

# Life table Analysis

Mortality experience of the  
Aruban population, 2010

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& Applications

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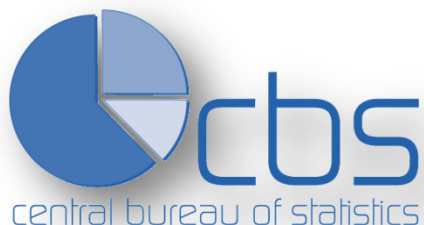
Fontys mentor: Chris Horlings

## Preface

In August 2011, undersigned, a fourth year student of the study Mathematics & Applications of the Fontys Hogescholen in Tilburg, started a study on the life expectancy of the Aruban population at the Central Bureau of Statistics (CBS) in Aruba. In order to make an calculation of the life expectancy for both men and women, life tables were constructed. The last life tables were set up ten years ago after the 2000 Aruban Population and Housing Census. During my internship, I found the atmosphere very pleasant at the CBS. This good atmosphere and the interesting content of the assignment have contributed to the successful completion of my internship. The findings of my work are presented in this report.

I could not have successfully completed my internship without the support of some people. A word of gratitude goes to my mentor and director of the CBS, Mr. Martijn Balkestein and also to Mr. Frank Eelens, who has helped me with any technical questions I had. I also like to thank the staff of the department of Project & Research, who were always ready to give me tips and suggestions. Finally, I thank Mr. Chris Horlings, who is my mentor at the Fontys Hogescholen.

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## 1. Introduction

The main goal of this research is to construct and analyze a life table using data from the Population Census 2010 and from other sources such as the Population Registry and Department of Public Health of Aruba. A life table is made to measure mortality, survivorship and life expectancy of a population by age and sex and is used by a variety of specialists in a large numbers of ways. Life tables are in essence, fitting the mortality experience of a population at different ages into a single descriptive statistical model.

Chapter 2 gives a summary of all the findings. In chapter 2 there will be a description of the assignment and its context and importance. Chapter 3 explains the methodology; the guidelines and techniques used for solving this research problem. The data source and the data processing are described in chapter 4. The results of this research can be found in chapter 5. Chapter 6 gives a summary of all the findings and recommendations for further research. The last chapter, chapter 7, contains the appendices of this report.

## 2. Problem Description

### 2.1 Assignment

A life table analysis is necessary to calculate the life expectancy for both men and women. On Aruba, only once in every ten years it is possible to make a life table using the data from the Population Census. By August 2011 the Census database from the 2010 Population and Housing Census became available. It was considered a high priority by the CBS of Aruba to construct a life table as soon as possible after the data became available.

To construct a life table for Aruba it is very important to use a number of data sources from outside the CBS. For this study data from the Social Security Bank (SVB), the Department of Public Health (DVG) and the Population Registry of Aruba (Bevolkingsregister) were also used. Last time, in the year 2000, the life expectancy decreased by about one year compared to 1991, probably because of the poor lifestyle of the Aruban residents (77% are overweight, the Quetelet-index (QI) for men was 30, the average man was obese). At the beginning of this research, is unknown to what extent the results will differ. There seems to be little improvement in the lifestyle of the Aruban population, and also the healthcare provided by AZV has reached a higher level and medical improvements have been made.

In connection with, among others, life insurances, pension and public health policies, it is clear that a solid research needed to be done to investigate the current situation.

Obviously, such an important research could not be given to an apprentice without any guidance. CBS has a doctor in demographics, who has already done this sort of work in the past. He has provided the technical details. Also, the director Mr. Martijn Balkestein has always had an affinity with population statistics and he wanted to supervise the construction of the life table. Even so, CBS always expects a considerable amount of independence of an intern.

The end product is a report that includes the results of this research and description of the use of the different data sources. Also, an explanation on how the data was processed. The new results must be compared with the results obtained in the past. There will be more topics linked to the research, but of course this is beyond the scope of this report.

## 2.2 The importance of the study

Mortality is an indicator of the health situation, living conditions and the ageing process of a population. The life table analyses are of interest to a number of disciplines and fields, including health, demography and actuary. It can be used for analyzing population growth as well as for making projections of population size and structure. In the actuarial field, the mortality and survival rates are used to make an estimation of the premium that has to be paid for insurances.

## 3. Methodology

### *Introduction*

As previously stated, life tables are a form of combining mortality rates of a population at different ages into a single statistical model. They are used to measure the mortality and survival rates and probabilities by age and sex of the population involved. The most used element found in a life table is the life expectancy. An important characteristic of life tables is that their statistics are comparable across different populations and over time, therefore they do not require the adoption of a standard population for adequate comparisons of levels of mortality.

Life tables differ on some aspects. One aspect is the reference period of the table. Another one is the age detail. There are two types of life tables according to the reference year: the current and the cohort life table.

The current life table is based on the mortality experience over a short period of time, such as one or three years. The statistics concerning the number of deaths that are used are then also taken over this period and the population data used is taken from the middle of that period (midyear population), usually close to the data of a Census. The current life table does not represent the mortality experience of an actual cohort; instead it assumes a hypothetical cohort that is influenced by the age-specific death rates observed in that particular period. The cohort life table is based on the mortality rates experienced by a particular birth cohort (for example all persons born in the year 1940). According to this type of table, the mortality experience of the persons in the cohort would be observed from their moment of birth through each consecutive year until all of them die. This means that data over a long period of time is needed to complete one life table.

Cohort or current life tables can be either complete or abridged. This refers to the length of the age interval in which the data are presented. A complete life table contains every single year of age from birth to the last applicable age. An abridged life table contains intervals of age, varying from 5 or 10 years (with the possible exception of the first year of age). This table is less demanding on the data as we can use five year age intervals. The life table used in this report is the current abridged life table.

## Functions

The basic life table functions are:  $q(x,n)$ ,  $l(x)$ ,  $D(x,n)$ ,  $L(x,n)$ ,  $T(x)$ ,  $e(x)$ <sup>1</sup>. These six indicators are generally calculated and used for every life table. In some cases, due to limitations of space, some of the columns are not presented. But because most of these functions can be directly calculated from others, there is no significant loss. In general, the probability of dying  $q(x,n)$  is the basic function in the table. To know the value of  $q(x,n)$  we must first calculate  $M(x,n)$ , the mortality rate. The life table used in this report will have the form shown below.

Age (x)	n	a(x,n)	Deaths d(x,n)	Census population P(x,n)	M(x,n)	q(x,n)	p(x,n)	l(x)	D(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	1	0.09	...	...	...	...	...	...	...	...	...	...	...
1	4	0.4	...	...	...	...	...	...	...	...	...	...	...
5	5	0.5	...	...	...	...	...	...	...	...	...	...	...

### Age, intervals and fraction last year lived

The age interval in this table is 5 for age 5 and above. The first interval is 1 and the second is 4. The last applicable age interval is 95+. The variable n stands for the length of the intervals.

An important element in a life table is the fraction of the last year lived,  $a(x,n)$ . Each person who dies during the interval  $(x, x+n)$  has lived  $x$  completed years plus some fraction of the year  $(x, x+n)$  in which he/she dies. Infant deaths tend to occur early in the first year of life. The  $a(x,n)$  value for this interval is around 0.1 in developed countries and higher where infant mortality rates are higher. If infant mortality per 1000 infants lies under 20 then the value used for  $a(x,n)$  is 0.09. The values for young childhood intervals are around 0.4. For adults is the value for  $a(x,n)$  0.5, on the assumption that deaths occur linearly throughout the year<sup>2</sup>.

### Deaths and midyear population

The next column represents the amount of deaths  $d(x,n)$  in the period between the 29<sup>th</sup> of March 2010 and 29<sup>th</sup> of March 2011 for each age category; this means that data are used over a period of one year. These dates are chosen because the Census of Aruba took place from September 29 to October 6, 2010. The enumeration is organized in such a way that all questions relate to the situation on

<sup>1</sup> The meanings of these function are the following:

- $q(x)$  = the age specific probability of dying between ages  $x$  and  $x+n$
- $l(x)$  = the function of survival, being the number of survivors in the life table at exact age  $x$ , out of an initial population of 100000 at age 0
- $D(x,n)$  = the function of death, being the number of deaths in the life table between ages  $x$  and  $x+n$
- $L(x,n)$  = the total number of person-years lived by the total population between ages  $x$  and  $x+n$
- $T(x)$  = the total number of person-years lived by the cohort after exact age  $x$
- $e(x)$  = the expectation of life, being the average number of years yet expected to be lived by a person at age  $x$

<sup>2</sup> Abridged life table. In *StatsDirect Statistical Software*. Retrieved from [http://www.statsdirect.com/help/statsdirect.htm#survival\\_analysis/abridged\\_life\\_table.htm](http://www.statsdirect.com/help/statsdirect.htm#survival_analysis/abridged_life_table.htm)

September 29, 2010 at midnight. This is called the Census moment. The population counted on the Census moment therefore represents the midyear population  $P(x,n)$ . The midyear population can also be considered as the total number of years lived during the interval by those alive at its start.

### **Mortality rate and derivation of age-specific probabilities**

The basic quantities are  $d(x,n)$  and the corresponding age-specific death rate  $M(x,n)$ . Mortality rates are calculated on the basis of observed deaths and the mid-period population. Let  $N(x)$  be the number of people alive at the exact age  $x$ , among whom  $d(x,n)$  deaths occur in the interval  $(x, x+n)$ . The age-specific mortality rate  $M(x,n)$  is the ratio of  $d(x,n)$  to the total number of years lived by the  $N(x)$  people during interval  $(x, x+n)$ . This total number is the sum of  $(N(x) - d(x,n)) \times n$  years lived by the survivors in each interval and  $a(x,n) \times d(x,n) \times n$  years lived by those dying during each interval. In formula:

$$M(x,n) = \frac{d(x,n)}{(N(x) - d(x,n)) \times n + a(x,n) \times d(x,n) \times n}$$

When the denominator is estimated with the corresponding midyear population then we have:  $(N(x) - d(x,n)) \times n + a(x,n) \times d(x,n) \times n = P(x,n)$ .

Therefore we have:

$$M(x,n) = \frac{d(x,n)}{P(x,n)}$$

The function  $q(x,n)$  is an estimate of the probability that an individual alive at the exact age  $x$  will die during the interval  $(x, x+n)$ . In formula this is written as:

$$q(x,n) = \frac{d(x,n)}{N(x)}$$

We do not know the value of  $N(x)$  because this is never used in everyday life. This is why this function has to be rewritten. To accomplish this we first must rewrite  $P(x,n)$ . Write  $N(x)$  outside parenthesis:

$$(N(x) - d(x,n)) \times n + a(x,n) \times d(x,n) \times n = P(x,n)$$

$$n \times N(x) = P(x,n) + d(x,n) \times n - a(x,n) \times d(x,n) \times n$$

Divide everything by  $n$ :

$$N(x) = \frac{P(x,n)}{n} + d(x,n) - a(x,n) \times d(x,n)$$

Now  $N(x,n)$  can be filled in the function  $q(x,n)$ :



$$q(x, n) = \frac{d(x, n)}{\frac{P(x, n)}{n} + d(x, n) - a(x, n) \times d(x, n)}$$

Now multiply the numerator and denominator (on the right side) by n:

$$q(x, n) = \frac{d(x, n) \times n}{P(x, n) + d(x, n) \times n - a(x, n) \times d(x, n) \times n}$$

Dividing the numerator and denominator (on the right side) by  $P(x, n)$ , we obtain the relation between  $q(x, n)$  and  $M(x, n)$ :

Remember that:  $M(x, n) = \frac{d(x, n)}{P(x, n)}$

$$q(x, n) = \frac{M(x, n) \times n}{1 + M(x, n) \times n - a(x, n) \times M(x, n) \times n}$$

$$q(x, n) = \frac{M(x, n) \times n}{1 + (1 - a(x, n)) \times M(x, n) \times n}$$

The function  $p(x, n)$  is the probability that a person alive at age  $x$  will survive during the interval  $(x, x+n)$ . This means that  $p(x, n)$  is equivalent to one minus the probability that someone alive at age  $x$  will die during the interval  $(x, x+n)$ . In formula:

$$p(x, n) = 1 - q(x, n)$$

### **Function of survival and death**

Function  $l(x)$  stands for the numbers of persons living at the beginning of the indicated age interval out of the total number of births assumed as the radix of the table. The cohort of newborn babies (radix) is usually taken as 100000. In other words, we are constructing an artificial cohort of 100000 and making them subject to the estimated mortality regime. Consequently, the first value in this column is 100000. The value for each  $l(x+n)$  we can calculate by multiplying  $p(x)$  and  $l(x)$ :

$$l(x+n) = p(x, n) \times l(x)$$

For example:  $l(30) = p(25) \times l(25)$ .

$D(x, n)$  is a function that gives the number of deaths in the life table between ages  $x$  and  $x+n$ . This is based on the function  $l(x)$ . The number of deaths in the life table is simply the difference of people living at the beginning and the end of each interval. In formula:

$$D(x, n) = l(x) - l(x+n)$$

### **Number of years lived and survival rate**

$L(x,n)$  is the total number of person-years lived by the total population between ages  $x$  and  $x+n$ . The total number of years lived can be calculated by summarizing the number of people alive at age  $x+n$  and the average years lived by the people who die between  $x$  and  $x+n$ . The number of people alive at age  $x+n$  contribute all  $n$  years to the number of years lived. For the people who die at an age between the age-intervals, they contribute  $n \times a$  living years. This written in a formula:

$$L(x,n) = n \times l(x+n) + a \times n \times D(x,n)$$

$$L(x,n) = n \times (l(x+n) + a \times D(x,n))$$

The length of the last interval is infinite and the necessary information for determining the average number of years lived by an individual beyond the last interval is unavailable. The ratio  $\frac{D(x,n)}{L(x,n)}$  is known as the life table death rate for age  $x$ . Since a life table is based on the age-specific death rates of the current population, the death rates computed from the life table is equal to the corresponding rates of the current population:

$$\frac{D(x,n)}{L(x,n)} = M(x,n) = \frac{D(x,n)}{P(x,n)}$$

This means that:

$$L(x,n) = \frac{D(x,n)}{M(x,n)}$$

Since each one of the people alive  $l(x)$  will die during the last interval, it can be concluded that  $L(x,n)$  in the last interval is calculated with the formula:

$$L(x,n) = \frac{l(x)}{M(x,n)}$$

The function  $S(x,n)$  gives the probability of surviving between two groups of completed years. This survival rate is necessary for the construction of demographic projection models. Survival rates for age groups of the population are computed from the  $L(x,n)$  values of the life table. The  $L(x,n)$  value for the initial age group being given in the denominator of the rate and the  $L(x,n)$  value for the terminal age group being given in the numerator:

$$S(x,n) = \frac{L(x+n,n)}{L(x,n)}$$

If survival from birth to a given age interval is wanted, then the form of the survival rate is:

$$S(0,5) = \frac{L(5,5)}{5 \times l(0)}$$

### **Total after lifetime and expectation of life**

The total number of person years lived beyond age  $x$  is calculated with  $T(x)$ . This total is equal to the sum of the number of years lived in each age interval beginning with age  $x$ :

$$T(x) = L(x,n) + L(x+n,n) + L(x+2n,n) + \dots$$

With the obvious relation:

$$T(x) = L(x,n) + T(x+n)$$

It can be concluded that the last interval for the function  $T(x)$  is equal to  $L(x,n)$  in the final age interval.

The observed expectation of life at age  $x$ , is estimated by  $e(x)$ . This is the average number of years yet expected to be lived by a person at age  $x$ . This column is the most important in the life table. As a rule, the life expectancy decreases as the age  $x$  increases. There can be an exception in the first year of life, when the reverse mentioned above can occur due to high infant and child mortality. In formula the life expectancy is calculated by:

$$e(x) = \frac{T(x)}{l(x)}$$

In order to calculate all these functions, some sources have to be used. The next chapter will elaborate more on this topic.

## **4. Data Source and Data Processing**

To construct a life table, a number of data had to be obtained. The last time a life table was constructed on Aruba, in the year 2000, only data from the Population Registry of Aruba (number of deaths by age) and the Census (population by age) were used. Currently, more data sources on mortality are available, which allows us to make a more detailed quality assessment of the number of deaths by age.

As already mentioned above, deaths were taken over the period between the 29<sup>th</sup> of March 2010 and 29<sup>th</sup> of March 2011 for each age category. The midyear population was taken from the 2010 Population Census of Aruba. The enumeration at the Census was organized in such a way that all information relates to the situation on September 29, 2010 at midnight. The population counted on the Census moment therefore represents the midyear population between the 29<sup>th</sup> of March 2010 and 29<sup>th</sup> of March 2011. The table below presents the population of Aruba.

Table 1: Population by age and sex

Age	Male	Female	Total
0	560	558	1117
1-4	2767	2624	5391
5-9	3597	3441	7039
10-14	3800	3698	7498
15-19	3780	3525	7304
20-24	2727	2554	5282
25-29	2555	2926	5481
30-34	2904	3505	6409
35-39	3513	3962	7475
40-44	3828	4435	8263
45-49	4355	4891	9246
50-54	3880	4530	8410
55-59	3198	3699	6897
60-64	2349	2787	5136
65-69	1721	2020	3741
70-74	1244	1691	2935
75-79	811	1166	1976
80-84	412	684	1095
85-89	171	327	498
90-94	56	160	217
95+	14	60	74
<b>Total</b>	<b>48241</b>	<b>53243</b>	<b>101484</b>

Source: Central Bureau of Statistics, Population and Housing Census 2010

The AZV is a general social health insurance that covers almost every resident on the island (98%). Data from AZV are important for our analysis because they also include persons, who were resident of Aruba but died abroad. The DVG is the Department of Public Health on Aruba. This department is involved in the development of health policies and programs and the epidemiology of Aruba. They collect data on the number of deaths by cause and other characteristics.

The DVG and AZV were contacted to obtain data on registered deaths. Data of the Population Registry of Aruba (Bevolkingsregister) was already available at the CBS. It was also considered to approach the Dr. Horacio Oduber Hospital of Aruba, but it became clear that this was not necessary, because the DVG had all the data on mortality already available from the hospital.

All three sources contained the variables sex, date of birth, date of death and address. The AZV data also had the variables name and place of birth. The variable place of birth was also available in the data of the Population Registry. The processing began by organizing and cleaning up the data in Excel. Access was also used to process the data of the three different sources. First the data of AZV and DVG were compared. When the data were not the same on all the variables, the records were checked one by one. A filter variable was created to make a distinction between both types of cases. Subsequently, data of AZV and the Population Registry were compared. Lastly, data of the Population Registry were compared to DVG. This had to be done only for those cases that were not present in the data of AZV. After processing the files, a table with the number of deaths was made.

Table 2: Number of deaths by age and sex

Age	Male	Female	Total
<b>0</b>	4	9	13
<b>1-4</b>	0	1	1
<b>5-9</b>	0	0	0
<b>10-14</b>	1	0	1
<b>15-19</b>	1	1	2
<b>20-24</b>	4	1	5
<b>25-29</b>	5	1	6
<b>30-34</b>	5	2	7
<b>35-39</b>	9	6	15
<b>40-44</b>	10	7	17
<b>45-49</b>	15	8	23
<b>50-54</b>	26	11	37
<b>55-59</b>	29	24	53
<b>60-64</b>	35	25	60
<b>65-69</b>	48	28	76
<b>70-74</b>	49	36	85
<b>75-79</b>	56	42	98
<b>80-84</b>	37	40	77
<b>85-89</b>	28	35	63
<b>90-94</b>	16	28	44
<b>95+</b>	6	16	22
<b>Total</b>	<b>384</b>	<b>321</b>	<b>705</b>

Source: AZV, DVG and Population Registry

## 5. Life expectancies of the Aruban Population

Human development is about building human capacities, the amount of things that people can do and what they can be. People are limited in what they can do with that freedom if they are, among other things, poor or ill. The most basic capabilities for human development are leading a long and healthy life. Also being educated and having adequate resources for a decent standard of living. In many countries it is known that life expectancy is rising in the last couple of years. In Aruba it was the case that in the year 2000 the life expectancy for both men and women fell by just over a year compared to 1991. It was unknown to what extent the results of life expectancy will differ this time. In this chapter we make a few analyses regarding the expectation of life of the Aruban population.



### A higher life expectancy

The higher the life expectancy, the better shape a country is in. More developed regions of the world generally have higher life expectancies than less developed regions. The last time a life table was constructed on Aruba, in the year 2000, only data from the Population Registry of Aruba for the number of deaths were used. Currently, more data sources on mortality are available, the General Health Insurance and the Department of Public Health of Aruba delivered these additional data. The data were linked to the data of the Population Census 2010. Today, life expectancy is 73.88 years for men and 79.75 for women. In the year 2000, the life expectancy for men and women were 70.01 and 76.02 years. It is satisfying to learn that the expectation of life has not only increased, but also with nearly four years for both sexes.

Figure 1: Life expectancy at birth by sex and year

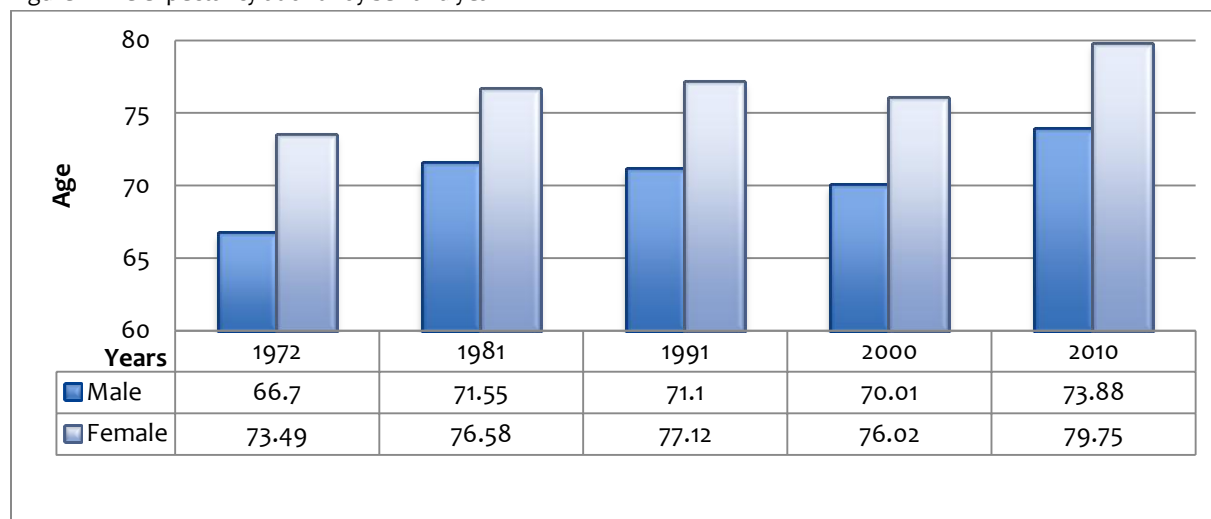


Figure 1 illustrates the calculated life expectancies over the last approximately forty years. It can be concluded that women live longer than men in Aruba. Since 1980, women are living longer than men in *all* parts of the world. And, in low-income countries, women now live 20 years longer on average than they did in 1960<sup>3</sup>. At every age group, women tend to have a lower mortality rate. The reasons for this are not entirely certain. People argue that it can be caused by some traditional socio-environmental factors; men have generally consumed more alcohol, tobacco and other drugs compared to females in most societies. This means they are more likely to suffer from associated diseases such as lung cancer. Men are also more likely to die from accidents, whether unintentional (such as car accidents) or intentional (suicide, violence, war). It is also known that men are more likely to die from most of the leading causes of death than women.

Since the year 1981 to 2000 life expectancy has only been decreasing. An increase can also be seen for the year 1972 to 1981, but in this year the increase in life expectancy for men was unequal to women.

Tables 3 and 4 present life tables for men and women on Aruba. Deaths are taken over the period of one year. There are some zero probabilities in the life tables; this is due to the fact that the numbers of death in these age groups are zero. In reality these probabilities are not zero, but just small.

Table 3: Life table Aruba 2010-2011 Males

Age (x)	n	a(x,n)	Deaths	Census population	M(x,n)	q(x,n)	p(x,n)	l(x)	D(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	1	0,09	4	560	0,00715	0,00710	0,99290	100000	710	99354	0,99290	7387957	73,88
1	4	0,4	0	2767	0,00000	0,00000	1,00000	99290	0	397160	0,99987	7288603	73,41
5	5	0,5	0	3597	0,00000	0,00000	1,00000	99290	0	496450	0,99934	6891443	69,41
10	5	0,5	1	3800	0,00026	0,00132	0,99868	99290	131	496123	0,99868	6394994	64,41
15	5	0,5	1	3780	0,00026	0,00132	0,99868	99159	131	495469	0,99569	5898871	59,49
20	5	0,5	4	2727	0,00147	0,00731	0,99269	99028	724	493332	0,99148	5403402	54,56
25	5	0,5	5	2555	0,00196	0,00974	0,99026	98305	957	489131	0,99084	4910069	49,95
30	5	0,5	5	2904	0,00172	0,00857	0,99143	97348	834	484652	0,98936	4420939	45,41
35	5	0,5	9	3513	0,00256	0,01273	0,98727	96513	1228	479494	0,98715	3936287	40,79
40	5	0,5	10	3828	0,00261	0,01298	0,98702	95285	1236	473332	0,98499	3456793	36,28
45	5	0,5	15	4355	0,00344	0,01707	0,98293	94048	1606	466226	0,97506	2983461	31,72
50	5	0,5	26	3880	0,00670	0,03295	0,96705	92442	3046	454597	0,96145	2517234	27,23
55	5	0,5	29	3198	0,00907	0,04434	0,95566	89396	3964	437072	0,94223	2062637	23,07
60	5	0,5	35	2349	0,01490	0,07182	0,92818	85432	6136	411823	0,89999	1625566	19,03
65	5	0,5	48	1721	0,02790	0,13038	0,86962	79297	10339	370636	0,84687	1213742	15,31
70	5	0,5	49	1244	0,03939	0,17930	0,82070	68958	12364	313879	0,76874	843106	12,23
75	5	0,5	56	811	0,06909	0,29458	0,70542	56594	16671	241291	0,67552	529227	9,35
80	5	0,5	37	412	0,08986	0,36687	0,63313	39923	14647	162997	0,55034	287936	7,21
85	5	0,5	28	171	0,16355	0,58042	0,41958	25276	14671	89703	0,34571	124939	4,94
90	5	0,5	16	56	0,28396	0,83034	0,16966	10605	8806	31012	0,13622	35236	3,32
95			6	14	0,42594	0,00000	1,00000	1799	1799	4224		4224	2,35

Source: AZV, DVG, Population Registry, Population and Housing Census 2010

<sup>3</sup> Economic World Bank Organization (2011). *World Development Report 2012: Gender Equality and Development*. Washington DC: The World Bank, p. 22.

The meanings of these functions are the following:

- $n$  = length of interval
- $a(x,n)$  = fraction of last year lived
- $M(x,n)$  = the age-specific mortality rate (number of deaths divided by the mid-year population in age group  $x$  to  $x+n$ )
- $q(x)$  = the age specific probability of dying between ages  $x$  and  $x+n$
- $p(x)$  = the age specific probability of surviving between ages  $x$  and  $x+n$
- $l(x)$  = the function of survival, being the number of survivors in the life table at exact age  $x$ , out of an initial population of 100000 at age 0
- $D(x,n)$  = the function of death, being the number of deaths in the life table between ages  $x$  and  $x+n$
- $L(x,n)$  = the total number of person-years lived by the total population between ages  $x$  and  $x+n$
- $S(x,n)$  = the probability of surviving between two year of completed years
- $T(x)$  = the total number of person-years lived by the cohort after exact age  $x$
- $e(x)$  = the expectation of life, being the average number of years yet expected to be lived by a person at age  $x$

Table 4: Life table Aruba 2010-2011 Females

Age (x)	n	a(x,n)	Deaths	Census population	M(x,n)	q(x,n)	p(x,n)	l(x)	D(x,n)	L(x,n)	S(x,n)	T(x)	e(x)
0	1	0,09	9	558	0,01614	0,01591	0,98409	100000	1591	98552	0,98259	7975199	79,75
1	4	0,4	1	2624	0,00038	0,00152	0,99848	98409	150	393276	0,99892	7876647	80,04
5	5	0,5	0	3441	0,00000	0,00000	1,00000	98259	0	491296	1,00000	7483371	76,16
10	5	0,5	0	3698	0,00000	0,00000	1,00000	98259	0	491296	0,99929	6992075	71,16
15	5	0,5	1	3525	0,00028	0,00142	0,99858	98259	139	490948	0,99831	6500779	66,16
20	5	0,5	1	2554	0,00039	0,00196	0,99804	98120	192	490120	0,99817	6009831	61,25
25	5	0,5	1	2926	0,00034	0,00171	0,99829	97928	167	489222	0,99772	5519712	56,36
30	5	0,5	2	3505	0,00057	0,00285	0,99715	97761	278	488108	0,99481	5030490	51,46
35	5	0,5	6	3962	0,00151	0,00754	0,99246	97482	735	485573	0,99230	4542382	46,60
40	5	0,5	7	4435	0,00158	0,00786	0,99214	96747	761	481834	0,99200	4056809	41,93
45	5	0,5	8	4891	0,00164	0,00815	0,99185	95987	782	477978	0,98990	3574975	37,24
50	5	0,5	11	4530	0,00243	0,01207	0,98793	95205	1149	473151	0,97807	3096997	32,53
55	5	0,5	24	3699	0,00649	0,03192	0,96808	94056	3002	462773	0,96220	2623846	27,90
60	5	0,5	25	2787	0,00897	0,04386	0,95614	91053	3994	445282	0,94484	2161073	23,73
65	5	0,5	28	2020	0,01386	0,06698	0,93302	87059	5831	420719	0,91657	1715791	19,71
70	5	0,5	36	1691	0,02129	0,10107	0,89893	81228	8210	385617	0,86853	1295072	15,94
75	5	0,5	42	1166	0,03603	0,16528	0,83472	73019	12069	334921	0,79378	909454	12,46
80	5	0,5	40	684	0,05852	0,25526	0,74474	60950	15558	265855	0,67355	574533	9,43
85	5	0,5	35	327	0,10699	0,42205	0,57795	45392	19158	179066	0,50989	308678	6,80
90	5	0,5	28	160	0,17465	0,60785	0,39215	26234	15946	91305	0,41956	129612	4,94
95			16	60	0,26855	0,00000	1,00000	10288	10288	38308		38308	3,72

Source: AZV, DVG, Population Registry, Population and Housing Census 2010



Figure 2: Probability of dying for men, 2000-2010

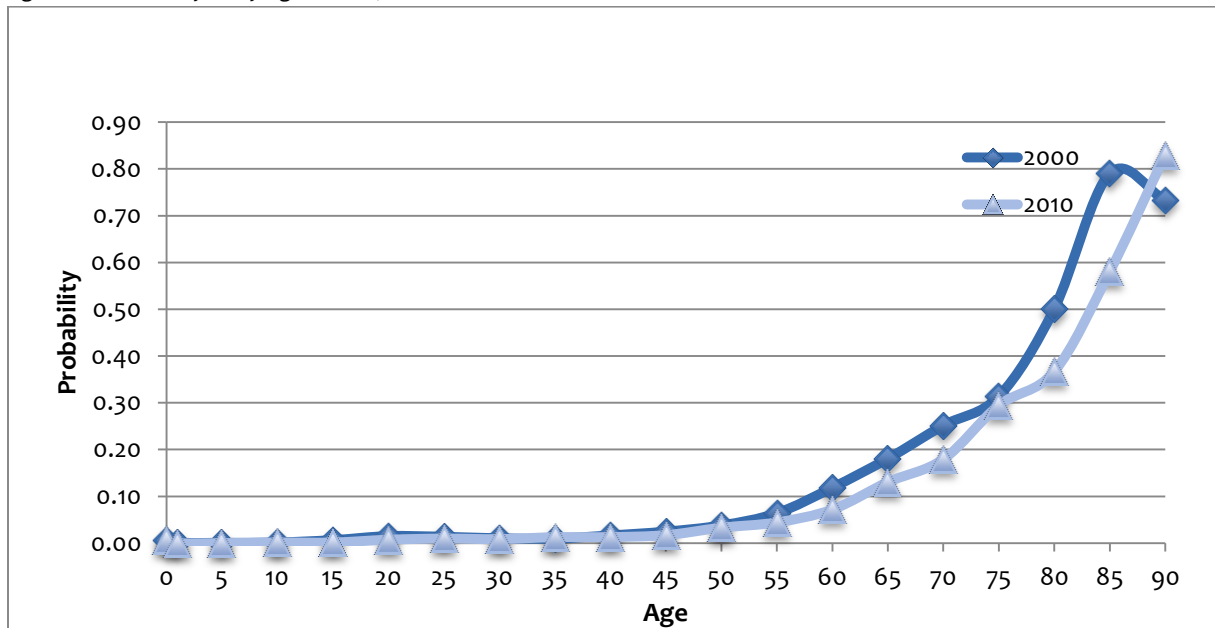


Figure 3: Probability of dying for women, 2000-2010

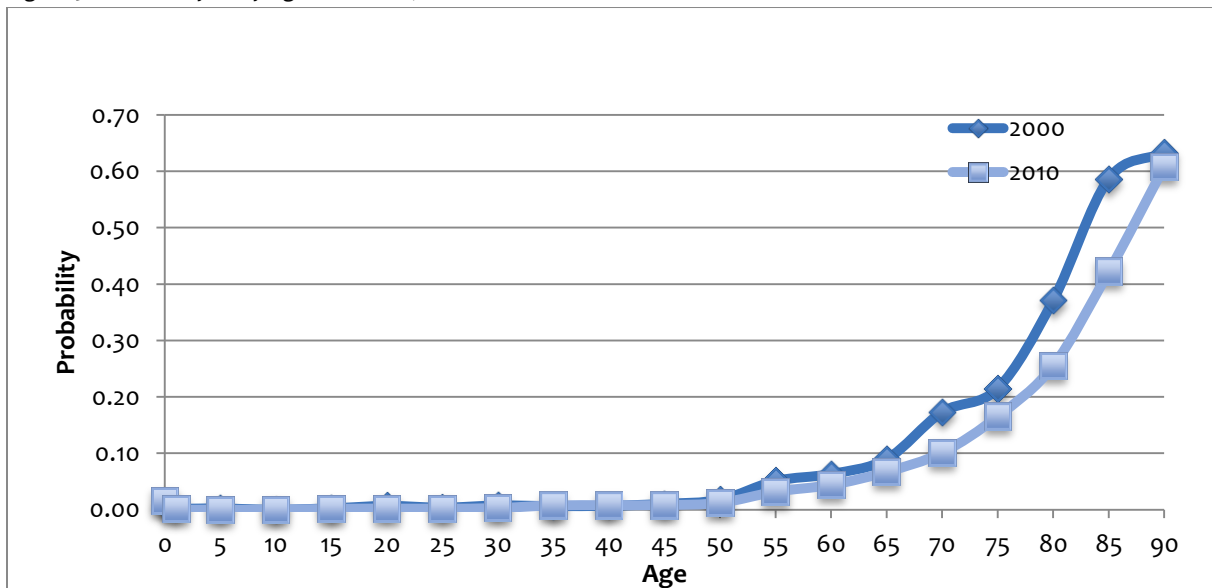


Figure 2 and 3 show the age-specific probability of dying for men and women for 2000 and 2010. Both graphs show that probabilities of dying in almost every age group for men and for women are lower in 2010 than in 2000. This is not the case for men between ages 35 and 40, where the probability of dying was 0.98 percent in 2000 and rose to 1.27 percent in 2010. Between ages 90 and 95 the probabilities for men dying were respectively 73.31 and 83.03 percent. For women between ages 35 and 40 the probability of dying also rose from 0.64 percent in 2000 to 0.75 in 2010. Between ages 40 and 45 these probabilities were respectively 0.68 and 0.79 percent. It is striking to notice

that the life expectancy for females increases at birth and then decreases. This is caused by the number of infant deaths.

### ***Possible reasons for a higher life expectancy***

The reasons for a higher life expectancy cannot be exactly determined. Since the last life tables were made, the healthcare system on Aruba has undergone some changes. The healthcare provided by AZV has reached a higher level and medical improvements have been made. Aruba was the first country within the Kingdom of the Netherlands that introduced a social health insurance for the entire population (the registered residents). It was officially introduced on January 2001. In the last couple of years, increasingly TV ads or programs concerning weight loss and exercising are presented that makes people more aware of their weight and bad eating habits. Improvements in infant and child mortality can contribute to a higher expectation of life. This is further discussed in the next paragraph. The reasons mentioned here are hypotheses and further research is highly recommended.

### ***Infant mortality***

In one year period, from March 2010 to March 2011, 13 babies died on Aruba, 4 boys and 9 girls. In most countries, mortality in the first year of life among baby boys is higher than among baby girls. This is not the case in Aruba. Current levels of infant mortality are 7.2 per thousand for boys and 16.1 for girls (11.6 for both sexes). Infant mortality is now higher, which means that in theory more infant die during their first year of life compared to 2000. In the year 2000 it was 5.6 per thousand for boys and 9.1 for girls. It has to be mentioned that 10 years ago babies who died shortly after birth were neither registered as births nor deaths at the Population Registry, there were also not as many data sources on mortality available as there is now. For this reason it can be concluded that the infant mortalities 10 years ago were most probably higher than mentioned above. However, it can be said that the current rate is not bad at all. A country that ranks very high is Iceland with an infant mortality rate of 1.6 per thousand. The mortality rate in the Netherlands was 3.6 per thousand in 2010. Countries that rank the lowest are Sierra Leone and Congo (Dom Rep), with an infant mortality of respectively 114 and 112<sup>4</sup>.

### ***Comparison to other countries, regions and the world***

From figure 4 it can be concluded that the life expectancy of Aruba is higher than of the average for the World and the average for the Caribbean. It is also nearly as high as the expectancy for the

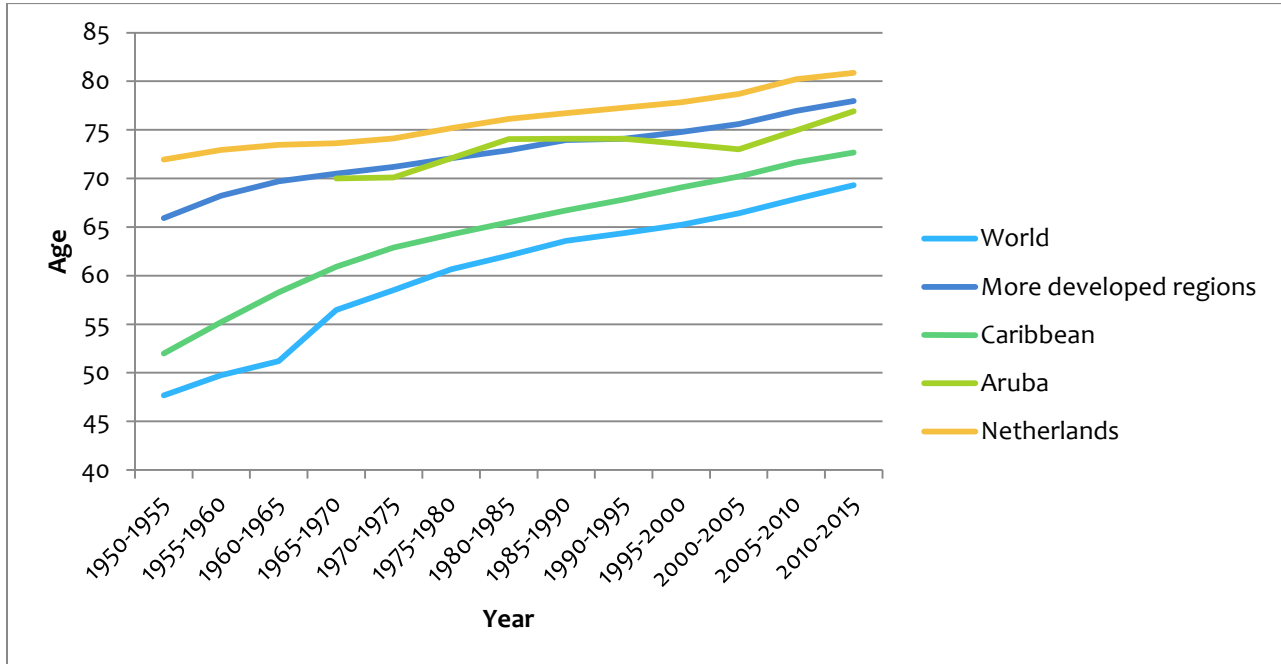
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<sup>4</sup> The World Bank Group (World Databank). Retrieved from:

[http://search.worldbank.org/quickview?name=%3Cem%3EMortality%3C%2Fem%3E+rate%2C+%3Cem%3Einfant%3C%2Fem%3E+%28per+1%2C000+live+births%29&id=SP.DYN.IMRT.IN&type=Indicators&cube\\_no=2&qterm=infant+mortality](http://search.worldbank.org/quickview?name=%3Cem%3EMortality%3C%2Fem%3E+rate%2C+%3Cem%3Einfant%3C%2Fem%3E+%28per+1%2C000+live+births%29&id=SP.DYN.IMRT.IN&type=Indicators&cube_no=2&qterm=infant+mortality)

developed regions of the World. Netherlands has the highest life expectancy in this figure. In comparison to the other graphs, the graph of Aruba shows an erratic course.

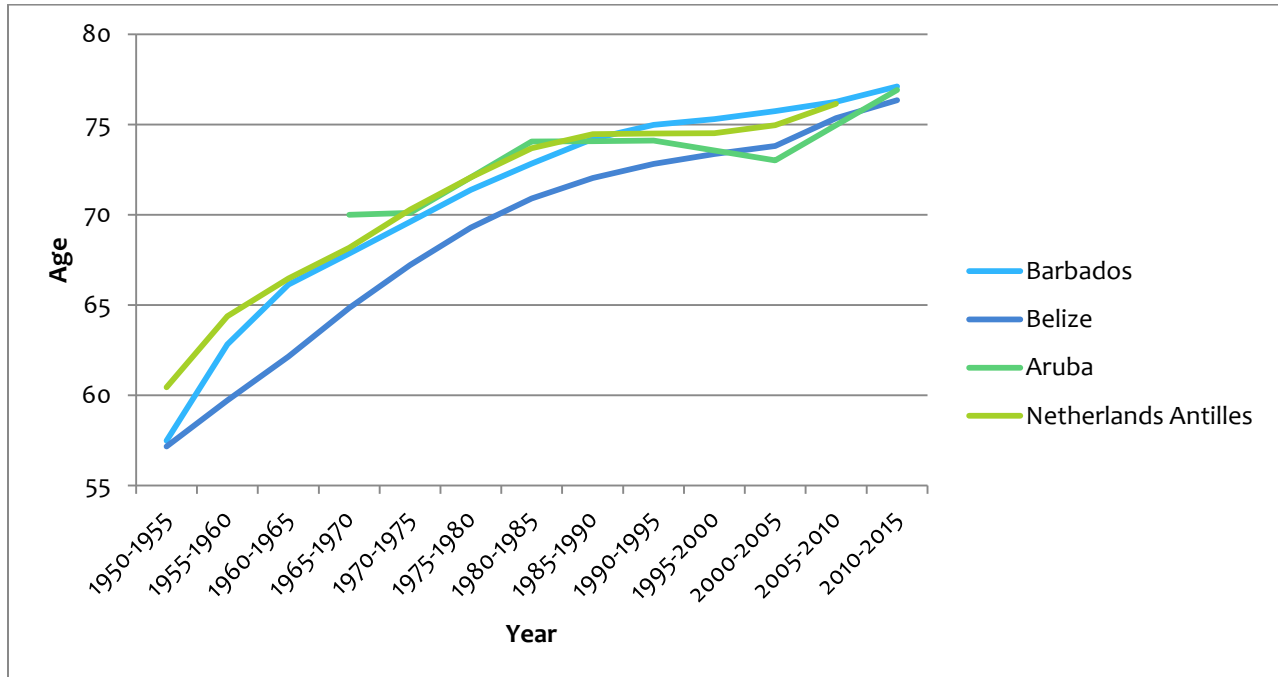
Figure 4: Life expectancy world, developed regions, Caribbean, Netherlands and Aruba, 1950-2015



Source: United Nations (Population Division)

The figure shown below gives an overview of the life expectancy of Aruba compared to other islands in the Caribbean and Central America. Also, the life expectancy of the Netherlands Antilles is given in the course of time (after 2010 this is not possible anymore). We can see that Aruba has a drop in life expectancy in the year 2000-2005, but in 2010-2015 it is almost equal to Barbados.

Figure 5: Life expectancy Barbados, Belize, Netherlands Antilles and Aruba, 1950-2015



Source: United Nations (Population Division)

### Good health, bad health

The Census 2010 of Aruba included a question on perceived health, phrased: “How is your health in general?”, with the possible answer: very good, good, regular, bad and very bad. Several studies have found that answers ‘regular’, ‘bad’ and ‘very bad’ give a good indication for the number of people not in good health<sup>5</sup>. A life table can also be made in combination with other variables. In the book ‘Readings in Population Research Methodology’ this is called a multiple decrement table. Mortality rates in the life table are then combined with other demographic data which measure the combined effect of mortality and changes in one or more characteristics. In this section we combine mortality rates with living in good or bad health.

Table 5 below represents the absolute and relative numbers of men and women according their own perceived health status, 14.16 percent of the total population says that their health is regular, bad or very bad. This was 11.60 percent in 2000. The table also shows that 15.16 percent of all women indicate that their health status is less than good. This is 2.12 percent more than men.

<sup>5</sup> Central Bureau of Statistics (2002). *The People of Aruba, Continuity and Change: Census 2000 Special Reports*.

Table 5: Absolute and relative number of persons by health condition and sex

Health Condition	Male		Female		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
<b>Very good</b>	1079	38,74	1074	34,29	2153	36,39
<b>Good</b>	1340	48,11	1575	50,29	2915	49,26
<b>Regular</b>	321	11,53	417	13,31	738	12,47
<b>Bad</b>	32	1,15	51	1,63	83	1,40
<b>Very bad</b>	10	0,36	7	0,22	17	0,29
<b>Not reported</b>	3	0,11	8	0,26	11	0,19
<b>Total</b>	2785	100	3132	100	5917	100

Source: Representative sample of Population and Housing Census 2010

In table 6 there is an overview of the age-specific life expectancies for men and women in good and poor health. At birth a baby boy can expect to live on average 63.25 years in a good health and 10.63 years in poorer health. Females live on average nearly six years longer than men; they will live 2.82 years of these six years in good health and 3.05 years in poorer health. Compared to the year 2000, both men and women have a perceived lower age to live in a good health. Logically, at higher ages the percentages of years living in a poor health becomes higher for both sexes and the difference between men and women in life expectancy becomes smaller. For instance, at age 60 men in Aruba expect to live on average 19.03 more years, while women have a life expectancy of 23.73. Life expectancies for men and women in poor health at this age are respectively 6.09 and 7.94 years. Which in turn means that men at age 60 can expect to live 32 percent of their remaining lifetime in a poor health, while for women this percentage is 33.46.

Table 6: Life expectancy in good and poor health by age and sex

Age (x)	Males			Females		
	$e(x)$	$e(x)$ Good Health	$e(x)$ Poor Health	$e(x)$	$e(x)$ Good Health	$e(x)$ Poor Health
0	73,88	63,25	10,63	79,75	66,07	13,68
1	73,41	62,78	10,63	80,04	66,14	13,90
5	69,41	58,93	10,47	76,16	62,32	13,84
10	64,41	54,23	10,18	71,16	57,43	13,73
15	59,49	49,56	9,93	66,16	52,55	13,61
20	54,56	44,79	9,78	61,25	48,10	13,15
25	49,95	40,23	9,72	56,36	43,61	12,76
30	45,41	36,07	9,35	51,46	38,99	12,47
35	40,79	31,72	9,06	46,60	34,74	11,86
40	36,28	27,55	8,73	41,93	30,46	11,47
45	31,72	23,29	8,43	37,24	26,30	10,95
50	27,23	19,47	7,76	32,53	22,26	10,27
55	23,07	16,08	6,99	27,90	18,74	9,15
60	19,03	12,94	6,09	23,73	15,80	7,94
65	15,31	10,09	5,22	19,71	12,58	7,13
70	12,23	7,88	4,35	15,94	9,59	6,36
75	9,35	6,08	3,27	12,46	6,79	5,66
80	7,21	4,00	3,21	9,43	5,39	4,03
85	4,94	3,46	1,49	6,80	3,45	3,35
90	3,32	1,66	1,66	4,94	4,02	0,92
95	2,35	1,17	1,17	3,72	2,48	1,24

Source: (Representative sample) of Population and Housing Census 2010, DVG, AZV and Population Registry

### Age-specific life expectancy in marital status

It is very interesting to see how long a person can expect to remain in each of the marital status: never married, married, divorced/separated and widowed. The variable marital status is combined with mortality rates in a new life table, the same way we did in the paragraph 'good and bad health'. The figures 6 and 7 can give a good picture of the expectancies for men and women. It is striking to notice that at birth a boy can expect to live 28.11 of his life as a married man. This against 24.30 years a woman can expect to live married. In 2000 this was 30.03 for men and 25.06 for women. This is a consequence for the fact that more women than men remain unmarried throughout their lives. It can also be partly because when a women divorces, she is less likely to remarry than a man. A woman can expect to live 10.02 percent of her lifespan as a divorcee, for men the percentage is 7.74. Women can expect to live more years widowed than men; this is logic, because women live on average longer than men.

Figure 6: Age-specific expectancy in specific marital status 2010 Males

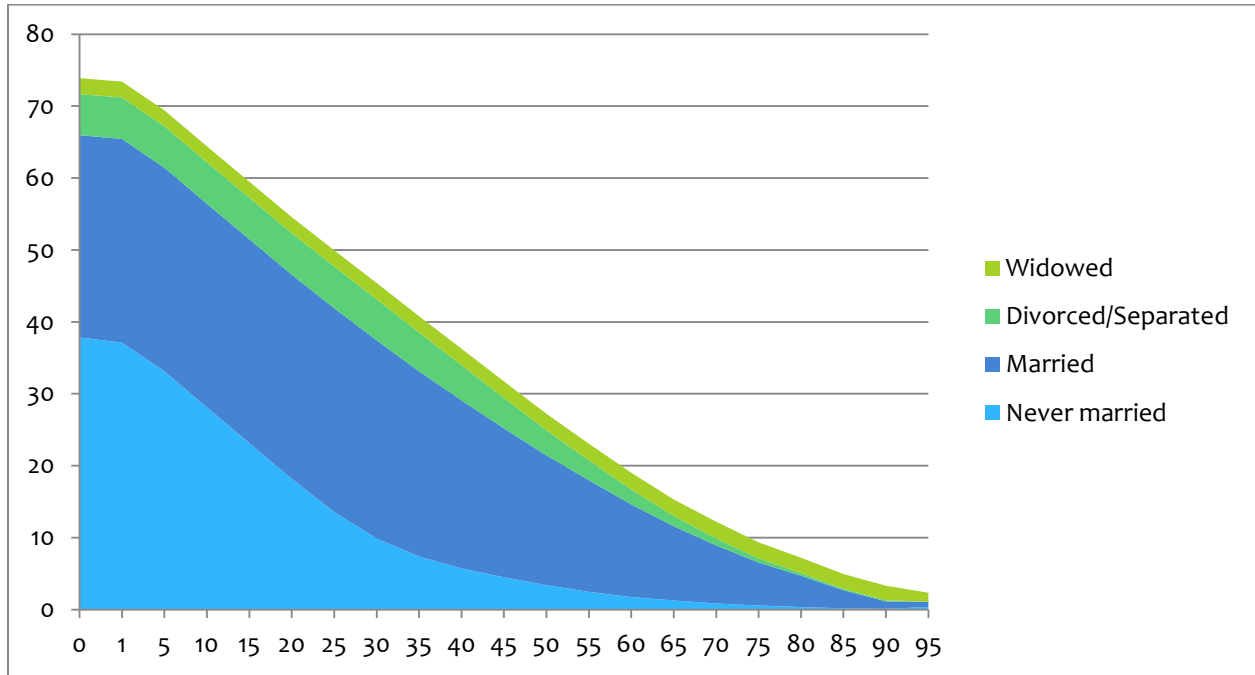
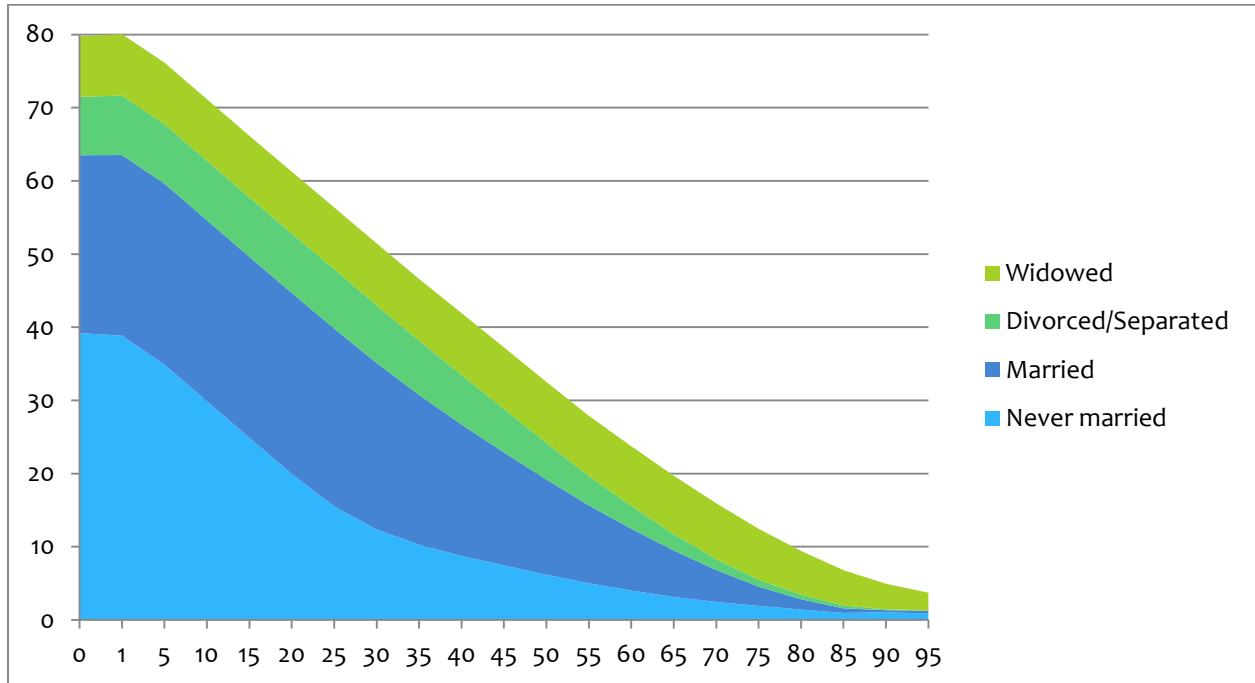


Figure 7: Age-specific expectancy in specific marital status 2010 Females



## 6. Summary and Recommendations

The goal of this research was to construct and analyze a life table. The last time a life table was constructed on Aruba, in the year 2000, only data from the Population Registry of Aruba for the number of deaths were used. Currently, more data sources on mortality are available, the General Health Insurance and the Department of Public Health of Aruba delivered these additional data. A life table analysis is necessary to calculate the life expectancy for both men and women. On Aruba, only once in every ten years it is possible to make a life table combining data of the Census with data from the Population Census. The data processing was a very important task of this research. After processing the different files, a life table was constructed.

Today, life expectancy is 73.88 years for men and 79.75 for women. In the year 2000, the life expectancy for men and women were 70.01 and 76.02 years. It can be concluded that women live longer than men in Aruba. Since the year 1981 to 2000 life expectancy has only been decreasing. An increase can also be seen for the year 1972 to 1981, but in this year the increase in life expectancy for men was unequal to women. The probabilities of dying in almost every age group for men and for women are lower in 2010 than in 2000. This is not the case for men between ages 35 and 40 and 90-95. For women between ages 35 and 40 and ages 40 to 45 the probability has also risen.

The reasons for a higher life expectancy cannot be exactly determined. Since the last life tables were made, the healthcare system on Aruba has undergone some changes. The healthcare provided by AZV has reached a higher level and medical improvements have been made. The increasing TV ads and programs concerning weight loss and exercising that are presented can also have the consequence of making people more aware of their weight and (bad) eating habits.

Infant mortality is now higher, which means that in theory more infants die during their first year of life compared to 2000. It has to be mentioned that 10 years ago babies who died shortly after birth were neither registered as births nor deaths at the Population Registry, there were also not as many data sources on mortality available as there is now. For this reason it can be concluded that the infant mortalities 10 years ago were higher than the officially published figures. It can be said that the current rate is not bad at all.

Aruba has a high life expectancy compared to a lot of countries and regions around the world. In the years 2010-2015 it is almost equal to Barbados.

At birth a baby boy can expect to live on average 63.25 years in a good health and 10.63 years in poorer health, for girls the numbers of years are respectively 66.07 and 13.68. Compared to the year 2000, both men and women have a perceived lower age to live in a good health.

It is striking to notice that at birth a boy can expect to live 28.11 of his life as a married man. This against 24.30 years a woman can expect to live married.

It is recommended to do a new research on the causes of death in Aruba to make this article more complete. Maybe it can be also an idea to make a more extended study on why the life expectancy has remarkably increased.



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