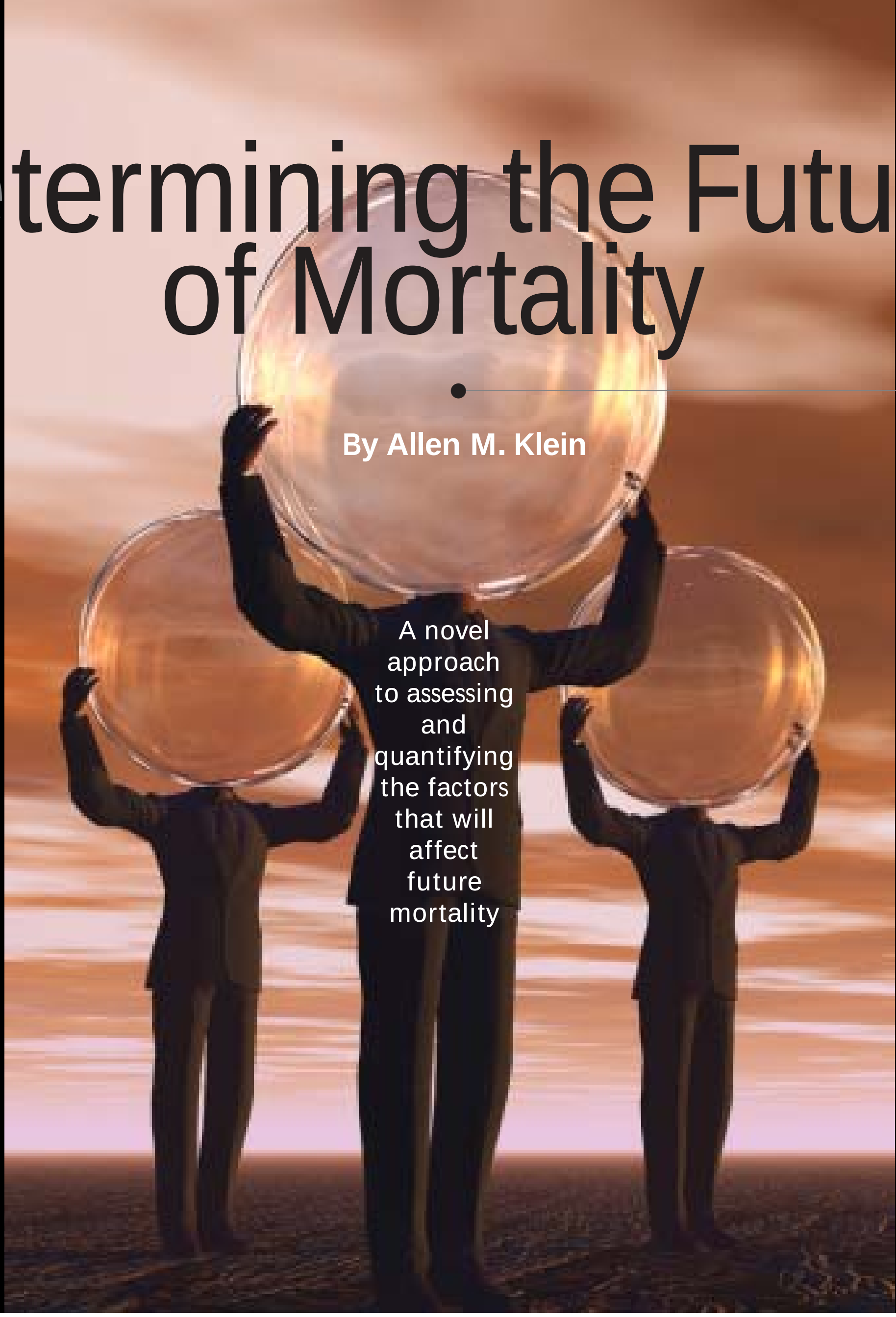
# Determining the Future of Mortality



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A novel approach to assessing and quantifying the factors that will affect future mortality

**THE YEAR IS 2250. "BACK WHEN I WAS YOUR AGE IN 2002 ..."**

Is this scenario possible? Yes. Is it likely? No. What is the future of mortality? Of aging? Of longevity? To answer these and similar questions, we first need to understand the concepts of aging, longevity, life expectancy, and mortality improvement, and the relationship between these concepts. This article will discuss these concepts and then take you through the development of a unique tool for projecting future mortality, using the cause elimination model as its basis.

Before we start any discussion on the future of mortality, it's important to distinguish between two terms that unfortunately have been used interchangeably, sometimes even among the experts. That is, the difference between life expectancy and life span. Life expectancy is the *average* age to which a group lives; life span is the *maximum* age to which a group can live.

Why is this important? We have seen tremendous improvements in life expectancy in the past century, while there has been absolutely no improvement in life span. According to the National Vital Statistics Report, Volume 47, life expectancy in 1900 was less than 50 for both males and females. In 1998, life expectancy for females had increased to almost 80. Life span is between 120 and 125 years and has remained at that level for as long as we know. There are a number of theories as to why this is, but these are beyond the scope of this article.

In order to expand life span, we first need to understand the aging process. A few issues are becoming clearer with ongoing research. Aging, the process involving the decline in function, begins after the reproductive years in most living organisms and continues until death. Aging doesn't kill people, but it makes them more susceptible to diseases; it's the diseases (or accidents) that kill people. However, we still don't really understand the process of aging today.

Although some research into the aging process is currently being conducted, greater resources are devoted to the more profitable task of finding cures for known diseases. A better un-

Table 1—Mortality Improvement vs. Life Expectancy (Based on the 1989–91 U.S. Life Tables)

| Mortality Improvement | Life Expectancy Male Ages 0 | 25 | 45 | 65 |
|---|---|---|---|---|
| None | 71.8 | 48.7 | 30.7 | 15.1 |
| 1% for 20 years | 74.3 | 50.9 | 32.5 | 16.0 |
| 2% for 20 years | 76.8 | 53.2 | 34.4 | 17.1 |
| 1% forever | 80.4 | 54.0 | 33.5 | 16.2 |
| 2% forever | 90.4 | 62.8 | 38.3 | 17.7 |
| **Percentage change** | **0** | **25** | **45** | **65** |
| 1% for 20 years | 3.5% | 4.6% | 5.9% | 6.1% |
| 2% for 20 years | 6.9 | 9.3 | 12.2 | 13.2 |
| 1% forever | 11.9 | 11.0 | 9.4 | 6.9 |
| 2% forever | 25.8 | 28.9 | 25.0 | 17.3 |

Table 2—Cause Elimination Effect on Life Expectancy

| Cause | Life Expectancy Age 0–1 | 45–50 |
|---|---|---|
| None | 75.4 | 33.4 |
| Tuberculosis | 75.4 | 33.5 |
| HIV | 75.6 | 33.5 |
| Diabetes mellitus | 75.6 | 33.7 |
| Motor vehicle accidents | 75.9 | 33.5 |
| Diseases of respiratory system | 76.3 | 34.4 |
| Major cardiovascular diseases | 82.1 | 40.3 |
| **Percentage change** | **0–1** | **45–50** |
| Tuberculosis | 0.0% | 0.0% |
| HIV | 0.3 | 0.2 |
| Diabetes mellitus | 0.3 | 0.7 |
| Motor vehicle accidents | 0.7 | 0.3 |
| Diseases of respiratory system | 1.3 | 2.8 |
| Major cardiovascular diseases | 8.9 | 20.5 |

*(Source: U.S. Decennial Life Tables 1989–91, Vol. 1, Number 4)*

derstanding of aging could eventually enable us to slow the aging process, and possibly even reverse it. Understanding the aging process might even allow us to better "immunize" individuals against certain diseases.

Much of today's research into increasing longevity has centered on diet (caloric restriction), free radicals and antioxidants, telomeres, and a number of other theories, again beyond the scope of this article. The key to longer life, besides inheriting good genes, is to eat well and to stay active physically, socially, and mentally. For some people, a diet with a little *more* fat and a lot *less* sugar could result in increased longevity.

Regarding increased longevity, it should be noted that researchers have been able to expand the life span of some multicelled organisms several times their original life span by lengthening the telomeres within the cells. It's unlikely that this approach will work on humans because our makeup is much more complex. But it's a start.

Can we live forever? That's doubtful. Consider inanimate objects. No matter how well we make them, they wear out. I don't know why that is, but if we can't create something that will last forever, how can we expect to live forever?

Even if we're able to replace human parts as they wear out (such as heart transplants), we will eventually have to replace all of our parts. What happens when we get to the brain? Would it even be the same person anymore?

### Mortality Improvement

How will mortality change over time? Improvements in mortality over the past century weren't smooth; in some years, mortality actually deteriorated. Will the overall improvements continue? Not as they have in the past, though new advances will help improve mortality.

There will also inevitably be setbacks along the way. No one expected the events of Sept. 11 and the ensuing war, but additional unexpected events (unknown diseases as we become more of a global community, catastrophes, etc.) could and probably will happen.

How far out can we push life expectancy? Without moving life span, certainly not beyond that. We might be able to move life expectancy to 90, 95, or even 100 with some major breakthroughs (e.g., eliminating heart disease and cancer), but we will never be able to reach beyond this without increasing life span. The cause elimination model, discussed below, can be used to more precisely quantify this maximum if we were to eliminate certain diseases.

When discussing mortality improvement, it's important to distinguish between the general population and the insurance population. Improvements in mortality in the general population can vary by

- Attained age
- Gender
- Socio-economic class
- Biological characteristics
- Behavioral characteristics
- Environment
- Medical resources

Improvements in mortality experience in the insurance population can vary by the same factors, plus

- Age and duration
- Product type
- Underwriting techniques
- Rate class
- Face amount of insurance

Table 1 provides a comparison between mortality improvement and changes in life expectancy for several ages. The purpose of this table is to provide a general idea about the relationship between mortality improvement and changes in life expectancy. It shows that in general, mortality improvement for a limited period has more of an impact on older ages while mortality improvement "forever" has more of an impact on the younger ages.

## The Cause Elimination Model

How will mortality (or life expectancy) change if a specific cause of death were to be eliminated? Many assumptions go into a model like this, but one of the most important is the assumption that the underlying disease is eliminated, rather than death due to that disease.

This is a subtle but important distinction. When eliminating the underlying disease, there are several theories on future longevity. One theory is that this person will live longer, no longer weakened by the disease. Another theory says that this person, while no longer vulnerable to this disease, is more apt to be vulnerable to other diseases. In this case, the person would live longer than he or she would have had the disease not been eliminated, but only moderately so. Yet another theory is that this person would now be subject to random events, coming down with another fatal disease either next year or 40 years from now.

If two or more causes of death are eliminated, the gains are not additive because these aren't independent events. The cause elimination model has fallen out of favor with some because of its dependence on causes of death as variables. But it serves as a fine basis for developing a tool for predicting the future of mortality.

Table 2 shows the change in life expectancy by eliminating certain causes of death; it's based on 1989 to 1991 U.S. Life Table data.

The table shows that there would be very little change in life expectancy at both birth and ages 45 to 50 if tuberculosis, HIV, or diabetes were eliminated. In recent years there have been significant increases in both tuberculosis and diabetes, and if the model were run today, the numbers would look somewhat different. Not surprisingly, the elimination of motor vehicle accidents would increase life expectancy more at the younger ages and an elimination of heart disease would increase life expectancy more at the older ages.

**Table 3—1998 Top Ten Causes of Death by Age Group for U.S. Population**

| | Ages 25–44 | | Ages 45–64 | | Ages 65+ | |
|---|---|---|---|---|---|---|
| 1 | Accidents | 20.7% | Cancer | 34.9% | Heart | 34.5% |
| 2 | Cancer | 16.3% | Heart | 26.3% | Cancer | 21.9% |
| 3 | Heart | 12.8% | Accidents | 4.8% | Stroke | 7.9% |
| 4 | Suicide | 9.3% | Stroke | 4.0% | COPD | 5.6% |
| 5 | HIV | 6.6% | Diabetes | 3.4% | Pneumonia/Flu | 4.7% |
| 6 | Homicide | 6.2% | COPD | 3.4% | Diabetes | 2.8% |
| 7 | Liver | 3.0% | Liver | 2.9% | Accidents | 1.9% |
| 8 | Stroke | 2.5% | Suicide | 2.1% | Kidney | 1.3% |
| 9 | Diabetes | 1.9% | Pneumonia/Flu | 1.6% | Alzheimer's | 1.3% |
| 10 | Pneumonia/Flu | 1.5% | HIV | 1.1% | Septicemia | 1.1% |

*(Source: National Vital Statistics Reports, Vol. 48, No. 11)*

## Predicting the Future of Mortality

In order to develop a tool for predicting future mortality, we must first identify the factors that will have an impact on future mortality improvement and deterioration.

The following lists, while not all inclusive, represent the suggestions of people at several sessions on this topic. Note that terrorist activities didn't show up on any list until after Sept. 11. Note also that some changes may cause both improvements and deterioration in mortality (e.g., globalization).

Items generating future mortality improvement:

- Improvements in healthcare
- Improvements in health education
- Improvements in safety
- Improvements in nutrition
- Medical advances
- Therapeutic advances
- Genetic research
- Early detection
- Improved access to medical care
- Globalization—more research and advances
- Environmental changes
- Shifting demographics
- Diet
- Telecommuting
- Cell phone usage
- Technology

Items generating future mortality deterioration:

- Catastrophes
- Terrorist activities
- War
- Globalization—prone to more diseases
- Natural disasters
- Nuclear accidents
- Global warming
- Outbreak of disease
- Stress
- Drug-resistant germs
- Pollution
- Smoking
- Side effects of new drugs
- Shifting demographics
- Increasing wealth disparity
- Cell phone usage
- Lack of sleep

The second item needed for the tool to predict future mortality improvement is the magnitude of the current causes of death. Table 3 shows this split by three age categories.

How do we tie all of this together and produce a tool for predicting future mortality improvement? First, determine the most important factors affecting future mortality improvement and

Table 4—Mortality Improvement Example—Effect of Improvements in Nutrition on Heart Disease as Cause of Death
*(Total share of Cause Eliminated—20%)*

| | Year | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| D—Discovery (% of Total) | | | 10 | | | 5 | | | | 25 | | | 5 | | | 5 | | | | 20 |
| I—Implementation (% of D) | 5 | 10 | 15 | 5 | 5 | 5 | 5 | 5 | 5 | | | | | | | | | | | |
| E—Effect (% of I) | 1 | 1 | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 9 | 9 | 10 | | | | | | | | |

Table 5—Mortality Improvement Example—Effect of Improvements in Nutrition on Accidents as Cause of Death
*(Total share of Cause Eliminated—2%)*

| | Year | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| D—Discovery (% of Total) | | | 5 | | | 5 | | | | 10 | | | 5 | | 10 | 5 | | | | 10 |
| I—Implementation (% of D) | 15 | 15 | 10 | 10 | 10 | | | | | | | | | | | | | | | |
| E—Effect (% of I) | 10 | 20 | 30 | 5 | | | | | | | | | | | | | | | | |

deterioration, and the current causes of death. Then, for each factor affecting mortality, determine the impact it has on each cause of death. This can be done in a series of five steps.

1 Determine the overall percentage of each cause that will be eliminated.

2 Determine when this event will be *discovered* and the magnitude of the discovery.

3 Determine when this event will be *implemented* and its magnitude over time.

4 Determine how long it will take for this event to become *effective* and its magnitude over time.

5 Finally, determine the sum across all causes and then all events.

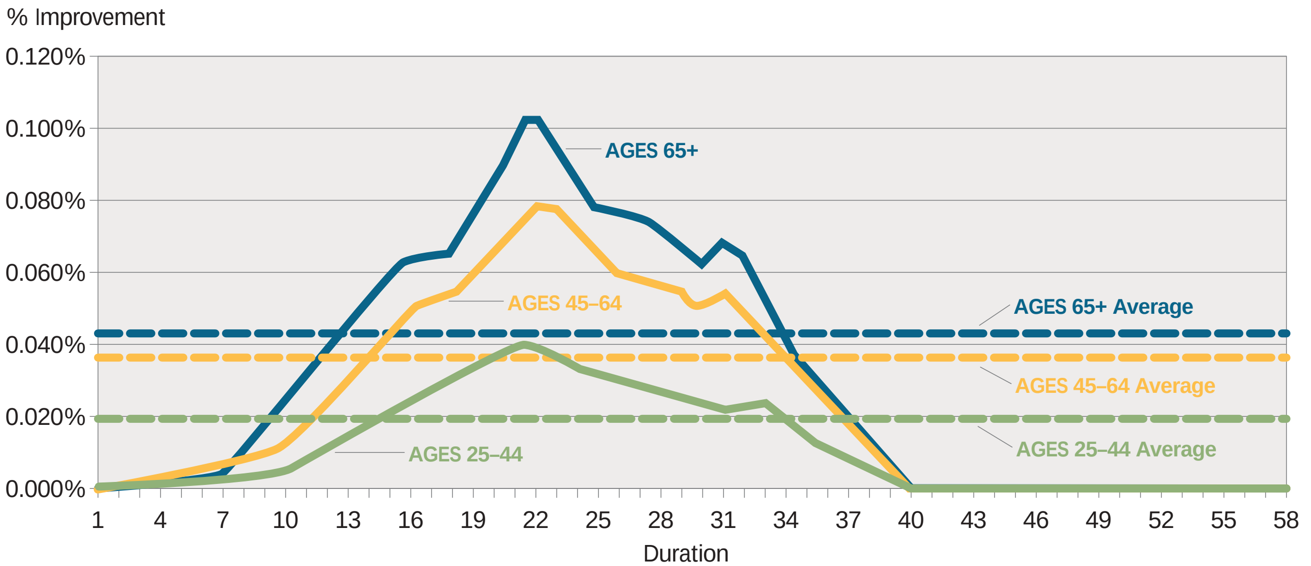
What does all of this mean? An example will illustrate how the tool works. Let's assume that we would like to determine the impact of advances in nutrition on heart disease and accidents.

Table 4 and Table 5 show my assumptions. First (Step 1), I'm assuming that 20 percent of all heart disease deaths will be eliminated due to improvements in nutrition (see Table 4). Whether you agree with this and my other assumptions doesn't matter at this point. These are for illustrative purposes only.

Second, I'm assuming that improvements in nutrition will be discovered about every three years, in this case in years 3, 6, 10, 13, 16, and 20. The magnitude of these discoveries varies. In year 3, 10 percent is shown. This means that of the overall 20 percent of the heart disease deaths that will be eliminated because of improvements in nutrition, one-tenth of these will be related to the discovery made in year 3. Note that if you add across on the *Discovery* line, you get 70 percent, which is less than 100 percent. I have done this deliberately because I'm showing only 20 years worth of data and I believe there will be more improvements in nutrition beyond the 20 years.

The third step is implementation. Once the discovery has been made, how quickly will people implement it? Here, I'm assuming it will be implemented over 9 years from the time of

Improvements in Nutrition



discovery. So for the 10 percent discovery in year 3, 5 percent will implement it that year, 10 percent will implement it the next year (fourth year from now) and so on.

For the 5 percent discovery in year 6, again 5 percent of those will implement the change that year, 10 percent the next year (seventh year from now), etc.

If you add the *Implementation* row across, it adds up to 60 percent (again, not 100 percent). The reason for this is that even though people know a certain improvement in nutrition will help with heart disease, not everyone will implement it.

For Step 4, just because it was implemented, it may take some time for it to become effective. For the 5 percent that implemented the change in year 3, 1 percent of those will realize the effect of their efforts in that year, 1 percent will realize it the next year (fourth year from now) and so on, based on the assumptions shown in Table 4.

Of the 10 percent that implemented in the second year following discovery, the same percentages apply. That is, 1 percent becomes effective that year (fifth year from now), 1 percent the next year, and so on. If you add across the *Effect* line, it totals 60 percent (again less than 100 percent). Just because something is implemented doesn't mean it will work for everyone. So there will generally be some percentage of individuals who, despite implementation, just won't benefit from the potential effect. Note that the 60 percent total for both *Effect* and *Implementation* is pure coincidence.

How will improvements in nutrition affect the cause of death by accidents? First, I've assumed that only 2 percent of the overall accidental deaths will be eliminated because of improvements in nutrition, as opposed to the 20 percent for heart disease. (see Table 5.) Next, I've made the same assumption for discovery every three years or so. However, here I'm assuming that each one will have a smaller impact on the overall elimination, and I've added an extra discovery in year 15.

I'm assuming that this extra discovery will increase alertness and reduce accidents, but will have no impact on reducing heart disease. I'm also assuming that these changes will be implemented more quickly and take effect more quickly than those for heart disease, as can be seen by comparing the numbers in Tables 4 and 5.

Now let's look at the results of these assumptions graphically and see what we can conclude. Graph 1 shows the results by age, based on the cause of death results previously discussed. As you can see, the largest improvement is for ages 65+ and the smallest is for ages 25 to 44. The horizontal lines show the average for each of the three age groupings. For ages 65+, based on the assumptions just presented, there's an average improvement in overall mortality of just over 0.04 percent. A peak of about 0.10 percent is reached about duration 22.

What can be concluded from this? If you were to do this calculation over all major events and the largest causes of death, you should be able to better predict future mortality improvement (and/or deterioration). From this example, it might be reasonable to assume mortality improvement based on improvements in nutrition on these two causes of something closer to the 0.10 percent peak, rather than the 0.04 percent average, because this example covered only the first 20 years.

This tool can best be used with other tools to help predict future mortality improvement. As with any model, the tool is only as good as the assumptions that go into it. The Excel spreadsheet used to help with this model can also be enhanced to provide more (or less) detail to suit individual needs and preferences.

In conclusion, there are many uncertainties as to the future of mortality. There will be improvements and deterioration coming at unexpected and surprising times in the future. We should look at this issue again in 100 or 200 years. Or maybe sooner!

And now, back to the future. The year is 2250 again. "Back when I was your age in 2002, research was just beginning on how to reverse the aging process. It wasn't until 55 years after that that the real breakthrough occurred—and just in time for me!"

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