Delft University of Technology

EPA133A, Advanced Simulation

Teachers Y. Huang & Prof.dr.ir. A. Verbraeck

Teacher Assistent: Gabriel Sher

Merijn Beemster	5380421
Tarik Bousair	5331900
Juliëtte van Alst	5402409
Vera Vermeulen	5127661
Suzanne Wink	5130697

TU Delft

Table of contents

1. Introduction

This segment of the study pertains to the model generation process and how a model can be constructed based on components. The Bangladesh model is utilized in this assignment, which is composed of components. Some advantages of using components include the ability to partially or entirely reuse certain parts of the model and breaking down complex and abstract concepts into more manageable pieces of code that exhibit understandable and codable behavior (Hofmann 2004).

In this assignment, a road is utilized between Chittagong and Dhaka, known as N1. Along this road, trucks are simulated to measure the effect of bridge failures, resulting in detours, on travel time. It is important to map this out because truck delays to the country's capital can have a negative economic impact. The trucking sector in Bangladesh serves as a vital component in maintaining efficient supply chain logistics within the country's densely populated landscape (Tata Motors, 2023). It is outlined how the data has been utilized. To obtain a comprehensive understanding of the impact of vulnerable bridges, various scenarios are applied.

2. Explanations of data & model

To be able to run the scenarios, first the creation process of the data will be explained. This process will be elucidated by using different steps.

2.1 Bridges

For the analysis, the dataset containing information about bridges and roads is utilized. Since the focus of the assignment is on the N1 highway from Dhaka to Chittagong, the dataset is filtered on N1. In addition, since the trucks only drive between Dhaka and Chittagong, we only selected that part of the road. This is achieved by looking at the JAVA file, and selecting a point in Chittagong: LRP249a. All LRPs after this point are dropped from the dataset.

In addition, there were some duplicate bridges in the dataset. Their names were almost the same (except from capital letters and extra spaces), and their longitude and latitude were also almost the same. But their LRP was not the same, for example LRP011a and LRP011c. When searching those duplicates on google maps, we found that they were indeed the exact same bridge, and we needed to delete them. This is done by selecting the first 6 digits of the LRP (to check if the numbers of the LRP were the same), and deleting the duplicates. Unfortunately, this created a big limitation: we did not focus on the condition of the bridge, and therefore, random bridges were removed instead of the bridges with the best condition. As a result, our N1 dataset did not contain bridges with condition “D” anymore.

Lastly, a new column named `model_type` is introduced, categorizing all bridges as 'bridge' for use in the simulation model.This approach ensures that the analysis concentrates on relevant bridges along the designated highway, preparing the data for further processing in the simulation model.

2.2 Roads

The roads dataset is filtered to focus on the road points leading to Chittagong, by filtering on “N1” and the LRPs until LRP249a. Subsequently, a new column named `model_type` is added to the roads dataframe, assigning the value 'links' to indicate their type.

A new column, 'length', is introduced to the DataFrame. This column contains the calculated lengths between successive points along the road. The calculation involves computing the difference between consecutive values in the 'chainage' column, which represents distances in kilometers. These differences are then assigned to the 'length' column in meters by multiplying them by 1000 for proper unit conversion.

This process ensures that the roads dataset is appropriately prepared with relevant information for further analysis.

2.3 Merged DataFrame

The DataFrame containing the roads is merged with the DataFrame of the bridges. This new DataFrame is then sorted based on the values in the 'lrp' column to reorganize it. However, the starting points (LRPs) were moved to the bottom of the dataset due to this sorting, and as a last step, we needed to move the starting points to the top.

To make it possible to use the dataset in the Bangladesh model, the LRPs are removed, and the column IDs are used as the new indexes. Only specific columns including 'road', 'id', 'model_type', 'name', 'lat', 'lon', 'length', and 'condition' are retained in the new DataFrame.

Additionally, manual addition of the source and sink is performed since only one road is simulated.

This process ensures that the DataFrame is structured appropriately for further analysis, with relevant columns retained and the source and sink points included for simulation.

2.4 Added Model components

First of all, a break_bridges function is added to make it possible for the bridges to break. The breaking process of the bridges is based on the scenarios, which are defined in a dictionary. This function iterates through the bridges and flags those that match the conditions outlined in the scenario dictionary. Second, a get_delay_time function is created to give the trucks delay times when the bridges break. Each truck gets a different delay time, based on random uniform distributions. As a result, the total_travel_time of each truck is different.

To calculate the average total_travel_time of the trucks, a few things have been done. Only trucks who made it to the end point should be taken into account, and therefore we did not use the Mesa DataCollector. The data of the trucks is collected at the end of the road, and this data is used to calculate the total_travel_time and total_waiting_time. This is done by creating a get_data function.

A disadvantage of the lack of DataCollector is that it was not possible to use the Mesa BatchRunner. The function run_model_batch was created, which orchestrates the simulation runs for multiple scenarios with different seeds. It systematically iterates through each scenario and seed combination, executing the simulation model, collecting data, and computing averages. Per scenario, the data is saved in a csv file.

3. Scenario outcomes

Based on the above datasets, different scenarios will be used to analyze the simulation outcomes. Based on the assignment description, a few assumptions about the delay times of the trucks are made:

- If a bridge length is over 200 meters and the bridge breaks down, this will cause a delay time for a truck, with a triangular distribution between 1 and 4 hours, with a mode of 2 hours.
- If a bridge length is between 50 and 100 meters and the bridge breaks down, the delay time for a truck is uniformly distributed between 45 and 90 minutes.
- If a bridge length is between 10 and 50 meters and the bridge breaks down, the delay time for a truck is uniformly distributed between 15 and 60 minutes
- If a bridge length is under 10 meters, and the bridge breaks down, the delay time for a truck is uniformly distributed between 10 and 20 minutes.
- On the N1 road there were 2 bridges that had a condition 'D', these bridges were removed because of the algorithm that removed both the duplicate bridges.

The scenarios used are shown in Table 1, the columns represent the chance that the bridge in a certain condition will break. Each scenario has run for 7200 steps (corresponding to five days), with ten different seeds. As a result, the random generated numbers (the delay times of the trucks) differ each run, and the average travel and waiting time is different. This shows how sensitive the model is to the randomly generated numbers.

Table 1, overview of scenarios

Scenario	Cat A%	Cat B%	Cat C%	Cat D%
0	Base scenario: no bridges break down			
1	0	0	0	5
2	0	0	0	10
3	0	0	5	10
4	0	0	10	20
5	0	5	10	20
6	0	10	20	40
7	5	10	20	40
8	10	20	40	80

3.1 Scenario 0 (Base scenario)

Scenario 0 is the base scenario. In this scenario there is no chance the bridges break down, disregarding their condition. The graph in Figure 1 shows that there is no delay time. Figure 2 shows that there is no waiting time. On average the travel time is 315.00 minutes, the waiting time is 0.00 minutes.

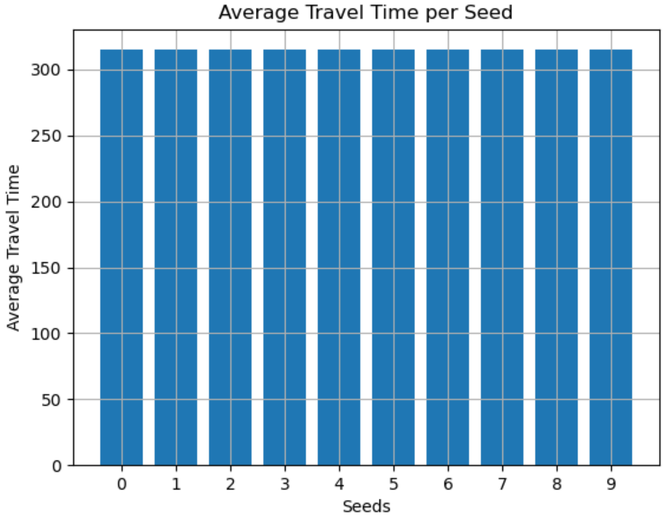


Figure 1, average travel time per seed scenario 0

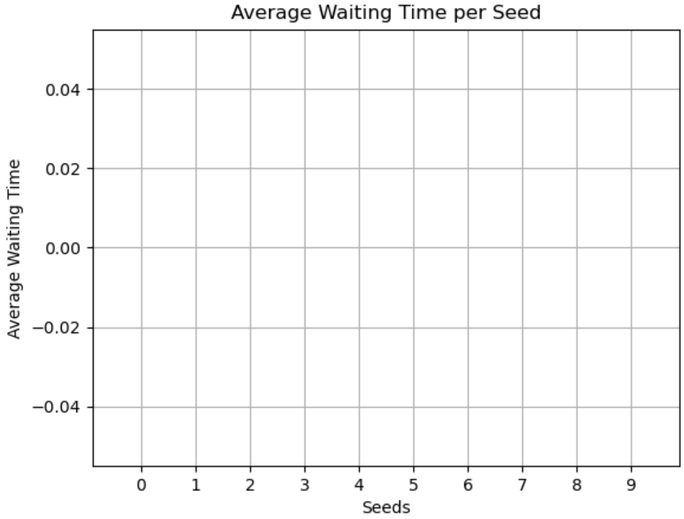


Figure 2, average waiting time per seed scenario 0

3.2 Scenario 1 & 2

The first and second scenarios exhibit similar results. This similarity arises due to the negligible impact of increasing the probability from 5% to 10% within category 'D', as there are no bridges classified under category 'D'. This observation is depicted through the average travel time illustrated in Figures 3 and 5, and the average waiting time depicted in Figures 4 and 6. On average, the travel time amounts to 315.00 minutes, while the waiting time remains at 0.00 minutes.

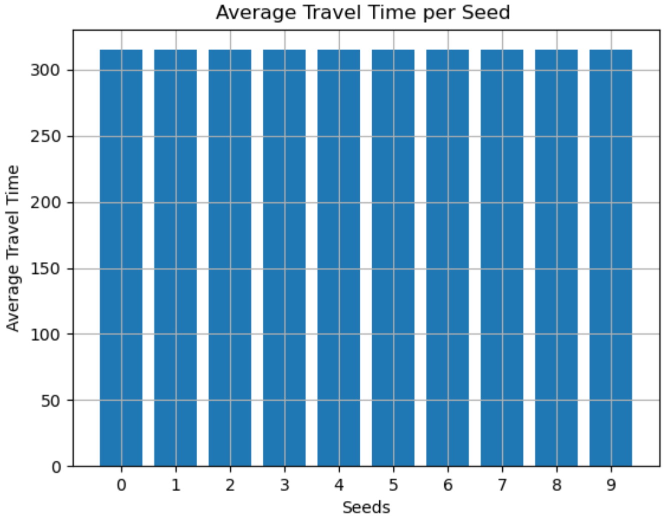


Figure 3 average travel time per seed in scenario 1

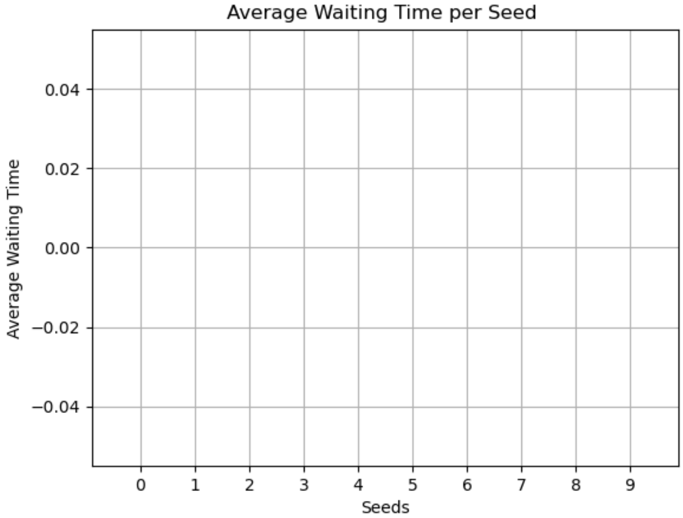


Figure 4, average waiting time per seed in scenario 1

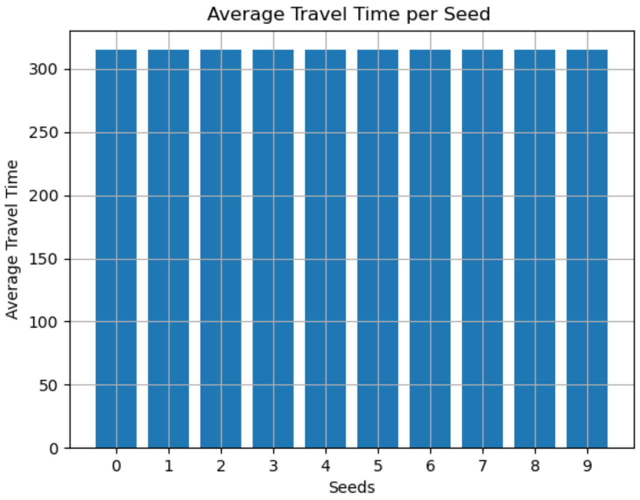


Figure 5, average travel time per seed in scenario 2

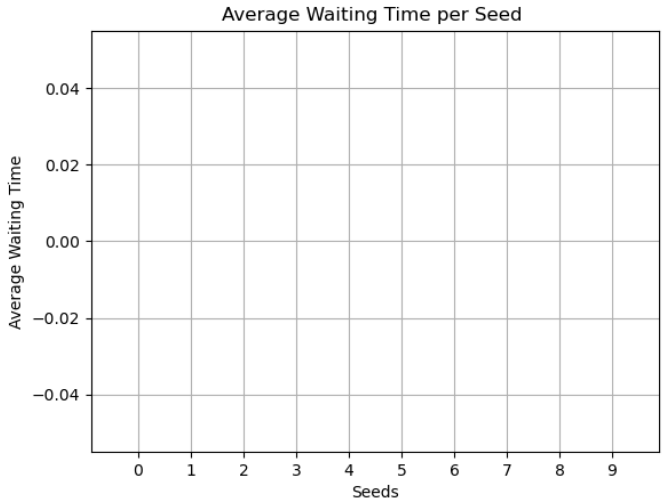


Figure 6, average waiting time per seed in scenario 2

3.3 Scenario 3

In the third scenario there is a 10% chance that the bridges of condition ‘D’ break down and a 5% chance the bridges of condition ‘C’ break down. As described before there are no bridges that have a condition of ‘D’.

But there are 19 bridges that have condition ‘C’. The chance of these bridges breaking down is 5%. 19 bridges are just insufficient to allow for the failure of one bridge. This event would occur with the presence of 20 bridges. Therefore still no bridges break down. This is visualized with the average travel time in Figure 7 and the average waiting time in Figure 8. On average the travel time is 315.00 minutes, the waiting time is 0.00 minutes.

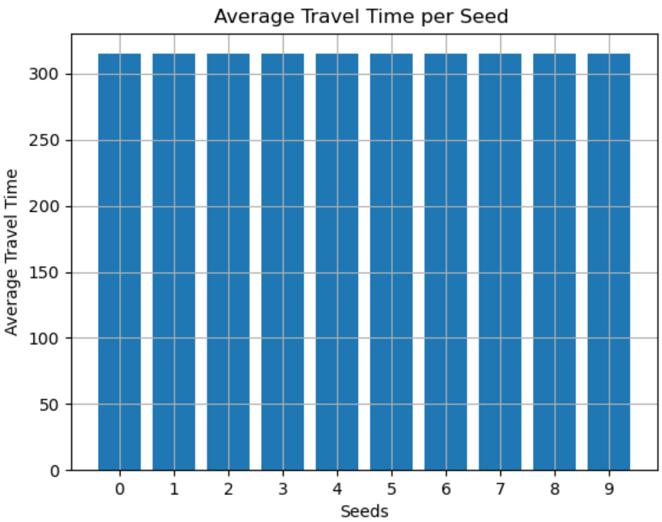


Figure 7, average travel time per seed in scenario 3

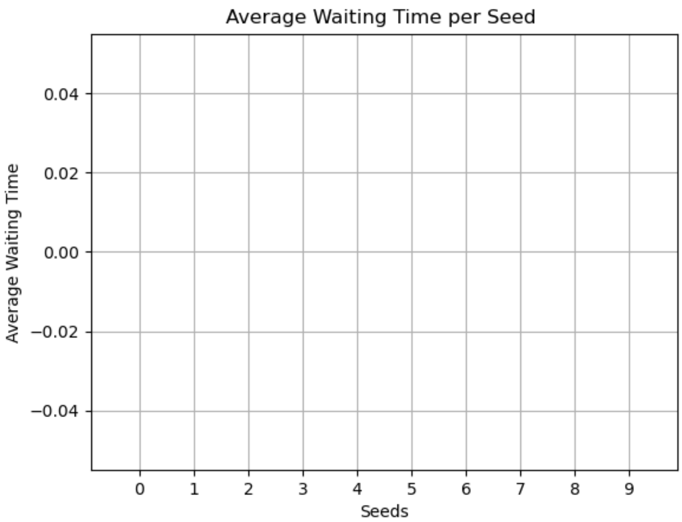


Figure 8, average waiting time per seed in scenario 3

3.4 Scenario 4

In the fourth scenario there is a 20% chance that the bridges of condition ‘D’ break down and a 10% chance the bridges of condition ‘C’ break down. As described before there are no bridges that have a condition of ‘D’. But there are 19 bridges that have condition ‘C’. The first bridges start to break down in this scenario. This is visualized with the average travel time in Figure 9 and the average waiting time in Figure 10. On average the travel time is 347.74 the waiting time is 32.84. The traveltime in this scenario has increased by 25 minutes.

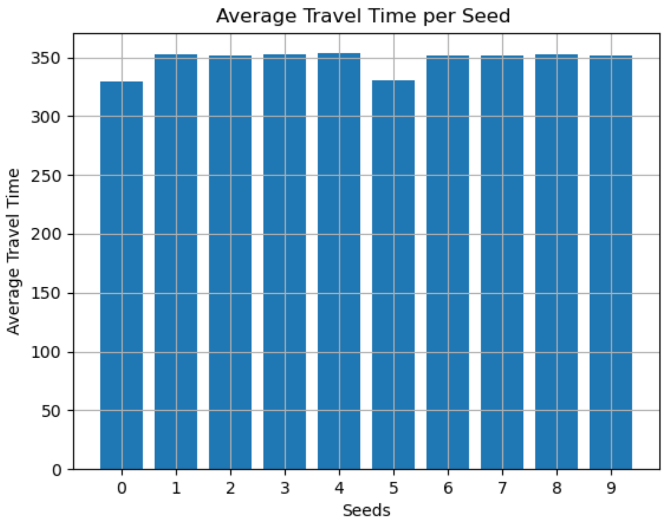


Figure 9, average travel time per seed in scenario 4

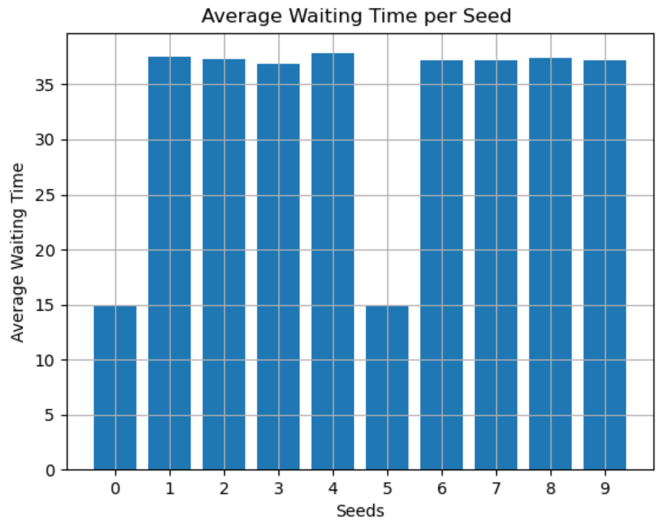
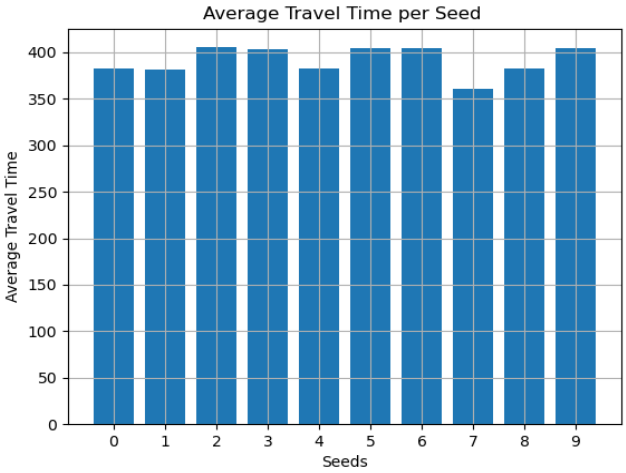


Figure 10, average waiting time per seed in scenario 4

3.5 Scenario 5

In the fifth scenario there is a 20% chance that the bridges of condition ‘D’ break down, a 10% chance the bridges of condition ‘C’ break down and a 5% chance the bridges of condition ‘B’ break down. As described before there are no bridges that have a condition of ‘D’. But there are many bridges that have conditions ‘C’ and ‘B’. The breaking down of the bridges is visualized with the average travel time in Figure 11 and the average waiting time in Figure 12. The average travel time is 391.25 minutes and the average waiting time is 76.45 minutes. The waiting time has doubled, compared to scenario 4.



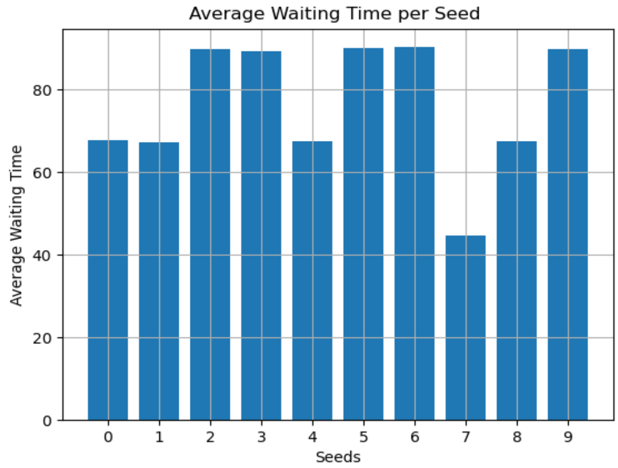
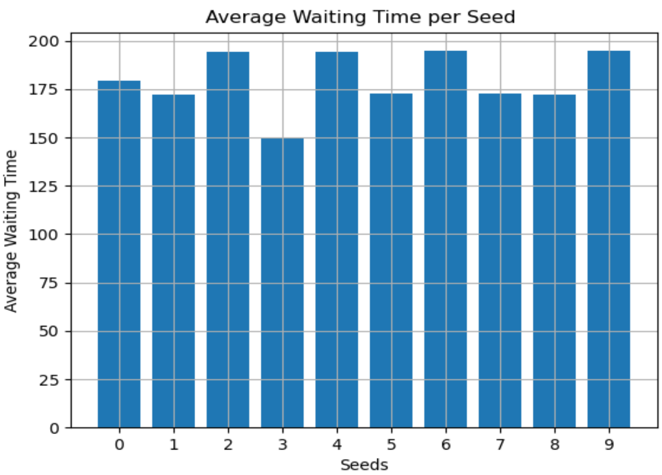


Figure 11, average travel time per seed in scenario 4

Figure 12, average waiting time per seed in scenario 4

3.6 Scenario 6

In the sixth scenario there is a 40% chance that the bridges of condition 'D' break down, a 20% chance the bridges of condition 'C' break down and a 10% chance the bridges of condition 'B' break down. As elucidated previously, no bridges exhibit a 'D' rating. But there are many bridges that have conditions 'C' and 'B'. The breaking down of the bridges is visualized with the average travel time in Figure 13 and the average waiting time in Figure 14. The average travel time is 494.37 minutes and the average waiting time is 179.67 minutes. The average waiting time is increased compared to scenario 5 with a factor of almost 2.5 times.



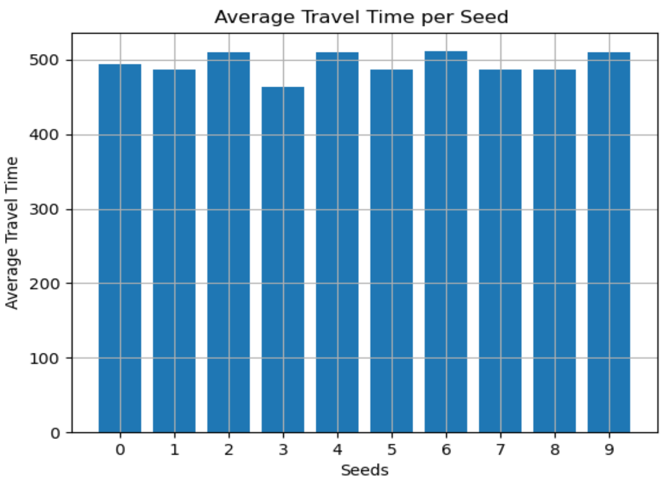


Figure 13, average travel time per seed in scenario 6

Figure 14, average waiting time per seed in scenario 6

3.7 Scenario 7

In the seventh scenario there is a 40% chance that the bridges of condition ‘D’ break down, a 20% chance the bridges of condition ‘C’ break down, a 10% chance the bridges of condition ‘B’ break down and a 5% chance the bridges of condition ‘A’ break down. As mentioned earlier, there are no bridges with a categorization of 'D'. But there are many bridges that have conditions ‘C’, ‘A’ and ‘B’. The breaking down of the bridges is visualized with the average travel time in Figure 15 and the average waiting time in Figure 16. The average travel time is 652.61 minutes and the average waiting time is 338.41 minutes. The average waiting time is almost doubled compared to scenario 6.

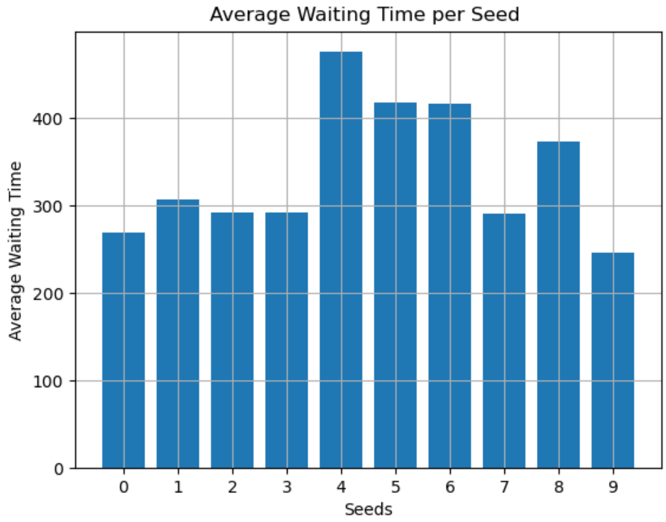


Figure 15, average travel time per seed in scenario 7

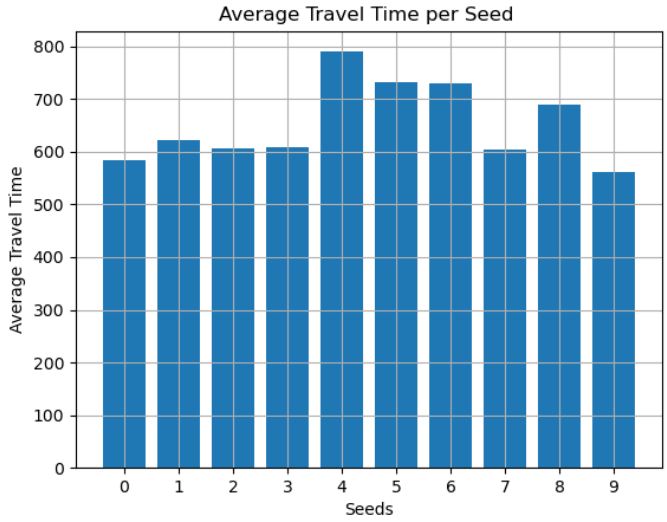


Figure 16, average waiting time per seed in scenario 7

3.8 Scenario 8

In the eight scenario there is a 80% chance that the bridges of condition ‘D’ break down, a 40% chance the bridges of condition ‘C’ break down, a 20% chance the bridges of condition ‘B’ break down and a 10% chance the bridges of condition ‘A’ break down. As previously stated, there are no bridges categorized as 'D'. But there are many bridges that have conditions ‘C’, ‘A’ and ‘B’. The breaking down of the bridges is visualized with the average travel time in Figure 17 and the average waiting time in Figure 18. The average travel time is 1041.21 minutes and the average waiting time is 725.92 minutes. The average waiting time is doubled compared to scenario 7.

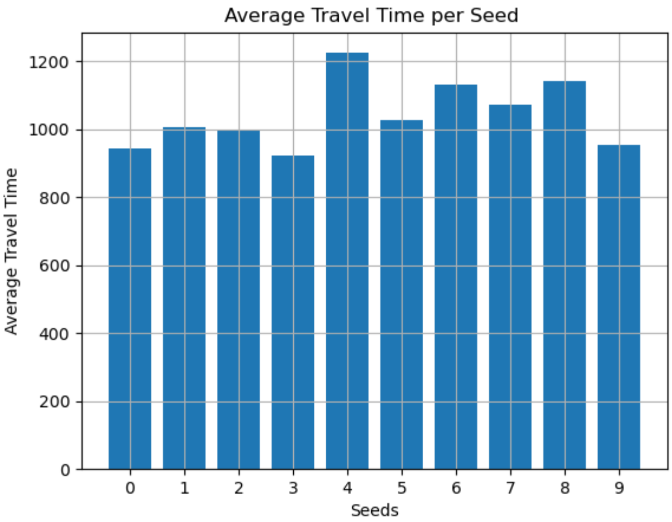


Figure 17, average travel time per seed in scenario 8

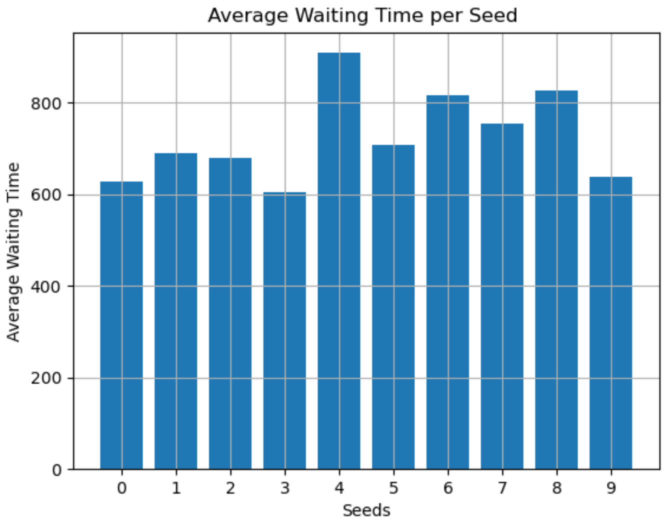


Figure 18, average waiting time per seed in scenario 8

4. Discussion on scenario outcomes

The scenario outputs show that in Scenario 0, the base case, there is no chance of bridge failure, regardless of their condition. This results in no delay time, as shown in Figure 1, and no wait time, as shown in Figure 2. As the probability of bridge failure is increased in the following scenarios, a gradual increase in both the average travel time and the average waiting time is observed. However, this increase only occurs when bridges in poorer condition begin to fail, as illustrated in Scenario 4 and beyond, due to the lack of mathematical impact on the model of the scenario conditions. The observed increase in waiting time is especially significant from Scenario 6, where the average waiting time is almost 2.5 times higher than in Scenario 5. In the most extreme situation, Scenario 8, in which the risk of bridge failure is highest, a double the average waiting time compared to Scenario 7. These findings highlight the importance of regular maintenance and preservation of bridges to minimize traffic congestion and travel time delays.

As can be seen in Figure 19, a waiting time only arises from scenario 4 onwards. In scenarios 5, 6, 7 and 8, the waiting time then increases considerably. Figure 20 shows that the travel time also increases from scenario onwards and is absolutely highest in scenario 8. These analyses show that the chance of a bridge breaking has a major influence on the travel time of trucks on the N1 from Chittagong to Dhaka.

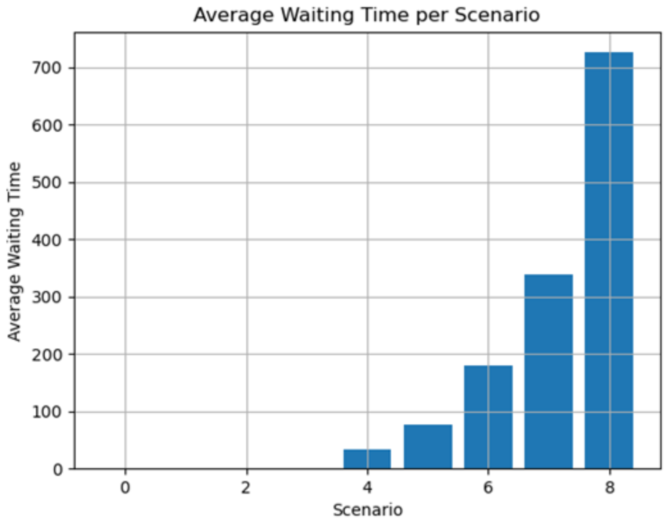


Figure 19, average waiting time per scenario

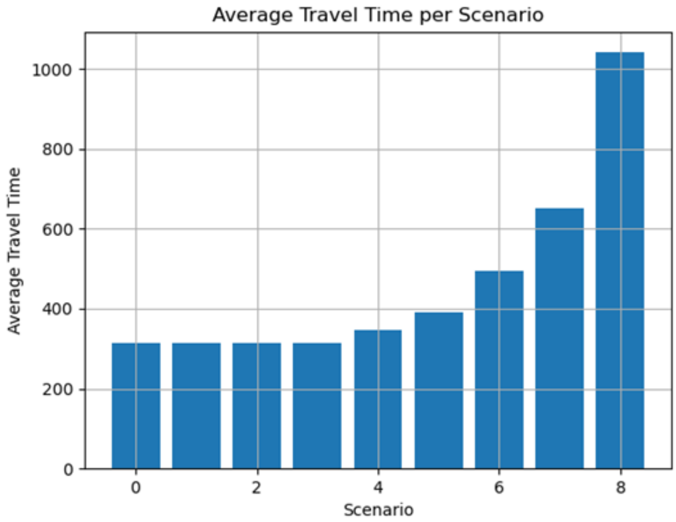


Figure 20, average travel time per scenario

5. Conclusion & Reflection

The analysis of the condition of the bridges along the N1 route from Chittagong to Dhaka in Bangladesh, shows several important insights on the importance of road maintenance in Bangladesh. Initially the base scenario and the scenario's 1 and 2 show exactly the same outcomes, which is that no bridges break down. As because of our cleaning process there are no bridges with a condition 'D' left. Then the third scenario is also the same without any delays, because we have 19 bridges of which 5% break down, exactly none of them break down. However from scenario 4 and 5, when the probability of bridges breaking down also increases, there is a notable increase in the bridges that break down, causing long waiting times and also longer travel times. The waiting time almost doubles for each additional scenario increase of breaking down per condition. These represent significant increases, underscoring the importance of maintenance for Bangladeshi bridges in terms of their impact on the economy due to the slowing down of trucks. From a maintenance perspective, it is recommended to allocate more resources to bridges.

The outcomes of various seeds within the same scenario can vary considerably. This is because the delay per bridge is determined by a uniform distribution that varies per seed. However, the disparities between them are limited, so it can be argued that the model is not highly susceptible to the influence of randomness.

The fact that no bridges break down in the scenarios 1-3 underscores the impact of bridge conditions on the simulation outcomes. Additionally, the substantial increase in waiting time from scenario 4 onwards emphasizes the critical importance of bridge maintenance to minimize travel time delays.

While the simulation provides valuable insights, it also has limitations. Firstly, the lack of bridges with condition 'D' due to data cleaning choices, restricts the analysis of scenarios where such failures could occur. Moreover, the modeling in the current way oversimplifies real-world dynamics. This is because all trucks drive the same speed constantly over time.

To provide better insights for Bangladesh, future versions of the model should include factors such as traffic dynamics, repair processes, and the spatial distribution of bridges. Another important limitation is that in scenario 3, from 19 bridges that are in the dataset with a 5% chance of breaking, none of them break. This is of course due to probability calculation, but in the real world this might not be realistic. Additionally, efforts to improve the dataset by ensuring representative samples of bridge conditions would strengthen the simulation's predictive capabilities.

Overall, this analysis underscores the significance of proactive infrastructure management in ensuring efficient transportation systems and minimizing disruptions.

6. Reference list

Hofmann, M. (2004). Criteria for Decomposing Systems Into Components in Modeling and Simulation: Lessons Learned with Military Simulations. *SIMULATION*, *80*(7–8), 357–365. https://doi.org/10.1177/0037549704049876

Tata Motors. (2023, November 6). Bangladesh Trucks: Backbone of the Supply Chain | Tata Motors BD. *Tata Motors*. https://www.tatamotors.com.bd/blog/bangladesh-trucks-backbone-of-the-supply-chain