Infectious Diseases and Life Expectancy:

Regional Trends in the Netherlands, 1890-1920.

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Date	12 July 2024
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Abstract

Since the 1870s, life expectancies began to rise in the Netherlands primarily due to a decrease in mortality from infectious diseases. Contributing factors behind this decrease are improvements in hygiene, nutrition, and public health policies. This research investigates to what extent this trend of a decrease in infectious diseases caused regional divergence or convergence between 20 municipalities in the Netherlands from 1890 to 1920. Period life tables were created to calculate the life expectancy at birth for each municipality and the Netherlands. The findings indicate convergence among the 20 municipalities between 1890 and 1920. Divergence likely already occurred between 1870-1890. Wider geographical areas do not explain differences between municipalities as the local economy and social history are important in determining life expectancy. The cases of the outliers ‘s Hertogenbosch and Tilburg are explicitly reviewed. The municipalities are placed in four trajectories, each reflecting different phases of the epidemiological transition model. The population size and growth rate of the municipalities may have determined life expectancy to some extent. The direction and size of the impact of infectious diseases on the difference in life expectancy differ among municipalities, with an overall decline in their influence between 1890 and 1920. Standardizing the mortality rate to the national average results in more absolute differences between municipalities, yet a trend of convergence is still observed from 1890 to 1920. Further research should test which characteristics of municipalities influenced the life expectancy at birth, and perform a more zoomed-in approach.

Concepts: historical demography, epidemiological transition, demographic transition model, divergence and convergence, mortality rate, life expectancy, urban penalty.

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1. Introduction

Infectious diseases were the main cause of mortality in the Netherlands until 1945 when this role was taken over by cardiovascular diseases (Kaptijn et al., 2015). The Netherlands was among the forerunners of the epidemiological transition (Omran 1973), which describes the process of mortality decline through a succession of phases defined by their main contributing causes of death. The Netherlands entered the age of receding pandemics relatively early (Van Poppel, 2011). In the 19th century, smallpox and cholera outbreaks repeatedly pulled down life expectancy. However, life expectancy began increasing from the 1870s until the end of the 1910s (Van Poppel, 2011). The Spanish flu pandemic in 1918 took life expectancy down for the first time in almost four decades (Van Poppel, 2011; Kaptijn et al., 2015; Harteloh & van Mechelen, 2024). The increase in life expectancy from the 1870s can almost entirely be attributed to the enormous decline in infectious diseases (Vallin & Meslé, 2005; Janssens, 2021). In the Netherlands, 1870 to 1940 can be defined as a period with a steep decline in mortality from infectious diseases. The transition from Omran's age of receding pandemics to the age of degenerative and man-made diseases in the Netherlands is happening in the timeframe of Figure 1, i.e. from 1875 to 1945.

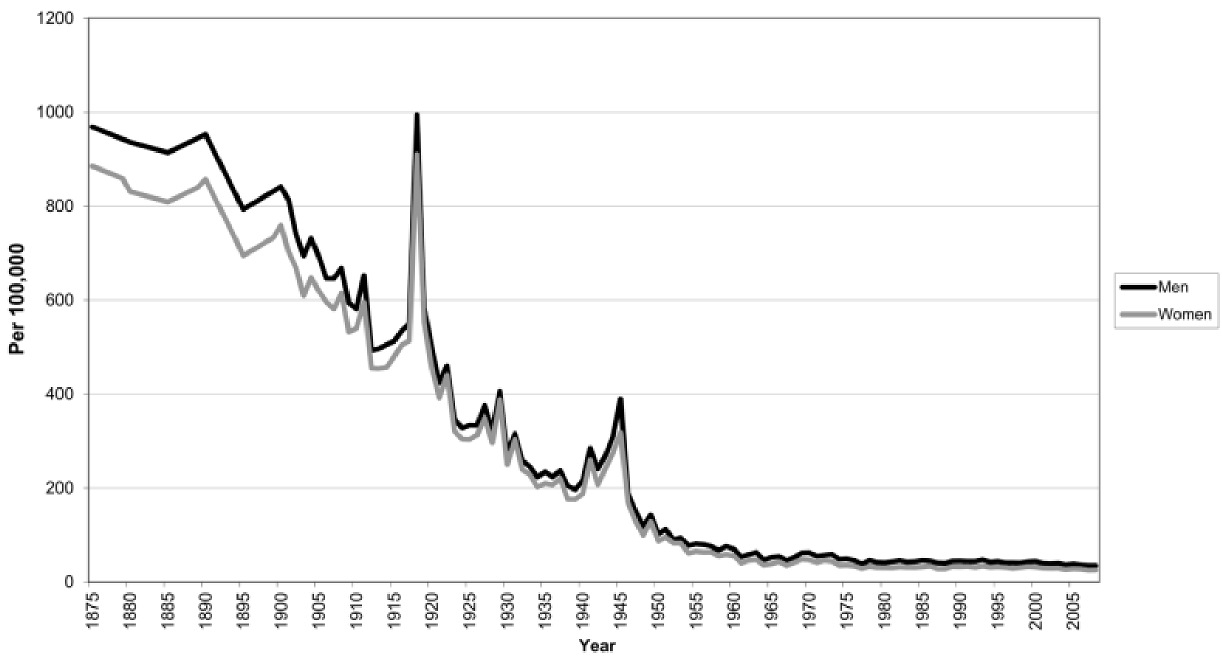

Figure 1: Age-standardized mortality from infectious diseases for men and women in the Netherlands, 1875-2005 (Kaptijn et al., 2015).

Janssens (2021) states that the decreased mortality from infectious diseases was the main driver behind the increase in life expectancy. Significant improvements were made even before the arrival of modern-day medicine and mass vaccination programs of the 1940s. Between 1870 and 1939, life expectancy increased from 37 to 67 years of age in the Netherlands. Contributing factors to a better living standard included better hygiene, improved nutrition and education, effective public health policies, and higher incomes (Janssens, 2021). Before 1900, living conditions for the average population were poor. The modernization in agriculture led to increased urbanization. In 1910, 53% of the Dutch population lived in urban areas (de Groot et al., 2010). Cities were unable to house all the new inhabitants, leading to the creation of slums. In these slums, workers and their families lived in small and poor-conditioned houses lacking clean water and sewage systems - the perfect conditions for the spread of infectious diseases. Around 1900, approximately one million Dutch people lived in slums (Van der Woud, 2010). To address poor and unhealthy housing and living conditions of the poor, the Housing Act of 1901 was introduced. Requirements included a separate bedroom, a toilet, and a kitchen in every home (Taverne, 1981).

This research presents a historical analysis focusing on divergence or convergence among Dutch urban municipalities from 1890 to 1920. The identification of socioeconomic and geographical inequalities and their origins is an important quality of this research. This study also investigated whether an urban versus rural divide can be identified in this period. In the Netherlands, the urban vs rural divide is a politicized subject that has significantly influenced the elections (NOS, 2023). This divide often centers around rural areas feeling less important and involved in politics compared to urban areas, often referred to as the Randstad (Huijsmans & Miltenburg, 2023).

The research could advocate for the importance of the vaccination rate, highlighting the detrimental influence that infectious diseases can have on public health and life expectancy. Currently, the vaccination rate of children is decreasing in the Netherlands, especially in major cities (NOS, 2024a). Recent outbreaks of measles in Brabant prove that infectious diseases are also a contemporary issue (NOS, 2024b). The main question guiding this research is:

To what extent did the dynamic of decrease in infectious diseases cause regional divergence or convergence in life expectancy in the Netherlands, 1890-1920?

The research question is answered using the following subquestions:

1. How did the pace and timing of the trend of increasing life expectancy differ across municipalities in the Netherlands in the period 1890-1920?
2. To what extent did infectious diseases contribute to the change in life expectancy in municipalities in the Netherlands in the period 1890-1920?
3. What are the contributing factors behind the divergence or convergence in life expectancy in the Netherlands in the period 1890-1920?

2. Theoretical Framework

2.1 Infectious diseases and their role in mortality convergence and divergence

Infectious diseases can be grouped into various categories: airborne diseases, water-and-foodborne diseases, and other communicable diseases (Van Poppel, 2011). Airborne diseases spread mainly through air and saliva. To this group belong tuberculosis, bronchitis, pneumonia, and childhood diseases like smallpox, measles, diphtheria, and whooping cough (Van Poppel, 2011). Airborne diseases can be accounted for as the most important group (Hillen et al., 2018). Water-and-foodborne diseases spread through contaminated drinking or washing water or bacterial, viral, and parasitic diseases that are conveyed via food. To this group belong cholera, diarrhea, dysentery, typhus, and typhoid (Van Poppel, 2011). This group mostly targeted infants and young children (Hillen et al., 2018). Examples of other communicable diseases that do not spread via air, water, or food are malaria, syphilis, and convulsions (Van Poppel, 2011).

The diseases that contributed the most to the decline of mortality from infectious diseases are airborne. Wolleswinkel-van den Bosch et al., (1998) conducted research identifying turning points with fast declining mortality. In the period 1880-1917, `debility' (mainly diseases affecting the newborn and old-age) diseases of the nervous systems and chronic respiratory diseases could have played a big role in the enormous decline in mortality from infectious diseases. In the turning-point year 1917, respiratory tuberculosis, acute respiratory diseases, and diarrhoeal diseases largely determined the accelerated decline in mortality (Wolleswinkel-van den Bosch et al., 1998).

The susceptibility to infectious diseases varies with age. The total increase in life expectancy since 1850 can be largely attributed to the declining mortality in age group 0-1 (Van Poppel, 2011). Between 1850 and 2002, age groups 5-20 and 20-50 contributed approximately 10% and 20% respectively to the increase in life expectancy. The contribution of the 50-65 age group is significantly less compared to these age groups. The contribution of the 65-80 and 80+ age groups was negligible (Van Poppel, 2011).

In a period of convergence, life expectancy trajectories of populations across space become increasingly similar over time. On the contrary, in a period of divergence, life expectancy trajectories of populations become increasingly different over time. The cause of these dynamics comes from the economic, social, and political context, meaning that several regions entered the transition to increasing life expectancy at different times. In the period when mortality from infectious diseases declines, geographical divergence in life expectancy is likely to increase as first, only the most prosperous populations can benefit from improvements (Vallin & Meslé, 2005). This phase of divergence is what Janssen et al. (2016) call the ‘Matthew effect’, where regions with already a high life expectancy experience even faster improvement. Selective migration and differences in lifestyles can also contribute to divergence in life expectancy (Janssen et al., 2016). Convergence occurs when the returns of improvement in health, education, and economy start to decrease (Janssen et al., 2016). The entire health transition process consists of successive stages of divergence-convergence (Vallin & Meslé, 2005).

The prevalence of infectious diseases is influenced by several factors in the social, political, economic, and physical environment. For instance, local aspects such as population density and the availability of healthcare play a significant role. These factors determine regional differences, leading to divergence between regions.

2.2 Social and Economic Factors

Man-made environmental changes related to medical advances, food supply, and the quality of social environments all made their contribution to the rising life expectancy in the Netherlands (Wintle, 2004). In addition to this, a number of infectious diseases declined in their effectiveness, while human immune systems became stronger due to an increased quality and quantity of food (Wintle, 2004). Due to industrialization, food became cheaper and there was more variety in the supply of food. Moreover, products such as soap became mass-produced and therefore affordable for more people (Wintle, 2004). Gradual advances in quality of life were driven by general development, but it was social reforms that demanded more rights, safety, and healthy living and working conditions for a better quality of life and public health. Important social reforms in this period were carried out by progressive liberals (Wintle, 2004). The Housing Act of 1901 was an important milestone for the liberals' social reforms. Several laws concerning working conditions aimed at limiting working hours for children and women and increasing safety, relatively quickly improving working conditions (Wintle, 2004). In this period, gradually more men and, from 1919 onwards, women could vote, empowering citizens to advocate for their rights (Wintle, 2004). This social progress led to a better quality of life and public health and in addition, countered mortality from infectious diseases.

The effectiveness of the reforms varied by region, and this difference caused regional differences. A key reason for these regional disparities was the local variation in the quality of economic and social environments, such as the quality of water and sanitation (Vallin & Meslé, 2005).

2.3 Healthcare

As modernization kept moving forward, significant advancements were made in healthcare in the Netherlands. There was growing awareness and knowledge of hygiene among an increasingly larger segment of the population. Public health campaigns, education, and vaccination programs all developed in this period (Hillen et al., 2018). In the 19th century, health insurance funds were established, specifically to assist the poor who could not support themselves in times of illness. Additionally, medical research progressed, not only in the Netherlands but in most Western countries (Hillen et al., 2018).

The legalization of healthcare created a better, safer, and more effective healthcare system in the Netherlands. For example, the new law of Thorbecke in 1865 stated that doctors had an obligation to report infectious diseases (Hillen et al., 2018). Next to this, the legal framework for the medical professional was formed by the new laws of Thorbecke. Since 1865 only doctors via academic training were qualified to practice medicine and in 1876, with the law Wet op het Hoger Onderwijs, the qualifications of a physician to complete medical school were detailed (Hillen et al., 2018). Doctors had compulsory training and hospitals were professionalized (Wintle, 2004). In this period, untrained, mostly rural, surgeons were gradually replaced by academic medics (Hillen et al., 2018). The pace of this transition varied by region, influenced by the local availability of medical professionals, which affected life expectancy. The availability of healthcare and medicine was determined by local resources since traveling for healthcare was often unaffordable. The cost of healthcare and the purchasing power of the citizens played important roles in public health outcomes.

Next to regional differences within urban areas, there was also an urban-rural divide in healthcare developments. Urban areas could seize the advances in medical science that created opportunities for a lower mortality rate easier than rural areas (Hofstee, 1958). In the 20th century, death rates decreased more rapidly in the western and northern parts of the Netherlands because the spreading of modern medicine and culture assimilated earlier in these regions. The urbanized character of the western part of the Netherlands contributed to this decrease (Hofstee, 1958). Other explanatory factors are market-oriented agriculture and maritime shipping, which facilitated good accessibility to the North and the West, allowing modern culture and science to spread more effectively (Hofstee, 1958).

2.4 Religious Composition

Religion influences mortality and health in various ways. The religious composition may influence life expectancy. Religion was already recognized as an important factor in regional mortality patterns since the 19th century (Van Poppel, 1991). According to Oman and Thoresen (2005), religion facilitates coping with stress. Being part of a religious community often provides social support, which can enhance accessibility to health care. On top of this, religion is associated with improved mental health (Oman & Thoresen, 2005). Religions have different health behaviors and concepts of hygiene, impacting life expectancy. For instance, early in the 20th century, it was noted that Jews had a lower mortality rate, possibly due to the Jewish dietary laws and the practice of breastfeeding Jewish mothers (Van Poppel, 1991). Another example is the difference in the suicide rate between Protestants and Catholics, which was attributed to the strong condemnation by the Catholic church of suicide (Van Poppel, 1991).

In the Volkstelling of 1889, only 1.48% of the Dutch population belonged to the group of no religion (‘onkerkelijken’), this increased to 7.77% in the Volkstelling of 1920. The largest group in this period was Dutch Reformed, followed by Roman Catholicism. Each religion has its ideas on sexual behavior, family size, and marriage, impacting fertility. For example, the Catholic church praises families with many children (Sobotka & Adigüzel, 2002). The church's prominent position in Dutch society could shape opinions about family size (Van Heek, 1956). However, the influence of churches diminishes as the group of atheists increases and religion has a weaker influence on their members’ lives (Sobotka & Adigüzel, 2002). Regarding fertility, a shift from a traditional to a postmodern demographic pattern took place. This postmodern pattern is characterized by fewer births, many extra-marital births, late timing, and relatively high childlessness (Sobotka & Adigüzel, 2002). Religiosity also influences mortality, a higher percentage of Roman Catholics is linked to a higher all-cause mortality in the Netherlands (Mackenbach et al., 1991). A high prevalence of Roman Catholics is also linked to high infant mortality (Van Poppel, 1992). Next to this, secularization has a positive correlation with infectious-disease mortality decline in the Netherlands from 1875-1924 ((Wolleswinkel-van den Bosch et al., 2001). Moreover, in regions with a high prevalence of non-religious people, mortality declined faster ((Wolleswinkel-van den Bosch et al., 2001).

2.5 Conceptual Model

The study examines regional mortality patterns of twenty urban municipalities and the Netherlands, including rural areas, to calculate life expectancy. The impact of infectious diseases and other death causes on regional mortality patterns is also investigated. The conceptual model considers four factors discussed in the theoretical framework that may directly or indirectly influence life expectancy, by affecting the likelihood of causes of death. The likelihood of the causes of death is moderated by age and societal differences between urban and rural. The four factors and the variable age are square as they are not tested (fig.2).

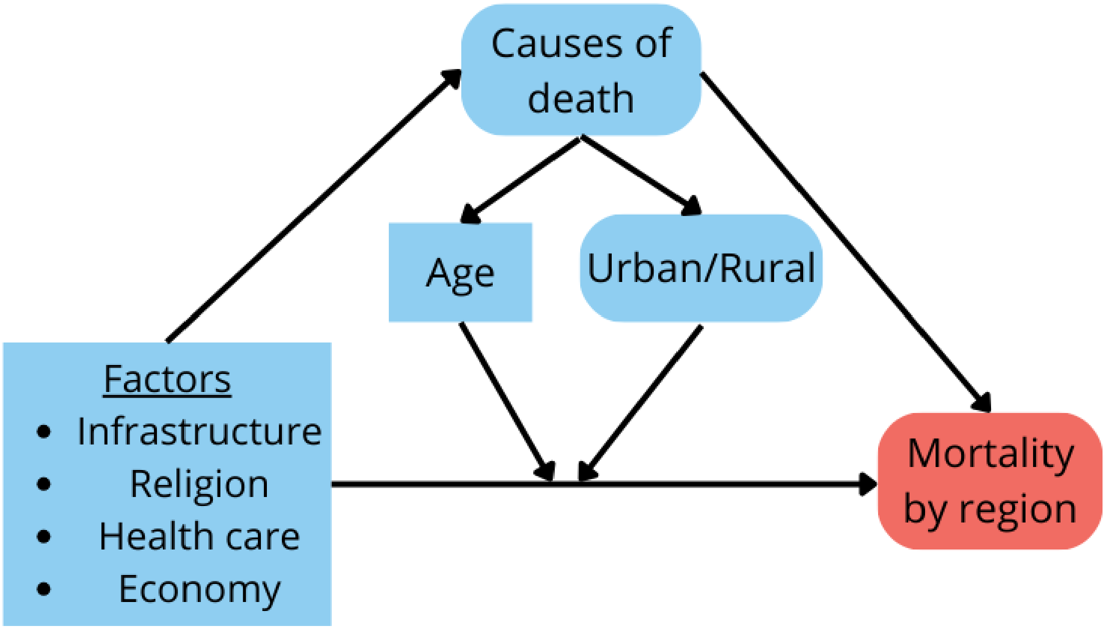

Figure 2: Conceptual model

2.6 Expectations

Based on Vallin & Meslé (2005) and Janssens (2021) the expectation is that life expectancy increases significantly as deaths from infectious diseases decline. This reduction in mortality from infectious diseases can largely be attributed to a decline in infant mortality (Van Poppel, 1992). Vallin & Meslé (2005) note that regional divergence initially increases as mortality from infectious diseases declines. It is expected that between 1890 and 1920 regional divergence in life expectancy occurs between the 20 Dutch urban municipalities. Differences in infrastructure, religion, healthcare, and economy determine the regional divergence. Regions with good housing, effective sewage systems, high secularization and low prevalence of Roman Catholics, accessible hospitals and public health awareness, and a strong economy have an advantage over regions that lack these qualities (Vallin & Meslé, 2005; Mackenbach et al., 1991; Hillen et al., 2018; Wintle, 2004). Moreover, urbanized regions are expected to have an advantage over rural areas (Hofstee, 1958).

3. Data and Methodology

3.1 Data

As a result of a passing law in 1865 that advocated for an institution of state medical supervision, the first national statistics on mortality, causes of death, and developments in health care and science were published in 1866 (Historisch CBS; Hillen et al., 2018). This report started a tradition of yearly statistics on mortality at national, regional, and municipality levels in the Netherlands. Each province appointed inspectors to oversee state medical supervision. Province inspectors had meetings to discuss health issues concerning water and air pollution, soil and food contamination, defusing corpses, disinfecting objects, and optimization of infant nutrition. These inspectors reported the number of deaths, the cause of their death, the age at dying, and their residential municipality to Centraal Bureau voor de Statistiek (CBS). The laws of Thorbecke of 1865 required doctors to draw up a death certificate including a death cause, prompting practitioners and doctors to report medical information about outbreaks of diseases and numbers of deaths to the provincial inspectors (Hillen et al., 2018; Van Poppel, 2011).

The data of this research is mortality by the causes of death and by age in Dutch municipalities and the Netherlands (fig. 3). This period data is available for the municipalities that had a population of more than 20.000 inhabitants and covers the years 1890 and 1920. Figure 3 illustrates the geographical distribution of these municipalities. The age categories and number of causes of death vary between the two sources (Table 1; Appendix, sheet 1). The data is retrieved from two different reports:

- Verslag aan de Koningin-Weduwe, Regentes, van de bevindingen en handelingen van het Geneeskundig Staatstoezicht in het jaar 1890.
- Statistiek van de sterfte naar den leeftijd en naar de oorzaken van den dood over het jaar 1920.

The reports are open source and available on Historisch CBS. Both reports were produced by the Centraal Bureau voor de Statistiek. For the total population in each age group for the 20 urban municipalities and the Netherlands, the Volkstellingen (censuses) of 31 December 1889 and 31 December 1920 are used. These Volkstellingen were also conducted by the Centraal Bureau voor de Statistiek in the period between 1795 and 1971. Regional censuses were carried out much earlier, for tax or military purposes (Ekamper, 2022). In 1830, the first national census was conducted to determine the size of the population and some of their demographic characteristics. The census of 1840 covered the current territory of the Netherlands for the first time, including Limburg (Ekamper, 2022).

Figure 3: The 20 municipalities with >20,000 inhabitants in 1890 and 1920

The reports emphasize both outbreaks of infectious diseases and general improvement of public health, indicating that the province inspectors were focused on high-quality statistics. These reports were meant to inform the Queen and the government, underlining the importance of good data. The quality of the datasets reflects the best practices that CBS could operationalize at that time. There are no incentives for physicians to corrupt the data. Although no document exists that contains the criteria for each death case, the judgment of the general practitioner is likely reliable, given that each physician had to complete medical education (Hillen et al., 2018). The inclusion of ‘unknown cause’ as a possible cause of death in the data indicates that cases, where the death cause was not sure, were not just put in a random category. However, due to overtyping from document to document there is the risk of typos in the reports and the Volkstelling. In some Volkstelling reports, numbers were hard to read and also incorrect numbers were found in some of the digitized versions in Excel. Additionally, the Volkstellingen, mostly the 1889 one, include also people of unknown ages. These unknown cases are excluded from the analysis as they generally presented only 1 or 2 people in most municipalities, with a maximum of 52 for Amsterdam in 1889 and 246 for the Netherlands in 1889 (Appendix, sheet 2).

3.2 Data Analysis

The initial step in the data analysis involved making the data suitable for analysis. As previously mentioned, the age groups vary between the two data sets (Table 1). In the report of 1920, it is mentioned that some changes have been made in the age groups to keep the agreement of the International Conference of 1920 in Paris. One of these changes is expanding the 5-13 group to 5-14. In this analysis, the same mortality rate is assumed between 13 and 14. Furthermore, the age groups 20-29, 30-39, and 40-49 are grouped to form the age group 20-49. This is also the case for age groups 50-59 and 60-79, to form the age group 50-79. For the 1890 report, the age group ‘unknown’ is considered negligible, as an unknown age occurred only a maximum of 31 times (Appendix, sheets 2 & 4).

Table 1: Age categories in both datasets

	1890	**1920**
Age categories	< 1	< 1
	1-4	1-4
	5-13	5-14
	14-19	15-19
	20-49	20-29
		30-39
		40-49
	50-64	50-59
	65-79	60-79
	80 or >80	80 or >80
	Unknown	

The two datasets also differ in the amount of and the grouping of causes of death. The dataset of 1890 used 35 distinct causes of death, while the dataset of 1920 used 38 main causes of death, with subcategories (Appendix, sheet 1). In 30 years, developments in medical knowledge led to the introduction of more detailed specialisms (Hillen et al., 2018), consequently, a greater variety of detailed death causes was added to the data. The causes of death attributed to infectious diseases, indicated by green in the appendix, have evolved. To ensure comparability, some causes of death, such as bronchitis, were excluded (Appendix, sheet 1, nr 20). The reason behind this is that the 1890 dataset just included the category acute/chronic diseases of the respiratory tract, which also contains other death causes. While it could be argued that fever, persistent or intermittent (Appendix, sheet 1, nr 8 & 9), should be included as an infectious death cause, it is decided not to include it, as fever is a symptom rather than a specific disease and the death cause is absent in the dataset of 1920. By creating comparable lists of causes of death, the comparison between 1890 and 1920 becomes more equitable.

For the analysis, period life tables were used (Appendix, sheets 3 & 5) to calculate the life expectancy at birth for each of the 20 municipalities and the Netherlands in both 1890 and 1920. A period life table shows what would happen to a hypothetical cohort when living with the mortality conditions of a certain period, in this case, 1890 and 1920 (Preston, 2001). The computation of the life tables started with the mortality rate, nMx (Preston, 2001). nDx is the number of deaths in a given interval and nNx is the population in that interval. The values of nDx and nNx were retrieved from the data.

$$nMx = \frac{nDx}{nNx}$$

The assumptions for nAx vary among the age groups. For age groups 5-13/5-14 and 14-19/15-19 half of the age group $\frac{N}{2}$ is used. The half could not be assumed for the younger and the older age groups as the years spent in the age group tend to be lower in the young age groups and higher in the middle-aged age groups (Preston, 2001). The values of nAx for age groups 0-1 and 1-4 are derived from Preston (2001). The nAx values for age groups 20-49 and 50-79 were computed by subtracting the starting age of the age group from the average age at death in that age group. With the values of nMx, nAx, and N, the probability of dying, denoted as nQx, and consequently, the probability of surviving, denoted as nPx, can be calculated. For the last interval applies $nQx = 1$.

$$nQx = \frac{n * nMx}{(1 + (n - nAx) * nMx}$$

$$nPx = 1 - nQx$$

The hypothetical cohort lx starts with a beginning population of 100,000 (l_0), which decreases through time because of mortality. The number of survivors of the hypothetical cohort in the next age group is calculated using the formula $lx_{n+1} = lx \times nPx$ (Preston, 2001). The outcome of the death rate, denoted as ndx, is the death rate for the hypothetical cohort.

$$ndx = nQx \times nlx$$

Using the death rate, the number of person-years lived in each age group, denoted as nLx, can be calculated. The number of person-years lived takes into account nAx, the number of person-years lived of the persons who died in that age group.

$nLx = lx_{n+1} \times n + ndx \times nAx$. For the last interval, nLx is: $\infty Lx = \frac{ndx}{nMx}$.

The total number of person-years lived after a certain age x, denoted as T_x, is calculated by summing all Lx after age x (Preston, 2001). The final step in computing the period life table is calculating the life expectancy, denoted as E_x.

$$Tx = \sum_{a=x}^{\infty} nLa$$

$$Ex = \frac{Tx}{lx}$$

Each municipality is compared to the Netherlands by calculating the difference in life expectancy, denoted as Δx. For this, the Arriaga (1984) decomposition method is used (fig 4; Appendix, sheets 3 & 5). The nlx, nLx, and Tx values of the municipality and the Netherlands are put in as data, where superscript 1 refers to the municipality, and superscript 2 refers to the Netherlands (fig. 4). Arriaga's (1984) method of decomposing life expectancies is called a discrete approach (Preston, 2001). The formula takes into account both the direct effect and the indirect and interaction effects (Arriaga, 1984). The last interval has a different formula as it only deals with the direct effect. $\infty\Delta x = \frac{l_x^l}{l_x^2} \times (\frac{T_x^2}{{l_x}^2} - \frac{T_x^l}{l_x^l})$

$$_n\Delta_x = \frac{l_x^1}{l_0^1} \cdot \left(\frac{_nL_x^2}{l_x^2} - \frac{_nL_x^1}{l_x^1} \right) + \frac{T_{x+n}^2}{l_0^1} \cdot \left(\frac{l_x^1}{l_x^2} - \frac{l_{x+n}^1}{l_{x+n}^2} \right)$$

Figure 4: Arriaga's (1984) formula (Preston, 2001).

As the last step, it is calculated to what extent mortality by infectious diseases and mortality by other death causes contributed to this difference in life expectancy, Δx. The mortality due to infectious diseases, denoted as mIx, is calculated for both populations by dividing the number of deaths from infectious diseases in a certain age group by the total population in that age group. The contribution of infectious diseases to Δx, represented as $\Delta xInf$, is calculated:

$$\Delta xInf = \Delta x \times \frac{(mIxMunicipality - mIxNL)}{(mxMunicipality - mxNL)}$$

3.3 Ethical considerations and positionality

In historical demography research, data accuracy is of great importance. Conclusions could be used to understand society from the past. To ensure reliability, data was retrieved from trustable sources and checked multiple times when entering the data into Excel. The data is open source and by providing the calculations in the appendix, the research can be redone. Since the data is aggregated there are no privacy issues. Additionally, the fallacy of presentism is avoided by explaining the results through academic sources.

As to positionality, it is worth noting that the researcher is Dutch and may have certain views on some geographical areas. However, the quantitative nature of this research is minimally susceptible to subjectivity. To maintain objectivity in descriptions and conclusions, parts of the thesis were peer-reviewed by fellow students, who provided feedback. Additionally, the supervisor provided feedback and advice to improve the quality of the research. GenAI (specifically ChatGPT) was used for inspiration for this thesis topic at the beginning of this process. Later, it assisted with grammar and spelling checks, as well as improving sentence structure and word choices.

4. Results

4.1 Life Expectancy

The main result of the life tables is the life expectancy at birth for Dutch municipalities and the Netherlands in 1890 and 1920. The life expectancy at birth is plotted in Figure 5.

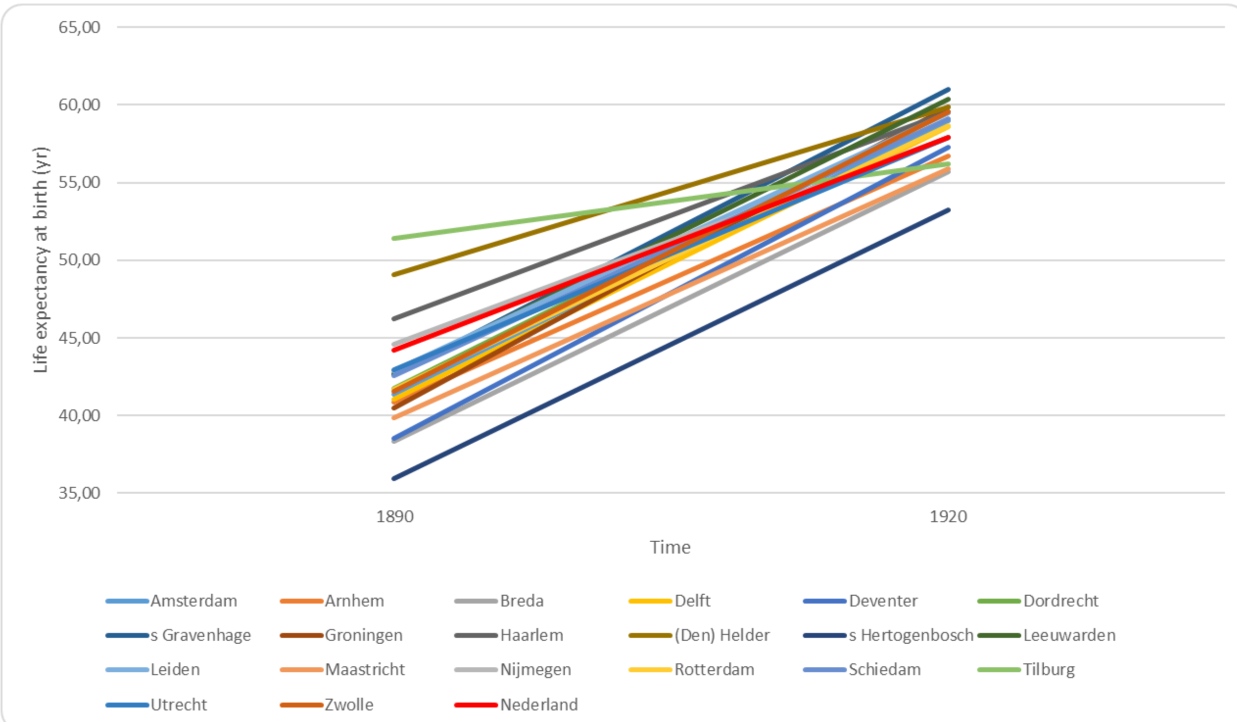

Figure 5: Life Expectancy at birth in Dutch municipalities and the Netherlands in 1890 and 1920.

One notable observation is the overall trend of convergence in life expectancy at birth (fig. 5). Life expectancy at birth is chosen as a parameter as it takes into account infant mortality. The difference between the lowest and highest life expectancy was 15.42 years (51.39-35.97) in 1890 and this declined to 7.73 years (61.00-53.27) in 1920 (Figure 5). This result differs from the expectations derived from the literature. The convergence can be explained by a divergence that already took place before 1890. Life expectancy began increasing from the 1870s onwards (Van Poppel, 2011), suggesting that divergence took place from 1870 to 1890, followed by convergence in the 1890s. As a consequence of major health improvements, divergence occurs as initially the most well-doing populations benefit most from these improvements. The phase of convergence begins when other populations catch up, gaining access to the same improvements (Vallin & Meslé, 2005). The age of receding pandemics is characterized as a period where life expectancy increases from under 30 to above 50 (Vallin & Meslé, 2005). In 1890 the lowest life expectancy already reached 35.97 years, indicating that the beginning of the age of receding pandemics started before this year. By 1920, not all municipalities had completed the age of receding pandemics yet, as some municipalities had not yet achieved a life expectancy above 50 years.

The results of the municipalities and the Netherlands are also shown in Figure 6. The median life expectancy at birth was 41.70 years in 1890 and increased to 58.65 years in 1920. The average life expectancy at birth was 42.32 years in 1890 and 58.28 years in 1920. The standard deviation was 3.43 years in 1890 and declined to 1.87 years in 1920.

When focusing on the Netherlands, it is important to note that in this population both rural and urban inhabitants are included. The average life expectancy at birth of municipalities with more than 20.000 inhabitants was 42.32 years in 1890 and 58.28 years in 1920. The average life expectancy at birth in the Netherlands was 44.19 years in 1890 and 57.91 years in 1920. In 1890, urban municipalities harmed the life expectancy at birth in the Netherlands. In 1890, 33.4% of the Dutch population lived in urban areas (Statista, 2009). Although reliable data on the percentage of the population living in urban areas in 1920 is unavailable, it was already 53% in 1910 (de Groot et al., 2010). By 1920, the average life expectancy at birth in urban areas rose above that of the Netherlands, though some municipalities still lagged behind. The concept of the urban penalty was evident in 1890, which suggests that in the early phases of the demographic transition model, mortality rates are higher and decline more slowly in urban areas (Reher, 2001). By 1920, more than half of the municipalities caught up with the national average, which is also a characteristic of the urban penalty. As mortality rates start to decline, it declines significantly faster in urban areas, eliminating the high urban mortality rate (Reher, 2001). This is supported by Hofstee's (1958) theory that urban areas are better positioned to seize the opportunities for reducing mortality rates than rural areas. According to Reher (2001), important factors behind this process are improved water supplies and education on public health and hygiene.

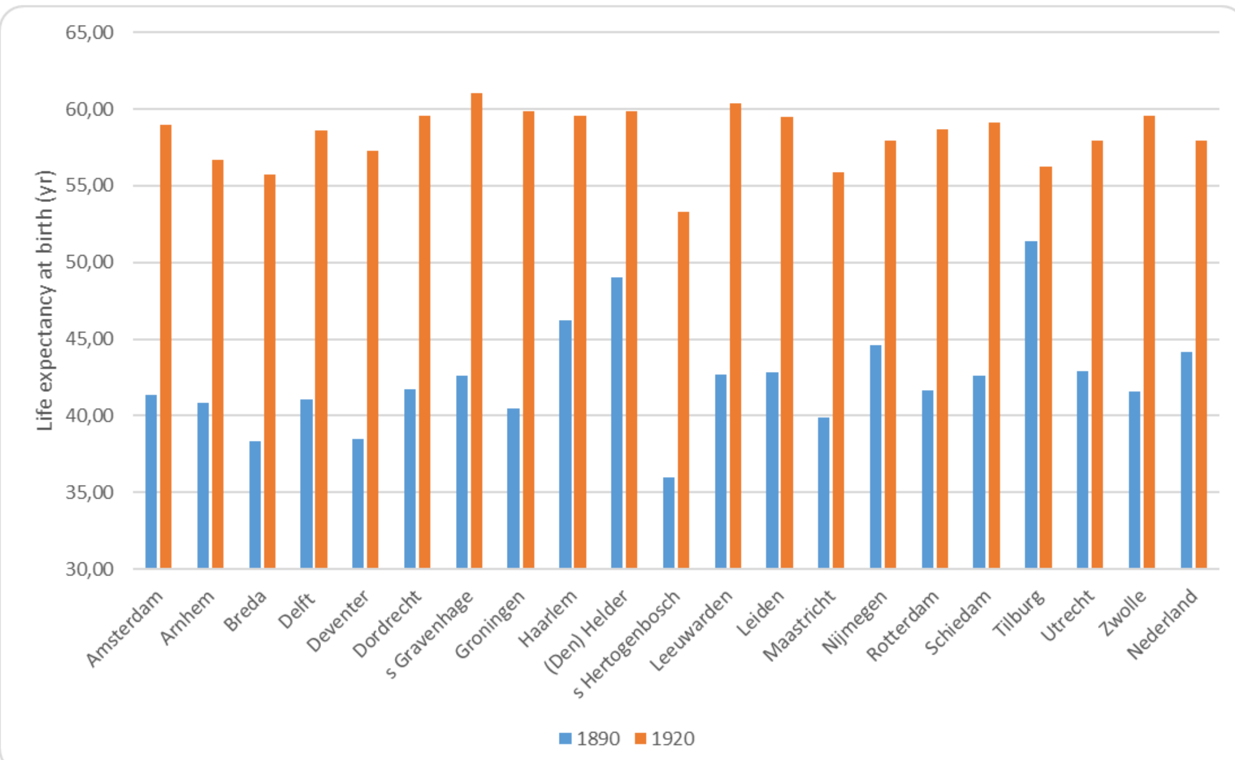

Figure 6: Life expectancy at birth in each municipality and the Netherlands in 1890 and 1920.

Two outliers that stand out in Figures 5 and 6 are ‘s Hertogenbosch and Tilburg. ‘s Hertogenbosch recorded the lowest life expectancy by some distance in both 1890 and 1920, while Tilburg had an exceptionally high life expectancy in 1890. Given that these municipalities are only 22 kilometers apart, this contrast raises questions. The first question is, why did ‘s Hertogenbosch experience such a low life expectancy at birth? During the period from 1885 to 1894, ‘s Hertogenbosch had the highest child mortality per 1000 born of all regions (Van Poppel, 1991). Van Poppel (1991) offers several possible explanations for this phenomenon. For example, ‘s Hertogenbosch only had 3,5 doctors per 10,000 inhabitants in the period 1885-1894, while municipalities like Den Haag, Amsterdam, and Utrecht all had more than 6 per 10,000 inhabitants. Additionally, the religion of ‘s Hertogenbosch, Catholic, may have played a role, as a higher mortality rate for Catholics was found (Van Poppel, 1991; Van Poppel, 1992). However, both ‘s Hertogenbosch and Tilburg are largely Catholic (CBS, 2023), and it is unclear why this would lead to different outcomes in the two municipalities. It is possible that Tilburg managed to achieve a higher life expectancy at birth despite the higher mortality rate for Catholics. A third contributing factor to a higher mortality rate is the higher number of pubs in the Southern areas of the Netherlands in 1890, which may have led to more use of harmful substances (Van Poppel, 1991).

The second question is, how did Tilburg develop from having the highest life expectancy at birth to one of the lowest? According to Van der Heijden (2005), this can be explained by ‘the law of the handicap of the head start’. Already in the Middle Ages, Tilburg was a textile city, and since 1827 the introduction of steam engines facilitated a large-scale textile industry. Unlike other industrialized cities, Tilburg’s housing featured larger houses on bigger lots, often with cellars (Van der Heijden, 2005). This can be attributed to the lack of slum landlords, instead individuals of the working class owned additional housing that they rented out (Van der Heijden, 2005), likely contributing to the high life expectancy in 1890. However, by around 1900, Tilburg lost its lead, primarily due to the rising child mortality. Many infants died of gastro-enteritis (Appendix, sheet 1, number 25) as a consequence of a shift from breastfeeding to bottle feeding (Van der Heijden, 2005). It is possible that in Tilburg this transition happened earlier or faster than in other municipalities, leading to a high child mortality. Next to the explanations of Van der Heijden (2005), there is also the possibility of incorrect data from Tilburg for the year 1890. Historical demography often presents examples of either intentional or unintentional incorrect data (Anderson & Silver, 1997). However, no sources explain why or how this should be the case for Tilburg.

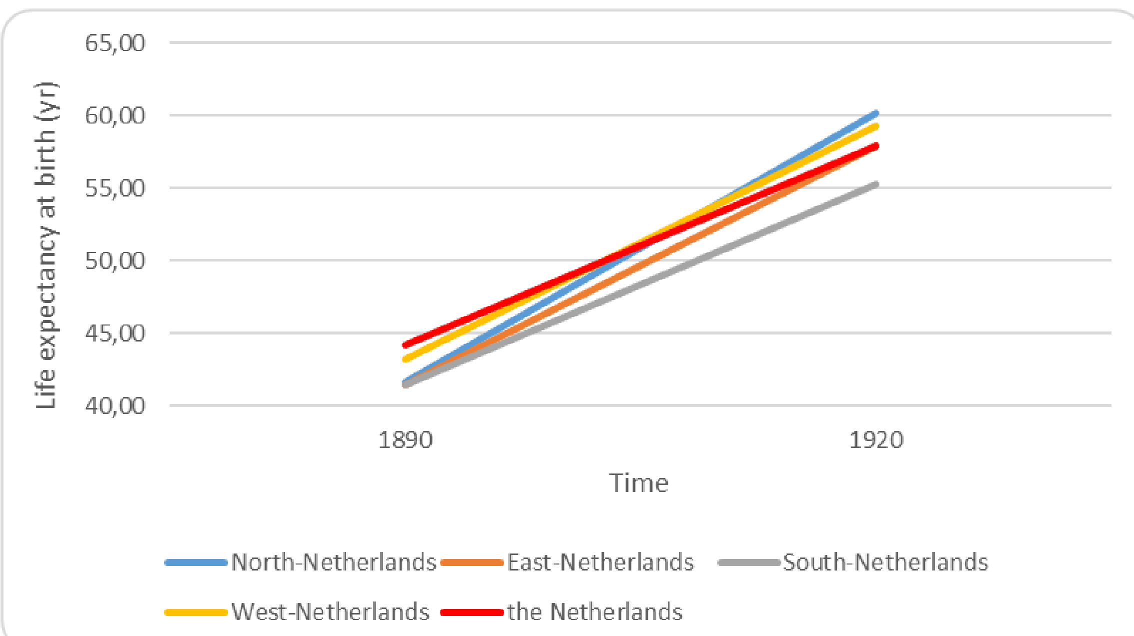

Figure 7: Life Expectancy at birth in Dutch regions and the Netherlands, 1890 and 1920.

In Figure 7 the municipalities are grouped according to their geographical location. The regions are based on the province of the municipality and organized based on the NUTS-1 areas. The division between these provinces is as follows:
North-Netherlands: Groningen, Friesland, Drenthe.
East-Netherlands: Overijssel, Gelderland, (Flevoland).
South-Netherlands: Noord-Brabant, Limburg.
West-Netherlands: Utrecht, Noord-Holland, Zuid-Holland, Zeeland.

In 1890, the average life expectancy at birth in the South, East, and North Netherlands was similar, around 41 years, while the. West Netherlands had a higher life expectancy at birth with 43.21 years. The overall life expectancy for the Netherlands was the highest with 44.19 years. By 1920, the South Netherlands recorded the lowest life expectancy, having ‘s Hertogenbosch, Breda, Maastricht, and Tilburg, the four lowest-ranked municipalities. The North Netherlands had the highest average life expectancy, exceeding 60 years. The North and West Netherlands have surpassed the Netherlands by 1920. It is important to take into account that the northern region only contains two municipalities in contrast to the western region which contains ten municipalities. The southern and the eastern regions each contain four municipalities. It is also important to note that the division of the regions is arbitrary; there can be larger distances between two municipalities in the same region than between two municipalities in a different region. The only significant regional difference is found in South Netherlands, where the life expectancies in ‘s Hertogenbosch and Tilburg can be attributed to their local economic and social histories. To better understand variations between municipalities, it is more effective to investigate smaller regions and municipalities, as the broader geographical regions tend to mask economic and social variations.

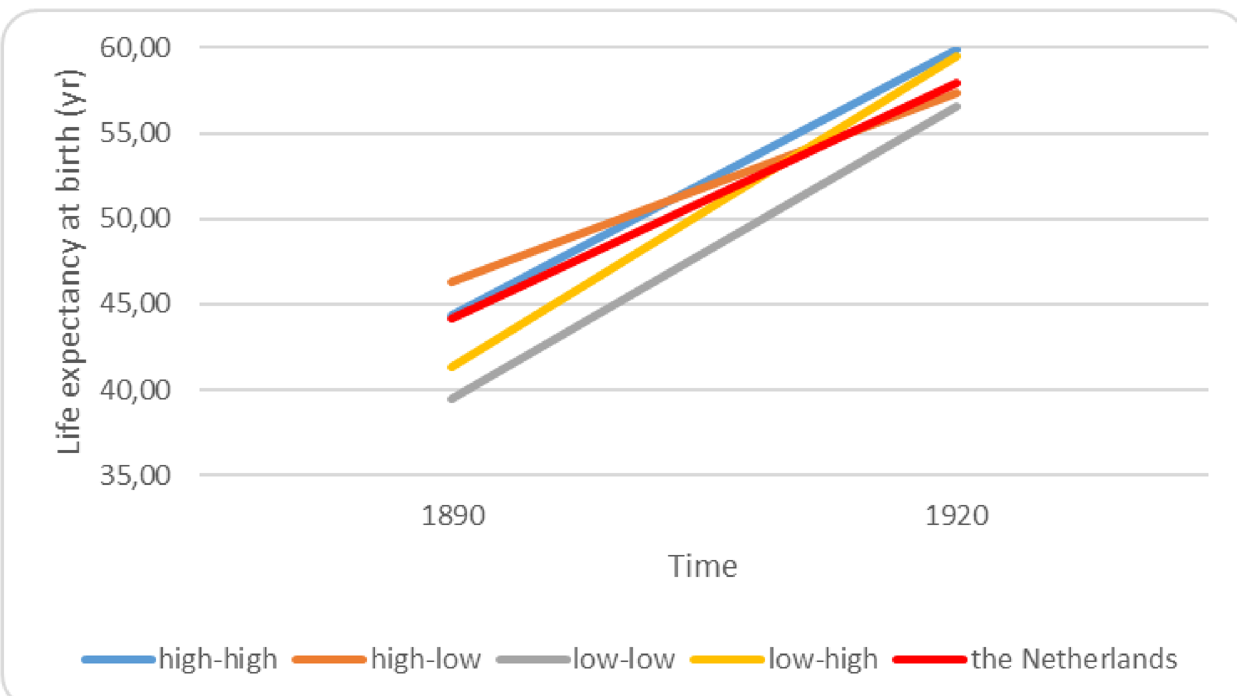

Figure 8: Life Expectancy at birth in groups of Dutch municipalities and the Netherlands, 1890 and 1920.

To determine if municipalities followed the same trajectories, all municipalities were ranked based on life expectancy at birth in 1890 and 1920. Municipalities within the top rankings were coded as ‘high’, while those outside the top 10 were coded as ‘low’. This coding produced four distinct groups of municipalities (Appendix, sheet 6), each at different stages of the demographic transition model (fig. 8). One notable observation is that municipalities transitioning from 'high' to 'low' have a higher life expectancy at birth than those ranked 'high' in both years. This phenomenon can be explained by the law of the handicap of the head start. This suggests that these municipalities may have only had an advantage in 1890 due to better accessibility to new improvements, rather than maintaining a consistently prosperous and healthy population with good facilities. Another notable finding is that municipalities moving from 'low' to 'high' already have a higher life expectancy at birth compared to those remaining in the 'low' category. Municipalities consistently outside the top 10 in both years likely have poorer facilities, working conditions, and healthcare, making them less able to benefit from new advances in living conditions.

Table 2: Characteristics of the four trajectories

	Water pipes	**Size 1890**	**Size 1920**	**% growth**
high high	1880	54806	101751	64.33
high low	1886	50115	90443	53.79
low low	1887	54905	111652	65.19
low high	1877	130762	207010	64.72

The question now is whether the grouped municipalities share any common characteristics. Table 2 presents the four trajectories, detailing the average year water pipes were installed, the average population size in 1890 and 1920, and the average population growth rate between 1890 and 1920.

In the second half of the 19th century, new ideas emerged about the relationship between health and clean water. Regarding sanitation, municipalities such as Leeuwarden, Dordrecht, Arnhem, Groningen, Leiden, Rotterdam, Amsterdam, Nijmegen, and Maastricht used a system known as the barrel system (‘tonnenstelsel’), where households had poop barrels collected several times a week (Havekes et al., 2021). This system remained popular until 1890 due to its low cost. Subsequently, the coil system (‘spoelstelsel’) gained popularity, as by the late 19th century, feces and dirty water were seen not just as smelly and unpleasant but as public health hazards (Havekes et al., 2021). The development of water pipes for clean drinking water preceded that of sewer systems, effectively paving the way for the installation of sewer systems (Havekes et al., 2021). However, the average year of water pipe installation does not explain the similar trajectories of the municipalities.

The size of the municipalities might partially explain their trajectories. On average, municipalities that transitioned from 'low' to 'high' have the largest populations. Initially, this large population size may have been a burden, putting pressure on problems like poor sanitation, disease spread, and housing shortages. However, once these problems were addressed through modern healthcare, improved facilities, and reforms, the large population size likely contributed to the city's rapid development.

From 1890 to 1920, all populations grew at a similar rate of around 64%, with one outlier: the 'high-low' trajectory, which had a population growth rate of 54%. This relatively low population growth may have caused these municipalities to fall out of the top 10, potentially hindering their economic growth.

4.2 Impact of Infectious Diseases on Life expectancy

To assess the impact of infectious diseases or local epidemics on life expectancy at birth in 1890 and 1920, the total deaths in each municipality were categorized into two groups: infectious diseases and other causes of death (Figures 9 and 10).

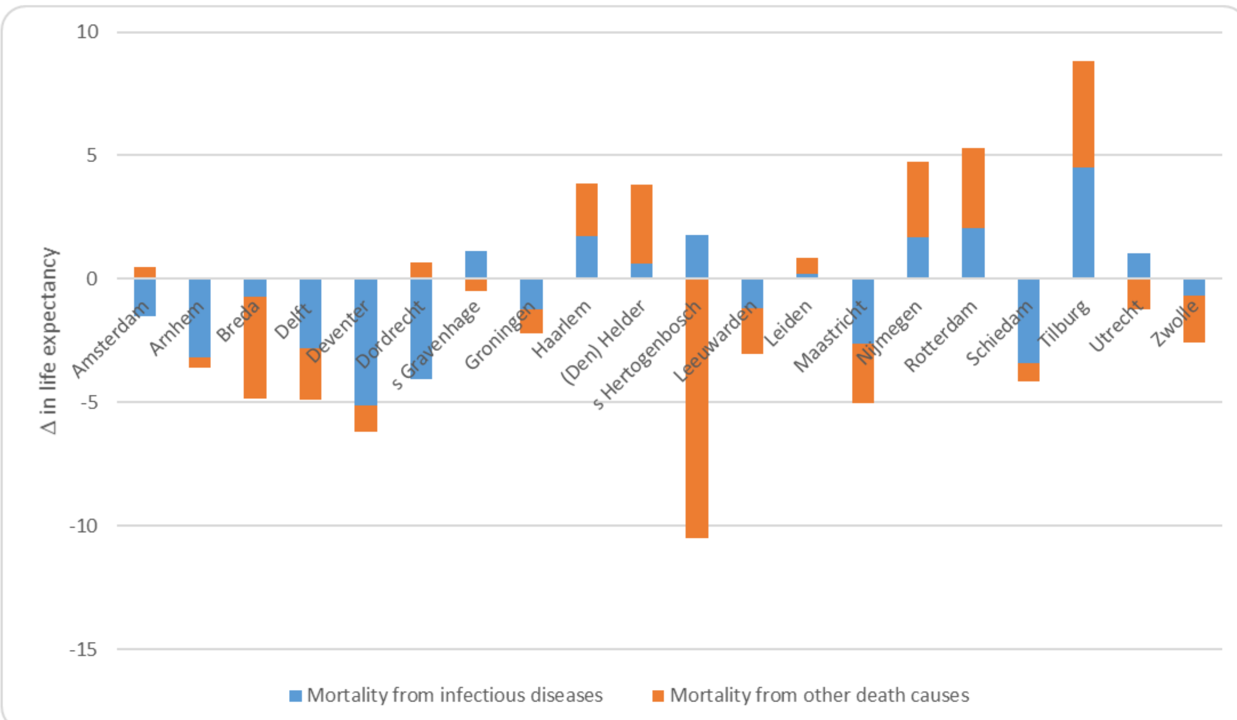

Figure 9: Contribution of infectious diseases and other death causes to the Δ in life expectancy at birth of Dutch municipalities compared to the Netherlands, 1890.

All municipalities plotted in Figures 9 and 10 are compared to the Netherlands as a whole. If the difference in life expectancy at birth is above 0, it is in favor of the municipality; if below 0, it is not. Municipalities that had an advantage due to fewer infectious diseases than the national average in 1890 include 's Gravenhage, Haarlem, Den Helder, 's Hertogenbosch, Leiden, Nijmegen, Rotterdam, Tilburg, and Utrecht. There is no clear trend indicating whether infectious diseases had a predominantly negative or positive effect on life expectancy at birth. An interesting case is 's Hertogenbosch, which had many deaths from other causes compared to the national average but fewer deaths from infectious diseases. Municipalities with a relatively high contribution of infectious diseases are Amsterdam, Arnhem, Deventer, Dordrecht, and Schiedam. The population of these municipalities was either more or less susceptible to infectious diseases compared to the average population, likely due to various factors.

In 1920, municipalities with less contribution of infectious diseases to their mortality rates had a lead in life expectancy compared to the national average, including Amsterdam, Delft, Dordrecht, 's Gravenhage, Groningen, Den Helder, Leeuwarden, Leiden, Nijmegen, Tilburg, Utrecht, and Zwolle. The populations in these municipalities were less susceptible to infectious diseases compared to the national average for various possible reasons. Despite this, Den Helder and Leeuwarden, which also exceed the national average, still had a relatively high contribution to infectious diseases.

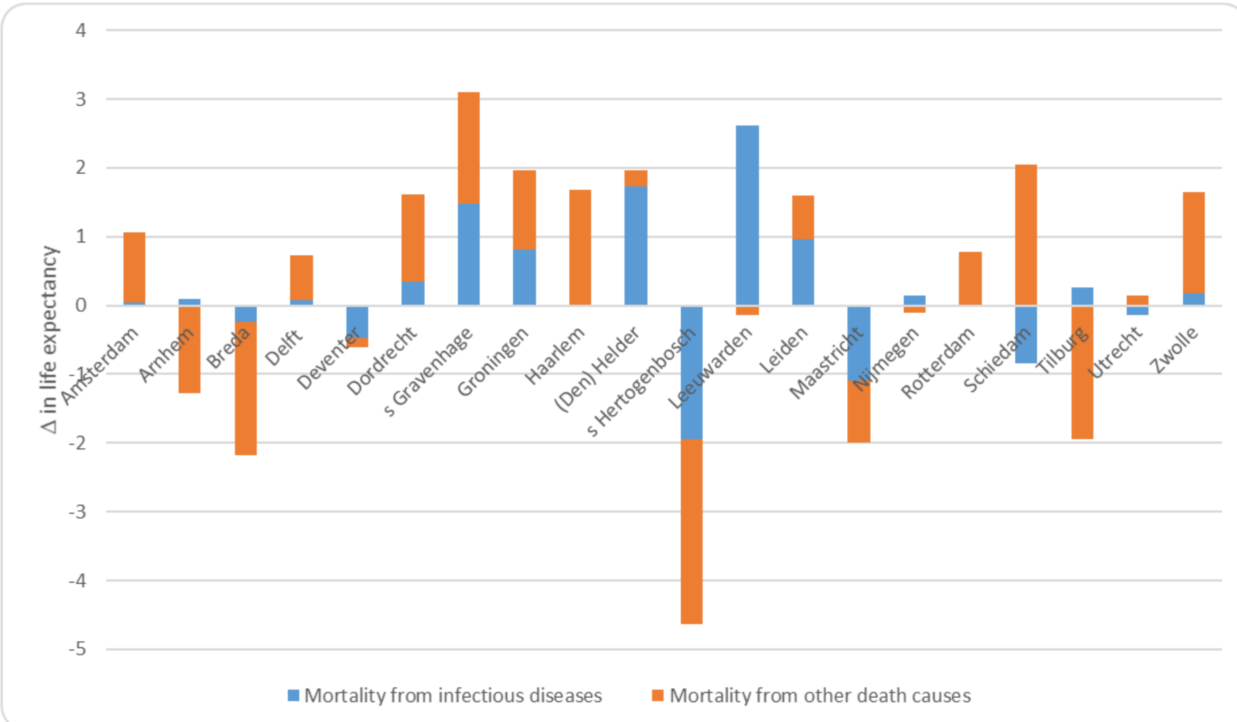

Figure 10: Contribution of infectious diseases and other death causes to the Δ in life expectancy at birth of Dutch municipalities compared to the Netherlands, 1920.

Compared to 1890, 's Hertogenbosch experienced a higher number of deaths due to infectious diseases in 1920. Leeuwarden made significant progress during this period by drastically reducing deaths attributed to infectious diseases. Overall, infectious diseases played a diminished role in life expectancy at birth in 1920 compared to 1890.

4.3 Standardizing Infectious Diseases

Another approach to visualize the impact of infectious diseases on life expectancy at birth is by standardizing the mortality rate due to infectious diseases across each municipality (fig. 11). All municipalities are given the same infectious disease mortality rate as the Netherlands.

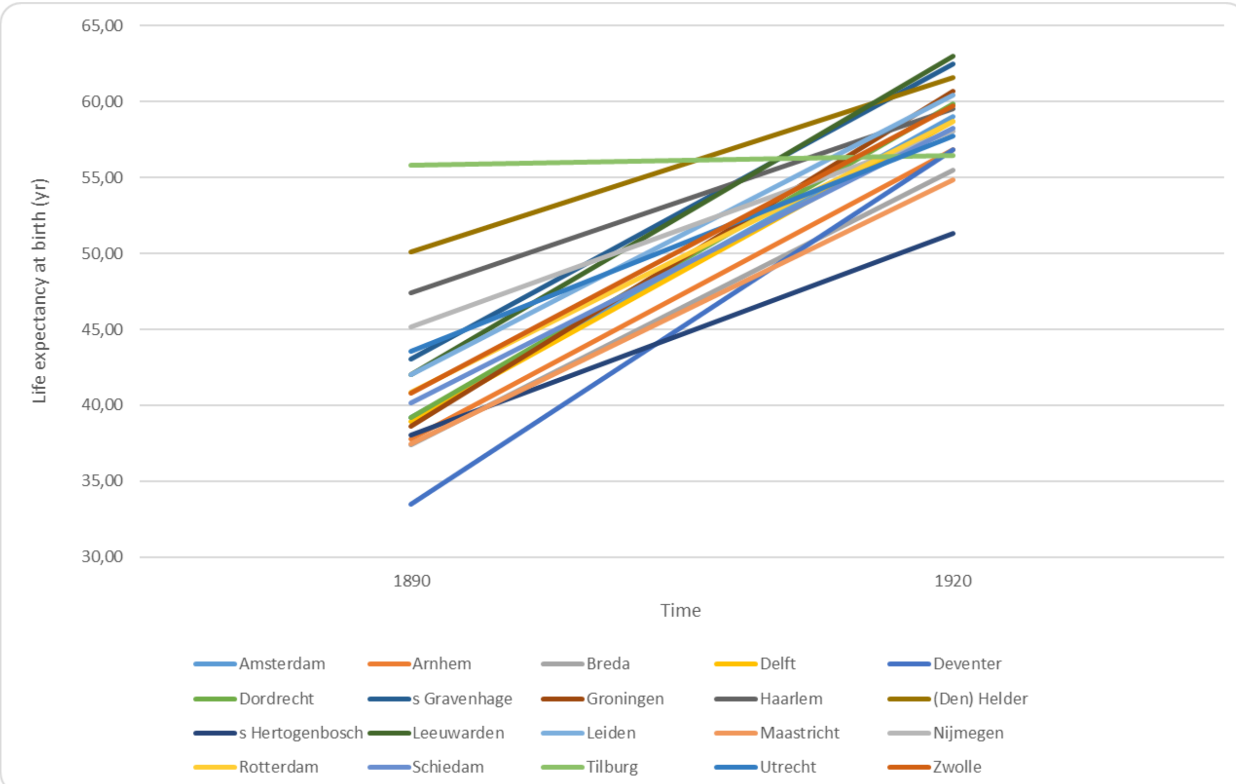

Figure 11: Life Expectancy at birth of Dutch municipalities if the mortality rate of infectious diseases was equal to that of the Netherlands, 1890 and 1920.

In Figure 11 there is more divergence compared to the real-life expectancy at birth (fig. 5). The difference between the lowest and highest life expectancy is 22.37 years (55.84-33.47) in 1890 and this declined to 11.67 years (63.01-51.34) in 1920 (fig.12). Compared to 15.42 years in 1890 and 7.73 years in 1920 in the original situation. Despite more divergence in both years, the trend of convergence is still visible (fig 11). Equalizing the mortality rate due to infectious diseases has different effects on the municipalities, depending on what their previous mortality rate due to infectious diseases was. Deventer goes down to a life expectancy at birth of 33.47 years in 1890, lower than any life expectancy in Figure 6. Tilburg stayed the highest in 1890 and even increased to a life expectancy at birth of 55.84 years. The highest life expectancy is also higher when equalizing mortality rates for both years.

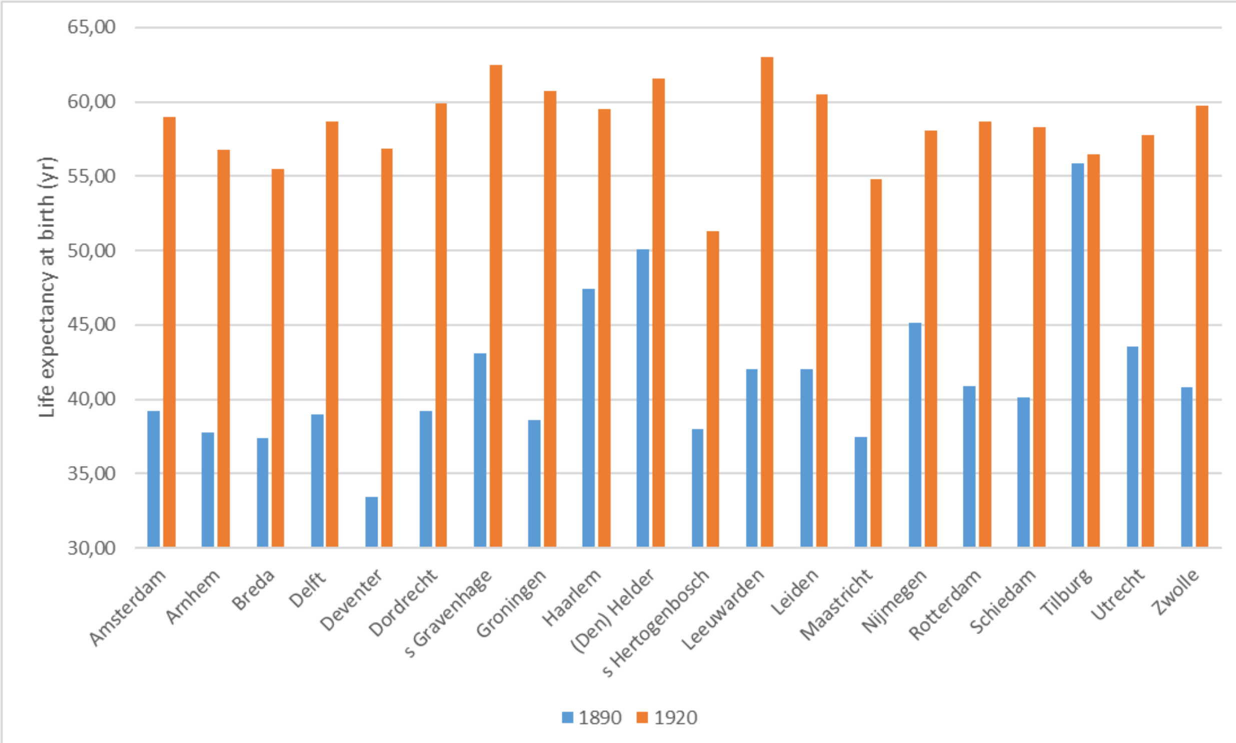

Figure 12: Life expectancy at birth in each municipality in 1890 and 1920 if the mortality rate of infectious diseases was equal to that of the Netherlands.

The standard deviation of the life expectancies at birth with an equalizing mortality rate was 4.93 years in 1890 and 2.68 years in 1920. There is an absolute difference of 2.25 years compared to the 1.56 years of life expectancy with their own levels of infectious diseases. However, the relative difference is in both cases 46%. Meaning that the life expectancies with their own levels of mortality from infectious diseases lie closer to each other in absolute terms than the life expectancies with equalizing mortality.

5. Conclusion

The main objective of this research was to calculate life expectancy at birth for 20 municipalities and compare them to the Netherlands. Despite a trend of divergence being expected, the observed trend is convergence. Given that life expectancy began to increase in the 1870s (Van Poppel, 2011) it is likely that divergence already occurred before 1890. The pace and timing of an increasing life expectancy varied across municipalities in the Netherlands, reflecting different phases of the demographic transition model due to local characteristics. Tilburg and ‘s Hertogenbosch are outliers: Tilburg due to quality housing and changing infant feeding practices and ‘s Hertogenbosch due to religion and the number of doctors. The concept of the urban penalty is observed as in 1890 most municipalities had higher mortality rates than the Netherlands. Most municipalities caught up with the national average in 1920. Key factors contributing to this catching up are improved water supplies and education on public health and hygiene (Reher, 2001).

The geographical distribution provides no significant explanation power as differences are primarily caused by local economic and social history. To group municipalities with similar characteristics, four trajectories were made based on life expectancy rankings. Population size and the growth rate of the population may explain a part of the life expectancy variations. There is no link found between the installation of water pipes and life expectancy.

The contribution of infectious diseases to the difference in life expectancy varies across municipalities. Overall, the contribution of infectious diseases to life expectancy decreased from 1890 to 1920. Causing factors behind the increase in life expectancy and differences between municipalities include infrastructure, social reforms, economic prosperity, religion, and healthcare. Standardizing the mortality from infectious diseases to the national average for each municipality, resulted in more absolute differences between them. The overall trend observed remains convergence.

Concluding, *to what extent did the new dynamic of decrease in infectious diseases cause regional divergence or convergence in life expectancy in the Netherlands, 1890-1920?* The new dynamic of decrease in infectious diseases that started from the 1870s caused an increase in life expectancy in all municipalities with first a phase of divergence followed by a phase of convergence between 1890 and 1920 (Van Poppel, 2011; Vallin & Meslé, 2005).

One limitation of this study is the data quality, with some unknown cases, and hard-to-read documents. Ensuring the accuracy of the data, especially in the case of Tilburg, provides challenges. Future research could perform statistical tests to investigate which characteristics of municipalities influenced the life expectancy at birth. Also, a more zoomed-in approach to the background and characteristics of the municipalities could offer insights into possible reasons behind the observed differences. Additionally, future research could focus on differences between infectious diseases.

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