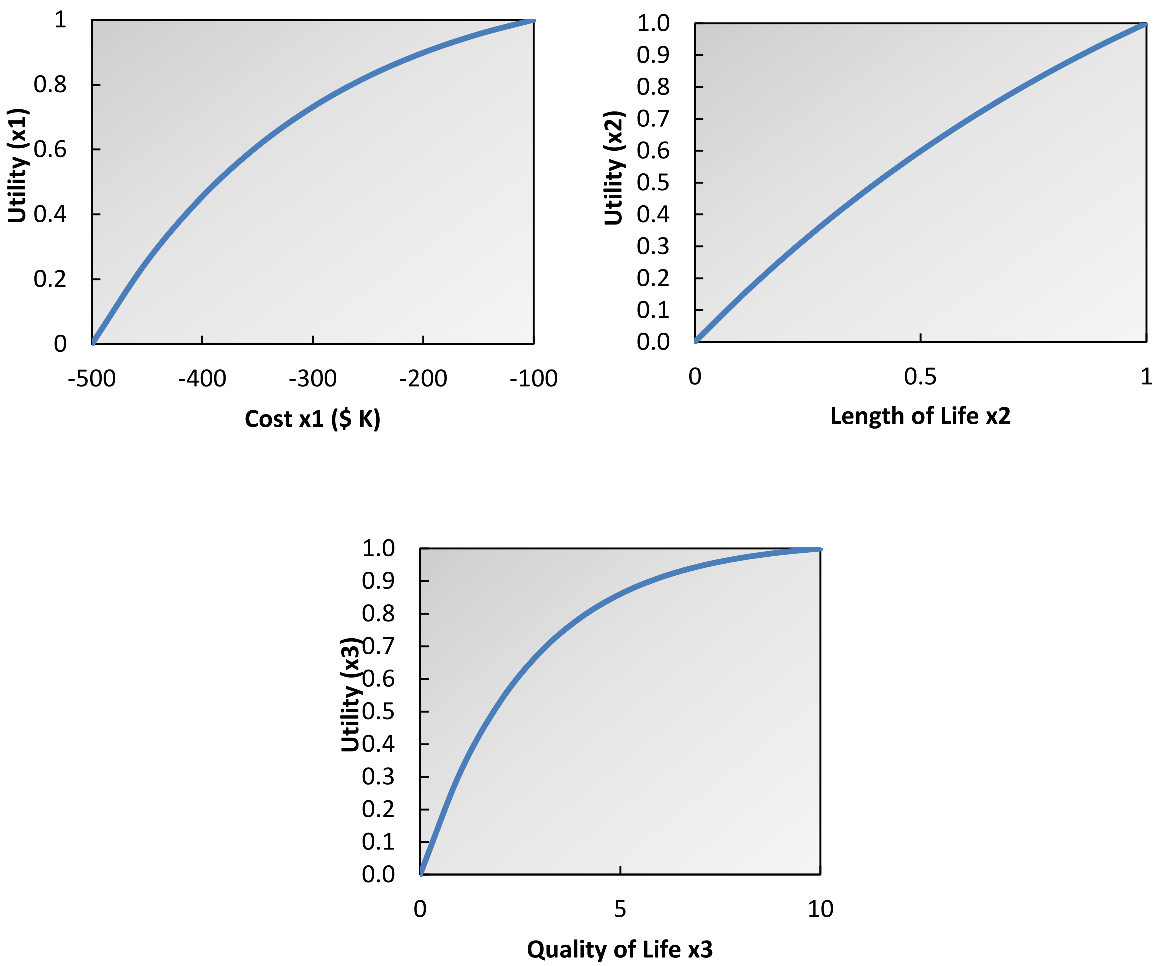
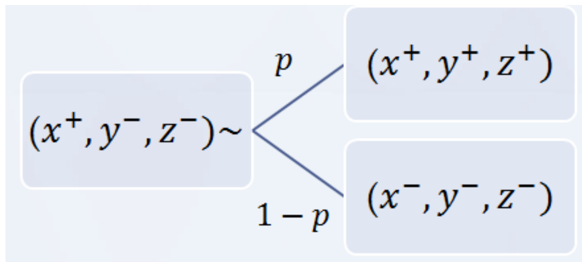


Figure 6. Singe attribute utility function plots

3.4 Scaling Constants

The scaling constants, which represent the willingness to make trade-offs over the different attributes were computed by asking the decision maker to state the probability p (or equivalently the odds ratio) that will make him indifferent between the certain equivalent and the lottery. The graphical illustration and results of the assessments are shown in Figure 7.



Scaling constant	odds ratio
k1 0.17	0.2
k2 0.67	2
k3 0.83	5

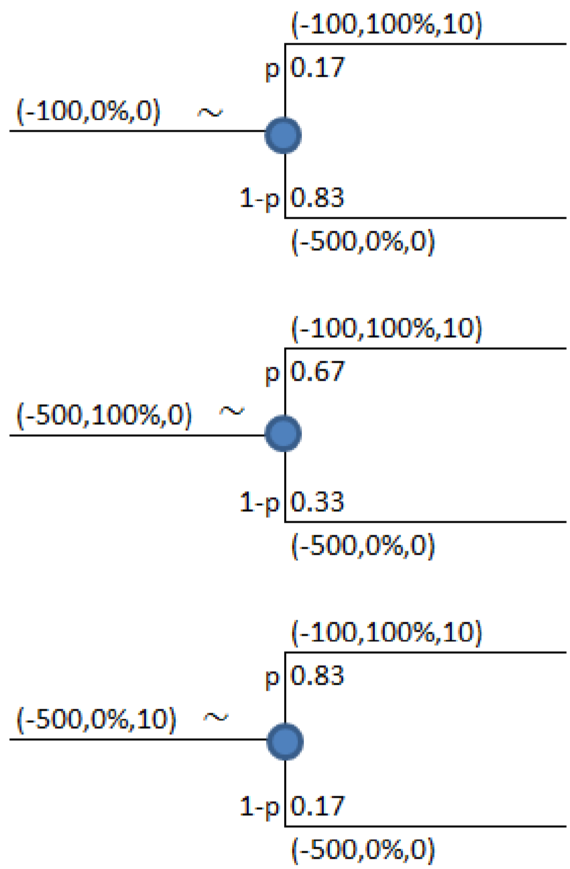


Figure 7. Scaling constants assessment

3.5 Multiattribute Utility Function

Because preferential independence and utility independence hold, then a multiplicative attribute function can be used. The general form of the utility function is:

$$\mathrm{U(x)} = \frac{1}{K}\left[\left[\prod_{i=1}^{n}[Kk_i U_i(x_i)+1]\right]-1\right]$$

where:

$U(\boldsymbol{x})$ = multiattribute utility characterized by attribute vector $\boldsymbol{x}$ = (x_1, ..., x_n), scaled from 0-1

x_i = performance level of attribute i

$U_i(x_i)$ = single attribute utility function for attribute i, scaled from 0-1

i = 1, 2, ..., n attributes
k_i = single attribute scaling constant
K = normalizing constant so that U(x) scales 0-1

The normalizing constant was found by finding a nonzero solution to the following equation:

$$1+K = \left[\left[\prod_{i=1}^{n}[Kk_i+1]\right]\right]$$

The parameters that completely define the multiattribute utility function are summarized below in Table 3.

Table 3. Scaling and normalizing constants

Multiattribute Utility	
Scaling Constants (k)	
Cost	0.17
Length of Life	0.67
Quality of Life	0.83
Normalizing Constant (K)	-0.926
	-7.774

For graphical representation purposes, the attribute cost was set to its mean value because it seems to be the one that decision maker is least concerned with. The plot of the multiattribute function and corresponding contour plot over the range of the other two attributes are shown below in Figure 8.

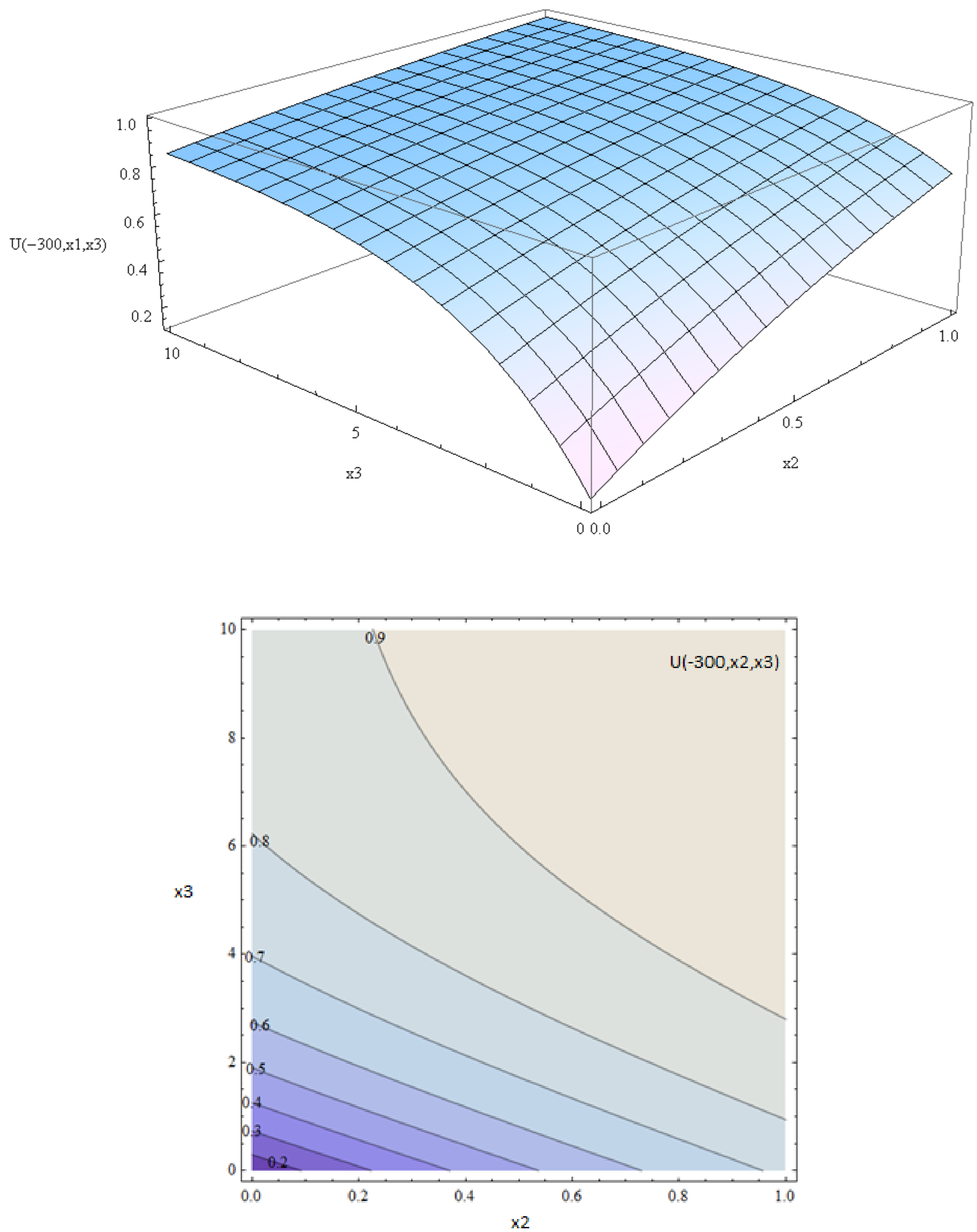


Figure 8. Multiattribute function plot for x1=-300

The contour plot above shows the indifferent curves for the length of life and quality of life attributes. It can be seen that there is clearly a tradeoff by the curvature of the indifferent curves (e.g. change in one attribute requires a large change in the other one to have the same utility). On the other hand, the contour plots for the cost attribute and the other two attributes (Figure 9) does not show the same kind of trade-off (e.g. large cost changes only require small changes in the other attribute to have the same utility). In other words, the decision maker is more willing to trade the attribute cost for the other attributes.

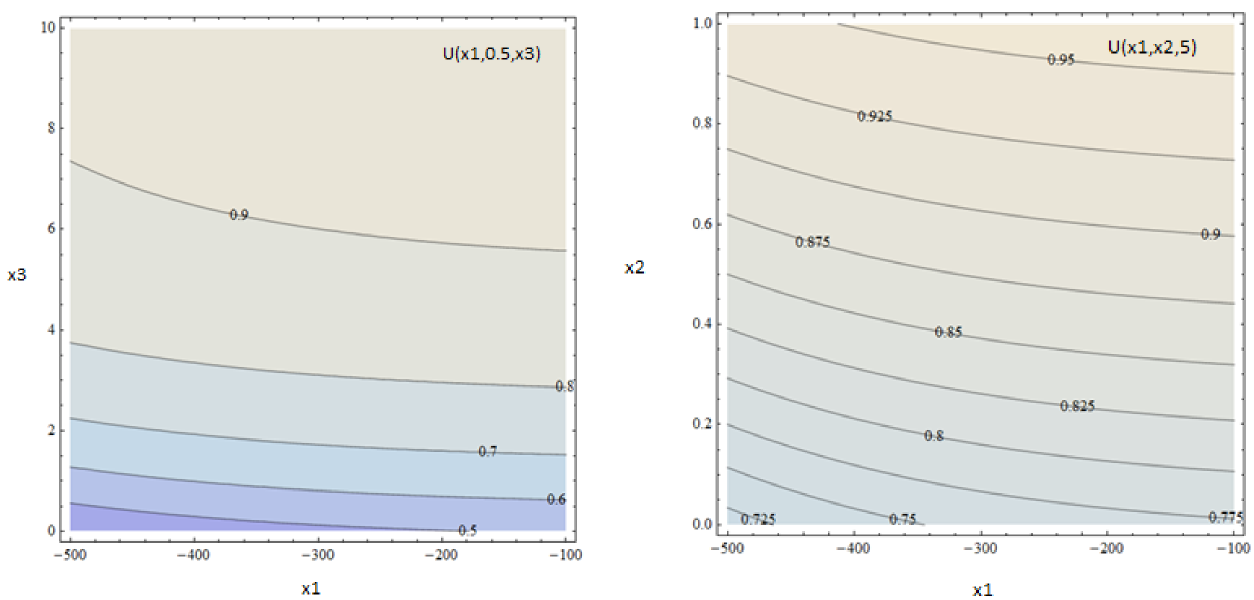


Figure 9. Contour plots for x2=0.5 and x3=5

4. APPRAISAL

4.1 Alternative systems

In order to apply the conduct the analysis, alternative systems were developed, and attribute levels and associated uncertainty for each alternative was estimated. The estimates are based on the medical literature, clinical case studied and assessment by the decision maker and. The probability assessment, cost estimates and attribute levels determination are summarized below in Table 4, Table 5 and Table 6 respectively.

Table 4. Probability Assessment

Uncertainty	Probability
P(Surgery Death)	0.02
P(Transplantation Rejection)	0.3
P(Treatment Success)	0.6
P(Death| Treatment Failure)	0.125
P("Transp Reject" | Transp Reject)	0.85
P("Transp Success" | Transp Success)	0.95

Table 5. Cost Estimates

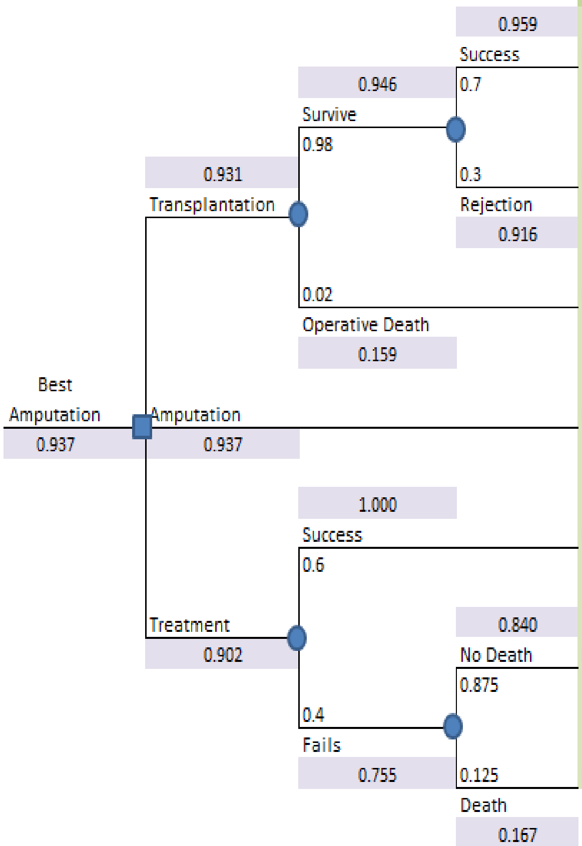
Costs ($ thousands)	Operation	Followup	Total
Transplant	-150	-350	-500
Amputation	-100	-300	-400
Treatment	-100	0	-100

Table 6. Attribute levels

Alternatives	Outcome	Cost	Length of life	Quality of Life
Transplantation	Foot transplant	-500	0.80	9
	Foot amputated	-450	0.80	5
	Death	-150	0.00	0
Amputation	Foot amputated	-400	0.90	5
Treatment	Foot saved	-100	1.00	10
	Leg amputated	-500	0.80	3
	Death	-100	0.00	0

4.2 Rank order of alternatives

The decision tree shown below in Figure 10 was solved using the multiattribute utility function assessed and rolling back the tree. The tree shows the outcomes and associated probably, attribute levels, single attribute values and multiattribute values for each outcome.



Outcome	Prob	x1	x2	x3	U(x1)	U(x2)	U(x3)	U(x1,x2,x3)
Foot transplant	0.686	-500	0.80	9	0.000	0.858	0.988	0.959
Foot amputated	0.294	-450	0.80	5	0.256	0.858	0.861	0.916
Death	0.02	-150	0.00	0	0.956	0.000	0.000	0.159
Foot amputated	1	-400	0.90	5	0.455	0.932	0.861	0.937
Foot saved	0.6	-100	1.00	10	1.000	1.000	1.000	1.000
Let amputated	0.35	-500	0.80	3	0.000	0.858	0.682	0.840
Death	0.05	-100	0.00	0	1.000	0.000	0.000	0.167

Figure 10. Decision tree

The results indicate that the best alternative is amputation, followed by transplantation, and treatment being the worse. Looking at the values, the preferences and willingness to make tradeoffs can be readily seen. For example, for the outcome foot transplant, the utility of cost is zero, but the overall utility is higher due to the very low scaling constant for the cost attribute. This also seen in the outcomes involving death, which have a very high utility in the cost but very low overall utility due the zero single attribute utilities of length of life and quality of life. These clearly illustrate that the decision maker is more willing to make trade the cost attribute.

4.3 Imperfect source of information

The possibility of purchasing (or waiting for) imperfect or sample information was also studied. In this analysis, the opportunity to test the success of the treatment before making the decision was considered. Given the prior probabilities (success or failure of the surgery) and probabilities of the test results in the assessed form (tests results given the surgery is a success/failure), the inferential or posterior probabilities (surgery success/failure given the test results) were computed by reversing the tree show below in Figure 11 .

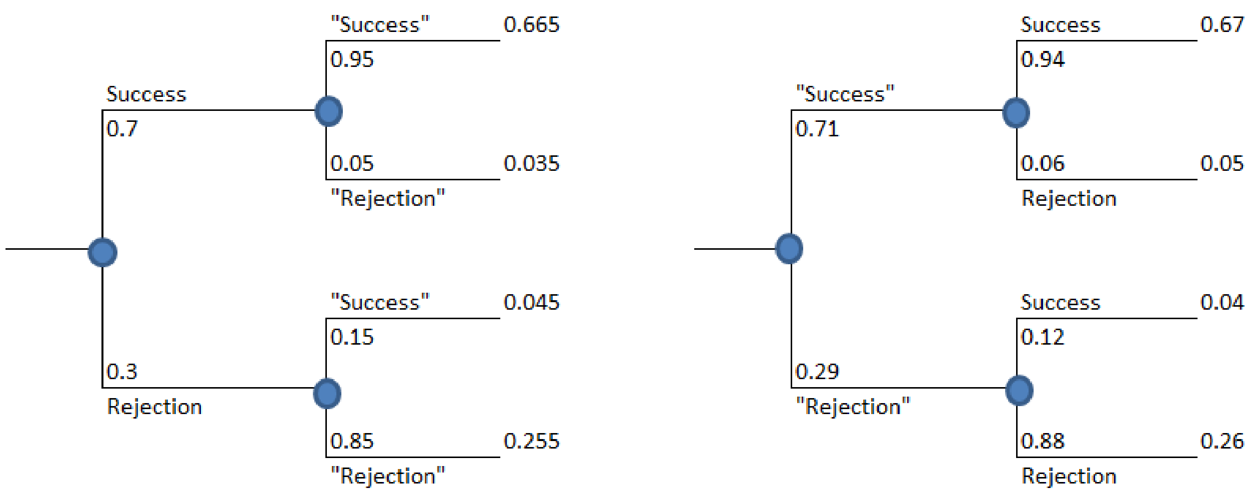


Figure 11. Probabilities of imperfect source of information

The computed probabilities were used and the decision tree was solved by adding the alternative of testing before making a treatment decision. The full tree along with the details of the calculation can be found in Appendix A. The solved decision tree is shown below in Figure 12 and indicates that the best decision is to test the compatibility of the transplantation (e.g. surgery success or failure). If the test indicates success, the best alternative is to transplant; otherwise the alternative amputation remains as the best course of action.

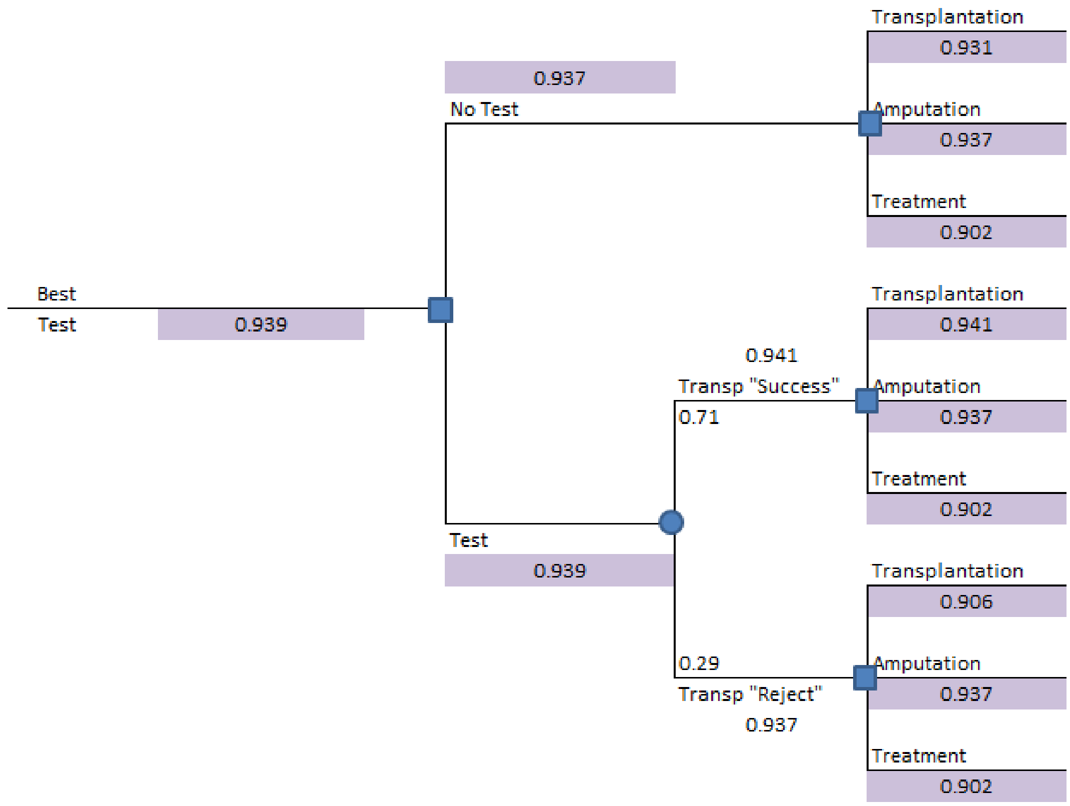


Figure 12. Decision tree with testing option

4.4 Sensitivity Analysis

A sensitivity analysis on the scaling constants was conducted to gain insights on the best alternative and the tradeoffs among the attributes. The sensitivity plots for the scaling constants are shown below in Figure 13 and indicate that the optimal choice is insensitive to the scaling constant of the cost attribute. On the other hand, the best alternative changes given the changes in the other scaling constants, suggesting that cost is not a very important concern for the decision maker and willing to trade it more for the other attributes. From the plots it can be seen that for both cases in which either the scaling constant of length of life or quality of life are changed (while keeping the rest constant), there is at least a region in which one of the three alternatives is the best. For example, when the scaling constant of quality of life is very high, then the best decision is to do the transplantation, which makes sense since the transplant has a much higher quality of life than the outcomes with foot amputation.

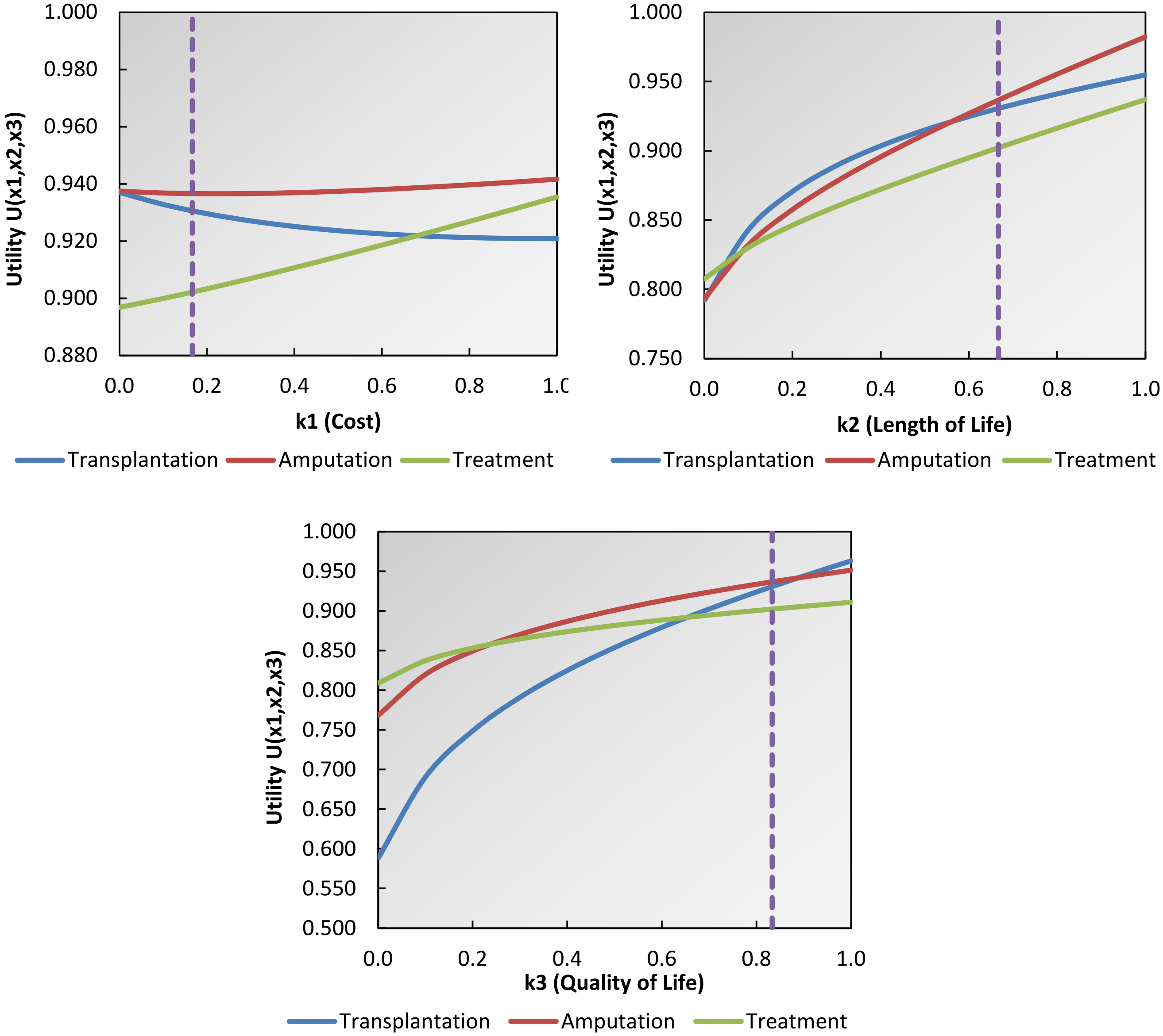


Figure 13. Sensitivity plots for scaling constants

Sensitivity plots were also conducted for the different probabilities assessments of the uncertainties. For example, Figure 14 shows that the best decision is insensitive to the probability of death for the treatment, but the best decision changes to transplantation when the probability of death due to surgery drop bellows 0.012. Similarly, transplantation becomes the best alternative when the probability of rejection drops below 0.16, and treatment becomes the best choice when the probability of treatment success exceeds 0.75 (Figure 15).

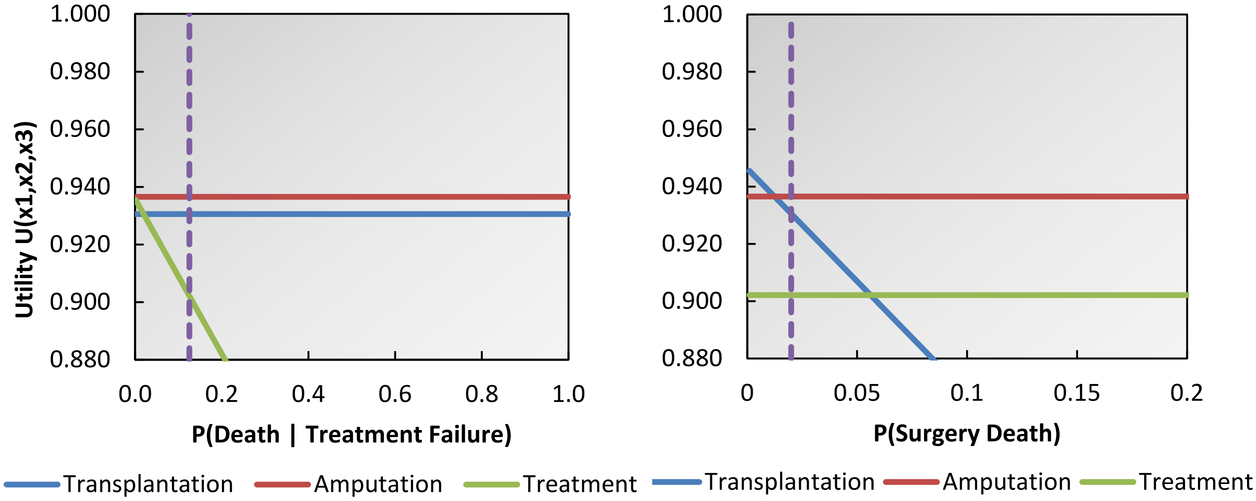


Figure 14. Sensitivity of death for treatment and surgery

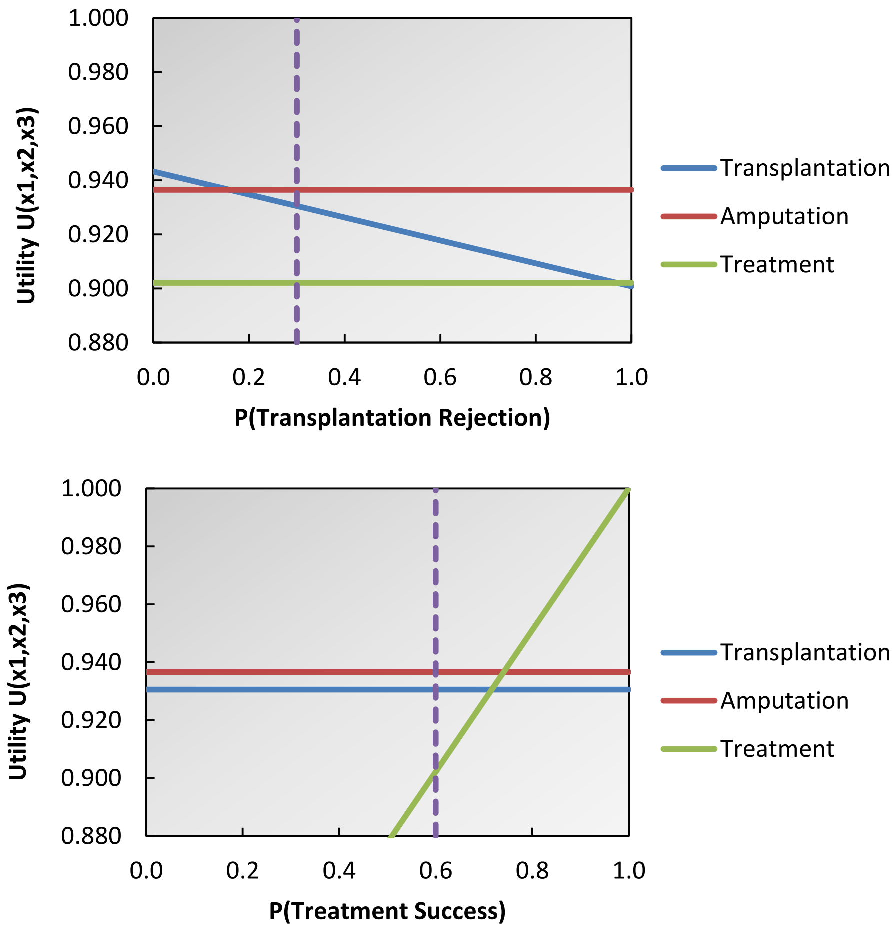


Figure 15. Sensitivity to probabilities of transplantation rejection and treatment success

A sensitivity analysis was also conducted on the input parameters of the models. For example, Figure 16 shows that the best decision is sensitive to the transplant and amputation cost, but not to the treatment cost.

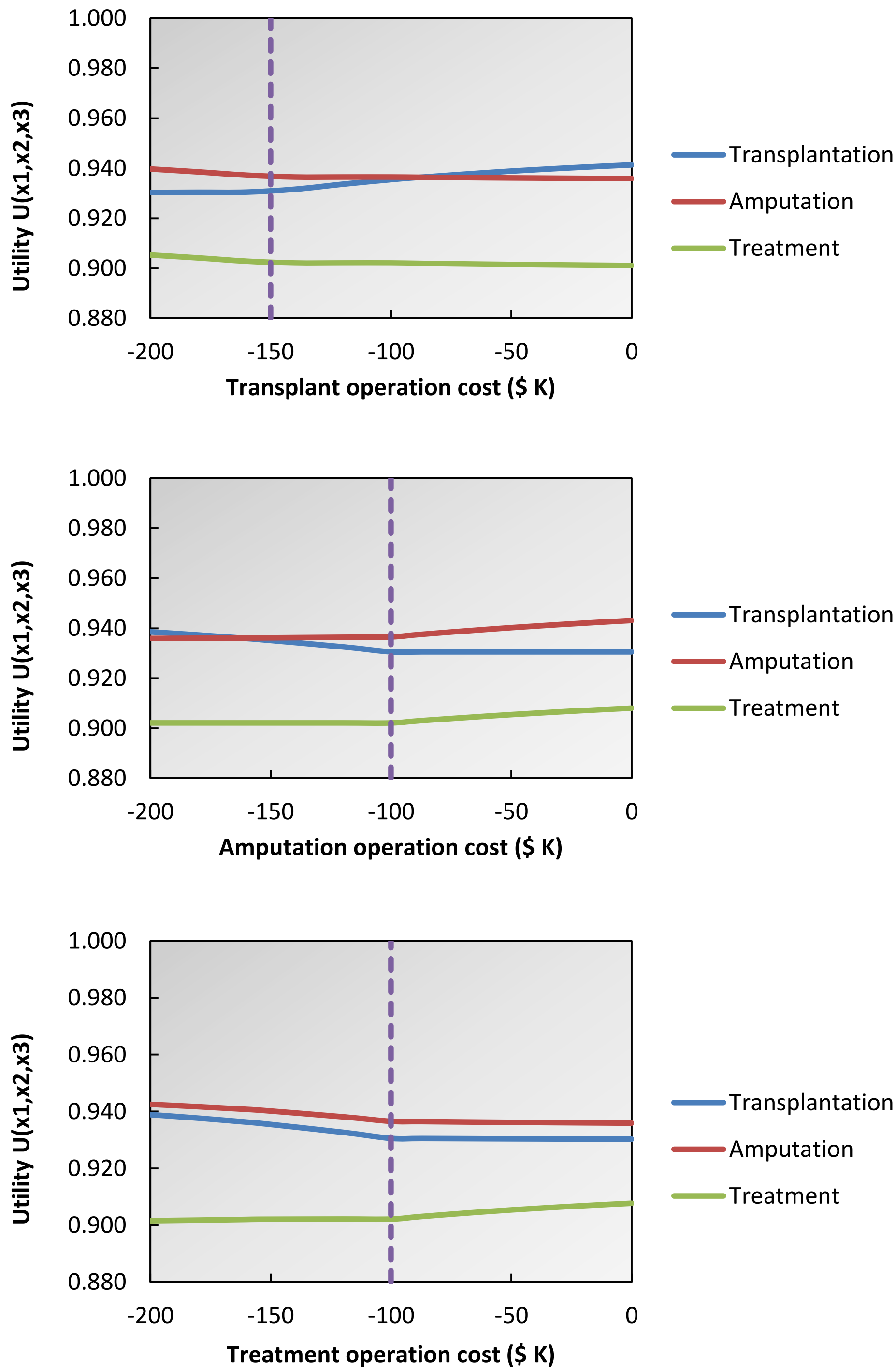


Figure 16. Sensitivity to cost parameters

A sensitivity analysis (Figure 17) was also conducted on the quality of life level of the leg amputated outcome since it seemed to affect the decision to its low value. Improvement of this attribute to a level above 7 changes the best decision to treatment.

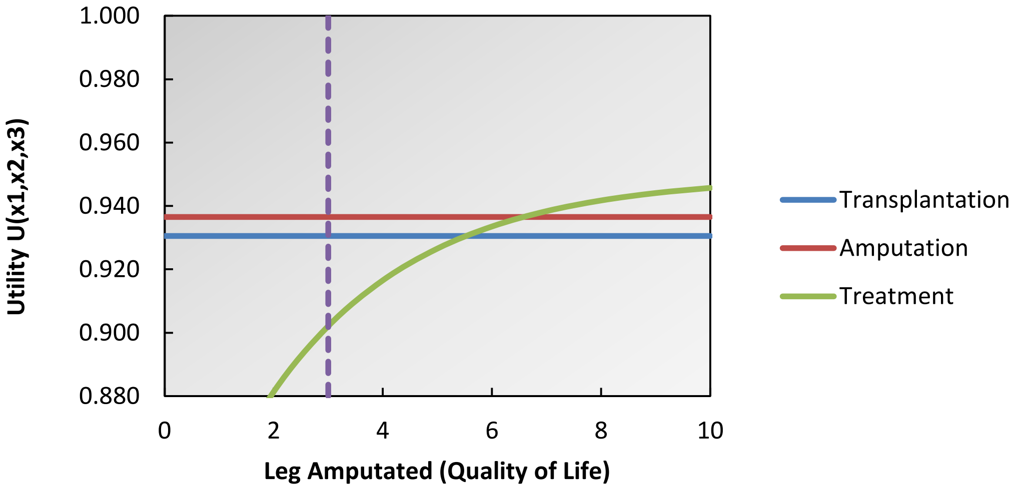
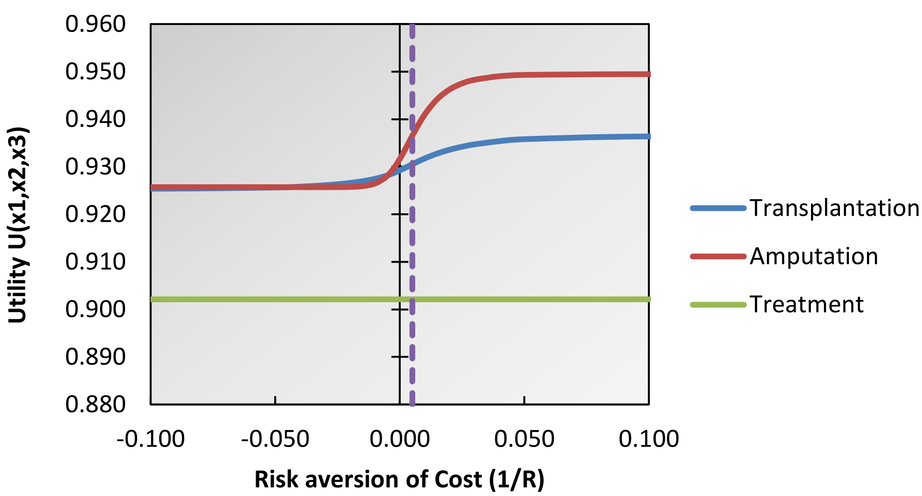


Figure 17. Sensitivity to quality of life of leg amputated

Finally, a sensitivity analysis was conducted on the risk tolerance (risk aversion is the inverse) assessed from the decision maker. The results (Figure 18) show that the optimal decision is insensitive to the risk tolerance of cost, with the exception of a small region. On the other hand, when the risk attitude changes in the other two attributes, the best decision also changes. It can be noted also that when the decision becomes risk averse on the quality of life attribute, the best decision is to undergo treatment.



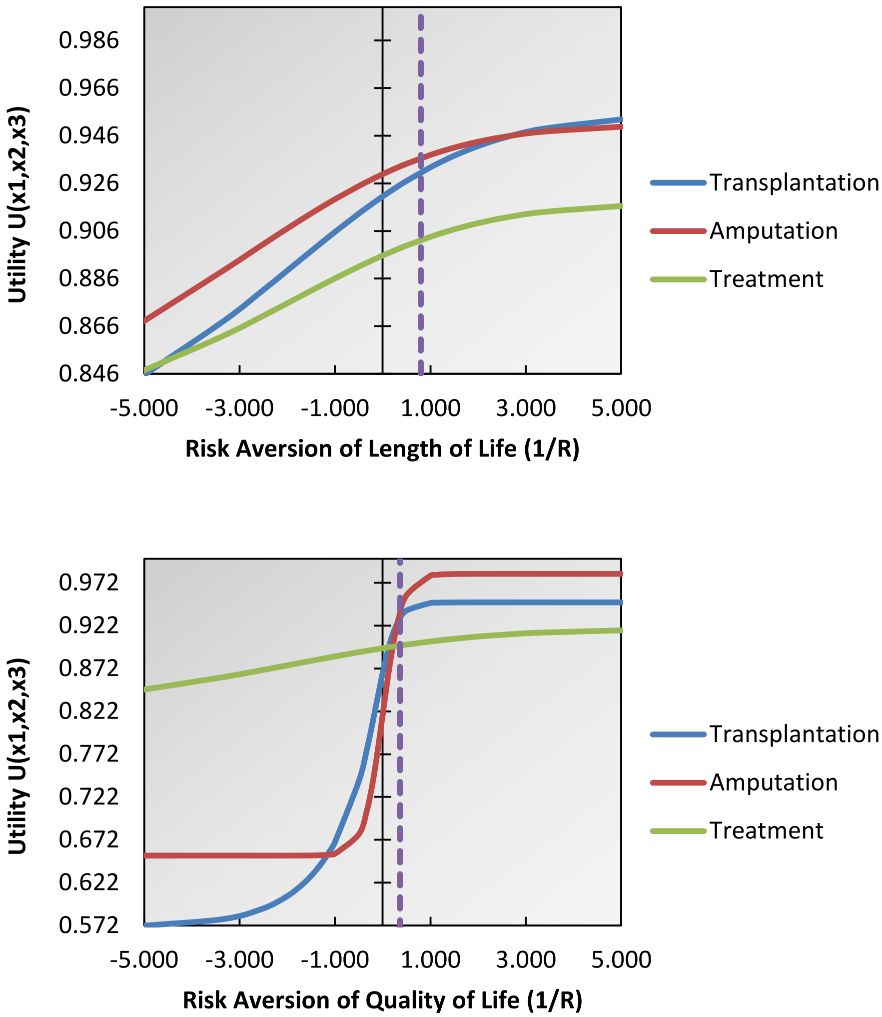


Figure 18. Sensitivity to risk tolerance/risk aversion coefficient

The results of the sensitivity analysis are summarized in Table 7. See Appendix B for details.

Table 7. Sensitivity analysis summary

Parameter	Original	If change...	To...	Best
P(Surgery Death)	0.02	-40.00%	0.012	Transplantation
P(Transplantation Rejection)	0.3	-46.67%	0.16	Transplantation
P(Treatment Success)	0.6	25.00%	0.75	Treatment
P(Death| Treatment Failure)	0.125	NA	NA	Amputation
Transplantation Operation Cost ($K)	-150	-42.00%	-87	Transplantation
Amputation Operation Cost ($K)	-100	55.00%	-155	Transplantation
Treatment Costs ($K)	-100	NA	NA	Amputation
Quality of Life of Leg Amputated	3	133.33%	7	Treatment

5. CONCLUSIONS

5.1 Summary

The multiattribute utility analyses provided a framework for considering tradeoffs and indicated that the best course of action is to amputate. However, sensitivity analysis should be used to determine the accuracy of the parameters and determine what would be the best alternative under different scenarios.

5.2 Limitations

One limitation of the study is that it does not take into account important patient information, such as age, sex and previous medical history. Determining the decision makers is also important. If the patient is the decision maker, this analysis would not be as useful because the attribute cost would be very irrelevant due to the outcome of death. From the health care policy maker's perspective, allocation of resources and money becomes a relevant issue. For example, at the end of life, it might not be optimal to spend a lot of money at the end of life.

5.3 Future Work

Future work might involve addressing the limitations pointed out. For example, doing a more thorough review of the medical literature to obtain the attribute levels and probabilities associated with each alternative. A different decision maker can also be chosen and test the robustness of the model. It would be also interesting to compare the results from the doctor perspective with that of the patient.

5.4 Challenges

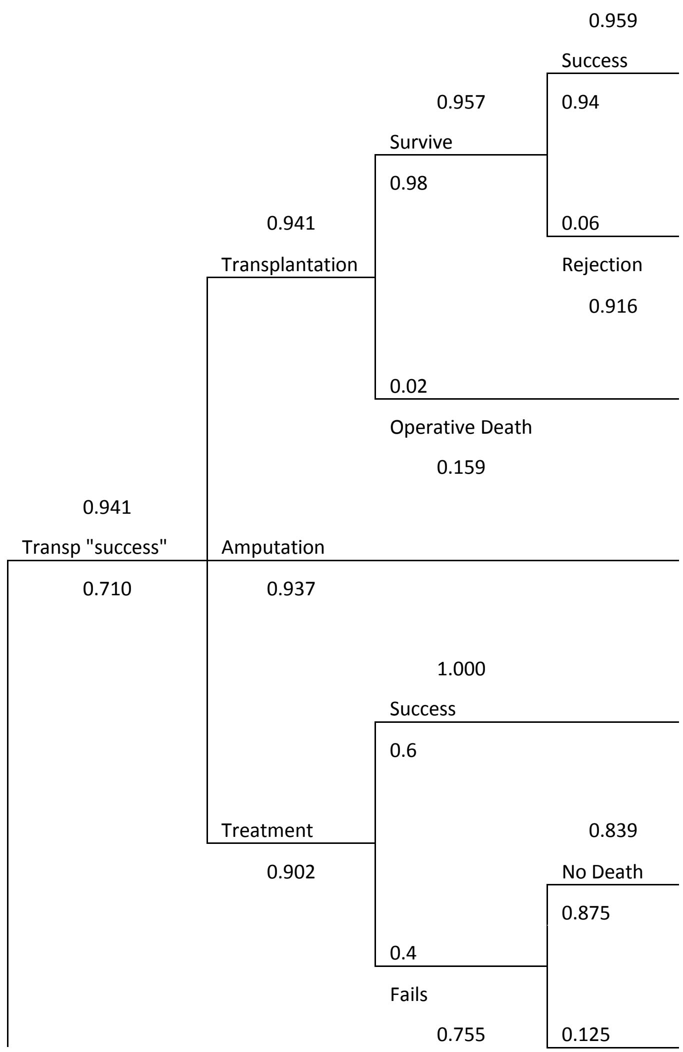
The main challenge of this report was the utility assessment. A clear communication with the decision maker was critical to avoid inconsistencies. In additions, simplifications and approximations were made to reduce the cognitive overload. For example, "common" probabilities (e.g. 0.5, 0.75) or odds ratios were used, assumptions of the utility function were made, and approximations of the parameters were taken.

REFERENCES

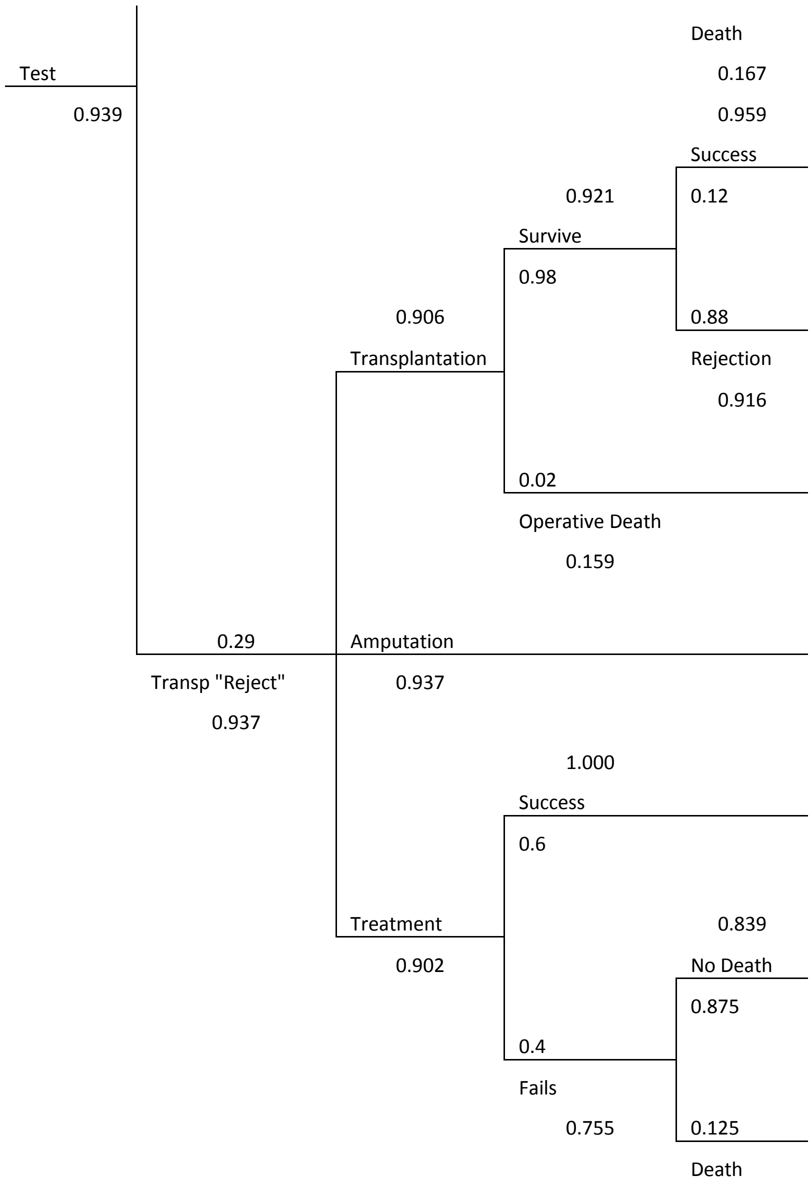
Clemen, R. T., (1991). *Making Hard Decisions*: An Introduction to Decision Analysis, Boston, MA: PWS-Kent

APPENDIX

A. Imperfect Information Tree



	prob	X1	X2	X3	U(x1)	U(x2)	U(x3)	U(X)
Foot transplant	0.91789	-500	0.80	9	0.000	0.858	0.988	0.959
Foot amputated	0.06211	-450	0.80	5	0.256	0.858	0.860	0.916
Death	0.02	-150	0.00	0	0.956	0.000	0.000	0.159
Foot amputated	1	-400	0.90	5	0.455	0.932	0.860	0.937
Foot saved	0.6	-100	1.00	10	1.000	1.000	1.000	1.000
Let amputated	0.35	-500	0.80	3	0.000	0.858	0.682	0.839
Death	0.05	-100	0.00	0	1.000	0.000	0.000	0.167



Foot transplant	0.11828	-500	0.80	9	0.000	0.858	0.988	0.959
Foot amputated	0.86172	-450	0.80	5	0.256	0.858	0.860	0.916
Death	0.02	-150	0.00	0	0.956	0.000	0.000	0.159
Foot amputated	1	-400	0.90	5	0.455	0.932	0.860	0.937
Foot saved	0.6	-100	1.00	10	1.000	1.000	1.000	1.000
Let amputated	0.35	-500	0.80	3	0.000	0.858	0.682	0.839
Death	0.05	-100	0.00	0	1.000	0.000	0.000	0.167

B. Sensitivity Calculations

k1	Transplantation	Amputation	Treatment	Best
	0.931	0.937	0.902	
0.0	0.937	0.937	0.897	Amputation
0.1	0.933	0.937	0.900	Amputation
0.2	0.930	0.936	0.903	Amputation
0.3	0.927	0.937	0.907	Amputation
0.4	0.925	0.937	0.911	Amputation
0.5	0.924	0.937	0.915	Amputation
0.6	0.922	0.938	0.919	Amputation
0.7	0.922	0.939	0.923	Amputation
0.8	0.921	0.940	0.927	Amputation
0.9	0.921	0.941	0.931	Amputation
1	0.921	0.942	0.935	Amputation

Indifferent Points	Change From	To as Parameter Increases

k2	Transplantation	Amputation	Treatment	Best
	0.931	0.937	0.902	
0.0	0.792	0.793	0.808	Treatment
0.1	0.843	0.832	0.830	Transplantation
0.2	0.870	0.857	0.846	Transplantation
0.3	0.889	0.878	0.860	Transplantation
0.4	0.903	0.895	0.872	Transplantation
0.5	0.915	0.912	0.884	Transplantation
0.6	0.925	0.927	0.895	Amputation
0.7	0.933	0.941	0.906	Amputation
0.8	0.941	0.955	0.916	Amputation
0.9	0.948	0.969	0.927	Amputation
1	0.955	0.982	0.937	Amputation

Indifferent Points	Change From	To as Parameter Increases
0.04	Treatment	Transplantation
0.57	Transplantation	Amputation

k3	Transplantation	Amputation	Treatment	Best
	0.931	0.937	0.902	
0.0	0.589	0.769	0.809	Treatment
0.1	0.690	0.820	0.837	Treatment
0.2	0.749	0.849	0.853	Treatment
0.3	0.791	0.870	0.865	Amputation
0.4	0.825	0.887	0.874	Amputation
0.5	0.854	0.901	0.882	Amputation
0.6	0.879	0.913	0.888	Amputation
0.7	0.902	0.924	0.895	Amputation
0.8	0.924	0.933	0.900	Amputation
0.9	0.944	0.943	0.906	Transplantation
1	0.963	0.951	0.911	Transplantation

Indifferent Points	Change From	To as Parameter Increases
0.24	Treatment	Amputation
0.89	Amputation	Transplantation

P(Treatment Success)	Transplantation	Amputation	Treatment	Best
	0.931	0.937	0.902	
0.0	0.931	0.937	0.756	Amputation
0.1	0.931	0.937	0.780	Amputation
0.2	0.931	0.937	0.804	Amputation
0.3	0.931	0.937	0.829	Amputation
0.4	0.931	0.937	0.853	Amputation
0.5	0.931	0.937	0.878	Amputation
0.6	0.931	0.937	0.902	Amputation
0.7	0.931	0.937	0.927	Amputation
0.8	0.931	0.937	0.951	Treatment
0.9	0.931	0.937	0.976	Treatment
1	0.931	0.937	1.000	Treatment

Indifferent Points	Change From	To as Parameter Increases
0.75	Amputation	Treatment

P(Surgery Death)	Transplantation	Amputation	Treatment	Best
	0.931	0.937	0.902	
0.0	0.945	0.937	0.902	Transplantation
0.012	0.937	0.937	0.902	Transplantation
0.2	0.789	0.937	0.902	Amputation
0.3	0.710	0.937	0.902	Amputation
0.4	0.631	0.937	0.902	Amputation
0.5	0.553	0.937	0.902	Amputation
0.6	0.474	0.937	0.902	Amputation
0.7	0.395	0.937	0.902	Amputation
0.8	0.317	0.937	0.902	Amputation
0.9	0.238	0.937	0.902	Amputation
1	0.159	0.937	0.902	Amputation

Indifferent Points	Change From	To as Parameter Increases
0.012	Transplantation	Amputation

P(Transplantation Rejection)	Transplantation	Amputation	Treatment	Best
	0.931	0.937	0.902	
0.0	0.943	0.937	0.902	Transplantation
0.1	0.939	0.937	0.902	Transplantation
0.16	0.936	0.937	0.902	Amputation
0.3	0.931	0.937	0.902	Amputation
0.4	0.926	0.937	0.902	Amputation
0.5	0.922	0.937	0.902	Amputation
0.6	0.918	0.937	0.902	Amputation
0.7	0.914	0.937	0.902	Amputation
0.8	0.909	0.937	0.902	Amputation
0.9	0.905	0.937	0.902	Amputation
1	0.901	0.937	0.902	Amputation

Indifferent Points	Change From	To as Parameter Increases
0.16	Transplantation	Amputation

P(Death| Treatment Failure)	Transplantation	Amputation	Treatment	Best
	0.931	0.937	0.902	
0.0	0.931	0.937	0.935	Amputation
0.1	0.931	0.937	0.909	Amputation
0.16	0.931	0.937	0.893	Amputation
0.3	0.931	0.937	0.855	Amputation
0.4	0.931	0.937	0.828	Amputation
0.5	0.931	0.937	0.801	Amputation
0.6	0.931	0.937	0.774	Amputation
0.7	0.931	0.937	0.747	Amputation
0.8	0.931	0.937	0.720	Amputation
0.9	0.931	0.937	0.694	Amputation
1	0.931	0.937	0.667	Amputation

Indifferent Points	Change From	To as Parameter Increases

Costs

Transplant	Transplantation	Amputation	Treatment	Best
	0.931	0.937	0.902	
-200	0.930	0.940	0.905	Amputation
-180	0.930	0.939	0.904	Amputation
-160	0.930	0.937	0.903	Amputation
-140	0.932	0.937	0.902	Amputation
-120	0.934	0.937	0.902	Amputation
-100	0.935	0.937	0.902	Amputation
-87	0.936	0.936	0.902	Transplantation
-60	0.938	0.936	0.902	Transplantation
-40	0.939	0.936	0.901	Transplantation
-20	0.940	0.936	0.901	Transplantation
0	0.941	0.936	0.901	Transplantation

Indifferent Points	Change From	To as Parameter Increases
-87	Amputation	Transplantation

Costs Amputation	Transplantation	Amputation	Treatment	Best
	0.931	0.937	0.902	
-200	0.939	0.936	0.902	Transplantation
-180	0.937	0.936	0.902	Transplantation
-160	0.936	0.936	0.902	Amputation
-155	0.936	0.936	0.902	Amputation
-120	0.933	0.936	0.902	Amputation
-100	0.931	0.937	0.902	Amputation
-87	0.931	0.938	0.903	Amputation
-60	0.931	0.940	0.905	Amputation
-40	0.931	0.941	0.906	Amputation
-20	0.931	0.942	0.907	Amputation
0	0.931	0.943	0.908	Amputation

Indifferent Points		Change From	To as Parameter Increases
	-155	Amputation	Amputation

Costs Treatment	Transplantation	Amputation	Treatment	Best
	0.931	0.937	0.902	
-200	0.939	0.943	0.902	Amputation
-180	0.938	0.942	0.902	Amputation
-160	0.936	0.941	0.902	Amputation
-155	0.936	0.940	0.902	Amputation
-120	0.933	0.938	0.902	Amputation
-100	0.931	0.937	0.902	Amputation
-87	0.930	0.936	0.903	Amputation
-60	0.930	0.936	0.905	Amputation
-40	0.930	0.936	0.906	Amputation
-20	0.930	0.936	0.907	Amputation
0	0.930	0.936	0.908	Amputation

Indifferent Points	Change From	To as Parameter Increases

Leg amputated

Quality of Life		Transplantation	Amputation	Treatment	Best
		0.931	0.937	0.902	
	0	0.931	0.937	0.809	Amputation
	1	0.931	0.937	0.852	Amputation
	2	0.931	0.937	0.881	Amputation
	3	0.931	0.937	0.902	Amputation
	4	0.931	0.937	0.917	Amputation
	5	0.931	0.937	0.927	Amputation
	6	0.931	0.937	0.934	Amputation
	7	0.931	0.937	0.938	Treatment
	8	0.931	0.937	0.942	Treatment
	9	0.931	0.937	0.944	Treatment
	10	0.931	0.937	0.946	Treatment

Indifferent Points		Change From	To as Parameter Increases
	7	Amputation	Treatment

Cost

Risk Tolerance	Risk Aversion	Transplantation	Amputation	Treatment	Best
		0.931	0.937	0.902	
-1.00	-1.000	0.925	0.926	0.902	Amputation
-1.11	-0.900	0.925	0.926	0.902	Amputation
-1.25	-0.800	0.925	0.926	0.902	Amputation
-2.00	-0.500	0.925	0.926	0.902	Amputation
-3.33	-0.300	0.925	0.926	0.902	Amputation
-5.00	-0.200	0.925	0.926	0.902	Amputation
-10.00	-0.100	0.925	0.926	0.902	Amputation
-20.00	-0.050	0.926	0.926	0.902	Amputation
-25.00	-0.040	0.926	0.926	0.902	Transplantation
-33.33	-0.030	0.926	0.926	0.902	Transplantation
-40.00	-0.025	0.926	0.926	0.902	Transplantation
-50.00	-0.020	0.927	0.926	0.902	Transplantation
-66.67	-0.015	0.927	0.926	0.902	Transplantation
-100.00	-0.010	0.927	0.926	0.902	Transplantation
-166.67	-0.006	0.928	0.928	0.902	Transplantation
-200.00	-0.005	0.928	0.928	0.902	Transplantation
-250.00	-0.004	0.928	0.929	0.902	Amputation
-333.33	-0.003	0.929	0.929	0.902	Amputation
-500.00	-0.002	0.929	0.930	0.902	Amputation
-1000.00	-0.001	0.929	0.931	0.902	Amputation
1000.00	0.001	0.929	0.933	0.902	Amputation
500.00	0.002	0.930	0.934	0.902	Amputation
333.33	0.003	0.930	0.935	0.902	Amputation
250.00	0.004	0.930	0.936	0.902	Amputation
200.00	0.005	0.931	0.937	0.902	Amputation
166.67	0.006	0.931	0.938	0.902	Amputation
100.00	0.010	0.932	0.941	0.902	Amputation
66.67	0.015	0.933	0.944	0.902	Amputation
50.00	0.020	0.934	0.946	0.902	Amputation
40.00	0.025	0.934	0.948	0.902	Amputation
33.33	0.030	0.935	0.948	0.902	Amputation
25.00	0.040	0.935	0.949	0.902	Amputation
20.00	0.050	0.936	0.949	0.902	Amputation
10.00	0.100	0.936	0.949	0.902	Amputation
5.00	0.200	0.936	0.949	0.902	Amputation
3.33	0.300	0.936	0.949	0.902	Amputation
2.00	0.500	0.936	0.949	0.902	Amputation
1.25	0.800	0.936	0.949	0.902	Amputation
1.11	0.900	0.936	0.949	0.902	Amputation
1.00	1.000	0.936	0.949	0.902	Amputation

Length of life

Risk Tolerance	Risk Aversion	Transplantation	Amputation	Treatment	Best
		0.931	0.937	0.902	
-0.20	-5.000	0.846	0.868	0.847	Amputation
-0.30	-3.333	0.868	0.889	0.862	Amputation
-0.40	-2.500	0.881	0.900	0.870	Amputation
-0.50	-2.000	0.889	0.907	0.876	Amputation
-0.60	-1.667	0.895	0.911	0.879	Amputation
-0.70	-1.429	0.899	0.914	0.882	Amputation
-0.80	-1.250	0.902	0.916	0.884	Amputation
-0.90	-1.111	0.904	0.918	0.885	Amputation
-1.00	-1.000	0.906	0.919	0.886	Amputation
-2.00	-0.500	0.913	0.925	0.891	Amputation
-3.00	-0.333	0.916	0.927	0.893	Amputation
-4.00	-0.250	0.917	0.927	0.893	Amputation
-5.00	-0.200	0.918	0.928	0.894	Amputation
-6.00	-0.167	0.918	0.928	0.894	Amputation
-7.00	-0.143	0.919	0.928	0.894	Amputation
-8.00	-0.125	0.919	0.929	0.895	Amputation
-9.00	-0.111	0.919	0.929	0.895	Amputation
-10.00	-0.100	0.919	0.929	0.895	Amputation
-100.00	-0.010	0.920	0.930	0.896	Amputation
-1000.00	-0.001	0.920	0.930	0.896	Amputation
1000.00	0.001	0.921	0.930	0.896	Amputation
100.00	0.010	0.921	0.930	0.896	Amputation
10.00	0.100	0.922	0.931	0.897	Amputation
9.00	0.111	0.922	0.931	0.897	Amputation
8.00	0.125	0.922	0.931	0.897	Amputation
7.00	0.143	0.922	0.931	0.897	Amputation
6.00	0.167	0.923	0.931	0.897	Amputation
5.00	0.200	0.923	0.932	0.897	Amputation
4.00	0.250	0.924	0.932	0.898	Amputation
3.00	0.333	0.925	0.933	0.899	Amputation
2.00	0.500	0.927	0.934	0.900	Amputation
1.00	1.000	0.933	0.938	0.904	Amputation
0.90	1.111	0.934	0.939	0.904	Amputation
0.80	1.250	0.935	0.940	0.905	Amputation
0.70	1.429	0.937	0.941	0.906	Amputation
0.60	1.667	0.939	0.942	0.908	Amputation
0.50	2.000	0.942	0.943	0.909	Amputation
0.40	2.500	0.945	0.945	0.911	Amputation
0.30	3.333	0.949	0.948	0.914	Transplantation
0.20	5.000	0.953	0.950	0.916	Transplantation

Quality of Life

Risk Tolerance	Risk Aversion	Transplantation	Amputation	Treatment	Best
		0.931	0.937	0.902	
-0.20	-5.000	0.572	0.654	0.809	Treatment
-0.30	-3.333	0.579	0.654	0.809	Treatment
-0.40	-2.500	0.592	0.654	0.809	Treatment
-0.50	-2.000	0.606	0.654	0.809	Treatment
-0.60	-1.667	0.621	0.654	0.809	Treatment
-0.70	-1.429	0.634	0.654	0.809	Treatment
-0.80	-1.250	0.647	0.654	0.809	Treatment
-0.90	-1.111	0.659	0.655	0.809	Treatment
-1.00	-1.000	0.669	0.656	0.809	Treatment
-2.00	-0.500	0.741	0.679	0.812	Treatment
-3.00	-0.333	0.777	0.706	0.817	Treatment
-4.00	-0.250	0.798	0.727	0.822	Treatment
-5.00	-0.200	0.812	0.742	0.826	Treatment
-6.00	-0.167	0.821	0.753	0.829	Treatment
-7.00	-0.143	0.828	0.762	0.832	Treatment
-8.00	-0.125	0.833	0.768	0.834	Treatment
-9.00	-0.111	0.837	0.773	0.835	Transplantation
-10.00	-0.100	0.840	0.778	0.837	Transplantation
-100.00	-0.010	0.864	0.814	0.848	Transplantation
-1000.00	-0.001	0.867	0.818	0.850	Transplantation
1000.00	0.001	0.867	0.818	0.850	Transplantation
100.00	0.010	0.870	0.822	0.851	Transplantation
10.00	0.100	0.891	0.858	0.865	Transplantation
9.00	0.111	0.893	0.863	0.867	Transplantation
8.00	0.125	0.896	0.868	0.869	Transplantation
7.00	0.143	0.900	0.874	0.871	Transplantation
6.00	0.167	0.904	0.883	0.875	Transplantation
5.00	0.200	0.910	0.894	0.880	Transplantation
4.00	0.250	0.918	0.909	0.887	Transplantation
3.00	0.333	0.928	0.930	0.898	Amputation
2.00	0.500	0.940	0.958	0.916	Amputation
1.00	1.000	0.948	0.980	0.939	Amputation
0.90	1.111	0.949	0.981	0.941	Amputation
0.80	1.250	0.949	0.982	0.942	Amputation
0.70	1.429	0.949	0.982	0.944	Amputation
0.60	1.667	0.949	0.982	0.945	Amputation
0.50	2.000	0.949	0.982	0.945	Amputation
0.40	2.500	0.949	0.982	0.946	Amputation
0.30	3.333	0.949	0.982	0.946	Amputation
0.20	5.000	0.949	0.982	0.946	Amputation