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A Mathematical Model for the Prediction of Alzheimer's Disease Prevalence in the Population

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Summary:

With the technological advancements in the health sector, there has been a substantial increase in the old population since the 1900's. As the average lifespan of people increases, the elderly population in need of care grows, and so do the costs associated with taking care of the dependent population. Along with the natural causes of diminishing physical and mental abilities due to aging, factors such as diseases also result in the need for the elderly to be under constant monitoring. Dementia is one of the major factors in diminishing cognitive abilities. And as Alzheimer's Disease makes up most of the dementia cases, it is expected to hold a significant position in the growing elderly population. The costs of Alzheimer's can range from economic to psychological; affecting the patients, their relatives and the carers. In our model, we consider the quantifiable effects of the growing elderly population and Alzheimer's cases through their economic impact.

In this paper, the methods used in predicting the Alzheimer's Disease cases were divided into four parts: prediction of the world population, estimation of the growth in elderly population, prediction of the number of Alzheimer's Disease cases until 2050 and the estimation of the total cost of Alzheimer's patients in each year. In the first section, data was gathered of the world population from 1960 to 2020. This data was made into a regression model which was used to predict the world population until 2050. In the second section, the data for the percentage of the old population (over the age of 65) in the total population was found from the year 1960 to 2020. This was again used to make a regression curve which was later used to predict the old population percentage increase for each year in between the years 2020 to 2050. The percentage of old population data was multiplied with the population predicted for each year and the number of old people were calculated. In order to separate the old population into 5 year age gaps, population by ages data from 2020 was used. In the third section, data for the percentage of dementia by age groups were gathered and were scaled for Alzheimer's cases by the factor of 0.6. Since only percentages of dementia cases for the population over certain ages could be found, a regression model and closed integral was used to determine the average percentiles for Alzheimer's in seperate 5 year age gaps from ages 64 to 99. These percentages were then multiplied by the old population at each age to estimate the number of people with Alzheimer's Disease until the year 2050. Finally, the number of Alzheimer's patients in each year were used to determine the increase in the total cost of Alzheimer's patients until the year 2050.

Introduction:

Dementia is a general term used to describe the deterioration of one's cognitive functions to an extent at which it interferes with their daily lives. It includes loss of memory, language, problem-solving and other thinking abilities. Around 5-8% of all people above the age of 60 are affected by dementia and it reaches to around 40% for people older than 90. Dementia symptoms have different variations that are dependent on the cause. Dementia's negative impacts can be observed both cognitively and psychologically. The most common cognitive symptoms can be listed as memory loss, difficulty in communication, difficulty with visual and spatial abilities, difficulty in problem solving, difficulty handling complex tasks, difficulty with planning and organizing, difficulty with coordination and motor functions, confusion and disorientation. The most common psychological symptoms can be listed as changes in personality, depression, anxiety, inappropriate behavior, paranoia, agitation and hallucinations. While there are many different types of dementia, the most common cause of dementia is Alzheimer's Disease, which makes up around 60-80% of all dementia cases. Alzheimer's Disease is a progressive neurologic disorder that causes the brain to shrink (atrophy) and brain cells to die.[1] Due to the fact that Alzheimer's Disease is the most diagnosed type of dementia it is anticipated that the increase in dementia rates are proportional to increase in Alzheimer's Disease rates. As the different age groups are examined in increasing age order, the possibility of Alzheimer's Disease diagnosis increases, as age is a major determinant of Alzheimer's. There are many factors that can have an impact on the occurrence of Alzheimer's Disease. Factors of Alzheimer's Disease can be listed as follows: age, gender (women have higher rates of Alzheimer's), family history, head injuries and other factors such as high cholesterol levels and high blood pressure. There's no cure for Alzheimer's Disease, although there are medicines available that can reduce the symptoms temporarily and precautions to be taken in order to slow down the progression of dementia. Medicines are prescribed to decrease the impacts of the ongoing symptoms.

Definition of The Problem:

It is known that one in every 9 people over the age of 65 is diagnosed with Alzheimer's. It is not only a common disease but also a major factor of death. It is known that the population of the world is increasing uncontrollably and technology is developing even faster every day. Over the last several decades, the average lifespan of a person has had substantial improvement. While age is not the sole factor in the progression of Alzheimer's, it is one of the main factors in its development. The increasing population and the developed health sector naturally causes the number of people with

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1 https://www.mayoclinic.org/diseases-conditions/alzheimers-disease/symptoms-causes/syc-20350447#:~:text=Alzheimer's%20disease%20is%20a%20progressive,person's%20ability%20to%20function%20independently.

Alzheimer's to increase. Among those, there are also factors such as increased stress levels, income levels and higher education. It is known that, today there are 55 million people who are diagnosed with Alzheimer's and this number is increasing with approximately 10 million every year. Even though Alzheimer mostly harms the individual, it has significant effects on that person's carers. These effects include both mental and economical ones. Firstly, the mental ones include keeping up with the pills the patient has to take, never letting them leave your site because they have hard time remembering short time memory and they might get lost, participation on activities, taking parts in support groups and most importantly seeing someone you love in a situation where they cannot take care of themselves. When it comes to the economic costs, it is known that an Alzheimer's patient's approximate cost per year is 25,000$. Under the light of given facts and modeling that we are going to crease, we are planning to estimate the number of patients in 2050 and the total economic cost for that particular year.

Assumptions and Variables:

Background Assumptions:

- Cases of Alzheimer's Disease below the age of 65 are considered to be negligible. According to statistics, young-onset Alzheimer's cases make up around only 5-6% of Alzheimer's diagnosis, which corresponds to about 0,01% of the whole population. This value can be considered negligible compared to the total number of people with Alzheimer's.

- It is assumed that developments in the medical sector do not change the economic cost of Alzheimer's patients. The improvements in the medical sector and the possible decrease in costs in caring for the elderly is considered to be negligible and remain constant for a span of 30 years.

- The average lifespan of an Alzheimer's patient is assumed to remain constant in the next 30 years. Technological advancements in the medical sector may result in an increase in the average lifespan of a person and in better treatments for known diseases. However, it is assumed that these treatments do not result in a significant increase in the average lifespan of an Alzheimer's patient, which lies between 3 to 11 years on average, in the 30 year time span considered.

- It is assumed that there is no progression in finding a cure for Alzheimer's Disease in the next 30 years. There is no permanent treatment for Alzheimer's.

- It is assumed that the care costs of Alzheimer's Disease patients are constant, independent of the increasing needs due to the increasing age factor. As Alzheimer's progresses, the patients become less able to fulfill their own needs without the support of a carer. However, it is difficult to gather information on the exact progression of Alzheimer's costs at each stage. So only the average costs were taken into consideration.

- The misdiagnosed cases are considered to be negligible. The falsely diagnosed with Alzheimer's Disease had other conditions that accounted for their symptoms, including Lewy body dementia, brain atrophy and other types of dementia. Since the similar cases result in similar economic costs from a carer and differentiating the misdiagnosed cases are difficult, the misdiagnosed cases are not taken into account.

- The undiagnosed cases are considered to be negligible. People who have Alzheimer's start to develop Alzheimer 10-20 years before the first symptoms. Because there are no symptoms and most people do not test for Alzheimer regularly, there might be cases which are not known yet. However, determining these cases are not possible without relevant data, so they are not considered in our model.

Model Assumptions:

- The distribution of ages in a 5 year age group population is equal. In a 65-69 age group, the number of people at each age is assumed to be equal.

Variables:

Age Factor	It is known that age is a major determinant of Alzheimer's Disease and the percentage of prevalence of Alzheimer's increases with age. Depending on this fact, the population over 65 was divided into groups by a steady increase of 5 years. The percentages of Alzheimer were calculated specifically for each age group.
Change in the World Population	The world population datas between the years 1960 and 2020 were taken into account when predicting the future population increase. The relation between years and the population of the world was found by forming different types of regression curves to create a best-fit curve. The best fit regression was then considered to create a prediction. From the regression equation, the world population predictions were made until the year 2050.
Change in the Percentage of Old Population	The values for the population over 65 years old were taken for the years between 1960 and 2020. By the change in the older population, an equation was created. The number of people over 65 years old for the years until 2050 was predicted by the equation found by regression.

Model:

Finding Variables for Alzheimer's:

At the beginning of our modeling journey, our first intuition was to look for dependents of Alzheimer's Disease. We came across age, genetics, stress, alcohol, sex, bilingualism etc. Our first decision was to create an equation with multi-variables and we started looking for data. We found the percentage of the older population, which corresponds to people over 65 years old, from the database of the world bank; again from the world bank, we deducted the alcohol consumption according to country. We found a study named "Construction of a risk prediction model for Alzheimer's Disease in the elderly population" which was made among 555 Alzheimer patients and 544 non-Alzheimer patients. Here we saw the seven variables affecting Alzheimer's: sex, marital status, education level, economic status, lifestyle (alcohol consumption and smoking), health status and genetic risk. Although, we had a hard time finding datas of the total Alzheimer values depending on the variables we saw before. So we decided to change our way into forming a relation between the age groups within the older population and the Alzheimer prevalence. So our variables were reduced to age groups, change in older population and change in total population.

Use of Regressions:

In order to estimate future data and data we couldn't obtain, regressions were used. The gaps in data were filled with findings from the regression curves in order to finalize the model. Cubic regression was the mainly used regression model due to the nature of our data. The selection of regressions were done through comparing the R values and the shapes of the graphs created by the regression. Some of the datas (clarify which) weren't usable before or after a specific timeframe due to the shape of the curve. In order to not be affected by this issue the accuracy of the data between the years of 2020 and 2050 were prioritized. The graphs for the regressions were done through Desmos.

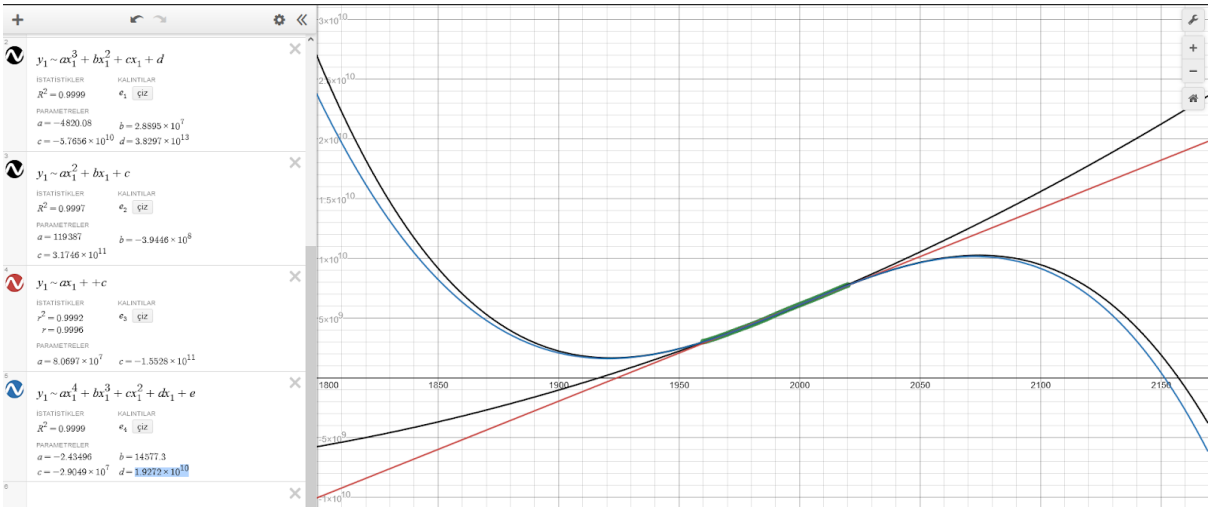
Finding the Total Population:

The reason for the increase in Alzheimer's is considered to be the increase in population and the increase in the percentage of the old population compared to the total population. In order to create a model for Alzhemer's a model for these two datas must also be created. The world population datas between the years 1960 and 2020 were taken into account when predicting the future population increase. These datas were provided from the website of the World Bank. An excel sheet was created

in order to find a regression for the data. The correlation between years and the population of the world was determined through the usage of different types of regression models including linear, quadratic, cubic and quartic regression to determine the best-fit curve.

YEAR	POPULATION	YEAR	POPULATION
1960	3032156070	1991	5368139818
1961	3071596055	1992	5452576967
1962	3124561005	1993	5537885402
1963	3189655687	1994	5622085293
1964	3255145692	1995	5706753581
1965	3322046795	1996	5789655178
1966	3392097729	1997	5872284397
1967	3461619724	1998	5954004340
1968	3532782993	1999	6034484369
1969	3606553753	2000	6114324044
1970	3681975908	2001	6193663732
1971	3760516757	2002	6272724236
1972	3836900801	2003	6351855732
1973	3912984371	2004	6431527221
1974	3988487336	2005	6511724848
1975	4062507027	2006	6592711655
1976	4135432265	2007	6674181848
1977	4207786422	2008	6757000414
1978	4281339378	2009	6839553692
1979	4356778367	2010	6921854591
1980	4432963653	2011	7003760440
1981	4511164132	2012	7089254548
1982	4592387213	2013	7175500378
1983	4674330282	2014	7261846543
1984	4755996689	2015	7347679005
1985	4839176734	2016	7433569330
1986	4924747934	2017	7519183459
1987	5012556248	2018	7602454161
1988	5101287675	2019	7683372259
1989	5189977062	2020	7761620146

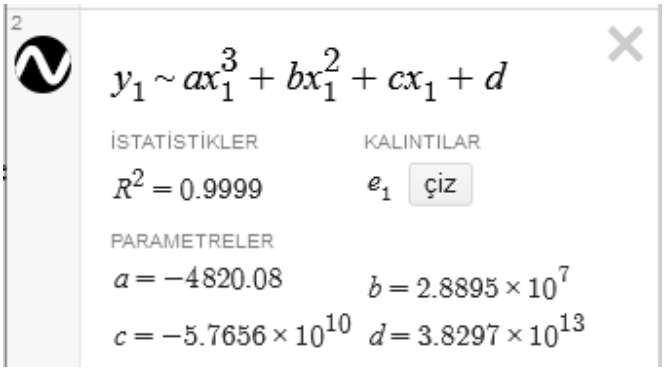
YEAR	POPULATION	YEAR	POPULATION
1960	3032156070	1991	5368139818
1961	3071596055	1992	5452576967
1962	3124561005	1993	5537885402
1963	3189655687	1994	5622085293
1964	3255145692	1995	5706753581
1965	3322046795	1996	5789655178
1990	5280062644		



Graph 1 The Regressions created from the data of population from 1960-2020

From the R^2 values and with consideration to other studies done about the topic, Cubic Regression was determined to be the most accurate. Linear regression wasn't fit to model the logorthnic increase of population. The Quadratic regression was more accurate, however, considering that population is set to reach a maximum of 10 million and then decrease it wasn't deemed to be accurate enough. The difference in shape and the accuracy between the cubic regression and the quartic regression was negligible. For this reason the less complicated cubic regression. The equation is then calculated as:

$$-4820,08x^3 + 2,8895 \cdot 10^7 \cdot x^2 - 5,7656 \cdot 10^{10} + 3,8297 \cdot 10^{13}$$



From the regression equation the world population was planned to be predicted until the year 2050 using excel. However during conversion the data calculated from excel was seen to be not equal to the values in the graph. This was most likely due to Desmos rounding some of the values which changed the value. In order to reduce this effect a different value for the constant was chosen while comparing to the real values. The new equation was found to be:

$$y = -4820,08x^3 + 2,8895 \cdot 10^7 \cdot x^2 - 5,7656 \cdot 10^{10} + 3,82987 \cdot 10^{13}$$

From this equation the values of population by year was found to be:

Year	Population	Year	Population	Year	Population
1960	3006117120	1991	5314089958	2022	7823223468
1961	3068607246	1992	5396517161	2023	7897795167
1962	3132174310	1993	5479124767	2024	7971650734
1963	3196789392	1994	5561883857	2025	8044761250
1964	3262423572	1995	5644765510	2026	8117097794
1965	3329047930	1996	5727740805	2027	8188631445
1966	3396633544	1997	5810780822	2028	8259333284
1967	3465151495	1998	5893856641	2029	8329174389
1968	3534572861	1999	5976939340	2030	8398125840
1969	3604868723	2000	6060000000	2031	8466158717
1970	3676010160	2001	6143009700	2032	8533244099
1971	3747968251	2002	6225939519	2033	8599353065
1972	3820714076	2003	6308760538	2034	8664456696
1973	3894218715	2004	6391443835	2035	8728526070
1974	3968453246	2005	6473960490	2036	8791532268
1975	4043388750	2006	6556281583	2037	8853446368
1976	4118996306	2007	6638378193	2038	8914239450
1977	4195246993	2008	6720221399	2039	8973882594
1978	4272111892	2009	6801782282	2040	9032346880
1979	4349562081	2010	6883031920	2041	9089603386
1980	4427568640	2011	6963941394	2042	9145623193
1981	4506102649	2012	7044481782	2043	9200377379
1982	4585135187	2013	7124624164	2044	9253837025
1983	4664637333	2014	7204339620	2045	9305973210
1984	4744580168	2015	7283599230	2046	9356757013

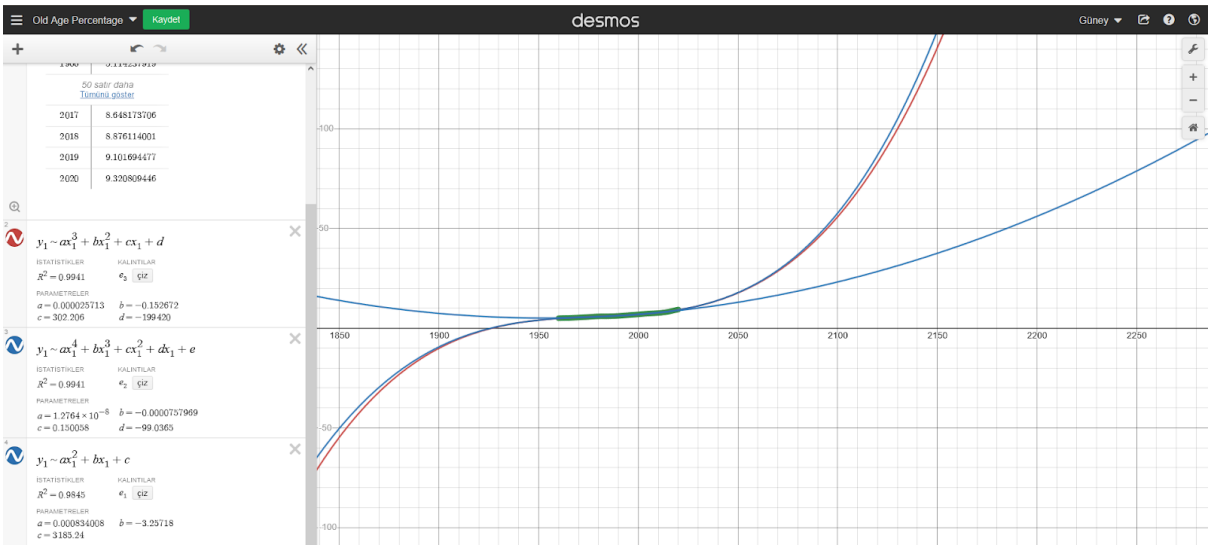
1985	4824934770	2016	7362374072	2047	9406159514
1986	4905672220	2017	7440635227	2048	9454151793
1987	4986763596	2018	7518353773	2049	9500704928
1988	5068179978	2019	7595500791	2050	9545790000
1989	5149892446	2020	7672047360		
1990	5231872080	2021	7747964559		

Finding the percentage of old population until 2050:

During our research, we were not able to find the data for the amount of old population year by year. However, we were able to find the percentage of the old population. The total data taken between 1960 to 2020 on the percentage of the old population was taken from the world bank can be seen here:

YEAR	% OF OLD POPULATION	YEAR	% OF OLD POPULATION
1960	4,970172277	1991	6,23488657
1961	5,016769657	1992	6,315064671
1962	5,042382596	1993	6,393632878
1963	5,052033206	1994	6,465075777
1964	5,056444973	1995	6,525810945
1965	5,057547368	1996	6,613459046
1966	5,114237919	1997	6,683427806
1967	5,168272596	1998	6,744057968
1968	5,218143246	1999	6,806000391
1969	5,262624896	2000	6,874085999
1970	5,301562489	2001	6,958160847
1971	5,368716701	2002	7,045473311
1972	5,427446495	2003	7,130409107
1973	5,479838355	2004	7,202309145
1974	5,529704282	2005	7,257547687
1975	5,579069742	2006	7,327525546
1976	5,658587682	2007	7,383336897
1977	5,736435601	2008	7,434613426
1978	5,806879857	2009	7,493188893
1979	5,860477964	2010	7,567130646
1980	5,892860279	2011	7,667986031
1981	5,927443881	2012	7,781270938
1982	5,93618528	2013	7,908978672

1983	5,93196788	2014	8,055742725
1984	5,930212265	2015	8,224308127
1985	5,93884483	2016	8,428535914
1986	5,975742037	2017	8,648173706
1987	6,016040262	2018	8,876114001
1988	6,060381731	2019	9,101694477
1989	6,109275029	2020	9,320809446
1990	6,161528175		



Graph 1 The Regressions created from the data of population from 1960-2020

Like the total population data, different types of regression were compared to find the best fitting curve. The quadratic regression was eliminated due to the R^2 value being the lowest. Quartic equation was similar to cubic however it wasn't as simple as the cubic equation. From these comparisons, the Cubic regression which was found to be the best fit for the data can be seen here:

$y=2,5713 \cdot 10^{-5} \cdot x^3 - 0,152672 \cdot x^2 + 302,206 \cdot x - 199421$

The equation created from the cubic regression was used to predict the values of the total population from 1960 to 2050. The old datas were then compared again in order to check for accuracy issues. While converting the equation to excel there was a decrease in accuracy which was fixed in excel. The fixed version can be seen here:

$y = 2,5713 \cdot 10^{-5} \cdot x^3 - 0,152672 \cdot x^2 + 302,206 \cdot x - 199421$

After that, the datas for the percentiles of the older population which corresponds to 65 or older was collected. These values were used to form an equation and the percentiles for the old population were found. The full table created with the regression equation from 1960 to 2050 can be found here:

YEAR	% OF OLD POPULATION	YEAR	% OF OLD POPULATION
1960	4,963968	2006	7,507370008
1961	5,031456553	2007	7,605513559
1962	5,096140264	2008	7,707949056
1963	5,158173411	2009	7,814830777
1964	5,217710272	2010	7,926313
1965	5,274905125	2011	8,042550003
1966	5,329912248	2012	8,163696064
1967	5,382885919	2013	8,289905461
1968	5,433980416	2014	8,421332472
1969	5,483350017	2015	8,558131375
1970	5,531149	2016	8,700456448
1971	5,577531643	2017	8,848461969
1972	5,622652224	2018	9,002302216
1973	5,666665021	2019	9,162131467
1974	5,709724312	2020	9,328104
1975	5,751984375	2021	9,500374093
1976	5,793599488	2022	9,679096024
1977	5,834723929	2023	9,864424071
1978	5,875511976	2024	10,05651251
1979	5,916117907	2025	10,25551563
1980	5,956696	2026	10,46158769
1981	5,997400533	2027	10,67488298
1982	6,038385784	2028	10,89555578
1983	6,079806031	2029	11,12376036
1984	6,121815552	2030	11,359651
1985	6,164568625	2031	11,60338198
1986	6,208219528	2032	11,85510758
1987	6,252922539	2033	12,11498208
1988	6,298831936	2034	12,38315975
1989	6,346101997	2035	12,65979488
1990	6,394887	2036	12,94504173
1991	6,445341223	2037	13,23905459
1992	6,497618944	2038	13,54198774
1993	6,551874441	2039	13,85399545
1994	6,608261992	2040	14,175232
1995	6,666935875	2041	14,50585167

1996	6,728050368	2042	14,84600874
1997	6,791759749	2043	15,19585749
1998	6,858218296	2044	15,55555219
1999	6,927580287	2045	15,92524712
2000	7	2046	16,30509657
2001	7,075631713	2047	16,6952548
2002	7,154629704	2048	17,0958761
2003	7,237148251	2049	17,50711474
2004	7,323341632	2050	17,929125
2005	7,413364125		

Calculating the total old population:

From the data collected for the percentage of the older population and the total population the total older population over the years can be calculated. The database for the total 65 or over population can be found here:

Year	65+ Population
2020	741316720
2021	765116073,3
2022	788787241,4
2023	812037551,5
2024	834759538,9
2025	856962989,4
2026	878714000,4
2027	900089294,1
2028	921147467,5
2029	941915246,3
2030	962385298,7
2031	982521821,9
2032	1002270459
2033	1021569813
2034	1040362526
2035	1058604654
2036	1076272658
2037	1093367768
2038	1109917834

2039	1125976992
2040	1141623562
2041	1156956645
2042	1172091889
2043	1187156820
2044	1202286094
2045	1217616932
2046	1233284958
2047	1249420551
2048	1266145796
2049	1283572073
2050	1301798257

Creating a Model to predict the amount of Alzheimer's patients:

From the data which was provided by the competition and our research, we were able to find the probability of Alzheimer's Disease patients per age group. From this we concluded that if we were to find the total number of people in certain age groups over 65 then we would be able to calculate the amount of Alzheimer's year by year. However, in order to achieve this we needed the number of people in the age groups, an algorithm to predict the yearly change within the age groups, and the risk factors of the age groups.

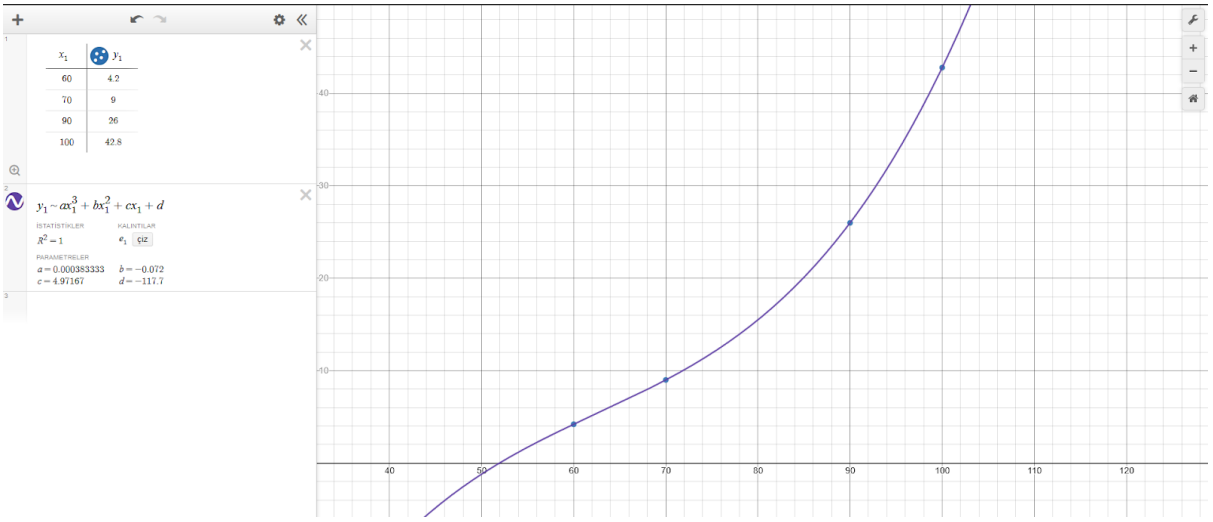
Finding The Probability of Alzheimer's Age by Age

The competition provided that dementia affected 5-8% of people over 60 which then increased to 40% with people older than 90. This data didn't benefit us directly as the model is specifically for Alzheimer's Disease however we were able to convert the given information to Alzheimer's and find new data from literature. From our research we were able to find these datas:

AGE	**% OF POPULATION**
60+	**4,2%**
70+	**9%**
90+	**26%**
100+	**42,8%**

These data weren't enough to create a model so we used desmos to create scatter plot using these data and created a cubic regression equation from this data with the equation:

$y=0{,}00038333 \cdot x^3 - 0{,}072 \cdot x^2 + 4{,}97167 \cdot x - 117{,}7$ and $R^2 = 1$



Using this function we found specific age groups by getting the average between the age groups 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, 95-99 and 100+. We then integrated this function to find the result of:

$y=x \cdot (38333 \cdot x^3 - 9600000 + 994334000 \cdot x - 47080000000)/400000000$

By using this as a definite integral with the boundaries of these age groups and dividing it to five we were able to find the average chance of Alzheimer's Disease within these age groups. From this method, with exception to 100+, these data were found:

Age Group	Chance of AD
65-69	5.993682584
70-74	8.083035904
75-79	10.60436042
80-84	13.78765414
85-89	17.86291506
90-94	23.06014118
95-99	29.6093305
100+	42.8

Finding The Percentages of Age Groups Within The Old Population:

After finding the chance of Alzheimer's Disease within an age group we needed the number of people within certain age groups in order to find the total amount of Alzheimer's Disease. The data for the percentages of age groups within the old population in 2020 were found from research. The data found included the age of all populations. The data for the 65+ population is:

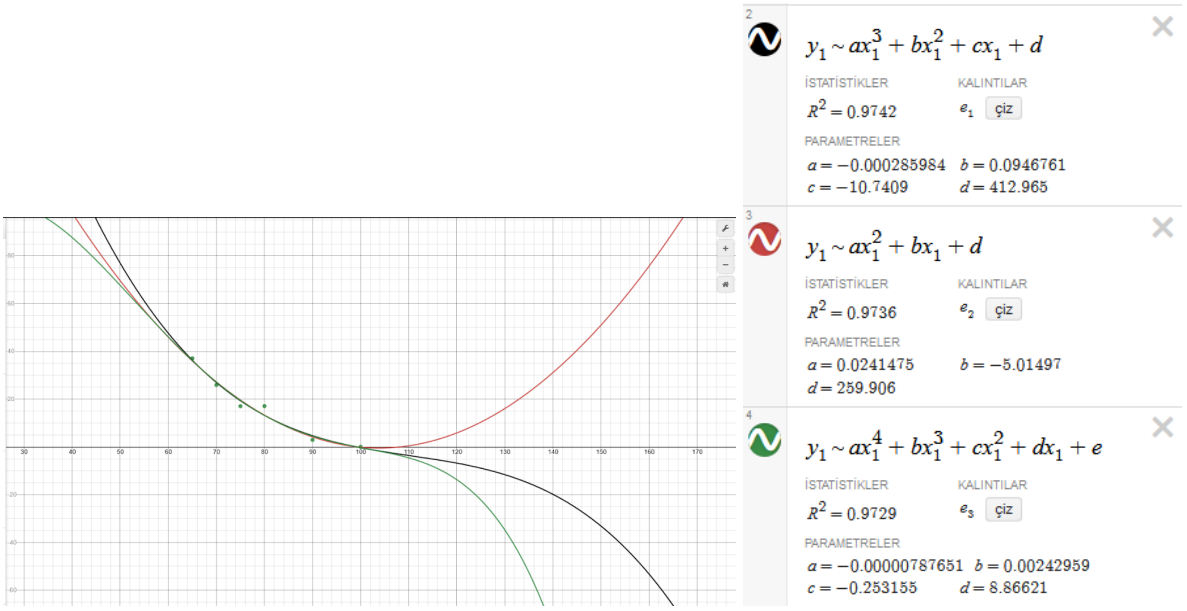
65+	727,606,340
70+	457,962,630
75+	269,285,300
80+	145,503,530
90+	21,387,110
100+	316,600

This however did not benefit us as the data of the ages after 75 years old were given in 10s instead of 5s and the data was for a population at and over a certain age and not an age group. This meant that the data represented everyone over 65 instead of people between 65-69. In order to make this data usable first the data was exported into excel and an algorithm was created to find the population in age groups of 5.

1. The algorithm chose 100+ a baseline as there aren't any populations that come after it.
2. It started from 90+ and subtracted the value from 100+ in order to create a 90-99 age group.
3. Then the values from the 100+ and 90+ group were subtracted from the 80+ group to create a 80-89 age group.
4. This repeated for every age until specific age groups were formed and these data were found:

Age	65-69	70-74	75-79	80-89	90-100	100+
Amount	269643710	188677330	123781770	124116420	21387110	316600

However, this still wasn't enough as in order to be more precise we needed age groups of five. So, these data were converted to percentages and a cubic regression was created in order to estimate the unknown values.



Due to the cubic regression giving the R^2 value closest to one for these data points, it was chosen as the most fitting regression equation for the age percentages. However, the problem was that the value for 100+ wasn't positive so the already existing value was taken. From these data the percentage and the amount for age groups were found to be:

Age Group	Predicted Amount	Predicted Percentage
65-69	269643710	37,05901051%
70	188677330	25,93123776%
75	90686645,8	12,46369648%
80	96078548,9	13,199%
85	61123689,27	8,39%7
90	21396416,07	2,93937928%
95	13393782,1	1,84%
100+	316600	0,04351254%

It should also be noted that the predicted percentage was above 100 due to inconsistencies regarding the values, however this amount was 101,87284% and so it was close enough to 100% that it was negligible. Since the age groups in 2020 and the average AD rate within an age group was known, the total amount of Alzheimer's in 2020 could have been estimated. It can be seen here:

Age Group	Year : 2020
65-69 Population Amount	269643710
65-69 AD Amount	16161587
70-74 Population Amount	188677330
70-74 AD Amount	19619516
75-79 Population Amount	90686645
75-79 AD Amount	10786269
80-84 Population Amount	96078548
80-84 AD Amount	19522260
85-89 Population Amount	61123689
85-89 AD Amount	12419760
90-94 Population Amount	21396416
90-94 AD Amount	7226985
95-99 Population Amount	13393782
95-99 AD Amount	4523966
100+ Population Amount	316600
100+ AD Amount	135504
Total Population	741316720
Total AD	90395847

Creating an Algorithm for the Change of Older Populations:

With all of the data the amount of people aged 65+ who have Alzheimer's Disease can be calculated, however, as years progress the amount of people in a certain age group may change which will create problems within the data. So in order to calculate upcoming years an algorithm was needed to predict the change in population between age groups. To allow this, the assumption that all of the people are distributed in an age group equally was created. With this assumption, an algorithm in excel has been created.

1. The algorithm chose 2020 as the baseline for future operations.

3. It assumed that the newly added population was added to the (65 - 69) age group.

2. Afterwards, for a (X - X+4) age group in 2021, the algorithm assumed that 1/5 of the population from the

(X-5 - X-1) age group came to the next age group. This meant that 1/5 of the people from a certain 2020 age group became the next age group in 2021

3. Then only 4/5 of the 2020 (X - X+4) age group was taken for the next year as 1/5 of the population became the (X+5 - X+9) population.

4. This occurred until 100+ and 1/5 of the population was assumed to be dead the next year.

With this algorithm the total number of older people from 2020-2050 and their respective age groups were able to be found. From this, the database which gives total number of older people, their respective age brackets and the total number of Alzheimer's Disease patients can be seen as:

YEAR	TOTAL NUMBER OF PEOPLE AGE BETWEEN 65-69	TOTAL NUMBER OF PEOPLE AGE BETWEEN 65-69 WITH AD	TOTAL NUMBER OF PEOPLE AGE BETWEEN 70-74	TOTAL NUMBER OF PEOPLE AGE BETWEEN 70-74 WITH AD
2020	269643710	16161587	188677330	19619516
2021	236144029	14153723	204870606	21303365
2022	210046917,2	12589545	211125290,6	21953755
2023	189892229,8	11381537	210909615,9	21931328
2024	174511829,8	10459685	206706138,7	21494232
2025	162971156,8	9767973	200267276,9	20824690
2026	154522482,5	9261587	192808052,9	20049047
2027	148567507	8904664	185150938,8	19252826
2028	144627445,6	8668509	177834252,4	18492004
2029	142319090,5	8530154	171192891,1	17801405
2030	141335659,4	8471210	165418131	17200920
2031	141431477,5	8476953	160601636,6	16700079
2032	142409715	8535586	156767604,8	16301399
2033	144112586	8637650	153896026,8	16002799
2034	146413500,8	8775560	151939338,7	15799334
2035	149210782,6	8943220	150834171,1	15684414
2036	152422650,1	9135729	150509493,4	15650653
2037	155983197,1	9349137	150892124,8	15690440
2038	159839173,7	9580252	151910339,2	15796319
2039	163947411,9	9826487	153496106,1	15961214
2040	168272768,5	10085735	155586367,3	16178569
2041	172786473,8	10356272	158123647,5	16442406
2042	177464813,1	10636677	161056212,8	16747348
2043	182288067,5	10925768	164337932,8	17088596
2044	187239667	11222551	167927959,8	17461903
2045	192305516,6	11526182	171790301,2	17863526
2046	197473448,3	11835931	175893344,3	18290179
2047	202732789,6	12151159	180209365,1	18738979
2048	208074010,7	12471295	184714050	19207396

2049	213488444,5	12795819	189386042,1	19693211
2050	218968064,6	13124250	194206522,6	20194466

YEAR	TOTAL NUMBER OF PEOPLE AGE BETWEEN 75-79	TOTAL NUMBER OF PEOPLE AGE BETWEEN 75-79 WITH AD	TOTAL NUMBER OF PEOPLE AGE BETWEEN 80-84	TOTAL NUMBER OF PEOPLE AGE BETWEEN 80-84 WITH AD
2020	90686645	10786269	96078548	19522260
2021	110284782	13117271	95000167,4	19303143
2022	129201946,8	15367279	98057090,32	19924281
2023	145586615,6	17316072	104286061,6	21189950
2024	158651215,6	18869975	112546172,4	22868327
2025	168262200,2	20013106	121767181,1	24741949
2026	174663215,6	20774442	131066184,9	26631420
2027	178292183	21206072	139785591	28403121
2028	179663934,2	21369228	147486909,4	29967957
2029	179297997,8	21325703	153922314,4	31275571
2030	177676976,5	21132899	158997451,1	32306791
2031	175225207,4	20841286	162733356,2	33065892
2032	172300493,2	20493420	165231726,4	33573537
2033	169193915,6	20123924	166645479,8	33860799
2034	166134337,8	19760018	167155166,9	33964362
2035	163295338	19422347	166951001,1	33922878
2036	160803104,6	19125921	166219868,5	33774318
2037	158744382,4	18881056	165136515,7	33554191
2038	157173930,8	18694267	163858089	33294427
2039	156121212,5	18569057	162521257,4	33022795
2040	155596191,2	18506610	161241248,4	32762710
2041	155594226,4	18506377	160112237	32533305
2042	156100110,7	18566547	159208634,9	32349702
2043	157091331,1	18684442	158586930	32223377
2044	158540651,4	18856825	158287810,2	32162599
2045	160418113,1	19080130	158338378,5	32172874
2046	162692550,7	19350651	158754325,4	32257390
2047	165332709,4	19664672	159541970,5	32417432
2048	168308040,6	20018558	160700118,3	32652757
2049	171589242,4	20408824	162221702,7	32961929

2050	175148602,4	20832174	164095210,7	33342608

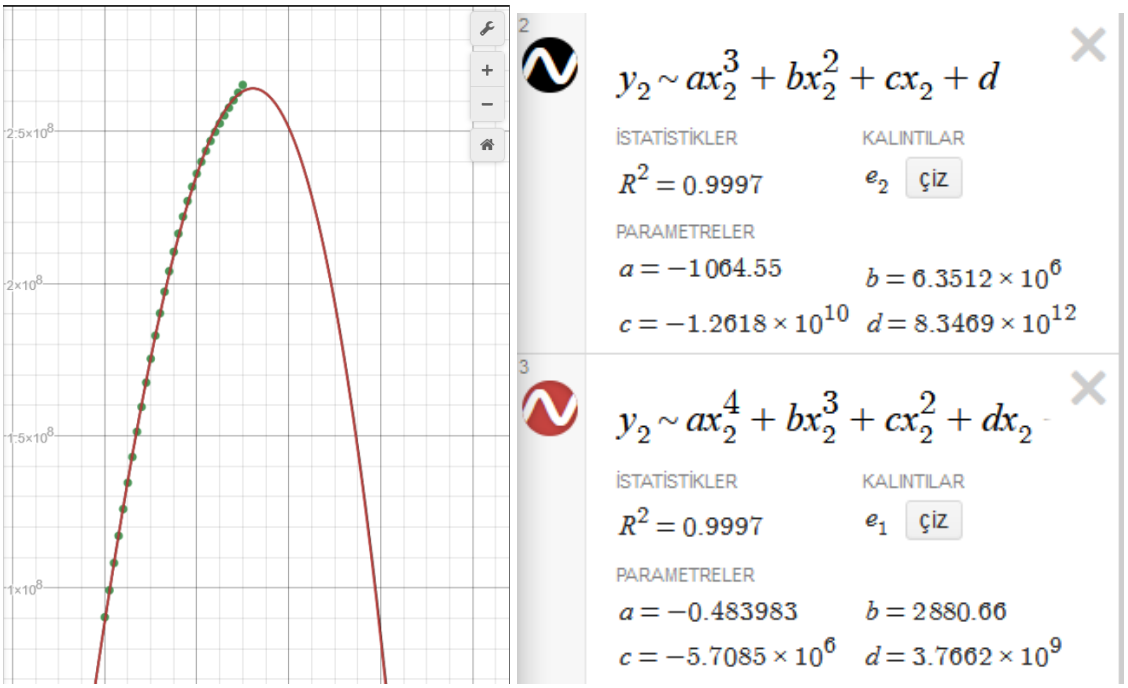
YEAR	TOTAL NUMBER OF PEOPLE AGE BETWEEN 85-89	TOTAL NUMBER OF PEOPLE AGE BETWEEN 85-89 WITH AD	TOTAL NUMBER OF PEOPLE AGE BETWEEN 90-94	TOTAL NUMBER OF PEOPLE AGE BETWEEN 90-94 WITH AD
2020	61123689	12419760	21396416	7226985
2021	68114660,8	13840260	29341870,6	9910691
2022	73491762,12	14932837	37096428,64	12529918
2023	78404827,76	15931125	44375495,34	14988541
2024	83581074,53	16982890	51181361,82	17287332
2025	89374094,11	18159978	57661304,36	19476038
2026	95852711,49	19476372	64003862,31	21618339
2027	102895406,2	20907381	70373632,15	23769832
2028	110273443,1	22406529	76877986,95	25966783
2029	117716136,4	23918815	83557078,19	28222754
2030	124957372	25390166	90388889,83	30530309
2031	131765387,8	26773491	97302586,27	32865522
2032	137958981,5	28031971	104195146,6	35193596
2033	143413530,5	29140284	110947913,6	37474452
2034	148059920,3	30084387	117441036,9	39667609
2035	151878969,6	30860382	123564813,6	41736014
2036	154893375,9	31472881	129227644,8	43648727
2037	157158674,4	31933169	134360791	45382530
2038	158754242,7	32257373	138920367,7	46922601
2039	159775012	32464784	142887142,7	48262443
2040	160324261,1	32576386	146264716,6	49403273
2041	160507658,5	32613651	149076625,5	50353041
2042	160428574,2	32597582	151362832,1	51125244
2043	160184586,4	32548006	153175980,5	51737665
2044	159865055,1	32483080	154577701,7	52211119
2045	159549606,1	32418984	155635172,4	52568296
2046	159307360,6	32369762	156418059,1	52832729
2047	159196753,6	32347287	156995919,4	53027911
2048	159265796,9	32361316	157436086,2	53176584
2049	159552661,2	32419604	157802028,4	53300187
2050	160086469,5	32528069	158152154,9	53418448

YEAR	TOTAL NUMBER OF PEOPLE AGE BETWEEN 95-99	TOTAL NUMBER OF PEOPLE AGE BETWEEN 95-99 WITH AD	TOTAL NUMBER OF PEOPLE AGE BETWEEN 100+	TOTAL NUMBER OF PEOPLE AGE BETWEEN 100+ WITH AD
2020	13393782	4523966	316600	135504
2021	16827394,5	5683724	4532563	1939936
2022	20273381,68	6847662	9494424	4063613
2023	23567881,56	7960433	15014824	6426344
2024	26694788,02	9016596	20886958	8939618
2025	29713937,87	10036363	26945838	11532818
2026	32708559,71	11047845	33088931	14162062
2027	35752118,91	12075856	39271917	16808380
2028	38891235,75	13136143	45492260	19470687
2029	42140332,91	14233579	51769405	22157305
2030	45483879,97	15362916	58126939	24878329
2031	48882841,18	16510970	64579329	27639952
2032	52282811,72	17659365	71123980	30441063
2033	55622147,53	18787280	77738213	33271955
2034	58839071,07	19873847	84380153	36114705
2035	61877248,89	20900041	90992329	38944716
2036	64689696,07	21849991	97506825	41732921
2037	67241094,45	22711767	103850988	44448222
2038	69508743,01	23477702	109952948	47059861
2039	71482418,68	24144343	115746431	49539472
2040	73163436,14	24712133	121174573	51862717
2041	74563175,01	25184918	126192601	54010433
2042	75701305,86	25569340	130769405	55969305
2043	76603902,11	25874207	134888090	57732102
2044	77301580,33	26109859	138545668	59297545
2045	77827769,77	26287588	141752074	60669887
2046	78217176,43	26419116	144528693	61858280
2047	78504477,2	26516156	146906566	62876010
2048	78723257,12	26590053	148924436	63739658
2049	78905185,39	26651502	150626766	64468255
2050	79079414,43	26710351	152061818	65082458

Year	Total Population	Total Population with Alzheimer's Disease
2020	741316720	90395847
2021	765116073,3	99252113
2022	788787241,4	108208890
2023	812037551,5	117125330
2024	834759538,9	125918655
2025	856962989,4	134552915
2026	878714000,4	143021114
2027	900089294,1	151328132
2028	921147467,5	159477840
2029	941915246,3	167465286
2030	962385298,7	175273540
2031	982521821,9	182874145
2032	1002270459	190229937
2033	1021569813	197299143
2034	1040362526	204039822
2035	1058604654	210414012
2036	1076272658	216391141
2037	1093367768	221950512
2038	1109917834	227082802
2039	1125976992	231790595
2040	1141623562	236088133
2041	1156956645	240000403
2042	1172091889	243561745
2043	1187156820	246814163
2044	1202286094	249805481
2045	1217616932	252587467
2046	1233284958	255214038
2047	1249420551	257739606
2048	1266145796	260217617
2049	1283572073	262699331
2050	1301798257	265232824

Solution of the Problem:

These data can then be created into a scatter plot in order to find a correlation between the year given as x and the number of Alzheimer's patients from 2020 to 2050. The graph for this function can be seen as:



The regressions for these data points both have similar R^2 and y values. Since it is simpler, the cubic regression will be used as a way of modeling. In this case the model for the total Alzheimer's Disease population in terms of years is:

Total Number of AD $= -1064.55x^3 + 6.3512 \cdot 10^6 \cdot x^2 - 1.2618 \cdot 10^6 \cdot x + 8.3469 \cdot 10^{12}$
(where x is in years)

Conclusion:

In this report, through the use of mathematical modeling the total number of people with Alzheimer's Disease In 2050 was calculated as 265,232,824 people. This value was estimated by estimating the total population, percentage of the old population to the total population, the estimation of age groups and the change of age groups within the 65+ years old population and their risk of AD. Considering that studies show that the average cost of AD per person is 27,672 dollars and informal care can cost anywhere from 10,400 to 34,517 dollars, the total cost of Alzheimer's to society may cost up to

7,339,552,705,728 dollars annually. In order to avoid these improvements in the caring of AD patients and potential cures for Alzheimer's Disease is needed for a sustainable future.

Reflection:

Positives:

1. Due to us using data which cover every year from 1960 to 2020 our regression curves had really close to 1 R squared values which means that our correlations are very close to the original numbers. This meant that accurate predictions were most likely able to be made. This shows that our data is most likely to be accurate to real life values.
2. We created many models such as population increase, Alzheimer's Disease probability in older ages etc. which may benefit other research or may be useful to further this model.

Limitations:

1. The economic cost of Alzheimer's Disease was not sufficiently discussed in the paper. The estimation of the cost could have been made more precise by further research into the number of cases of formal and informal care of Alzheimer's. This was not done due to constraints in time and the main focus on the estimation of Alzheimer's cases were prioritized.

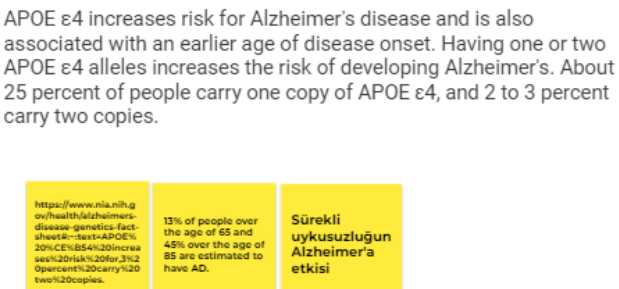
3. Due to lack of data on the ages within the 65+ population an algorithm was needed to be developed. There were many estimations due to lack of sufficient data in our model which could result in a decrease in the accuracy.

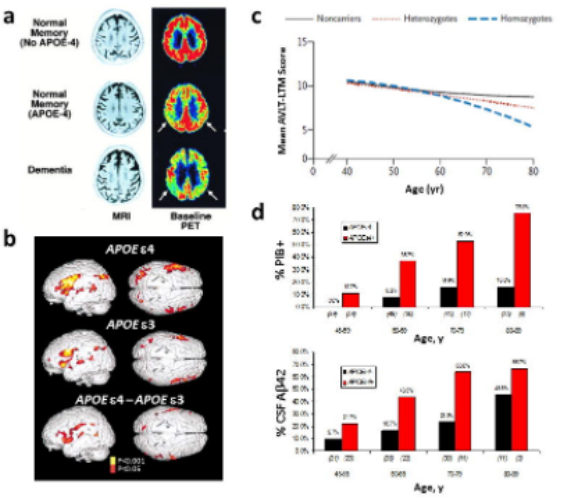
Appendix:

Appendix 1 First Research:

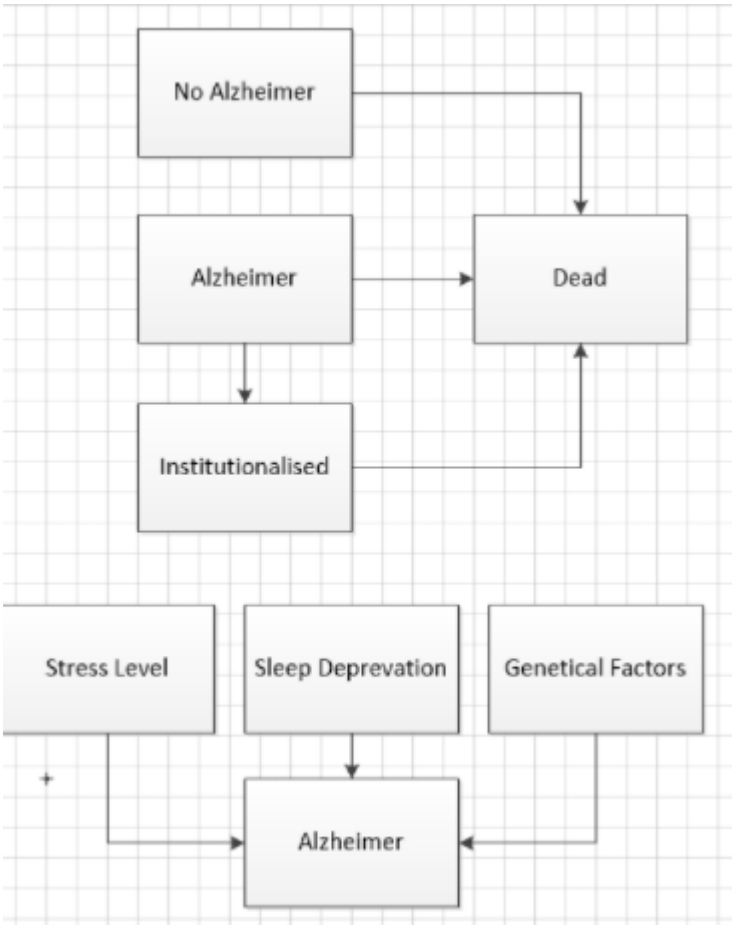
Appendix 1.1

Appendix 1.2



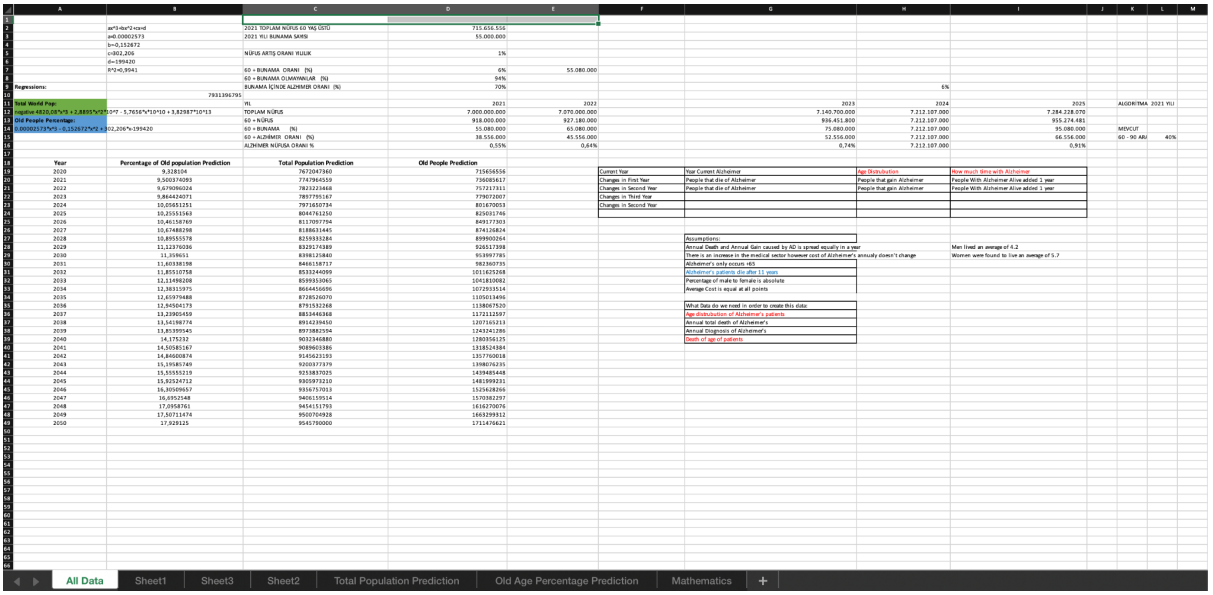


Appendix 1.3

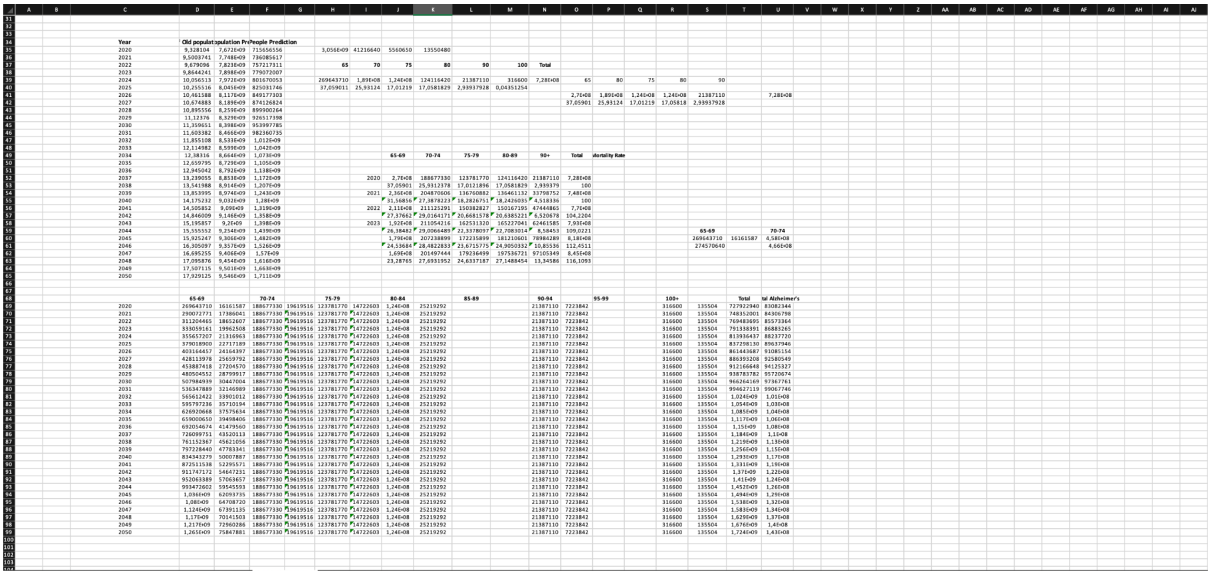


Appendix 2 Excel Sheet

Appendix 2.1



Appendix 2.2



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