Investigating the factors that contributed to the outcome of World War 2 using topic modelling and GIS

INTRODUCTION

World War 2 (WW2) is known to this day as the deadliest war in history[1]. Other than the estimated death toll between 70 and 85 million, the impact of this event has influenced the global economy, the technological advancements, and the political dynamic [2] of our world today. Even though we have just marked 77 years since the end of WW2, it is important to understand the historical significance of this tragedy and how we can learn from it in the present day [1]. As George Santayana said, “Those who cannot remember the past are condemned to repeat it” [3] and we will follow this quote to support our motivation for this report: investigating the factors that contributed to the outcome of WW2. This is especially relevant whilst we are approaching tensions between many superpowers today [4]. As we are developing in the technological era, computational modelling has been successful for improving our analysis and understanding of large and complex data, which we did not have the advantage of using in the past [5]. Therefore, by using computational modelling on historical data, we aim to effectively shed light on how key drivers of the war, such as military resources and leadership, influenced the overall death toll and the success of the allies over the axis.

SOURCES OF DATA

- For analysing leadership during WW2, we will focus on speeches of one leader from each side: Hitler and Churchill. The sources of these texts are:
    - **Hitler:** “Adolf Hitler: Collection of Speeches 1922-1945” [6]
    - **Churchill:** “"Never Give In! - The Best of Winston Churchill's Speeches" [7]
- **World War II Database** – The equipment section has data about military equipment used in World War 2 by country. We focus on 5 datasets, **aircrafts, facilities, ships, vehicles, and weapons**. [8]
- **Kaggle (scraped from the World War II casualties page) –**gives the death toll of World War 2 by country and cause. [9]
- **Shapefile –** Contains the geographic coordinates of 256 countries, represented by polygons outlining the latitude and longitude. [10]
- **Libraries used for our LDA model:** nltk, pandas, sklearn, word cloud, matplotlib

World War II Database

Data Cleaning

Though we will be pre-processing all five datasets separately, we will discuss data cleaning techniques that they all used. In the datasets, there were no null or missing values, therefore, we did not drop any rows. However, we found many Unicode errors that we removed from the dataset. The aim will be to demonstrate whether the quantity and quality of each equipment contributed to the outcome of the war. To evaluate the quality, we will be ranking each type of resource with an ascending score based on their effectiveness [13] as shown in Figure 1. For each dataset we will only need the Countries and the role/type, any other columns were not fit or meaningful for the data being modelled i.e. names of weapons and city(would not fit our shapefile).

TABLE I

	Top 3	Bottom 3
Aircraft	"Heavy Bomber", "Fighter" , "Ground Attack Aircraft"	"Prototype Aircraft", "Transport", "Renaissance Aircraft"
Vehicles	"Heavy Tank", "Cruiser Tank", "Infantry Tank"	"Auxiliary vessels", "Gunboats" , "Coastal Defence Vessels"
Ships	"Aircraft Carriers", "Battleships", "Submarines	"Aircraft Autocannon", "Naval Gun", "Launcher"
Weapons	"Aircraft Autocannon", "Naval Gun", "Launcher"	"Air Raid Shelter", "Munitions Fuze","Uniform"
Facilities	"Military Headquarters", "Fortification", "Army Base"	"Prison Camp", "Government Building", "Shipyard"

Figure 1: Top 3 and Bottom 3 impactful military resource by function

Once we have established the scorings of our resources, we will be ready to add them up by country in preparation for merging with the death toll and shapefile dataset.

WW2 Casualties Dataset

Data Cleaning

TABLE II

	Country	Total population as of 1/1/1939	Military deaths from all causes	Civilian deaths due to military activity and crimes against humanity	Total deaths	Deaths as percentage of1939 population	Average Deaths as percentage of1939 population	Military wounded
count	80	80	56	71	79	80	80	35
unique	80	60	42	42	52	60	60	26
top	Albania	188,793,000	10700000	13684448	24384448	12.9159704	12.9159704	14,685,593
freq	1	8	8	8	8	8	8	7

Figure 2: Describing our dataset

As shown in Figure 2. "Military wounded" has over half missing values and "Average Deaths" is a duplicate of "Deaths"

One issue in fitting this dataset to our shape file is that many countries during WW2 have different names today, therefore, we must clean our dataset to reflect this. Examples of these are the Soviet Union and French Indochina which do not exist today [12]. We also observed that several times it was written that a country's figures were included within

another ie Spain : “Included with France. Therefore, for all the examples above, we made sure to give the countries included (ie Spain, Russia), the same number of losses as the original(ie France, Soviet Union). We also found that some values had ranges, so we took the middle value (ie 1000-2000:1500).

For extracting the useful columns, we will drop the duplicate column “AverageDeathsaspercentage” and “MilitaryWounded” as it had too many missing values for us to analyse effectively

An interesting statistic for us to see is the most deaths is a large 24,384,448 which [13] backs up as claiming that the Russa had 25-27 million war related deaths.

This dataset has 80 countries in the world, therefore, when merging, we find many missing values from the remaining countries in the shapefile that were not mentioned in any of our datasets. To prevent blank spaces in our map, we won’t drop any rows, but we will be filling all our null values with 0.

METHOD

We will us geographic information systems (GIS) to model the quality of military equipment by Country using our shape file plot coordinates and geopandas. When initially plotting, we found that many of the countries with lower values weren’t visible on the map, therefore, we decided to scale/log our values to get a better comparison analysis. For this to work, we also had to replace “0” with a very small number.

EVALUATION

Below displays results along with observations which we will evaluate against sources of literature in the next section.

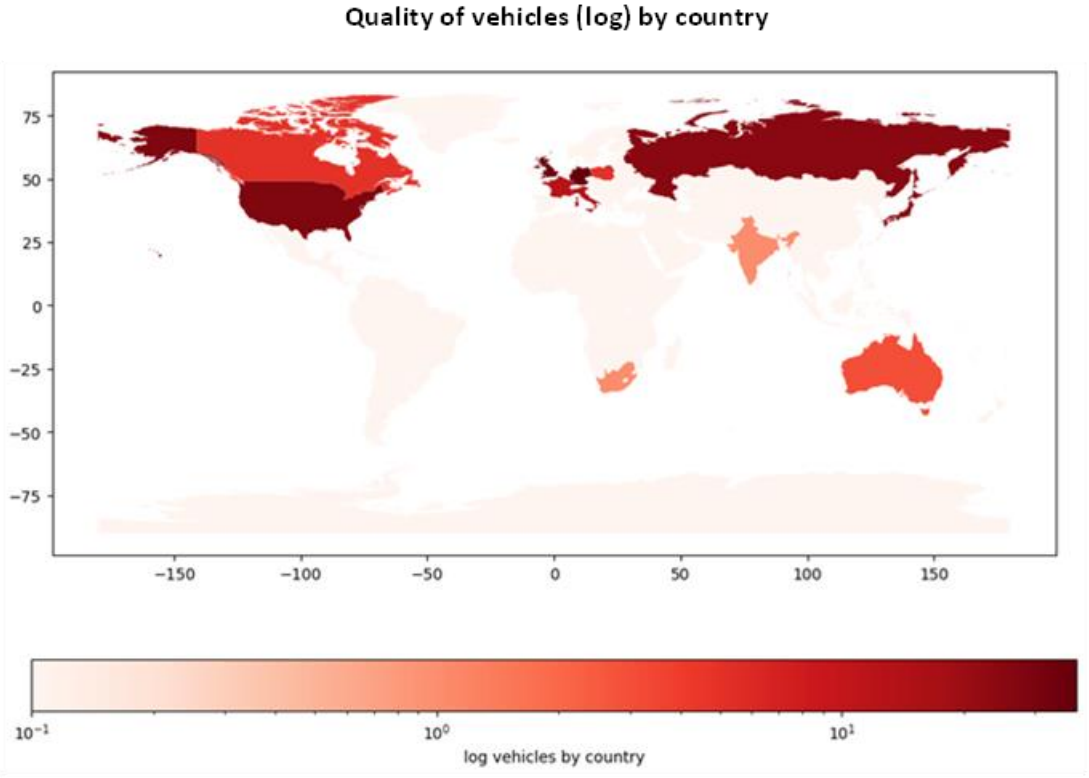


Figure 3: Quality of vehicles (log) by country

Vehicles: we can see that the countries with the best vehicles are Germany, Russia, US, England, and Japan. Out of the main countries we can see that France has less, whilst Poland is close behind.

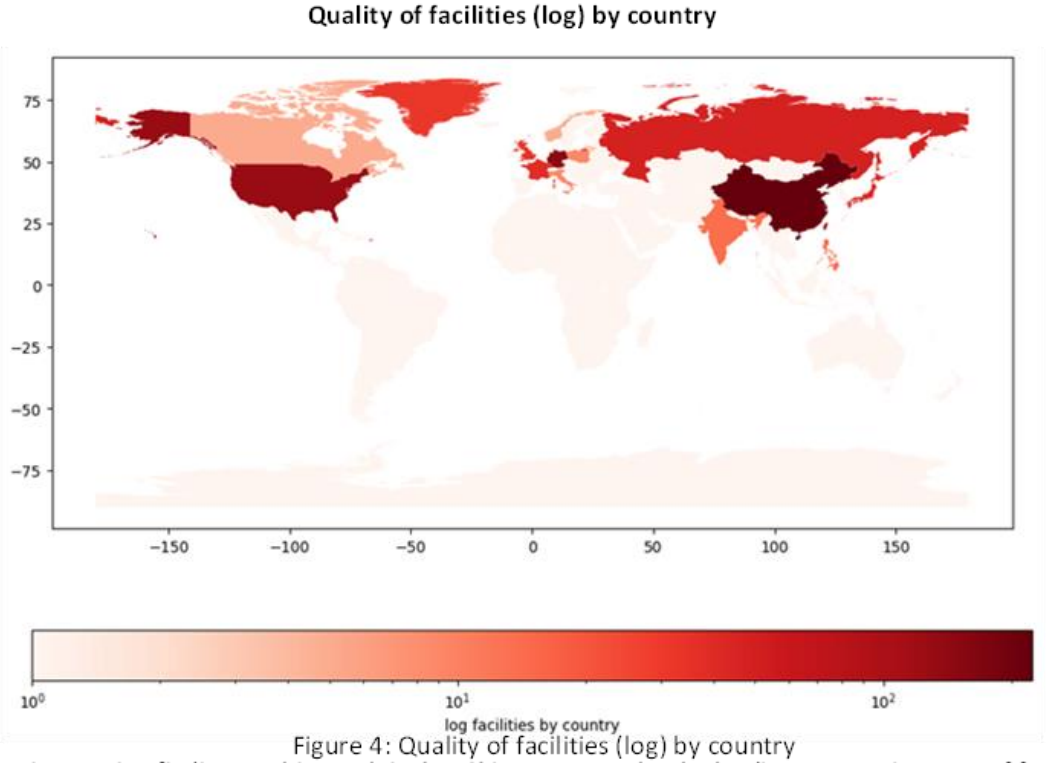


Figure 4: Quality of facilities (log) by country

Facilities: One interesting finding on this graph is that China seems to be the leading country in terms of facilities in the world. This is followed by the US and Germany. Another curious observation is that Greenland seems to be on the same scale with England and France and that India seems to have more than Canada.

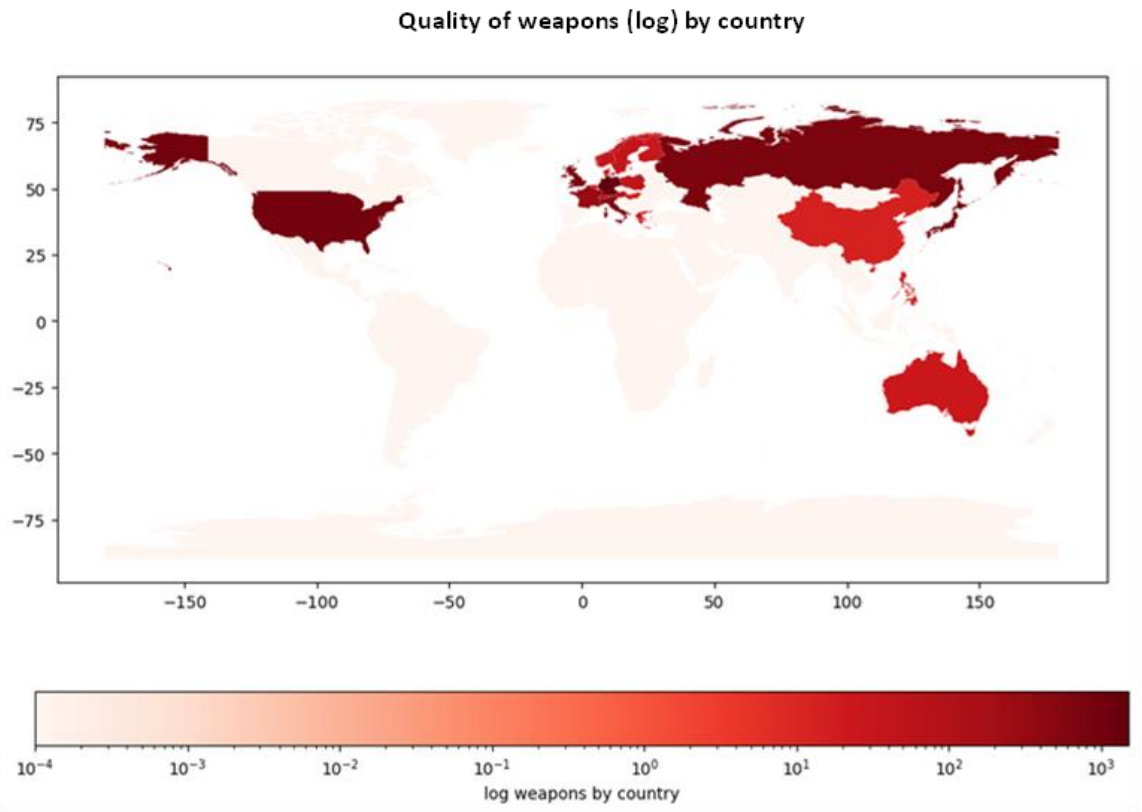


Figure 6: Quality of weapons (log) by country

Weapons: For weapons, we can see all the main powers have a large use, however, a difference seen from other graphs is that Sweden and Norway have a higher use of weapons.

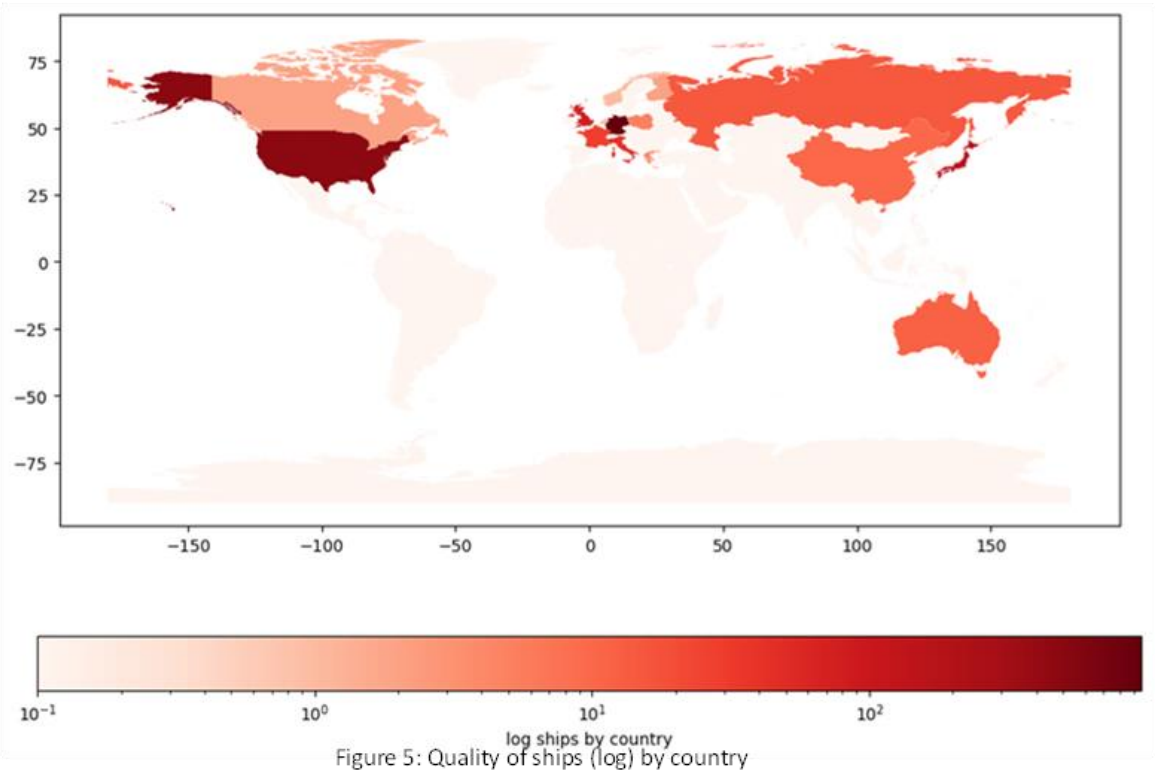


Figure 5: Quality of ships (log) by country

Ships: We find in this graph that the US and Germany are the leading countries for ships with Japan closely behind, whilst the UK is surprising lighter in colour.

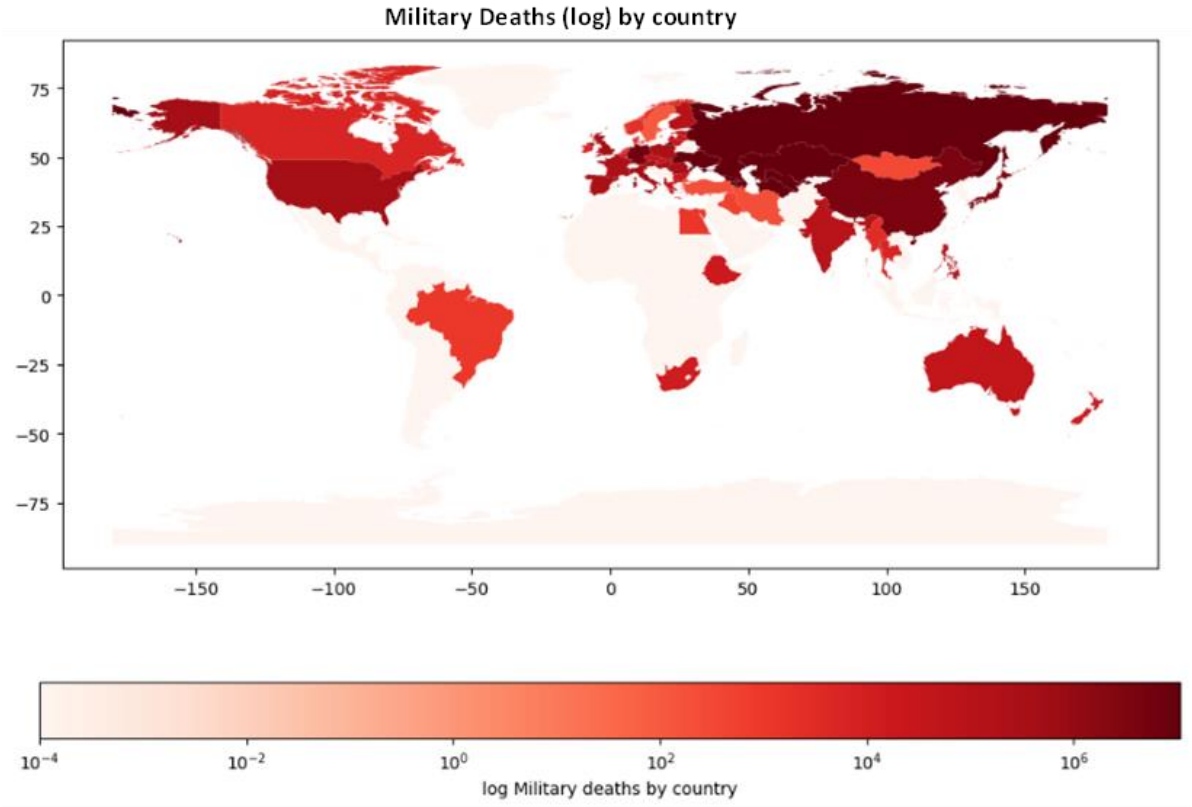


Figure 8: Military Deaths (log) by country

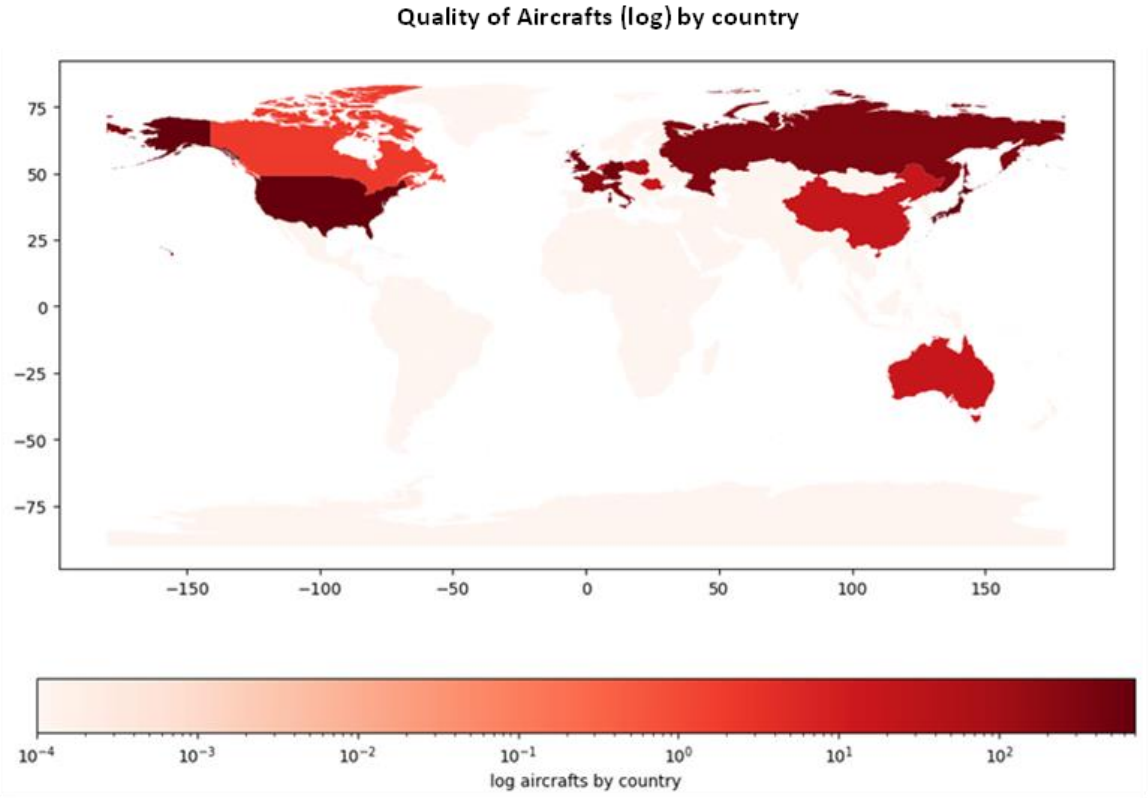


Figure 7: Quality of Aircrafts (log) by country

Aircrafts: Aircrafts seem to be in heavy use equally amongst all the main powers of the war. The US, Germany, Japan, Russia, England, France, and Italy.

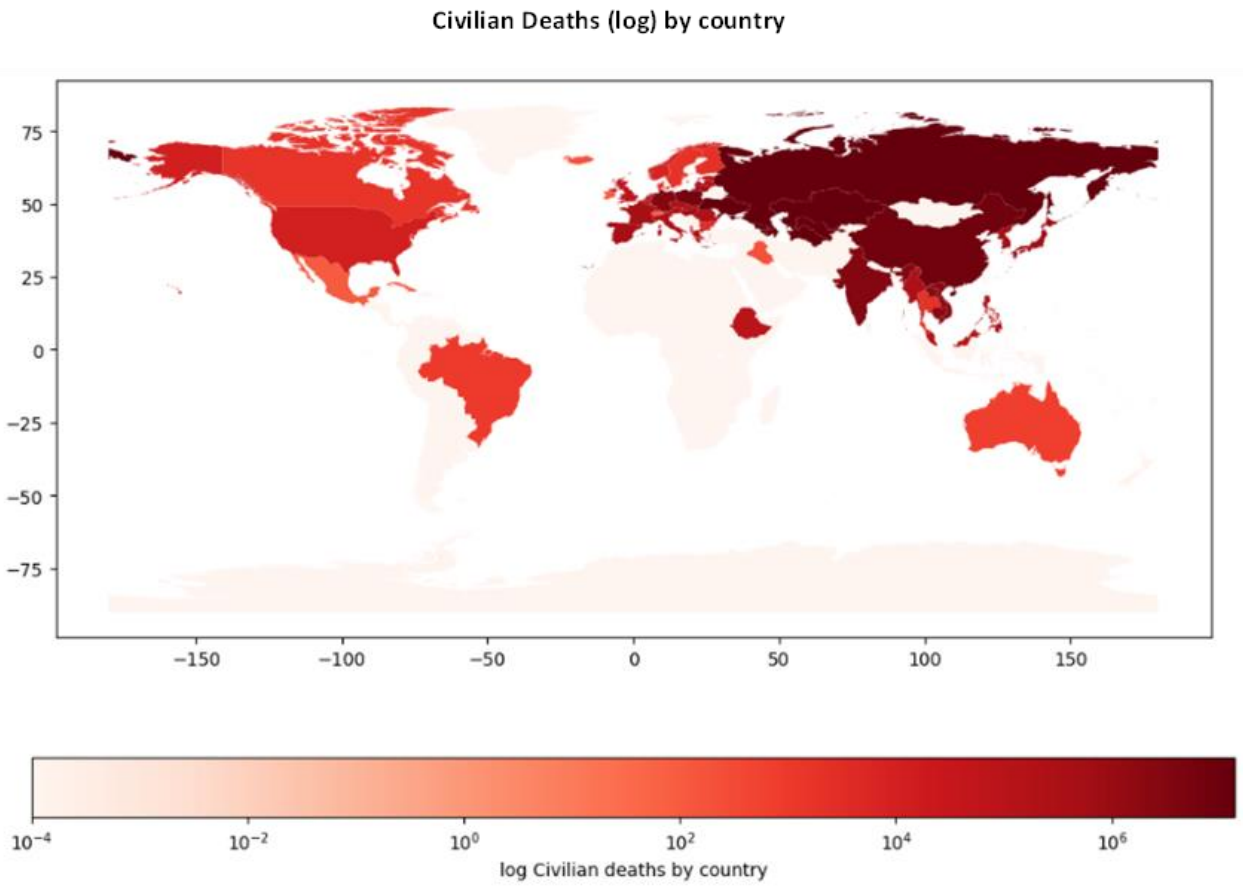


Figure 10: Civilian Deaths (log) by country

Deaths as a percentage (log) by country

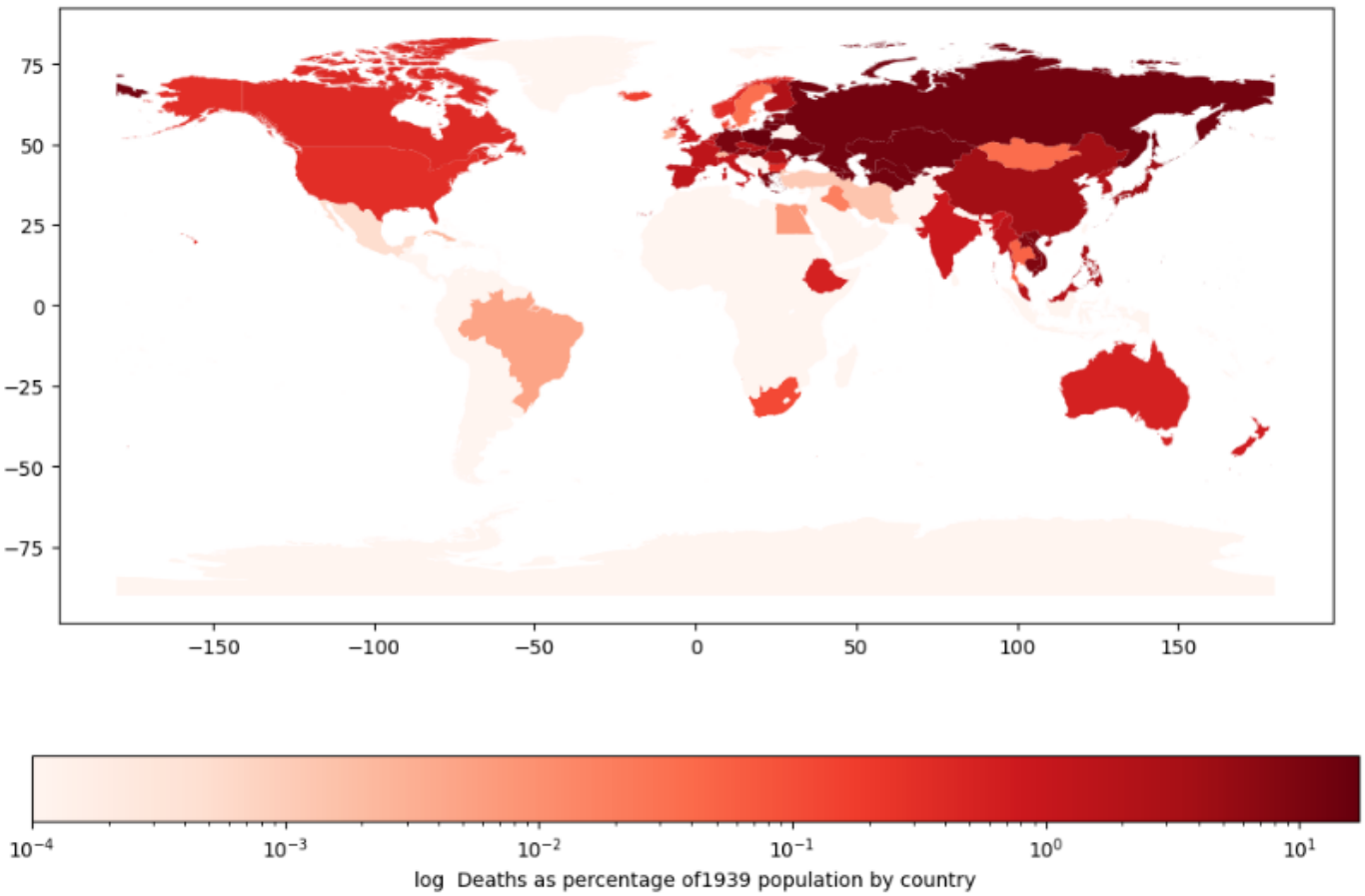


Figure 9: Deaths as a percentage (log) by country

EVALUATION – AXIS

[14] Explains Germany's most effective tactic, Blitzkrieg used its superior weapon quantity and quality to succeed initially, supporting our overall magnitude of resources shown Figure 6.

[15] also backs up our findings of Germany's high possession of ships and explains Germany's tactic of using U-boats to intercept ally merchant ships by a tactic called "Wolf's pack".

Though Germany had better quality aircrafts than other countries, Figure 7. shows that they lagged the US and Japan. This is explained in [16] as they focused on producing small diver bombers resulting in a disadvantage against the allies. Though they invested in new aircrafts such as V2 rockets and the wind cannon [17] they failed to be completed due to the unrealistic visions for their development [18] and eventually WW1 successful inventions ie U-boats were defeated with 743 sunk and 30,000 submariner casualties [14]. All casualties from the lack of quality weapons can contribute to Figure 8. as well as Figure 10. [19] explains the darkness in Figure 4. ie Prison camps which contributed the Holocaust, resulting in millions of deaths and how Germany's lack of aircraft defence led to Allied bomb raids on homeland.

Japan's result in Figure 7. Is explained in [20] as they invested most of their production and resources on aircrafts, which achieved initial success. However, Japan couldn't keep production of planes consistent and lacked the resources to maintain the aircrafts ie fuel[21] which we are not able to see the effects of in the map. This contributed to their loss in WW2 as it proved to be a strain in the Battle of the Pacific resulting in them also losing the naval battle, despite the quality of their navy shown in Figure 5. Japan's use of Kamikaze attacks, (suicide plane crashes) [22] resulted in significant casualties amongst the Japanese military, which supports the high death toll in Figure 8. This can be linked further to Japan's invasion of China and their colonisation of Vietnam, Malaysia, Bangladesh, and Cambodia, causing many deaths, as shown in Southeast in Figure 11. Japan's dark appearance on all death toll maps is also explained by the US's use of atomic bomb on their homeland [23].

EVALUATION – ALLIES

The allies had the best aircrafts (Figure 7.) during WW2 [24] and their use of bombing campaigns negatively affected Germany's war effort and the production and maintenance of their aircrafts (Figure 7.). Aircrafts, also heavily contributed to their success in the D-day invasion. [25]

Despite Germany's U-boat tactics, by May 1943, the allies got the upper hand by increasing production of shipping (Figure 5.), introduced new convoy tactics and technology (Figure 7.) ie anti-submarine patrol planes which were equipped with radar [26] As a result, the allies' new submarines were much faster than U-boats and axis submarines could be detected and destroyed [27]. Radar technology also aided the expansion of new naval guns which were

effective in locating and tracking enemy ships in the Battle of the Atlantic[28]. An observation in our death maps, is the low death toll in comparison to countries that weren't on the front lines i.e. India. [25] confirms our findings by explaining how the ally's geographical location helped defend against air and sea attacks. More contributing factors were, England's evacuation of children, air raid shelters [29] and America's support in 1941, who's late entry also contributed to their low death toll.

France and Poland lack of vehicles Figure 3. is supported by [30] as they were prioritising other resources and were limited compared to its allies. The correlation between France and Poland having a low number could be due to Germany's invasions which halted the production of vehicles. [31] theorises that number of vehicles they possessed could have played a role in their defence against German invasion whilst also confirming a death toll that matches our death maps.

Though Russia had a winning number of resources during the war, it suffered with Germany's invasion of the Soviet Union. The surprise invasion, Operation Barbarossa, was the largest invasion in the history of warfare[32] which is confirmed on all our death maps as the country with the most deaths. Despite having all high numbers in all resource Figures, they had poor military tactics, preventing them from effective use in the initial defence against the Germany.

COLONYS/INVADED COUNTRIES

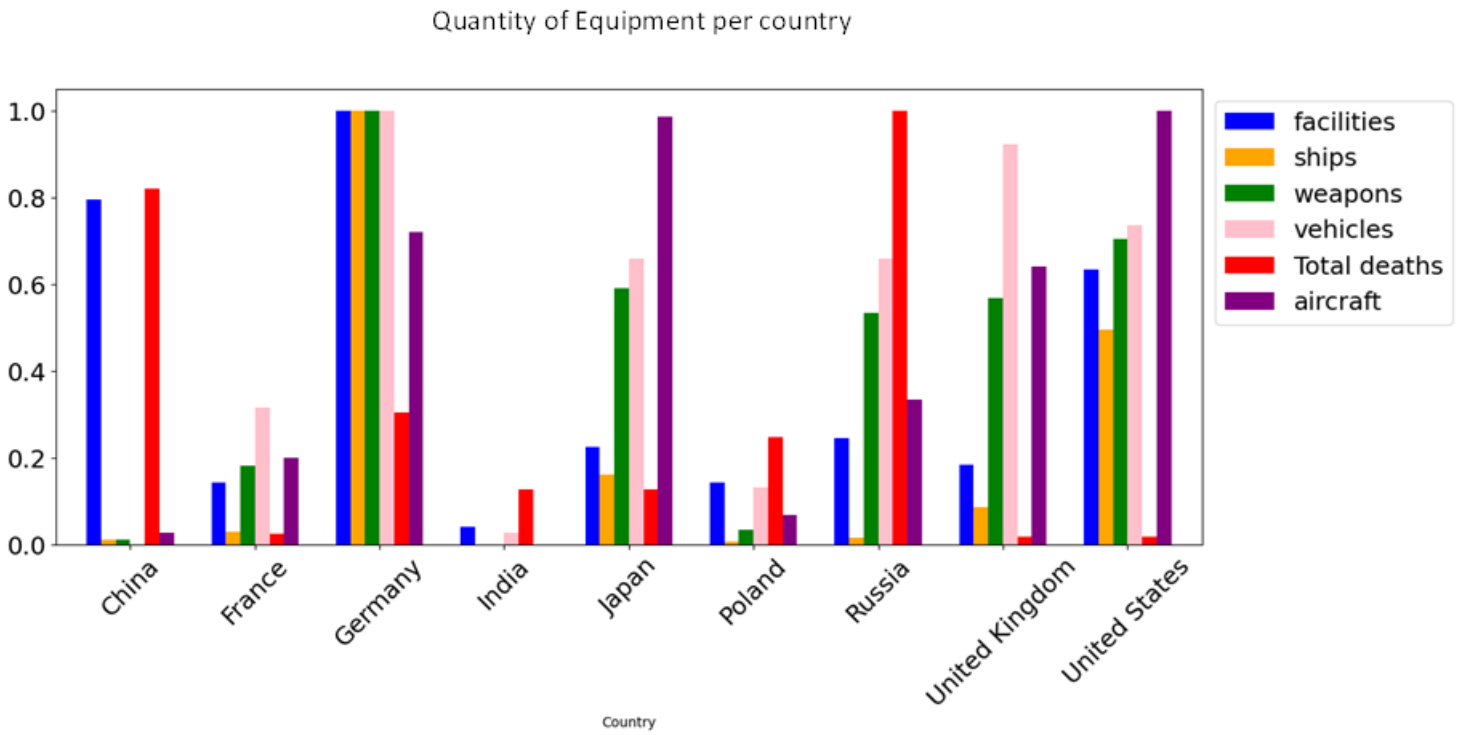
As a result of Civil War and Japanese attacks, China armed themselves with many weapons[33]. Despite this, these conflicts contributed to a very high civilian death toll as shown as a very dark appearance on our map. China had many facilities as one of the largest producers which could be used in the war and provide resources for the allies [34], supporting Figures 4 and 5. However, it also suffered from transporting difficulties, which can be reflected in Figure 3.

India has strong appearances Figure 4 and 5 yet have no appearance on the most impactful resources can show the exploitation used by the British. [35] backs up our findings by explaining how India had many facilities which contributed to its contribution in providing the British with vehicles, as well as for its use in the transportation of troops and supplies. In turn the Indian economy was heavily taxed and regulated to support the war at the expense of the people's well-being. This led to many deaths of the military and civilians due to famine and disease [36] which explains the unreasonably high death toll in our maps.

Our GIS maps find military and civilian deaths in Philippines, Mongolia, Egypt, Brazil, Iraq, Iran, Turkey, and Ethiopia which can be traced back to war conflict whether it was through fighting or invasion [37]. These targets were a target to superpowers based on their geographical location.

[7] Can help justify this by explaining that the Spanish Civil War, led to many fleeing to France and died during German occupation.

To be able to better analyse our death toll vs our resources, we will be plotting the countries with the most interesting findings in a bar plot.



This agrees with our sources on how India, China and Poland had such a high death toll compared to resources. However, Russia was the only main power who has such a high death toll despite more resources than France. The rest of the main powers follow the correlation that amount of military equipment, leads to less deaths.

TOPIC MODELLING(LDA)

Data Cleaning

For our Hitler speeches, we used a text file of all speeches 1922 onwards. From this text file, we create a dataset which contains columns: title, date, and speech. To process this file, we: put everything into lower case, we use NLTK to remove stop words, lemmatization and re for removing special characters. Once we use a marker to split up our text, we will extract

POS tags. For our Churchill dataset, there were no null values or missing rows, but we only had two columns, the title, and the speech. Each title included the date; therefore, we create a separate column for dates.

Since our plan is to topic model speeches from Hitler and Churchill, we would like to replace particular words that have different meanings to both. Figure 11 demonstrates examples of this:

TABLE II

Hitler	Churchill	Word replaces
Germany	England	our country
German	English	native
England, United Kingdom, Great Britain, British, United States, USA, France, America	Japan, Japanese, Germany, German	the enemy
Japan, Japanese, Germany, German	England, United Kingdom, Great Britain, British, United States, USA, France, America	the allies
Churchill, Roosevelt	Hitler	The villain

Figure 11: Table showing countries and origins replaced to share common meaning over the two speeches

Analysing words

Using word cloud, we can visually see the word frequency for Hitler and Churchill's speeches separately:

Churchill's common words

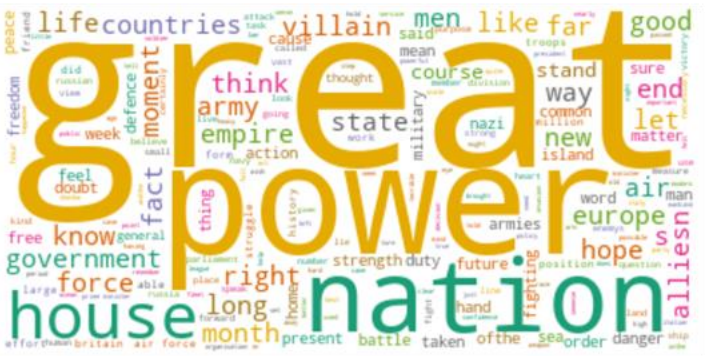


Figure 12

Hitler common words

Figure 13

TABLE III

	words	inference
Similarity	“great”, “nation”, “Reich/empire”, “Europe”, “future” and “new”	can symbolize the leader’s personalisation with their audience and its aspirations for change
Similarity	“men”, “soldier”, “fighting”, “force” and “army”	put a high focus on the combat in war
Similarity	“peace”, “freedom”, and “end”	both present a happy future to their audience to boost morale.
Hitler	“enemy” (allies) and “Jews”.	focus more on blaming others
Hitler	“National socialist”, "believe", “political”	Political views are influenced more on his beliefs than the what’s right for the country
Hitler	history”, “struggle” and “past”	he uses the tactic of victimisation from previous events to influence his audience.
Hitler	“sacrifice”, “work” “necessary”	firm use of language, sense of urgency
Churchill	"villain" (Hitler) and “present”	rather than blaming the axis as an entirety he only condemns the leader. we may theorise that Churchill does not use scape-goating or victimising tactics as frequently as Hitler
Churchill	“allies”, “hope”, “power”, “strength”	can represent a sense of unity and positive moral
Churchill	“duty”	Less bold language

Figure 14: Looking at the similarities and differences in word choice between the two

For topic modelling we decided to use LDA (Latent Dirichlet Allocation. It is good for handling a lot of text and unique words, so we found it to be a good fit for our large corpus. We also found that as a probabilistic model it can be easily interpretable, for us to be able to understand our results.

After cleaning, will create a Term-Document Matrix from our dataset. First, we will create an index for our dataset to be able to differentiate and identify each speech. This will consist of a combination of our title and date column. To create our matrix, we will be using the CountVectorizer library from sklearn to eliminate the stop words we have found previously.

For the LDA model we will be using the genism library and inputting our corpus, number of topics and passes. To set these parameters we used hyper parameter tuning and evaluate this using coherence. We found that our optimal alpha was 0.61 and beta was 0.1, and num_topics: 4.

Our final evaluation score was 0.867348 which represents that we created a good model. Figure 15 demonstrates the distribution of the topic along with the words associated.

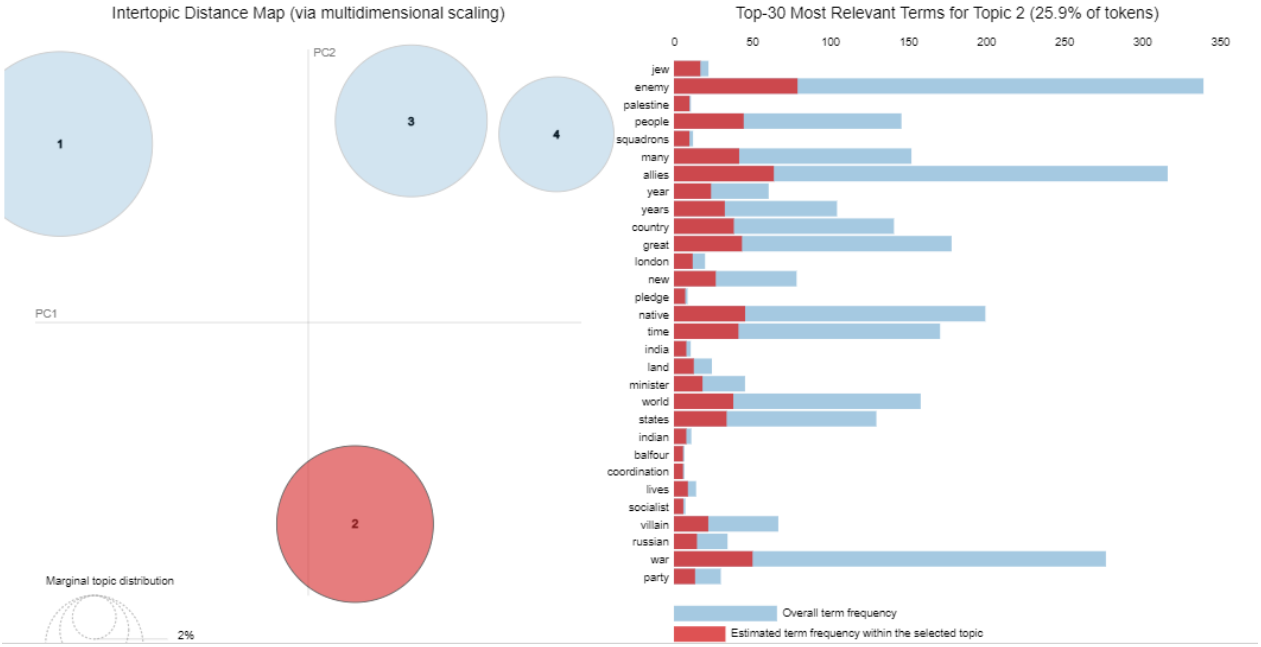
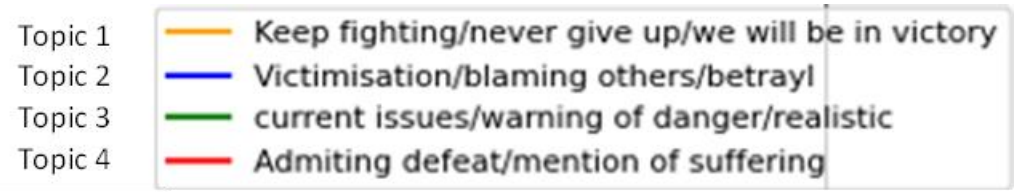


Figure 15

From our own interpretation using the diagram above we labelled our 4 topics as such:



With further evaluation, we will be plotting a graph showing us how the topics for each leader progressed over the years of the war

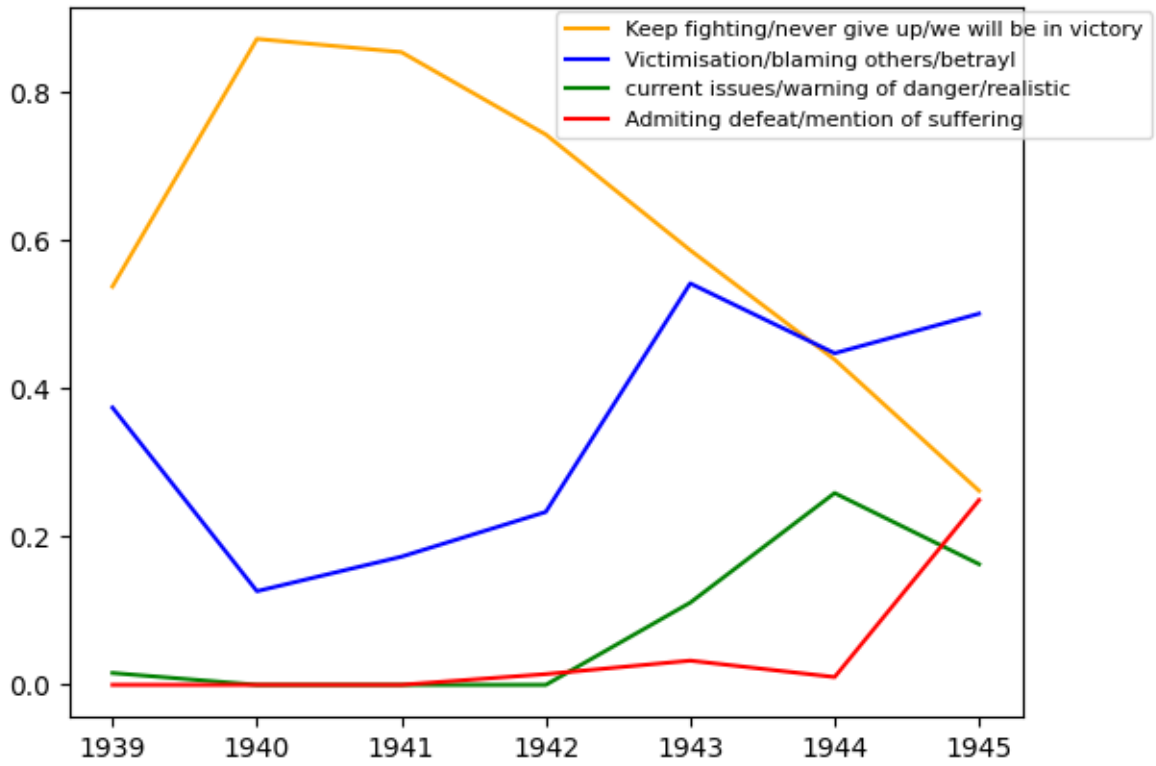


Figure 16: Hitler's distribution of topics over the years

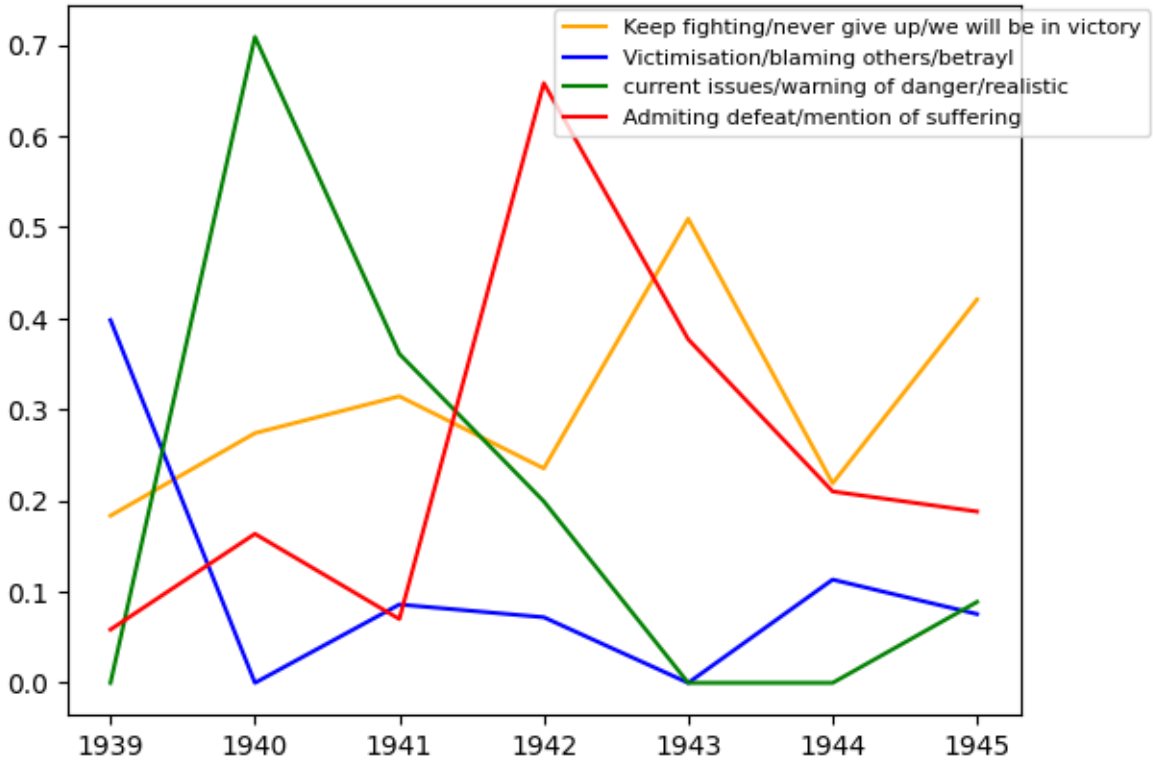


Figure 16: Churchill's distribution of topics over the years

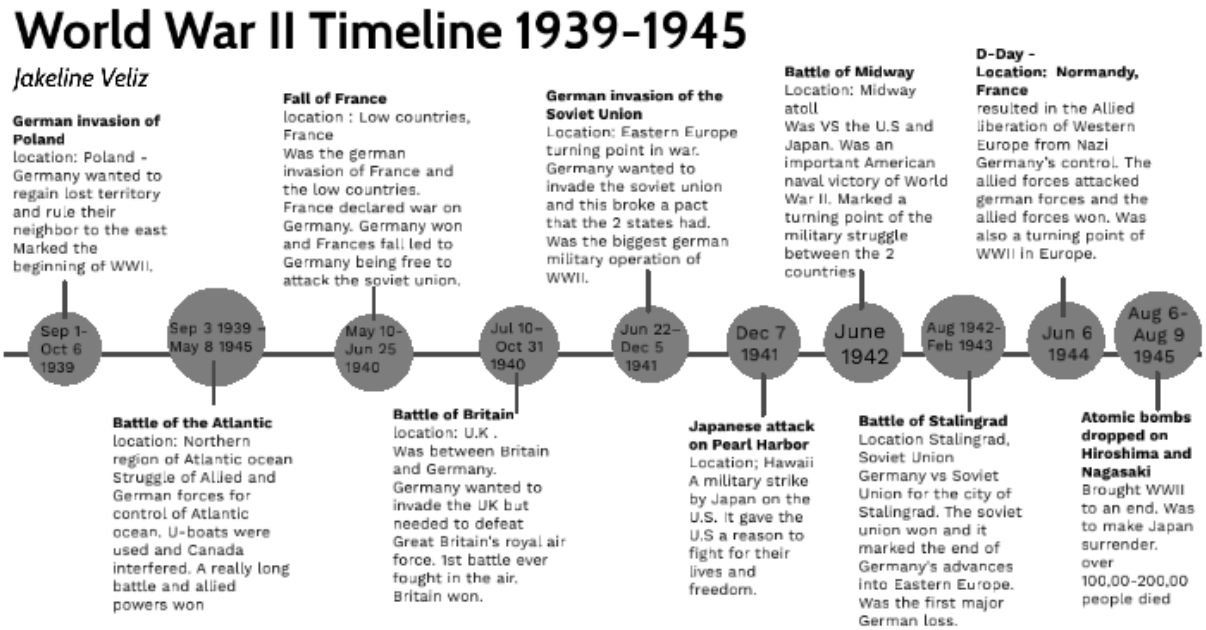
From Churchill's graph we can see a peak in 1940 surrounding topic 3 whilst the peak of topic 4 is in 1941. We also find that the encouragements of topic 1 tend to peak slightly after the 1940 and 1941 events. Our model also shows that topic 2 is highest at the very start but stays consistently low afterwards.

On the other hand, Hitler's topic 1 peaks in 1940 and 1941 and consistently descends 1941 onwards. Topic 3 alongside topic 2 seem to feature the most towards the end of the war and topic 4 is extremely low until the very last moment.

To support our findings on topics 2, 3 and 4 for Hitler, [39] mentions that Hitler's speeches used scapegoating to distract from Germany's failures and issues during the war. Rather than admitting any form of defeat until his final speech and suicide, he used speeches to blame the setbacks and losses of the war on others, such as Jewish people and put less emphasis on "never giving up". Hitler intended to keep unity within Germany by creating a common enemy. However, our source does not agree with our findings of the low use of "fear" shown in our line graph, as Hitler has been known to use aggressive and fearful language to address his audience.

To support topic 3 and 4, Churchill is very transparent and honest about the current downs of the war and the potential defeat[40]. By being realistic with his audience he gained trust from his people hence higher morale. One of Churchill's most famous speeches "Never Give in" supports the use of Topic 1, where the use of keep fighting seems to come after the hardest times[41].

The below timeline demonstrates how 1940 and 1941 were the hardest times for the allies, i.e. the fall of France, battle of Britain and the German invasion of the soviet union and turning points after 1942 which follows the pattern of our graphs above.



Conclusions Drawn

In conclusion, our report uses computational modelling to find how factors such as warfare and the speeches of key leader's influenced the outcome of WW2. We present a large analysis on the resources used by each country and modelled the results using GIS mapping. Alongside this we used LDA to topic model speeches made by Hitler and Churchill in the lead up to and during WW2.

When looking at our speeches graph, we found that the biggest correlation towards the turn of the real-life events is our topic on "never giving up" and "keep on fighting". Churchill's increased use of this topic and Hitler's decreased use correlated to the allies' victory in the war. However, as we found that our model does not effectively capture Hitler's use of fear, we are unable to support our accuracy to the same level as our GIS mapping.

Considering the high number of warfare that the axis had, we still found a negative correlation towards the number of deaths and its outcome. Though, our literature supports our model, we found that many of the failures of the axis were due to the quality of the resources over time and poor planning ahead. Whilst the Axis chose quality over quantity, the Allies invested in new technologies such as radar and atomic bombs which took out the axis' warfare. We also found that the allies use of colony's benefitted them for the outcome of the war, but at the expense of their lives rather than their own. The exploitation of colonies such as Africa and the middle east proved to influence a high death toll. We found that the worst hit was India where its establishment of facilities and vehicle productions involved them in the conflict whilst not being provided with any forms of attacking warfare to defend themselves. This demonstrates to us the greater importance ships and aircrafts have towards the outcome of the war.

In our analysis we found that our biggest contributor was aircrafts from England's which enabled the detection and destruction of powerful enemy submarines, and the atomic bombs issued by America. These constant technological advancements have developed today into the biggest threat to war: nuclear weapons.

Our analysis of Russia, however, proves that no matter how many powerful weapons you have, without the proper tactics or use, they're impact is greatly reduced. Which leads us on to evaluating the limitations of our models.

Limitations

The number of factors contributing to the outcome of the war are numerous, many in which are difficult to analyse with data.

Though we investigated our leader's speeches, our analysis of Russia shows the lack of investigating they're tactics and strategies. As we have found it to be a great contributor in our model and from our sources of literature, we would like to add this to future work to be done in this investigation.

Another, limitation of our model, is that in using LDA we haven't been able to evoke emotion, repetition and parallelism as mentioned by our sources of literature. Churchill used these tactics to reinforce his messages to make them more powerful and memorable. This makes our model bias towards meanings of words that could be complete errors due to the translation of Hitler's speeches or context.

Another limitation is the reliability of our dataset. There are many country's deaths not shown separately such as Spain. This bias of our data, hence our model is debated based on the allies writing the war and the potential lack of transparency of other operations happening during the war [43] Our War casualties data has been known to be "notoriously unreliable" [1] and there is no way to know for sure how much the deaths and casualties correlated to the military equipment or outcome. Computational Models are powerful, to an extent, where the physical collection of data and analysis needs to accompany it for the best results.

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[7] (https://archive.org/stream/never-give-in-the-best-of-winston-churchills-speeches-2003/Never%20Give%20In%21%20-%20The%20Best%20of%20Winston%20Churchill%27s%20Speeches%20%282003%29_djvu.txt)

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[9] https://www.kaggle.com/datasets/notkrishna/world-war-2-causalities-by-country

[10] https://opendata.arcgis.com/datasets/a21fdb46d23e4ef896f31475217cbb08_1.geojson

[11] https://ww2db.com/equip.php

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