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2018
MCM/ICM
Summary Sheet

Health care is one of the most important factors in a person's life, as it allows individuals suffering from illnesses to recover and continue to live a meaningful life. Among all institutions, hospitals are the place where people turn to when they get sick. However, choosing the best hospital is not always straightforward as there are many factors involved in a medical decision, including costs, waiting time, available equipment in the hospital and so forth.

Our group creates a model to scrutinize many factors and aims to decide the best hospital for an individual. We first consider the mortality rate. The rate displayed by the hospital's statistics is not an accurate representation, because some deaths are unpreventable. The hospital's quality is only shown in the number of preventable deaths. We examine a dataset that contains 85,400 entries to discover a relationship between age, income, and mortality rates. Then we look at death rates associated with each disease and finally the effects of comorbidity – the effects of having multiple illnesses simultaneously. Combining these pieces of information, we are able to predict the expected number of deaths in a hospital and compare that to the observed amount of deaths to get an accurate number for death rate.

The mortality model is tested by a simulation to make sure that it can determine the optimal hospital even when randomness obscure the results. Sensitivity analysis reveals that our model is applicability under a wide range of circumstances.

Upon completing our analysis of mortality, we examine ten other factors that define the quality of a medical facility. We consider both the overall hospital as well as particular departments in the hospital concerning the illnesses of the patient. For each factor, we form a ratio between the score of the hospital to the average of all the hospitals being considered. This allows the value for each factor to be easily compared. We then utilize a simple ranking system for the user to determine the relative weighting of each factor according to his/her preferences.

We test our model by simulating data from 100 hospitals, which yielded satisfying results. In reality, the data provided by hospitals may have slight inaccuracies, so a sensitivity analysis was also conducted. We discovered that the best hospital, calculated without errors, still appeared in the top 5 hospitals with errors for most of the time. This shows that our model can be used even if there are slight inaccuracies in the parameters provided.

One of the largest advantages of our algorithm is that it can be easily modified to fit many circumstances. By using different data to calibrate our model, it can be applied in any region of the world, and it can also find hospitals that best detect certain illness. Furthermore, individuals' ability to determine the relative importance of each factor allows the model to be tailored to their needs and identify the truly "best" hospital.

THE BEST HOSPITAL **ONLY** FOR YOU

Name:	
Primary Diagnosis Result:	

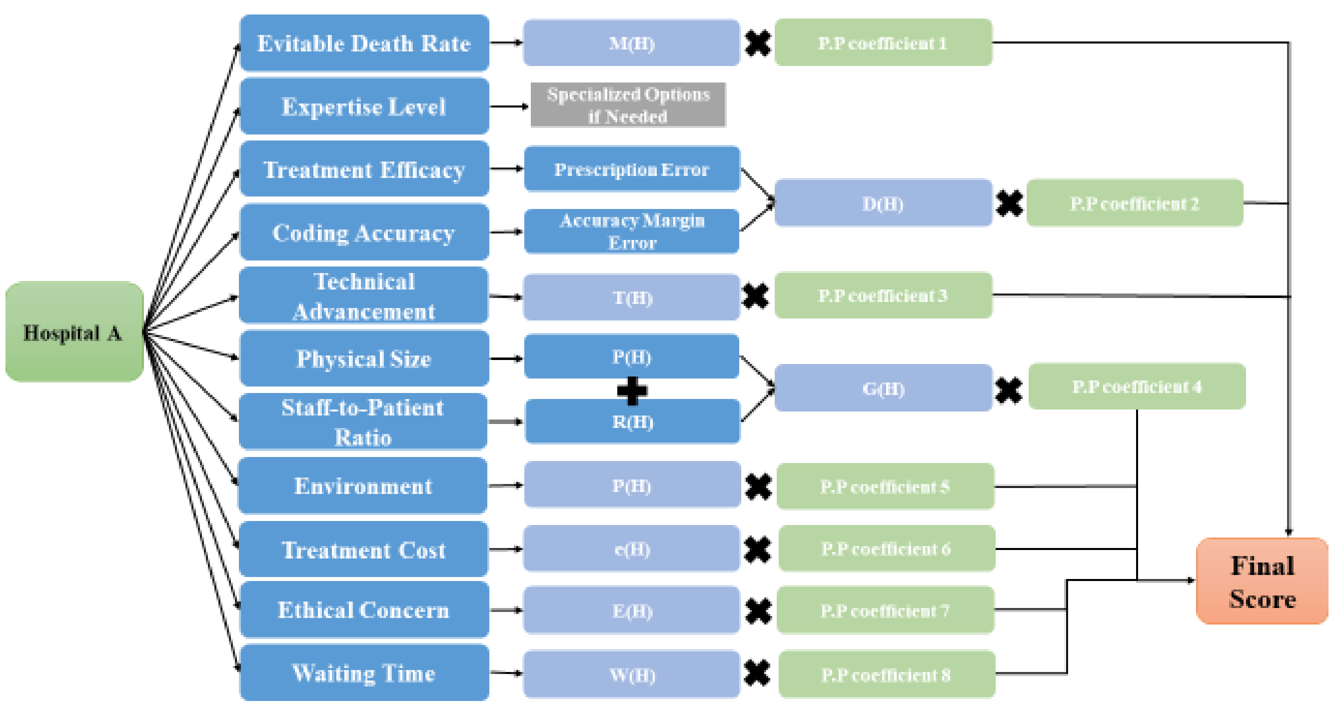
Welcome fine patient. You have received this letter as you have requested a Most Suitable Hospital For You form. Our team of logistic specialists have carefully designed the following questionnaire to get to know your preferences and assign you the perfect hospital. We ask you to read the questions carefully and give a score as accurately as you desire the factor to be present throughout your treatment. For all given factors, please try your best to give us a sense of their **relative importance**. Information you present in this questionnaire will be held confidential.

Factor of A Hospital	**Importance to You**				
	LITTLE	**Fair**			**Very**
1. Evitable Death Rate (if a hospital is able to prevent deaths from a treatable disease)	1	2	3	4	5
2. Expertise Level (if a hospital is general or specialized; e.g. mental, dental clinics)	1	2	3	4	5
3. Treatment Efficacy (if a hospital offers the most effective treatment)	1	2	3	4	5
4. Coding Accuracy (if a hospital offers the most accurate diagnosis after on checkup)	1	2	3	4	5
5. Technical Advancement (if a hospital owns advanced medical equipment)	1	2	3	4	5
6. Physical Size (if a hospital manages to accommodate a large number of patients)	1	2	3	4	5
7. Staff-to-Patient Ratio (if a hospital has enough doctors/nurses to spare attention to every patient)	1	2	3	4	5
8. Environment (if a hospital offers additional recreation; if a hospital has a desirable hygiene level)	1	2	3	4	5

9. Treatment Cost (if a hospital is economically friendly)	1	2	3	4	5
10. Ethical Concern (if a hospital self-reports valid data to authorities; if a hospital uses environmental-friendly operation system)	1	2	3	4	5
11. Waiting Time (if a hospital has short wait times)	1	2	3	4	5

Each set of scores is likely different for individuals, thus the final result will be highly customized. With the given raw scores of a hospital, calculated based on our models, (the light blue section of the flowchart) we are able to assign a numerical score to each hospital. **The score is relative regarding all options you intend to compare but does not represent the overall "ranking" of a hospital among its counterparts.** Follow the instruction below to reach some simple personal preference (P.P) coefficients for later use:

P.P coefficient 1 = score 1
P.P coefficient 2 = average score of (3+4)
P.P coefficient 3 = score 5
P.P coefficient 4 = average score of (6+7)
P.P coefficient 5 = score 8
P.P coefficient 6 = score 9
P.P coefficient 7 = score 10
P.P coefficient 8 = score 11



1 The Best Hospital?

1.1 Introduction

As the saying goes, "one man's trash is another man's treasure", and in a world full of thinking and the frowning upon of indecision, subjectivity of choices certainly plays the often role. This can be as trivial as forming a group decision of where to have dinner at, or can be as grand as deciding where to hold a global conference to reduce the amount of jet lag and maximize productivity. However, for many problems in life, concluding with an informed decision is difficult even with more than sufficient information and resources available.

One of these aspects of life - healthcare - has brought its way from antiquity to today. Whether it is a crushed joint or a bleeding of heart, doctors always have a solution for, or at least a way to better, our health issues. Yet in a society full of opportunities, can only the vast expanse of the hospital or the modest price tag be the sole incentive to choose your local hospital as the be all and end all of your health problems? The surge of technological and social advances along with access to data has enabled anyone to find the hospital of their choice, for their needs. We examine the factors that the general public will consider in choosing a suitable hospital and produce a model that will output the best hospital among a provided set. To allow the possibility of individual customization, we will further devise a memo that any person in need of medical attention will be able to find their top choice.

1.2 Problem Restatement

According to the Health and Medicine Division of the National Academies in the United States, the quality of a health institute is defined as the degree to which health services for individuals increase the likelihood of desired health outcomes and are consistent with current professional knowledge. Further, it is categorized into three criteria:

- Structural quality (general health system)
- Process quality (patients experience and wait time)
- Mortality (ability for the hospital to prevent deaths)

The first two factors are easier to deal with since they are the same regardless of the number of people that arrive at the hospital or the severity of a patients illness. The third factor cannot be calculated using the deaths in a hospital as some hospitals may have more patients with severe diseases which elevates their mortality rates. As the official definition states, some negative outcomes are inevitable with current professional knowledge and should be taken out of consideration when evaluating a hospital. Specifically, the objective quality of a hospital is best determined by its ability to minimize evitable deaths.

We split our paper into two sections. The first section will deal with calculating the mortality rate of patients whose deaths are avoidable. The second focuses more on general aspects of the hospital.

1.3 Assumptions and Justifications

- Data provided by the hospitals is accurate - it becomes difficult to predict the best hospital if hospitals provide false or inaccurate data. Therefore we assume that all data that is given to us is valid.

- One patient receives the most effective treatment of the primary diagnosis from only one hospital - this makes it easier to determine the skill of hospital staff. In reality most patients pick a hospital and always go to that hospital if possible because they are more familiar with the hospital and their doctor.

- Travel time to the considered hospitals are small - we assume that an individual with severe diseases can get to the best hospital in a timely manner. This is quite realistic as most people consider getting treatment a top priority

- A person's biological age (measured by their body's maturity) is the same as their chronological age - we assume that the patients organs and health are reflective of the age. This is true for most people. For example, a 20 year olds health would in almost every case be better than a 70 year olds.

- A specific income percentile determines a fixed, specific set of circumstances - individuals with similar incomes will likely lead lifestyles of similar depth. In this way, a person's cost preference may be determined solely by their income.

- The sampled patients seek for treatment from a hospital on a reasonably average time - since the time to receive treatment affects the effectiveness of the treatment to a certain extent, an average admission time of the patients is assumed. In order to make use of the average mortality rate to measure the quality of the hospital, this assumption is reasonable due to the large sample size.

- The condition of a hospital stays the same year-round - the time of year affects all hospitals equally.

- We only consider non-emergency situations - in case of an emergency, the patient will go to the closest hospital.

1.4 Definition of Terms

- **Hospital**: Any institution maintained for the reception, care and treatment of those in need of medical, surgical or dental attention

- **Survivability Index**: Our method of estimating the probability someone will survive at the hospital considering the factors in our criteria.

- **International Classification of Diseases (ICD)**: A division of illness into fixed categories issued by Centers for Medicare and Medicaid Services (CMS). The version used in our paper is the tenth revision: ICD-10-CM.

- **Charlson Comorbidity Index (CCI)**: An integer value from the set {1, 2, 3, 6} assigned to nineteen specific illness categories adjusted to accurately reflect the illness' degree of synergy with other illnesses. Individuals create a running total of the integer values corresponding to all their illness and and sums up each value to calculate their final CCI factor which can be converted to survival possibilities. The CCI used in our paper is based on the categories given by the ICD-10-CM.
- **Primary Diagnosis**: the illness within an individual that most adversely affects their standard health status
- **Principal Diagnosis**: the initial diagnosis result as the cause of admission of a patient to a hospital (not necessarily the same as primary diagnosis)
- **Comorbid Diagnoses**: the set of illnesses that an individual possess that are not the primary diagnosis
- **Odds Ratio**: The odds of a treatment being able to cure a disease.

1.5 Variables Used

Variable	Meaning
x_A, x_I	a individual's age and income
$f(x_A, x_I), m(x_A, x_I)$	an individual's predicted mortality rate given x_A and x_I
SI	an individual's survivability index
C_i, I	each of several costs associated with treatment
$AADR$	age adjusted death rate pertaining to specific illness
$CCI_{probability}$	probability of a comorbid death dictated by CCI
$M(H)$	evitable mortality rate of a hospital H
$D(H), G(H), P(H), E(H), W(H), e'(H), T(H)$	various other factors determining the quality of a hospital H

2 Evitable Mortality Model

2.1 Problem Restatement

To find the actual mortality rate in a hospital we need to first determine the number of expected deaths. In any hospital there will be patients whose condition is so severe that their death is highly likely regardless of the hospital. These patients should have minimal effect on the evitable mortality rate of the hospital.

2.1.1 Criteria

The following criteria will determine how likely an individual is to survive given their circumstances without considering the quality of treatment by the hospital.

1. Morbidity-independent Status: the aggregate effect of factors not related to the actual illness(es) that may adversely affect the ability for an individual to recover. The factors we used are
   (a) Chronological age: the degree to which one's physiological aging influences their ease of recovery
   (b) Biological sex: the degree to which one's gender at birth (female or male) affects their recovering rate, based on life expectancy data
   (c) Income level: the relative effect that one's socioeconomic circumstances have on their ability to recover
2. Primary Diagnosis: diagnosed illness that has the greatest impact on the survivability of the individual
3. Comorbidity: the combined level of severity of the additional illness(es) other than primary diagnosis result; related or unrelated to primary diagnosis

2.1.2 Overview

If we can isolate each of these event and make them independent, then the probability of a person surviving is $P(\text{surviving}) = (1 - \text{chance of dying from morbidity independent status})(1 - \text{chance of dying from primary diagnosis illness})(1 - \text{chance of dying from comorbidity factors})$.

The probability of someone living is complementary to that of someone dying so the probability that someone dies in the hospital is $1 - P(\text{surviving})$. In the following sections we determine the equations related to each factor.

2.2 Morbidity-independent Status

2.2.1 Biological sex (female or male)

It is quite clear that males and females have different lifespans, with females generally living longer than males. Also there are biological distinctions between the two, so it would make more sense to calculate this separately. Therefore we generate two separate equations modelling the morbidity independent factors.

2.2.2 Age

The overall health of people are dependent of the persons chronological age. Aging is a non-reversible process taking place in every individual, accompanied with weakened immune system responses and overall sub-optimal functional ability. For example, a hospital has less responsibility over someones death whose age is far beyond the average lifespan of the region. To address this issue, we can find a correlation between mortality rate and age.

2.2.3 Socio-economic Status

However, life expectancy is not the same for all individuals even if they are in the same region, meaning that the correlation of age and mortality will be dependent of the person. Wealthier individuals are able to purchase the most advanced health care products, hire personal trainers, and have the necessary nutrients each day. These people may have a much larger chance of living longer compared to others. Moving to the other end of the spectrum: those in poverty may not even have daily nutritional needs sufficed and may be unable to afford basic health care. As a result of such social deprivation, the overall life expectancy of the poor will be lower. We will address this issue in this section as well.

2.2.4 Analyzing these factors

We qualitatively discussed the relationships of the events above. Now we seek to model the situations above with equations, so we can predict the expected mortality.

To deal with issues we use a database provided by healthinequality.org. A copy of the first few rows are included in Figure 1 for easy reference.

1 **Online Data Table 15: National mortality rates by gender, age, year, and income percentile**

	Gender	Household Income Percentile	Age at Death	Year of Death	Income Lag	Mortality Rate	Count at Beginning of Year	Mean Household Income
3								
6	F	1	40	2001	2	0.0044	21,545	365
7	F	1	40	2002	2	0.0058	21,431	384
8	F	1	40	2003	2	0.0050	21,203	375
9	F	1	40	2004	2	0.0048	20,890	371
10	F	1	40	2005	2	0.0047	19,684	356
11	F	1	40	2006	2	0.0054	18,986	347
12	F	1	40	2007	2	0.0035	18,722	346
13	F	1	40	2008	2	0.0036	18,796	361
14	F	1	40	2009	2	0.0050	19,467	278
15	F	1	40	2010	2	0.0038	20,078	390

Figure 1: Data on factors

For our analysis we use the columns containing gender, household income percentile, age of death, and mortality rates.

We choose to use income percentile instead of income as it removes some of the problems involving inflation and the economic condition. This allows us to output the correct values in currently even though we are using past data.

The other information are not needed in the context of the problem. In total there are 85400 entries in the data with the females appearing first and the males afterward. Due to the large sample size, it should be representative of the overall society. We import the code into MATLAB for analysis and the code is included in the Appendix.

To analyze the data we first split the data set into two groups containing male and female data separately. We first visualize the data by plotting it. Color has been added based on the mortality rate of the individuals to show the relationship of the factors clearer.

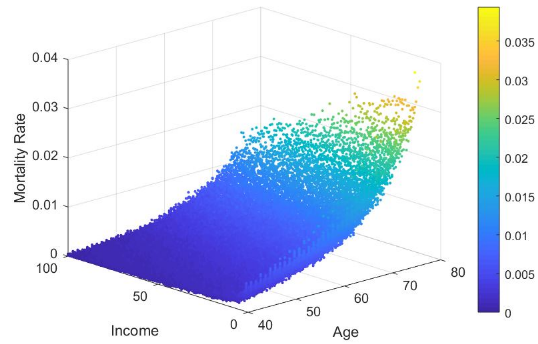


Figure 2: Age and Income vs. Mortality - Female

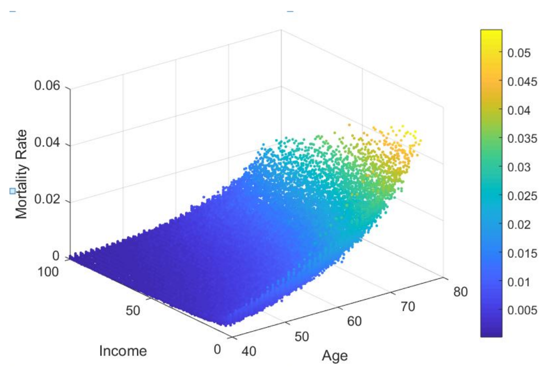


Figure 3: Age and Income vs. Mortality - Male

From the charts, it can be clearly seen that the three variables x_A, x_I, and $f(x_A, x_I)$ (or $m(x_A, x_I)$) are correlated as previously predicted. We use a curve fitting algorithm to determine the needed coefficients for fitting the data.

While sometimes a portion of the data points are excluded for back testing, we choose not to do so. Since the recorded age is a discrete number (people do not write 60.5 years old), we are not interpolating and all input values are the same as the input values used for model calibration. Therefore we include all the data in hopes of a better model calibration.

Figure 4 and 5 shows an image of the data points (dots in black) and a graph of the surface of best fit. As we can see the surface matches the plane very well.

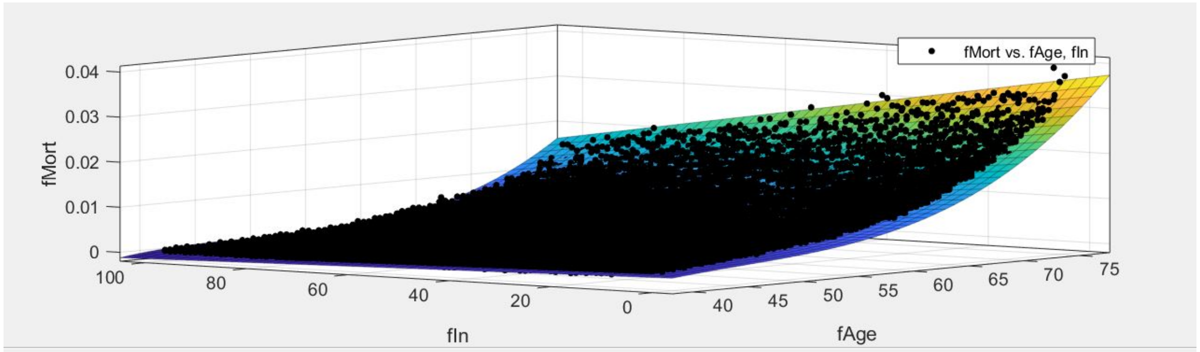


Figure 4: Curve Fitting (Female)

$$f(x_A, x_I) = \frac{1}{10^7}(-952700 + 61010x_A - 2458x_I - 1310x_A^2 + 120.5x_Ax_I + 9.988x_A^3 - 1.702x_A^2x_I)$$
$$r^2 = 0.9649$$

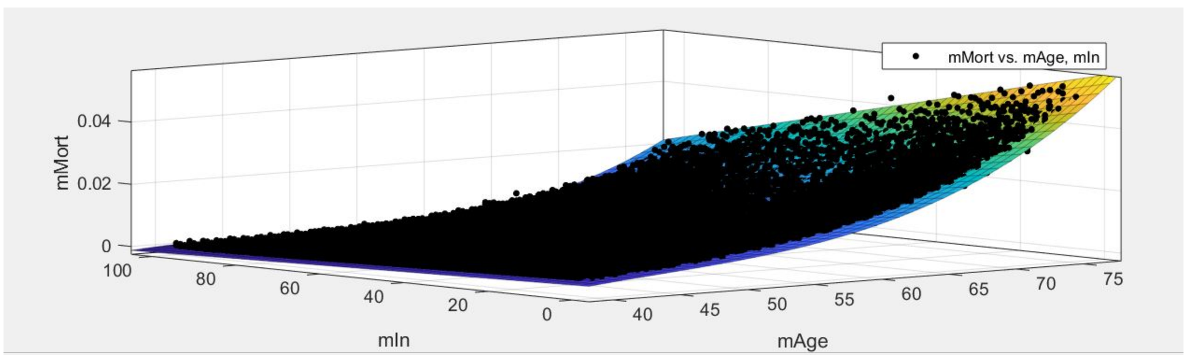


Figure 5: Curve Fitting (Male)

$$m(x_A, x_I) = \frac{1}{10^7}(-738000 + 47760x_A - 2426x_I - 1028x_A^2 + 106.5x_Ax_I + 7.665x_A^3 - 1.286x_A^2x_I)$$
$$r^2 = 0.9615$$

The r^2 values are very high, so we are quite confident that the surface generated accurately reflects reality closely for the values that were included in the interval.

As with most regression analysis models, we have to be very careful when extrapolating the data from dramatically different inputs. This is also the case with this model. While the output values are accurate for the range of 40 years old to 80 years old.

We can fix this problem by redefining it as a piecewise function. Since mortality for individuals below 40, regardless of their income level, is quite low (usually in the tenths of a percent) we can define any age below 40 as having an age related mortality of 0%.

2.3 Primary Diagnosis

Some diseases are more threatening than others and this is an important factor in determining inevitable death. For example, if a patient dies from a flu, the hospital should take more responsibility than if a patient dies from a malignant tumor. Furthermore, chronic illness may have unknown cures, and acute diseases leave minute time for effective treatment. There are large amounts of data provided by multiple sectors to quantify the probability of death of an individual once being afflicted with certain diseases.

Yet most calculations do not isolate the severity of the disease itself, but instead contain factors like age. This is troublesome because, a young person is afflicted with a threatening disease normally only found in seniors, his/her death rate is not correctly predicted by those. We can fix this issue by using age-adjusted death rates (AADR), which accounts for the age factor. This data is also readily available and is calculated by weighing age groups with less cases of death heavier. As a result, there is a death rate independent of age. Since AADR is computed from a large sample of people, by the law of large numbers, the probability of dying from a sickness is the AADR.

2.4 Comorbidity

An illness by itself is usually easier to cure. However, when multiple illnesses occur at the same time, it is much harder to cure them independently, and the survival rate decreases dramatically. For example, a patient with AIDS will have a much more difficult time recovering from other diseases due to immune deficiency, and a complicated surgery may lead to adverse outcomes. Other times, people with chronic health issues may not be allowed to use the most effective medications. In the case of Clarithromycin, an antibody used widely for bacterial infections, it inhibits enzymatic activity of metabolizing calcium-channel blocker, another drug commonly used to control hypertension. Patients taking the latter, if at the same time being afflicted by bacterial infection, will experience medication interferences and likely develop acute kidney injury. Thus these people would have to turn to less effective options.

The effect of comorbidity can be quantified using Charlson Comorbidity Index (CCI) that covers 19 common comorbidity conditions, ranging from AIDS/HIV infection to dementia. (A description of how CCI works is included in the definitions). Since we have already included the probability of dying from the primary diagnosis, for our CCI factor in the equation we consider all illnesses except for the primary illness. The study done by Quan et al. (2011), with national samples from 6 different countries, compared actual in-hospital mortality rates to individuals CCI scores calculated to predict death rates. For example, a final sum higher than 6 calculated from assigned CCI index indicates low survivability.

Their CCI score calculations fit the actual results in all 6 nations, specifically the CCI and the in-hospital death rate. A table summarizing the conversion results from their research is included in Table 3 of the Appendix. Thus, we use their data and convert the scores as single numerical possibilities of in-hospital death for all comorbidity conditions, and (1- death from morbidity factors) becomes our third factor to predict ones likelihood of survival.

2.5 Final Combination

We now have the necessary equations to complete the complete the modelling outlined in the overview. There is a small error in the independence of morbidity-independent status and AADR. Suppose someone has illness A. Part of the death rate from the equation in the overview includes the death rate for illness

A. However, even the most common cause of death is only a small portion of all causes of death, the error introduced is very small. Therefore, we can approximate it as being independent. Combining all factors as discussed above, we obtain:

$$SI = \begin{cases} (1-f(x_A, x_I))(1-AADR)(1-CCI_{\text{probability}}) \text{ if patient is female} \\ (1-m(x_A, x_I))(1-AADR)(1-CCI_{\text{probability}}) \text{ if patient is male} \end{cases}$$

We can modify this model to find the expected death of a patient in the hospital: $1 - SI$. This value represents the average amount of deaths in the region. To compare this value to the deaths in the hospital, we can take a ratio between actual deaths in the hospital and the expected deaths. Mathematically we can say that $M(H) = \dfrac{\text{actual deaths}}{\sum(1-SI)}$.

This ratio allows us to compare values much better than simply looking at deaths or mortality rates. Looking at the values, we can see that the higher the value of $M(H)$, the worse the hospital because their deaths exceed the regional expected rate. A lower $M(H)$ signifies that this hospital is good as it can prevent more deaths than the overall regional rate.

2.6 Testing

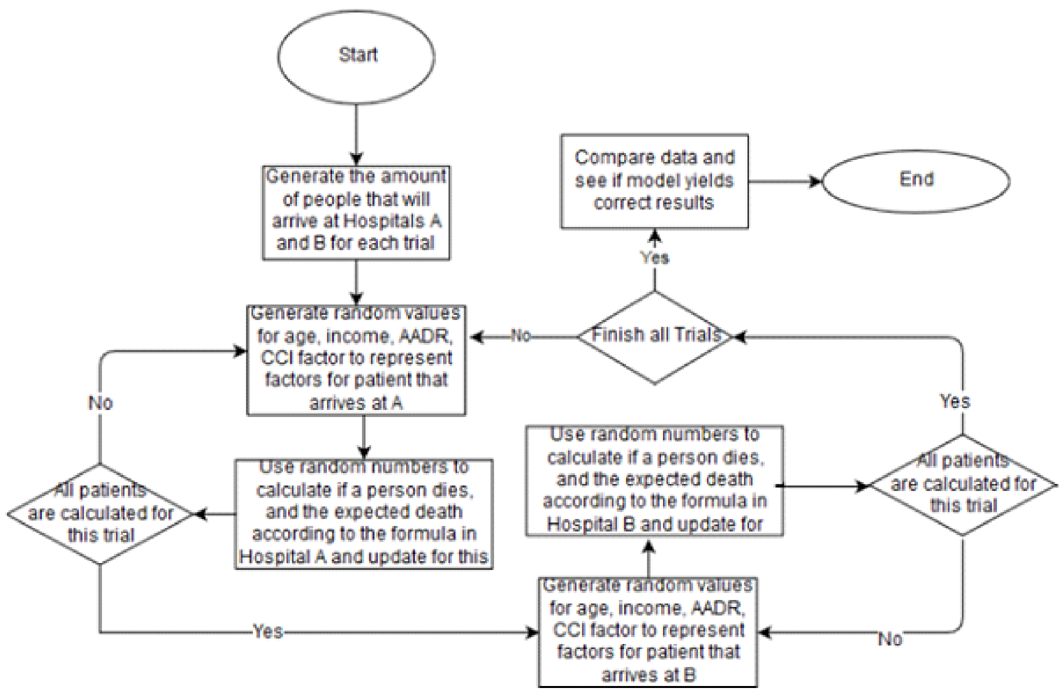
Due to the difficulty in obtaining real data regarding hospitals, we create a simulation that can be used to test the model with two hypothetical hospitals, Hospital A and Hospital B. In these two, we assume 10% of all the patients that come to the hospital dies. However, Hospital A, in general, has people that are older, have less income, worse illnesses (diseases with higher mortality rates), and more comorbidities than Hospital B. The ranges and probability distributions of the variables are shown in Table 1.

Variable	Hospital A	Hospital B
Patients	Uniform $[500, 1000]$	Uniform $[500, 1000]$
Age	Uniform $[60, 100]$	Uniform $[40, 80]$
Income	Uniform $[1, 60]$	Uniform $[40, 100]$
Sickness	Normal distribution with mean= 0.15 and SD= 0.025	Normal distribution with mean= 0.1 and SD= 0.025
Morbidity	Normal distribution with mean = 0.25 and SD = 0.025	Normal distribution with mean = 0.2 and SD = 0.025
Biological Sex	1 or 0 to determine the gender	1 or 0 to determine the gender

The patients variable determines how many people will arrive at the hospital, while the other variable are concerned about an individual patient. Just by looking at the values, we can see that Hospital A is better than Hospital B because the same percentage of patients die, but Hospital A has patients that are harder to save. However, in real life it is often hard to find such a clear distribution and the results are often hidden due to randomness and noise in the system. We run this simulation to verify that our model can make the correct choice and we compare the results afterward.

Note that the probability distributions of the variables may not reflect reality, but that is not an important factor. Our model is not dependent on the distribution of the input data and should be able to find the best hospital regardless.

The logic of our code is shown in the flow chart below.



The results for running 1000 times are shown below in a histogram that is in binary format. 1 represents the correct choice and 0 represents the incorrect choice.

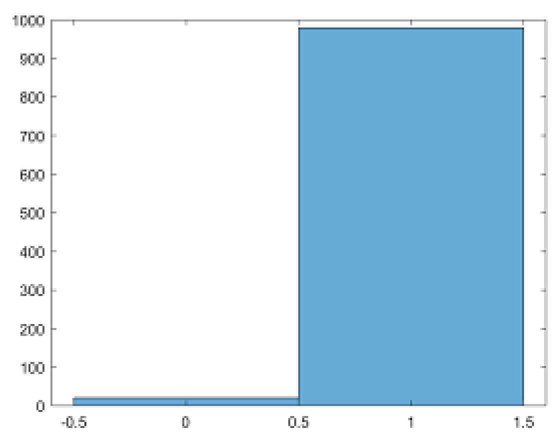


Figure 7: Graphical representation of binary trials

From the histogram, we can see that our model is accurate for almost all the trials.

2.7 Uncertainty analysis

There are inherent uncertainties in our model that will affect the expected death rate. For example, the death rate and comorbidities are estimates of the population based on a sample. In this section, we take a random chosen input values according to the distribution of the dataset and pass it through our model to see the possible range and statistical distribution of the set.

Suppose there is a person who is 60 years old, his income is in the 50th percentile, his sickness has a mortality rate of 20%, and the probabilities that he dies from comorbidities is 20%. Each of these estimates have inaccuracies which is summarized in the table below.

Variable	Inaccuracy
Age	The age may be underestimated by at most 1 year depending on how close he is to his birthday (60 years old and 364 days is recorded as 60 years old). This is a uniform distribution between $[60, 61)$.
Income	His income percentile may be inaccurate since some peoples incomes are not reported in government census data. The error from this should be no more than 1% in either direction of the mean. For normal distributions, the range is approximately between the 5th and 95th percentile, which is $2(1.645) \approx 3.3$ standard deviations. The standard deviation is approximately 0.5.
Sickness Mortality Rate	PPIC provides data on all age adjusted death rates with standard errors. Taking the worst case scenario, we take the largest standard deviation on the table which is 0.000314.
Comorbidity	According to Quan et al., the range for in-hospital mortality rate related to comorbidity can be converted into a standard deviation of 0.76.

Using MATLAB to generate random inputs according to the specified distributions, we run our formula 1000 times. The output range is shown in Figure 8.

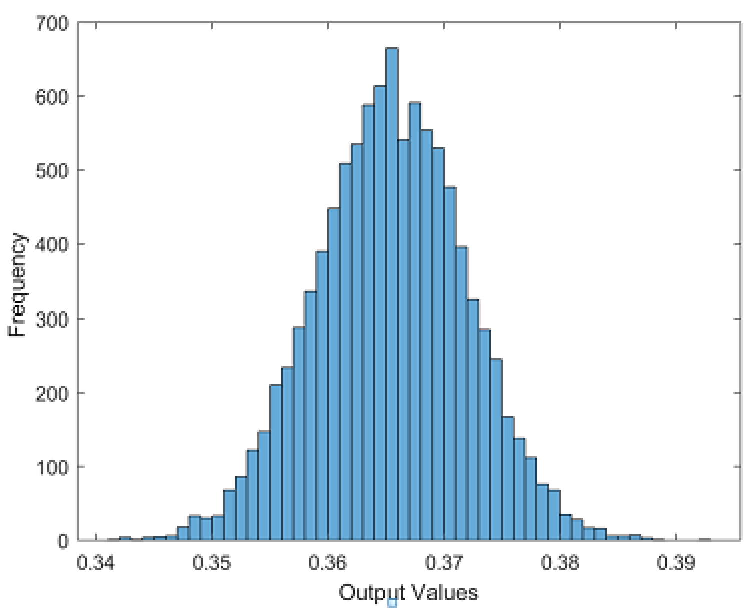


Figure 8: Variation of final result using input range of factors

The range of the output values is only 0.05 meaning that our results are not too sensitive to the input values. Therefore we can use this model in a variety of circumstances.

2.8 Strengths and Weaknesses

2.8.1 Strengths

- Isolated factors: In the model, much of the various factors are isolated before calculating the survivability index of a patient. Such a way is beneficial since the estimation is more accurate with different factors considered independently for an individual. As a result, the difficulty in giving treatment and the probability of passing away are ensured to vary based on a persons actual condition. For example, the survivability index for a strong youth will be higher than a weaker elder with other factors being the same.

- Tolerance within the model: Other than the criteria that are explicitly listed, each criterion also implicitly contains many factors. For instance, the urgency of a disease is generically comprised in the type of the disease. While each persons urgency is different, when a large amount of people arrive at the hospital, all with different urgencies, they arrive approaches the AADR or the disease. Therefore, when calculating the lethality of the disease, its urgency does not need to be considered again. This simplifies the number of equations used in the number

- Use of the law of big numbers: As long as sample sizes are large, then the number of inevitable deaths will approach our estimated value. For example, because of the large sample size, the time of admission, whether early or late, can be seen as an average.

- Ability to have variants: The model can easily be localized based on specific situations. While US data is currently used in the model, it can be easily calibrated to different regions around the world based on the local death rate and other factors. We can also change our model to focus on a single disease.

2.8.2 Weaknesses

- This model only looks at mortality and does not check at whether the illness was cured by his/her treatment. We also do not consider whether a patient has received full treatment according to what a doctor had suggested. These non-mortality factors are manipulated in our general factors model presented later.

- Our model needs to use a large amount of accurate data to calculate the expected death rate. Problems in data collection will result in errors of the predicted rate. However, even if hospitals are somewhat generous when presenting their findings, the percentile of a hospital's placement is unlikely to alter significantly.

- Though the equation is developed based on age-adjusted death rate of certain diseases, we believe the statistical data do not isolate the role of the severity of disease on ones possibility of dying after being afflicted. Fortunately as discussed above, this is only a slight error.
- We manage to incorporate age and income level of a given individual into the equation but take ethnicity into a lesser account. Secondly, the data set used to develop criterion 1 is derived from national statistics in the United States. Although ethnicity is not included in the report, the 85,400 entries should have helped to count the factor of diversity and provide a fair average even if local sectors are relatively uniform in ethnicity.

2.9 Conclusions

The Mortality Model is effectively designed to evaluate a hospitals quality based on the very fundamental and absolute standard of mortality ratio. As the basis of a hospital is to help people out from diseases and torment, this model is aimed to measure the quality of a hospital through the solid gist of mortality rate. The mortality rate is an exceptional index of how well a hospital can avoid unnecessary and crucial mistakes. In conclusion, what this model measures give a fairly good idea of how effective a hospital is in saving peoples' lives.

3 General Hospital Quality Model

3.1 Redefining the problem

We will create a model that allows us to find the best hospital for patients overall. In other words we need to consider the following factors.

- Accuracy of Diagnosis - if the hospital has correctly detected the major morbidity of a patient and has chosen the optimal treatment for the specific illness
- Waiting time - the amount of time before the patient receives treatment; does not include effects on mortality
- Resources available in the hospital
- Cost of treatment
- Mortality Rate
- Physical attributes
- The degree in which the ethical standards are abided to with respect to societal values

To determine the best hospital, we compare a given hospital to all hospitals in a region to be considered. The region is determined by the severity of the disease and how many hospitals the patient is willing to consider.

3.2 General Hospital Qualities

In this section we look at general hospital qualities which are independent of the cause of the hospital visit. For this section we use the data from a hospital.

3.2.1 Coding Accuracy and Prescription Practice

Normally, patients voluntarily go to a hospital without knowing the cause of their discomfort. They then rely solely on the hospital of first choice to detect the disease correctly. We believe the ability of a hospital giving accurate diagnoses largely speaks for the overall quality of the hospital.

We denote a patients principal diagnosis result as p and assume his/her primary diagnosis to be q, each with a numerical value to determine the severity of the disease. The level of severity will be calculated using the APACHE II scoring system, in which each morbid condition is assigned with an integer score A from $[0, 71]$ after considering multiple physiological variables of the patient. We then take the difference between two diagnosis results, $\frac{|A_p - A_q|}{A_q}$, which represents the amount of error of the two diagnosis.

Other than whether a hospital is able to offer the most accurate diagnosis for patients, the efficacy of given treatments also defines the quality of a hospital. Though the objective quality of a hospital regarding curing a patient has been discussed as mortality rate (mentioned later as well), we believe a capable hospital is responsible of providing the most effective pharmaceutical treatments. Patients with non-deadly diseases have a minute effect on measuring the mortality rate, and they should be taken into account.

The treatment of a general disease is denoted as B_n, where B_1 is the most effective treatment one can get (adjusted for socio-economic status and drug interaction for individual patients), and $B_2, B_3, \ldots, B_k$ being the rest of all treatments available. The efficacy of each treatment in the set is the odds ratio of that curing the respective disease. We can determine the relative efficiency of the treatment by comparing the doctor prescribed treatment, OR1, to the OR of the best possible treatment. Thus, the relative efficacy of prescribed treatment is $\frac{\text{ORn}}{\text{OR1}}$ where ORn is the chosen treatment. A ratio closer to 1 means the treatment is generally effective in curing the patient, while a ratio closer to 0 indicates a less meaningful treatment.

In general, the coding accuracy of a given hospital can be $D(H) = -\sum(\frac{|A_p - A_q|}{A_q}) + \sum \frac{\text{ORn}}{\text{OR1}}$. We can then divide $\frac{D(H)}{\text{average } D(H) \text{ in region}}$.

3.2.2 Resources

The overall carry capacity of a hospital is determined by multiple factors, including its physical size, equipment supply, and staff-to-patient ratio.

Physical size of a hospital is not considered as a variable in the model but more likely a constant, being dependent of local situations: for example, a town with 10000 population will likely have its largest hospital incompatible with the average hospital found in a city with 300000 residents. It does not necessarily mean the larger a hospital is, the better it will be. Nonetheless, a hospital of good quality should be able to accommodate enough people in respect to local population size so that patients daily or emergent conditions will still be sufficed. A less concentrated public space will as well reduce the risk of populating infectious diseases or adding discomfort to already sick patients. Carrying capacity of a hospital can then be measured as $P(x) = \frac{\text{maximum capacity}}{\text{population responsible}}$.

Aside from the physical size, the number of total staff with medical training in a hospital also defines its functional ability: certified nurses gives professional care, improving patients interpersonal experience during their periods of morbidity; sufficient number of doctors ensure the continuous flow of inpatients, maximizing the efficiency of a hospital. The total number of staff is believed to be a constant over one report time. Thus, the amount of care someone can receive from a given hospital is roughly quantified as $R(x) = \frac{\text{staff}}{\text{average no. patient in a day}}$. We can compute this factor as $G(x) = P(x) + R(x)$. We want this value to be relative to an average, so we can compute $\frac{G(H)}{\text{average } G(H) \text{ in region}}$.

3.2.3 Physical Attributes

Staying at a hospital is more than just receiving treatment as usually a long amount of time is spent waiting in a lobby. Hospitals may choose to improve the satisfaction of this waiting time by improving sensual inputs that its environment provides. These factors include

- Stimuli (posters, books, television, toys etc.)
- Hygiene
- Navigation difficulty of hospital (pointers, patient guidance)

We can find a dataset that contains ratings of hospitals on their overall physical attributes. As before we can compare each hospital with all others in the region by taking a ratio of the score for physical attributes of one hospital, $P(H)$, to the average score to arrive at the multiplier $\frac{P(H)}{\text{average } P(H) \text{ in region}}$.

3.2.4 Mortality Rate

Another important factor is mortality rate. We have examined mortality rate extensively in the first part of this paper, so we can just use that factor here. The denominator is already the average number of deaths in the region, so we do not need to do another average for this value.

3.2.5 Ethics

Like all organizations, a hospital assumes responsibility for satisfying the moral standards that its patients and non-patients within its vicinity follow. We take into consideration common ethical issues that many societies would agree on:

- Maximizing the use of solar, wind, or other renewable energy - measured as the amount of its energy being produced using renewable sources

- Non-profit - for private hospitals, measured as the proportion of its profit being used for funding a charity. For government-owned hospitals, it is the proportion of the taxes the government spends that is subject to charitable purposes (either directly by the government or through a charity).
- Patient confidentiality - subjective score; depends on the degree in which the hospital satisfies the patient's desire
- Appropriately telling the truth or lying to ensure minimal grief - score is based on the degree of effective the doctors handle such situations

A score $E(H)$ can be calculated for a specific hospital and compared with the average value in the region to get a multiplier of $\frac{E(H)}{\text{average } E(H) \text{ in region}}$.

3.3 Disease specific qualities

Some qualities of the hospital are specific to one disease and it would not make sense to consider the hospital as a whole. For example, waiting time and costs are dependent on the hospital department and individual visits. $1000 is a lot to pay for a flu shot, but only a small amount for surgery. Also it is unlikely someone going to a liver treatment will care about the technology in other departments. For the following factors we look at data from a particular department in the hospital.

3.3.1 Waiting Time

Overall patients want to have shorter waiting time and see their doctor as fast as possible and the longer the waiting time the less satisfied the patient will be. However, when going to a hospital, individuals expect to wait a certain amount of time before seeing a doctor.

The departments wait time factor starts at a positive number and decreases as time passes. When just starting to wait, patients satisfaction would decrease slowly because while they are less pleased with the speed, they expected it. Near their expected time, their satisfaction will decrease quickly and at a waiting time equal to the average waiting time, the waiting time for the factor should be 0 since this department neither has an advantage or disadvantage over the average. At extreme waiting times, the change in their satisfaction is still negative but much smaller. For example, waiting 100 days is a long wait and has low satisfaction, but at that point an additional day does not make a large difference. The situation described is similar to a negative hyperbolic sine function.

The individual should expect to his/her wait time to be the same as the average in the region, T, because his/her standards are based on those. The wait time, t, a patient experiences can be approximated by the average wait in the department.

Because of expected waiting time discussed above, we need to shift the equation right, so $c = T$. Combining these factors, the value of the waiting time for a specific hospital to be $W(H) = -\text{arcsinh}(t - T)$. Comparing to the average, our multipler is $\frac{W(H)}{\text{average } W(H) \text{ in region}}$

3.3.2 Cost of Treatment

Expenses for a treatment include

- Cost of seeing the doctor (include taxes if from tax) = $C_1(x)$, adjusted for insurance
- External costs (parking, phone) = $C_2(x)$
- Amount of medication discount = $C_3(x)$, adjusted for insurance
- Insurance cost (one time treatment) = I

Total expenses is modelled using an expense function $e(x) = C_1(x) + C_2(x) + C_3(x) + I$. Because we are comparing this function between different hospitals, we only need to consider the portions that change from one hospital to the next. We then arrive at the new function $e'(x) = C_2(x) + C_4(x) + C_5(x)$, where $C_4(x)$ is $C_1(x)$ and $C_5(x)$ is $C_3(x)$ without being adjusted for insurance.

We can compare the costs of one hospital to another by considering the ratio $\dfrac{e'(x)}{\text{average } e'(x) \text{ in region}}$. A value greater than 0 than signifies that the hospital is more expensive than the average while a value lower than 1 signifies that the hospital is cheaper.

3.3.3 Technology

Having more suitable medical equipment enables doctors to finish a job more effectively and efficiently. The degree of technology can be approximated by the price. Expensive equipment should be able to perform the task better than cheap equipment. We can look at the average cost of one machine in the department.

Advanced equipment is good but it also depends on the experience of the doctors in handling higher level equipment, which can be denoted by a number from $[0, 1]$, where 0 means unable to use the technology and 1 means the cost of purchasing the equipment is put to full use.

Overall the effective use of in the hospital equipment is $T(H) = \text{Cost of Machinery} * \text{Usage Efficiency}$. We multiply the equations together because effective use depends both on the quality of the equipment and a doctors ability in using it. For the value of this factor we look at the $\dfrac{T(H)}{\text{average } T(H) \text{ in region}}$.

3.4 Final Combination

All the factors listed above have been adjusted so that they reflect an amount with respect to the average. That means for a final score of the hospital, we can take a weighted sum of all the factors. Since high cost and mortality rates should be avoided, those factors are subtracted from the total score.

$$w_1\left(\frac{D(H)}{\text{average } D(H) \text{ in region}}\right)+w_2\left(\frac{G(H)}{\text{average } G(H) \text{ in region}}\right)+w_3\left(\frac{P(H)}{\text{average } P(H) \text{ in region}}\right)-w_4M(H)+ w_5\left(\frac{E(H)}{\text{average } E(H) \text{ in region}}\right)+w_6\left(\frac{W(H)}{\text{average } W(H) \text{ in region}}\right)-w_7\left(\frac{e'(H)}{\text{average } e'(H) \text{ in region}}\right)+ w_8\left(\frac{T(H)}{\text{average } T(H) \text{ in region}}\right)$$

The weighting is difficult to determine since it varies for each person. For some patients with severe illnesses mortality rate is the most important factor. Other times, costs may be an important consideration due to monetary concerns. These factors are different for everyone, so the best hospital also varies depending on an individuals circumstance. Therefore we let the user decide the specific weightings to place on each factor. (See memo.)

3.5 Testing

Due to the difficulty of obtaining data that is free, we will create some arbitrary hospitals to check that our model outputs reasonable values. We make all probability distributions for each factor from 1 to 10. This makes it easy to determine how good each hospital is relative to the weight factors. The input values will have issues in magnitude, but since we can simply change the units since the units cancel out when calculating a ratio with respect to the average. Also the input distribution may differ from reality. However, the model should not be affected by input distribution of the data and should work for any set of hospitals.

For the testing we generate 100 sets of data with each corresponding to a hospital. We run the program for the weighting factors below. The MATLAB code is included in the Appendix. The test results are shown in the the last column of Table 2.

Factor	Weighting	Value of Optimal Hospital
Coding Accuracy	5	9.0243
Resources	2	7.2793
Physical Attributes	3	6.7616
Mortality Rate	4	0.3026
Ethical Factors	1	7.9513
Waiting Time	2	7.44
Cost of Treatment	2	2.014
Advanced Equipment	4	7.016

Table 2: MATLAB output of best hospital with listed weights

From the table above, we can see that the factors that the user cared about (coding accuracy, mortality rate, and advanced technology) have a high amount of emphasis and are all at reasonably high values.

3.6 Sensitivity Analysis

Our model takes in various input data from different hospitals. We will assume that hospitals try their best to provide accurate information. However, sometimes there are calculation errors. For example a waiting time of 7 days and 8 hours may be recorded as 7 days. This introduces some uncertainty in the model. We run our simulation again for the testing with the same weights.

First we find the best hospital without any randomness. Then we run 1000 trials with each variable having a random factor drawn from a normal distribution with $\mu = 0, \sigma = 0.1$. To see how sensitive our model is, the code checks if the best hospital without error is in the top 5 of the hospitals with error. The results are shown in Figure 9.

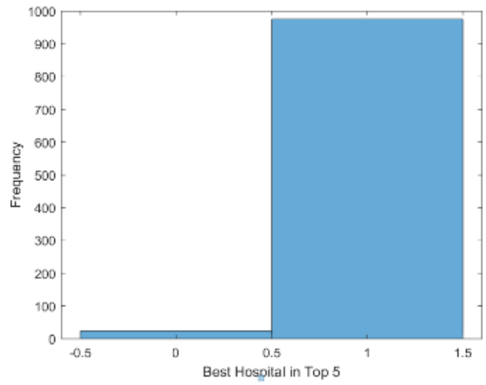


Figure 9: Results of binary trial with predicted μ and σ

3.7 Strengths and Weaknesses

3.7.1 Strengths

- Our coding and treatment accuracy complements our earlier evitable mortality model to include cases where the illness is not fatal and considers it from the standpoint of patient satisfaction. Also, the variables are independent of the illness, as only the relative efficiency of the optimal treatment compared to the other treatments are used in our calculation.
- The waiting time function takes in the full range of of possibilities with its symmetric nature modelled accurately with the arcsin function. - We have separate the total investments that a hospital has into several portions including its carrying capacity, staff-to-patient ratio, and level of technology. This enables separate weights to be put on these factors and results in an accurate final resource score.
- Our final cost function is independent of whether the patient has insurance as in the end, the amount the patient pays (either through taxes, insurance, or cash) is accounted for using adjustments.
- The physical attributes are based on regional preferences, so differences in demographics are taken into account when determining the scores for each individual attribute.
- Our ethics take into account non-patient experience, which indirectly affects the quality as these may be patients later.

3.7.2 Weaknesses

- While a treatment may be more effective in curing a disease than another treatment, the former does not necessarily satisfy the patient more, as the it may be less physically relaxing to go through and a patient may prefer the latter in this case. Furthermore, this is directly usable only on patients without comorbid illnesses. These are, however, rare cases and can be specifically dealt with using an extended questionnaire.

- Our waiting time does not take into account multiple separate stays but deals only with a single stay. A patient may, for instance, deal with long wait times by going outside the hospital for activities (and therefore the amount of these activities in close proximity to the hospital is another variable). Patients however, would most likely still view the *hospital's quality* as being negatively influenced by long wait time than being positive influenced by external satisfaction.

- We do not consider the preferences of the staff in dealing with patients in our staff to patient ratio, and this may result in staff procedures being incompatible with patients' desires. However, this is unlikely to influence the overall experience as patients are generally concerned more with the staffs' ability to treat or relieve illness, which is correlated with the aforementioned ratio.

- The use of insurance by a patient may not harm his/her overall income and therefore satisfaction, as this insurance is many times provided by their employer as a benefit.

- It is difficult to quantify how much of an impact and therefore calculate a score that physical attributes would have on a patient's experience. This can however be quite accurately determined using the hospital's budget to size ratio as a way to quantity its average quality throughout.

- A failure to reach the ethical standards may not be be sole fault of the hospital, as, for instance, government policies may prevent hospitals from utilizing renewable sources and use such sources on other projects. Although this can be recognized by the patient beforehand and therefore not rate ethical concerns to be high for hospitals in such a region.

4 Final Remarks

In summary, we developed separate models to consider the inevitable mortality rate, non-mortality hospital qualities, and disease-specific factors and later combined them to determine the best hospital for any patient. We first worked on finding the expected death in a hospital and comparing it to the actual death resulting in an accurate measure of a hospital's success rate in handling the overall patient's issues. We then extended this model with several other components of a hospital's service. This final model consists of weight factors set by the user through our memo, allowing them to customization the best hospital according to their needs.

If given more data, we can calibrate our model for specific data sets to yield precise information on the optimal hospital and this information can be customized to reflect particular regions and illnesses. Overall our models work well and, when given fixed parameters, can be depended on to give an accurate recommendation of a hospital.

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Appendix

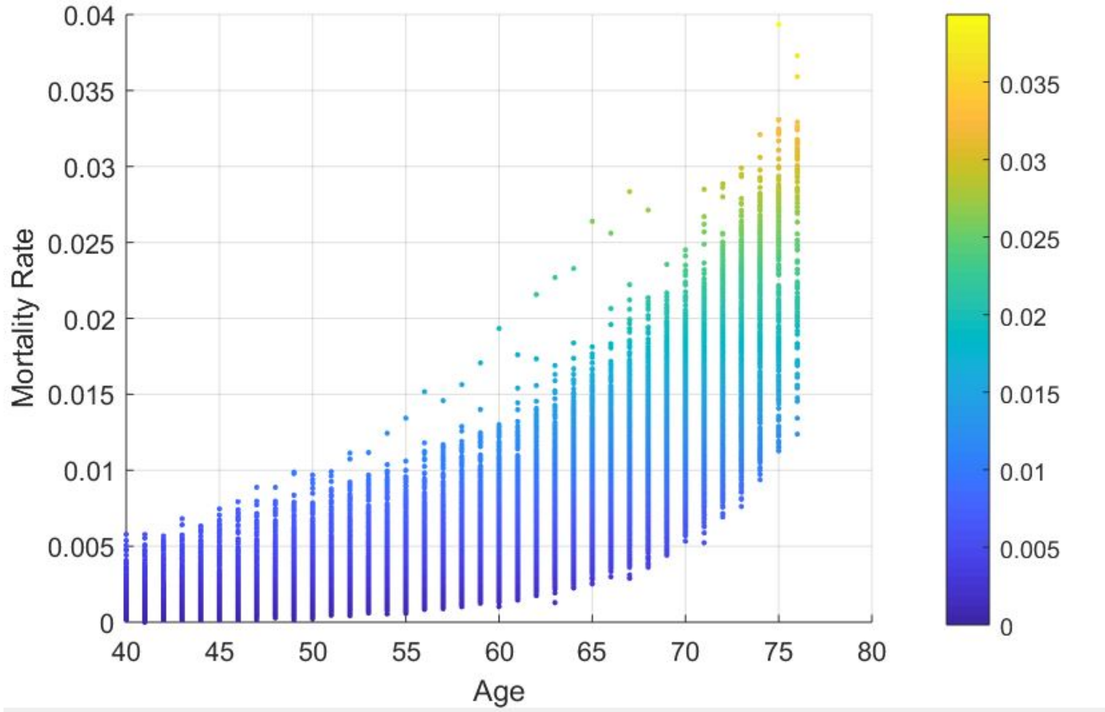

Figure 10: Age vs. Mortality Plot - Female

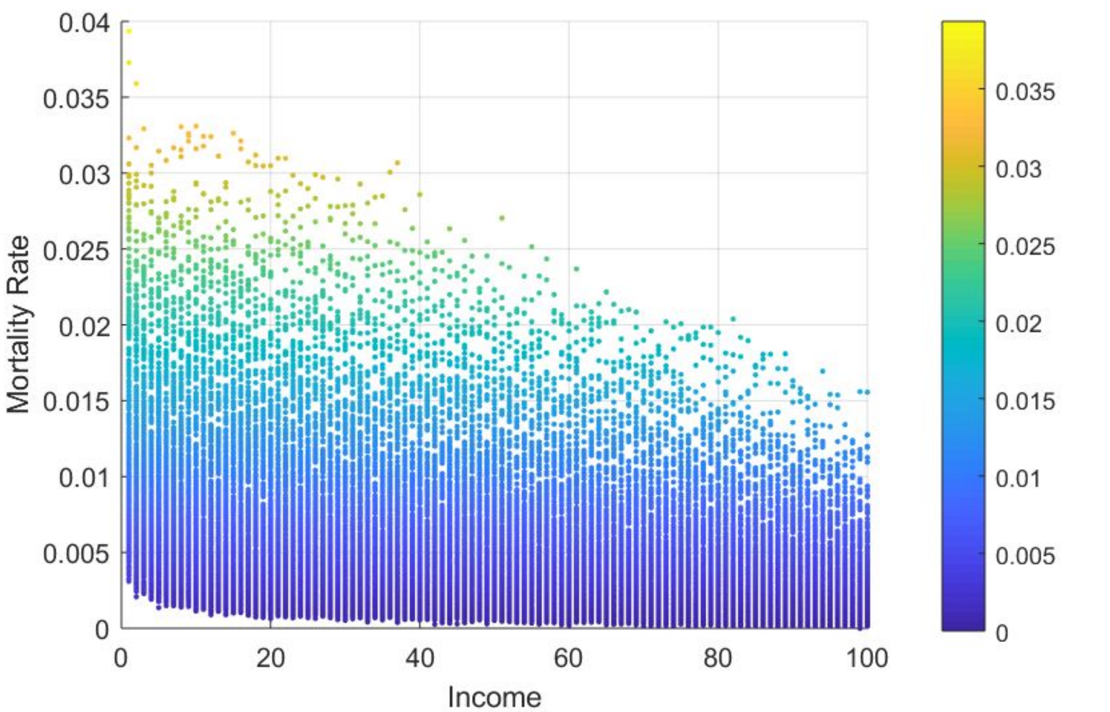

Figure 11: Income vs. Mortality Plot - Female

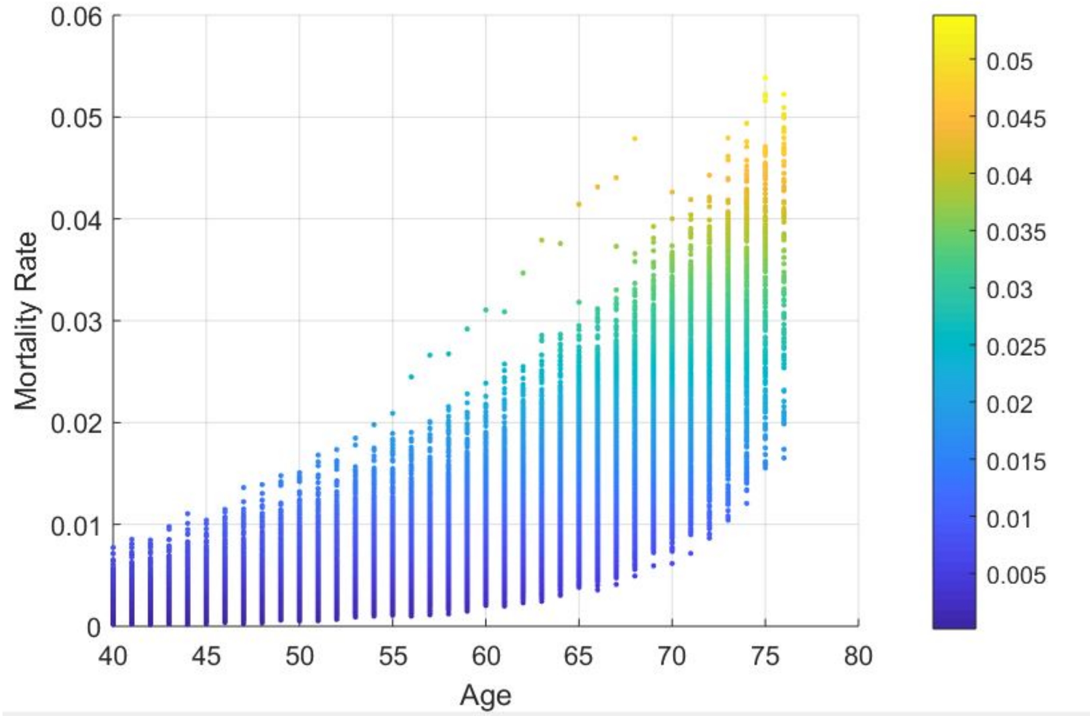

Figure 12: Age vs. Mortality Plot - Male

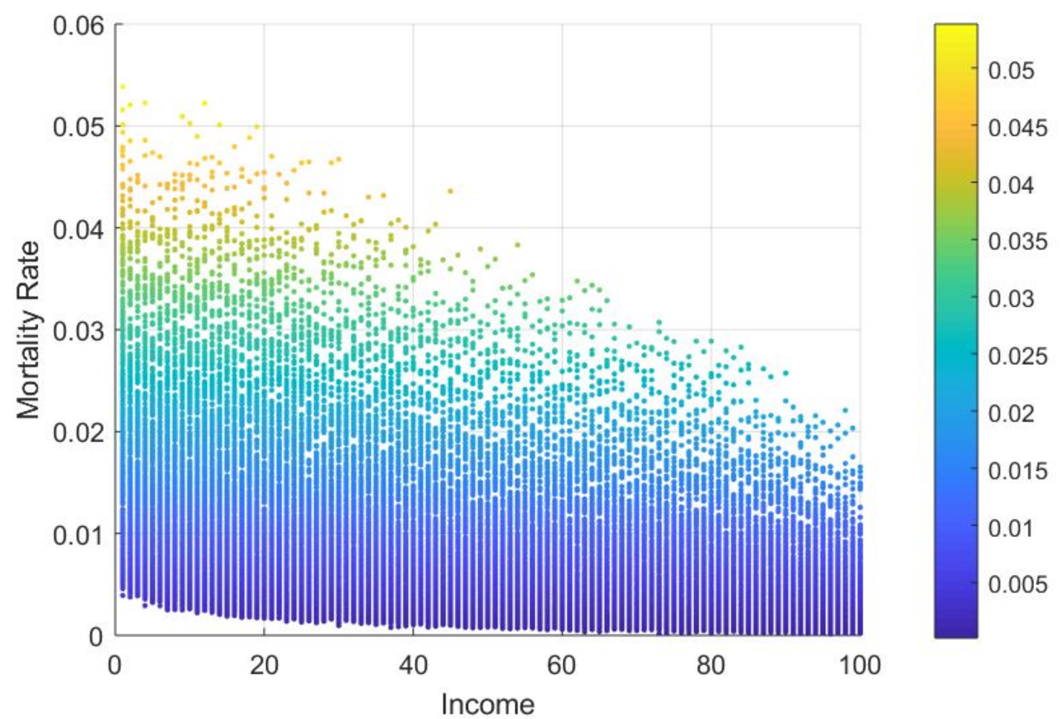

Figure 13: Income vs. Mortality Plot - Male

Study of Comorbidity Score vs. Mortality Rate							
Country (year of data)	CCI score → Mortality Ratio (%)						
	0	1	2	3	4	5	≥6
Australia (2008)	1.2	3.1	6.8	9.2	13.6	18.3	20.0
Canada (2008)	1.7	6.1	11.1	14.9	19.0	23.6	24.7
France (2004)	0.9	2.4	8.0	13.5	15.4	22.7	31.9
Japan (2008)	2.6	4.6	6.9	9.9	13.4	17.8	20.0
New Zealand (2008)	0.5	2.2	4.5	10.0	10.3	16.6	7.8
Switzerland (2008)	0.9	4.6	8.7	15.2	18.4	21.7	31.4
Average	**1.3**	**3.8**	**7.7**	**12.1**	**15.0**	**20.1**	**22.6**

Table 3: CCI to mortality rate translation for various countries

MATLAB CODE:

Curve Fitting Code:

```
%% Import data from spreadsheet
%% Import the data
[~, ~, raw] = xlsread('IMMC 2018\Female.xlsx','Sheet1','B2:D1401');
raw(cellfun(@(x) ~isempty(x) && isnumeric(x) && isnan(x),raw)) = {''};

%% Exclude rows with non-numeric cells
I = ~all(cellfun(@(x) (isnumeric(x) || islogical(x)) &&
~isnan(x),raw),2); % Find rows with non-numeric cells
raw(I,:) = [];

%% Create output variable
data = reshape([raw{:}],size(raw));

%% Allocate imported array to column variable names
Pecentile = data(:,1);
Year = data(:,2);
lifeEx = data(:,3);

%% Clear temporary variables
clearvars data raw I;

%% Format the data into groups to distinguish between male and female
idx = Gender ~= 'F';
fAge = Age(idx);
fIn = Income(idx);
fMort = Mort(idx);

mAge = Age(~idx);
mIn = Income(~idx);
mMort = Mort(~idx);

%% Fit: 'untitled fit 1'.
[xData, yData, zData] = prepareSurfaceData( fAge, fIn, fMort );

% Set up fittype and options.
ft = fittype( 'poly31' );

% Fit model to data.
[fitresult, gof] = fit( [xData, yData], zData, ft );

% Plot fit with data.
figure( 'Name', 'untitled fit 1' );
h = plot( fitresult, [xData, yData], zData );
legend( h, 'untitled fit 1', 'fMort vs. fAge, fIn', 'Location',
'NorthEast' );
% Label axes
xlabel fAge
```

```
ylabel fIn
zlabel fMort
grid on
view( -62.6, 22.5 );
```

Testing for the Mortality Model:

```
% Simulation of Mortality Model
% Perpose: to test the correctness of the model
% Simulation result: Mortality Model outputs the best choice of
hospital

%% Constants for female factors
fp00 = -0.09527;
fp10 = 0.006101;
fp01 = -0.0002458;
fp20 = -0.000131;
fp11 = 1.205e-5;
fp30 = 9.988e-7;
fp21 = -1.702e-07;

%% Constants for male factors

mp00 = -0.0738;
mp10 = 0.004776;
mp01 = -0.0002426;
mp20 = -0.0001028;
mp11 = 1.062e-05;
mp30 = 7.665e-07;
mp21 = -1.286e-07;

%% Hospital A
actualA = zeros (1,1000);
expectA = zeros (1,1000);
% Number of patients that will come on this trial
patA = 500 +randi(500,1, 1000);

%% Hopsital B
actualB = zeros(1,1000);
expectB = zeros (1,1000);
%Number of patients that will come on this trial
patB = 500 + randi(500, 1, 1000);

%% Simulation
for i = 1:1000
    %Hospital A
    for j = 1 : patA(i)
        % Random patient for Hospital A
        age = 60 + randi(40);
        income = randi(60);
        sickness = normrnd(0,1)*0.025 + 0.15;
        Cfactor = normrnd(0,1)*0.025 + 0.25;
```

```
        female = randi(2) - 1;
        % Actual death occuring
        if rand() < 0.1
            actualA(i) = actualA(i) + 1;
        end
        % Calculation for expected death at Hospital A
        if female == 1
            factor= fp00 + fp10*age + fp01*income + fp20*age^2 +
fp11*age*income + fp30*age^3 + fp21*age^2*income;
        else
            factor= mp00 + mp10*age + mp01*income + mp20*age^2 +
mp11*age*income + mp30*age^3 + mp21*age^2*income;
        end
        expectA(i) = expectA(i) + 1 - (1-factor)*(1-sickness)*(1-
Cfactor);
    end

    % Hospital B
    for j = 1 : patB(i)
        % Random patient for Hospital B
        age = 40 + randi(40);
        income = 40 + randi(60);
        sickness = normrnd(0,1)*0.025 + 0.1;
        Cfactor = normrnd(0,1)*0.025 + 0.2;
        female = randi(2)-1;
        % Actual death occuring
        if rand() < 0.1
            actualB(i) = actualB(i)+1;
        end
        % Calculation for expected death at Hospital B
        if female == 1
            factor= fp00 + fp10*age + fp01*income + fp20*age^2 +
fp11*age*income + fp30*age^3 + fp21*age^2*income;
        else
            factor= mp00 + mp10*age + mp01*income + mp20*age^2 +
mp11*age*income + mp30*age^3 + mp21*age^2*income;
        end
        expectB(i) = expectB(i) + 1 - (1-factor)*(1-sickness)*(1-
Cfactor);
    end
end

%% Comparison of Hospital

ratioA = actualA./expectA;
ratioB = actualB./expectB;
ABetter = zeros(100,1);

for i = 1: length(ratioA)
    if ratioA(i) < ratioB(i)
        ABetter(i) = 1;
    end
```

```
end
```

Uncertainty Analysis of Mortality Model

```
list = zeros(10000,1);

%% Uncertainty Analysis
for i = 1:10000
    fp00 = -0.09527;
    fp10 = 0.006101;
    fp01 = -0.0002458;
    fp20 = -0.000131;
    fp11 = 1.205e-5;
    fp30 = 9.988e-7;
    fp21 = -1.702e-07;
    sickness = 0.2 + normrnd(0,1)*0.003;
    Cfactor = 0.2 + normrnd(0,1)*0.0076;
    age = 60+rand();
    income = 50+norm(0,1)*0.5;

    factor= fp00 + fp10*age + fp01*income + fp20*age^2 +
fp11*age*income + fp30*age^3 + fp21*age^2*income;
    list(i) = 1 - (1-factor)*(1-sickness)*(1-Cfactor);
end
```

Testing for General Model:

```
%% Generate Hospitals
codeacc = 10*rand(1,100);
wait = 10*rand(1,100);
res = 10*rand(1,100);
cost = 10*rand(1,100);
mort = 10*rand(1,100);
phys = 10*rand(1,100);
ethic = 10*rand(1,100);
tech = 10*rand(1,100);
%% Getting user input to run model

disp ('Enter a value between 1(not important) and 5 (really important)
for all the following options.')

Wcodeacc = input('Accuracy of diagnosis: ');
Wres = input ('Resources (size, amount of nurses...): ');
Wphys = input ('Physical Attributes (Hygiene, User-friendly
environment): ');
Wmort = input('Mortality Rate: ');
Wethic = input ('Ethical factors (non-profit, confidentiality): ');
Wwait = input('Waiting time: ');
Wcost = input('Cost of Treatment: ');
Wtech = input ('Amount of advanced equipment: ');
```

```
%% Finding the Best Hospital
fCodeacc = codeacc ./ mean(codeacc);
fwait = asinh(wait-mean(wait));
fwait = fwait./mean(fwait);
fres = res./mean(res);
fcost = cost./mean(cost);
fmort = mort./mean(mort);
fphys = phys./mean(phys);
fethic = ethic./mean(ethic);
ftech = tech./mean(ethic);

rating = Wcodeacc*fCodeacc + Wwait*fwait + Wres*fres - Wcost*fcost -
Wmort*fmort + Wphys*fphys + Wethic*fethic + Wtech*ftech;

[~, idx] = max(rating);

disp('Here is some information about your hospital');

disp('Hosptital Name');
disp(idx);

disp('Coding Accuracy: ');
disp(codeacc(idx));

disp('Resources: ');
disp(res(idx));

disp('Physical Attributes: ');
disp(phys(idx));

disp('Mortality Rate: ')
disp(mort(idx));

disp('Ethics: ');
disp(ethic(idx));

disp('Wait time: ');
disp(wait(idx));

disp('Cost ');
disp(cost(idx));

disp('Advanced Technology ');
disp(cost(idx));
```

Sensitivity analysis for General Model:

```
%% Generate Hospitals
codeacc = 10*rand(1,100);
wait = 10*rand(1,100);
res = 10*rand(1,100);
```

```
cost = 10*rand(1,100);
mort = 10*rand(1,100);
phys = 10*rand(1,100);
ethic = 10*rand(1,100);
tech = 10*rand(1,100);
%% Getting user input to run model

disp ('Enter a value between 1(not important) and 5 (really important) 
for all the following options.')

Wcodeacc = input('Accuracy of diagonsis: ');
Wres = input ('Resources (size, amount of nurses...): ');
Wphys = input ('Physical Attributes (Hygiene, User-friendly 
environment): ');
Wmort = input('Mortality Rate: ');
Wethic = input ('Ethical factors (non-profit, confidentiality): ');
Wwait = input('Waiting time: ');
Wcost = input('Cost of Treatment: ');
Wtech = input ('Amount of advanced equipment: ');

%% Finding the Best Hospital
fCodeacc = codeacc./mean(codeacc);
fwait = asinh(wait-mean(wait));
fwait = fwait./mean(fwait);
fres = res./mean(res);
fcost = cost./mean(cost);
fmort = mort./mean(mort);
fphys = phys./mean(phys);
fethic = ethic./mean(ethic);
ftech = tech./mean(ethic);

rating = Wcodeacc*fCodeacc + Wwait*fwait + Wres*fres - Wcost*fcost - 
Wmort*fmort + Wphys*fphys + Wethic*fethic + Wtech*ftech;

[~, idx] = max(rating);

%% Simultion
best = zeros (1,1000);

for i = 1:1000
    codeacc = codeacc + normrnd(0,1)*0.1;
    wait = wait + normrnd(0,1)*0.1;
    res = res + normrnd(0,1)*0.1;
    cost = cost + normrnd(0,1)*0.1;
    mort = mort + normrnd(0,1)*0.1;
    phys = phys + normrnd(0,1)*0.1;
    ethic = ethic + normrnd(0,1)*0.1;
    tech = tech + normrnd(0,1)*0.1;

    fCodeacc = codeacc ./ mean(codeacc);
    fwait = asinh(wait-mean(wait));
    fres = res./mean(res);
```

```
    fcost = cost./mean(cost);
    fmort = mort./mean(mort);
    fphys = phys./mean(phys);
    fethic = ethic./mean(ethic);
    ftech = tech./mean(ethic);

    rating = Wcodeacc*fCodeacc + Wwait*fwait + Wres*fres - Wcost*fcost
- Wmort*fmort + Wphys*fphys + Wethic*fethic + Wtech*ftech;

    [~,index] = maxk(rating,5);

    if ismember(idx, index)
        best(i) = 1;
    end
end
histogram(best)
```