Surviving "The Great War" – a model of the secondary market for The Eras Tour resales in Buenos Aires, Argentina, dedicated to the STEM Swifties

Introduction & Background

"It's been a long time coming", in fact, almost two months since Taylor Swift came to Argentina. The Eras Tour has proudly become a global phenomenon, one of the most successful tours in history, and arguably the most successful tour by any female artist in history. Besides being a commercial success and cementing Swift as a pop pariah, the tour also yields a multifaceted impact, both globally and locally with respect to politics, cultures, and different economies.

Swiftmania has a strong impact on the current affairs of Argentina, a country in the midst of an economic crisis and a heated election that sparked debate. One of the notable markets surrounding The Eras Tour was the market for second-hand tickets: while the act is presumably banned by AllAccess, the Argentinian host of The Eras Tour, many informal sales occur, and secondary ticket websites like StubHub and Viagogo were still able to provide tickets to fans to attend.

The assignment aims to create a simulation of this informal secondary market using dynamic networks to model transactions and the movement of tickets within Buenos Aires. Given an initial condition, post-official sales on June 6, 2023, how many people actually end up buying the tickets to attend The Eras Tour?

Basic model: purely buying and selling tickets, no price included

Update rules, parameters, and assumptions

To answer our exploratory challenge, we begin with the simplest potential model. Assuming a network of Swifties, we classify each Swiftie as a node: one is either a potential seller (referred to in this model as "seller") or a potential buyer ("buyer"). A seller is classified as someone who has a ticket, while a buyer has no ticket. Beginning with a small world network of Buenos Aires, there is a probability that a random undirected edge between any two nodes forms. This connection between the two nodes can represent what Taylor Swift would call "making the friendship bracelet" or just an interaction. In real life, this interaction may act as potential sellers saving slots for each other during the 6-month long camping period. This edge, or connection, only represents a potential transaction if the nodes between the buyer and the seller, as there is demand from the buyer's side to purchase the ticket. As an edge forms, there is a random chance of a transaction happening at a determined probability. Once this transaction is successful, the edge is severed, a buyer now becomes a seller, and vice versa. This process of random rewiring and random severing happens until The Eras Tour has concluded, which we assume to be a pre-determined number of time steps.

As such, several parameters that we wish to initialize in this simulation include

- p_d, the demand probability, or the probability of forming an edge between any two random buyer or seller nodes, and
- p_t, the transaction probability, or the probability of a transaction occurring, is also seen as the probability of severing an already existing connection

Of course, this model is an oversimplification of the market for the following assumptions.

- Each agent in the simulation holds only 1 ticket when in reality, each individual is capable of holding up to 4 tickets.
- The simulation does not account for the price of resale tickets and assumes that the probability of a transaction is pre-determined instead of being independent of the price. Considering that some ticket prices are worth 1-2 times the average salary of a Buenos Aires resident, this assumption is unreasonable in a real-life scenario.
- The simulation assumes a fixed probability for the demand of the tickets over different time steps. In reality, the popularity of the tour would increase as we approach the tour dates, which would in turn affect the demand probability
- The model assumes that there is a total fixed number of people in the market, which may not be the case in real life, as every day there might be new people entering the market, either with demand to buy or supply to sell.

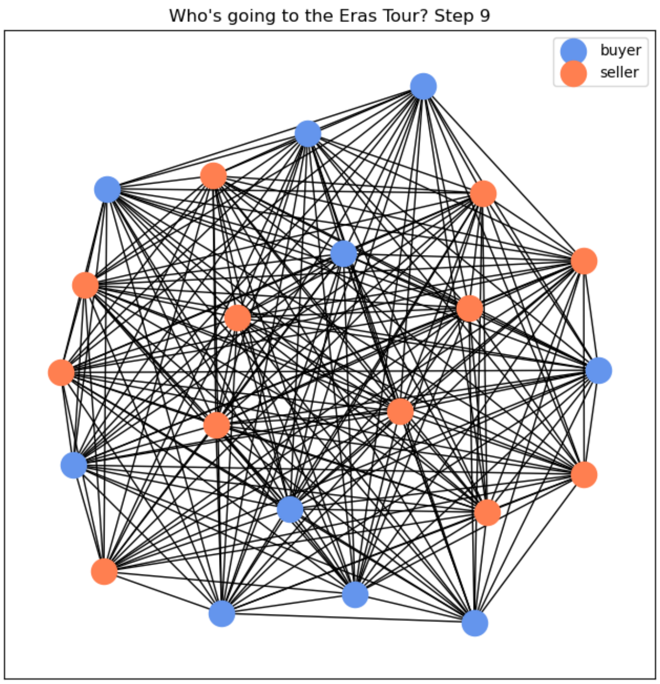
Despite its oversimplifications, implementing this model can still be a useful starting point to learn about the dynamics of networks over time.

Implementation

The assignment uses a Watts-Strogatz ring lattice network to model the small-world network of Swifties in this secondary market of Buenos Aires. The Watts-Strogatz algorithm aligns with the assumption of a fixed number of agents in the market and the probability of rewiring nodes randomly with a certain probability. While the ring lattice graph is not bipartite in nature, which would be ideal, we implement the rules of our simulation by mainly focusing on the deletion of the edges afterward, and any connection formed between two agents of the same class (buyer-buyer, seller-seller) does not result in a transaction. This, however, will affect our degree distribution. We implement the simulation with a demand probability of 0.1 and a transaction probability of 0.2. The rationale for this starting point is that when a connection between a buyer and a seller is connected, they are more likely to conduct the transaction. Running the simulation for 22 nodes (just like how Taylor Swift is feeling 22) after 50 time steps, we obtain the following resultant network. An evolution of the steps over time can be seen in the complementary Jupyter Notebook.

Figure 1.

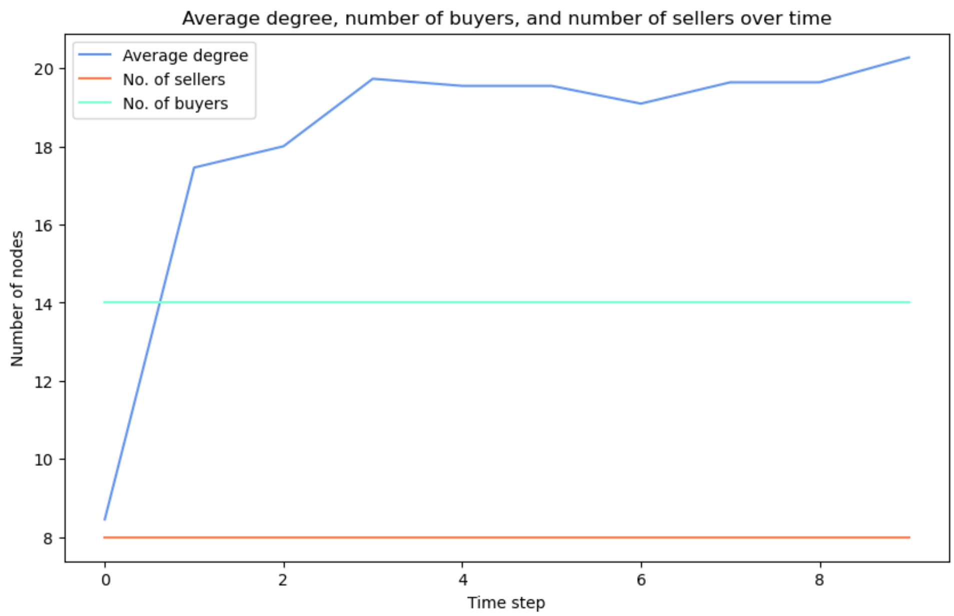
Network of the basic model of The Eras Tour reselling after 10 steps (starting from step 0)



Examining the average degree of nodes, the number of buyers, and the number of sellers over time, we have the following observations seen in Figure 2 below.

Figure 2.

Average degree, number of buyers, and number of sellers over time.



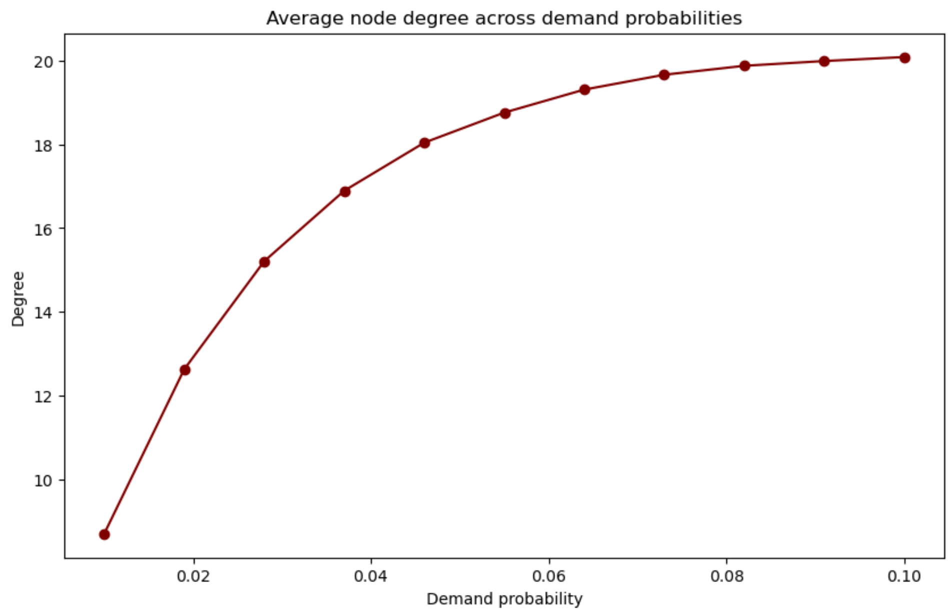
By the rules of our simulation, the number of sellers and the number of buyers are predictably constant, as at every time step, should there be a transaction, a buyer and a seller swap roles with each other. We can also show mathematically that regardless of the probability, the number of buyers and sellers would remain constant using mean-field approximation, where we examine all the possible state transitions of the nodes from current state to next state. The probability of the next state being the seller is exactly the same as the probability of the next state being the buyer for any given probability of demand and probability of transition, due to the symmetric nature of the model rules.

However, over time, the average degree of the nodes would eventually approach the maximum number of connections it can make. This can be explained by the nature of the small world network and its ability to form clusters. In this scenario, the probability of edge deletion is actually dependent upon edge formation, so naturally, the rate at which edges form is greater than the rate at which edges are deleted.

Examining the average degree at the end of the simulation for each demand probability yields the following results.

Figure 3.

Average node degree across different demand probabilities



Intuitively, one explains that as there is a higher demand probability, there is a higher probability of connection. Considering the highly clustered nature of the Swiftie network, lower demand probabilities mean more time is needed for a fully connected network, and conversely, higher demand probabilities mean a shorter time needed for a full connection. While Taylor Swift said "You're On Your Own, Kid", the empirical results show otherwise.

***Is It Over Now?* Adding complexity to the model**

Is our model over now? Without sugarcoating, we know that our original model is an oversimplification of the complex system, and the results are simply… uninteresting and not that insightful. We continue to improve upon our assumptions from our original model.

Additional rules, parameters, and assumptions

Several features (and additional assumptions) we attempt to add include:

- Changing the number of tickets: we change the maximum number of tickets possible for each individual to hold from 0 to 4. A buyer would presumably have no ticket, while a seller would have 1 or more tickets, meaning a seller can only become a buyer once all their tickets have been sold
- Adding more dynamics to the demand probability and transaction probability parameter: inclusion of an external environment parameter, and the popularity index of the concert in Buenos Aires, would change the demand for the ticket and the probability of the ticket having a successful transaction. We assume that over time, this popularity

index increases, thus increasing both the demand probability and the transaction probability

- Considering the workings of a transaction: the probability of a transaction is also dependent upon the price. Within a transaction, when a buyer purchases a number of tickets for $x, the seller is now $x richer, while a buyer is now $x poorer. The amount of money owned by an individual at any point in time also determines how likely the purchase is going to be made

Looking at the prices of The Eras Tour by AllAccess (2023) and gathering information from resale sites such as StubHub and Viagogo, we assume that the price follows a normal distribution of $200 with a standard deviation of $20. The original prices for The Eras Tour are generally around $75-100 for most tickets, and knowing the price-inelastic demand for Taylor Swift tickets, many resales took the opportunity to double, or even triple the original price.

The model proposes the following metrics for the parameters at each time step. For a baseline demand probability of p_d, the demand probability at step *n* of the simulation is defined as

$$p_n = p_d + e_n$$

with e_n being the environment parameter, or the popularity index of the Eras Tour, on day n. The more popular the show, the higher the demand for the ticket. On the other hand, the model calculates the transaction probability as

$$P_n' = p_t + e_n - 0.001(\text{price})$$

The value 0.005 is a chosen arbitrary scale to represent the negative relationship between price and willingness to buy while changing this to a reasonable probability.

Implementation & Results

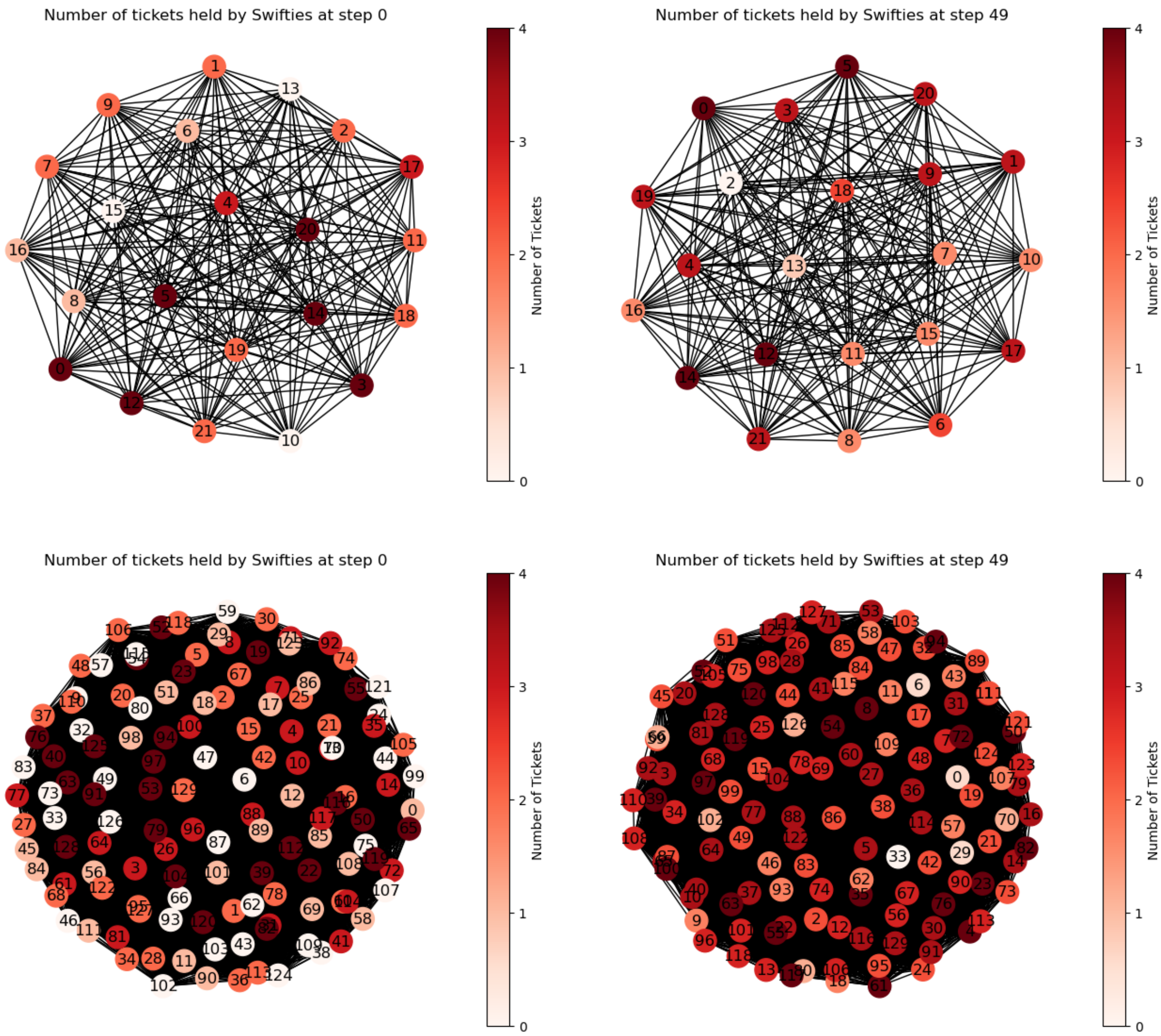
After implementing this model in Python and running the network simulation for 50 steps, we obtained the following.

Figure 4.

The evolution of the small-world network from step 0 to step 49 for 22 nodes and 130 nodes, respectively, using the "red" color map – a "maroon" shade would mean 4 tickets, a "flamingo pink" shade means 3 tickets, and so on.[1] From this network diagram, one can observe that the number of tickets begins to spread out, and more people are now considered as "sellers." In a

[1] These are all puns with reference to Taylor Swift's use of the color red across her albums. All these puns are (all-too-)well-intended.

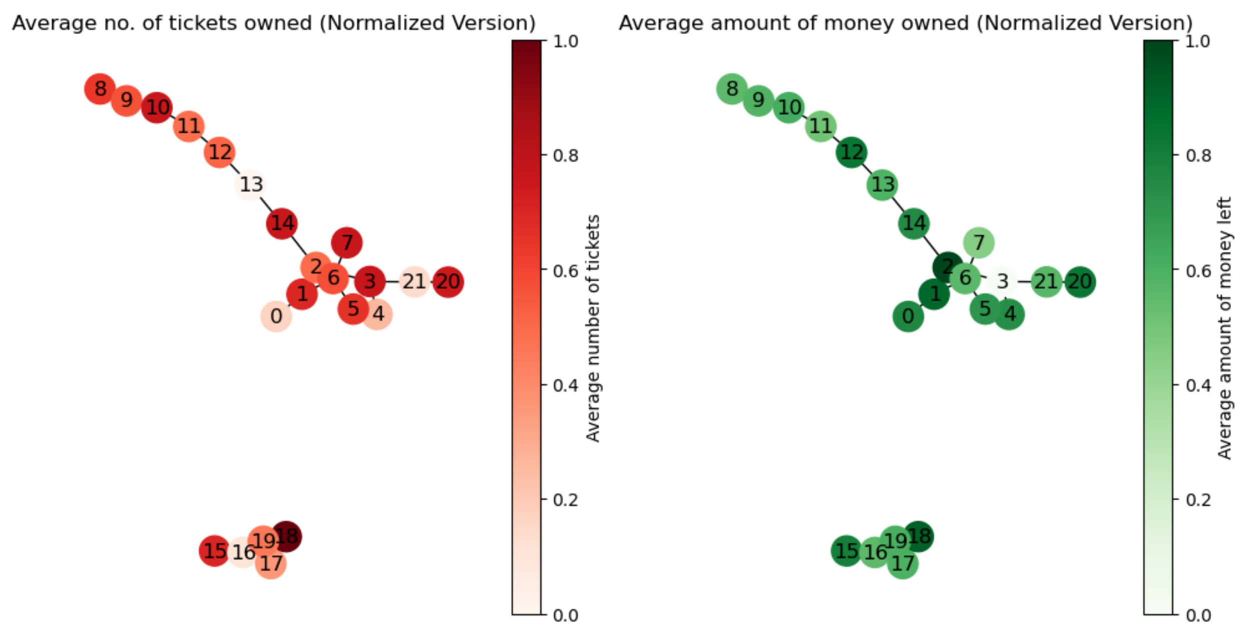
real-life scenario for the Buenos Aires Eras Tour, more fans are able to attend the concert once the resale is over, and the distribution is spread out.



As one may question whether the amount of money left for the Swifties has a straight-forward negative correlation with the number of tickets that they purchased, our results reveal that the resulting patterns may be much more complex. It is possible that nodes that have lots of money, as well as lots of tickets, are nodes that are well-connected, thus leading them to have more opportunities for transactions and reselling. Figure 5 shows a side-by-side comparison of each node, the number of tickets they own, and the remaining amount of money left, averaged out over 1000 trials of the simulation.

Figure 5.

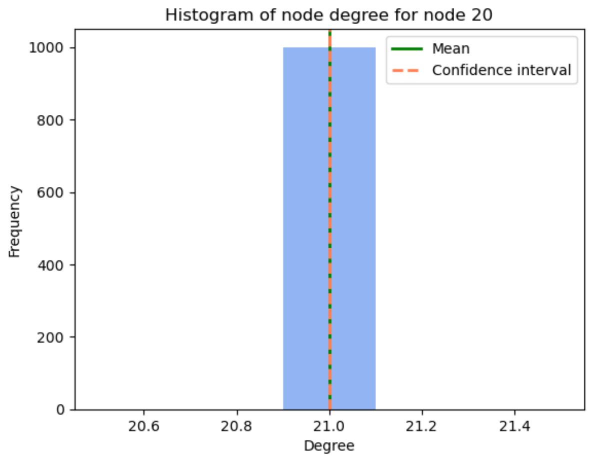
A side-by-side comparison between the number of tickets vs. the amount of money remaining after 50 time steps, averaged out over 1000 trials.

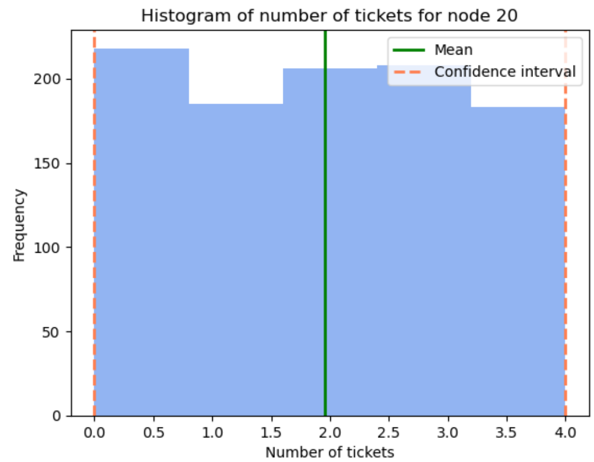


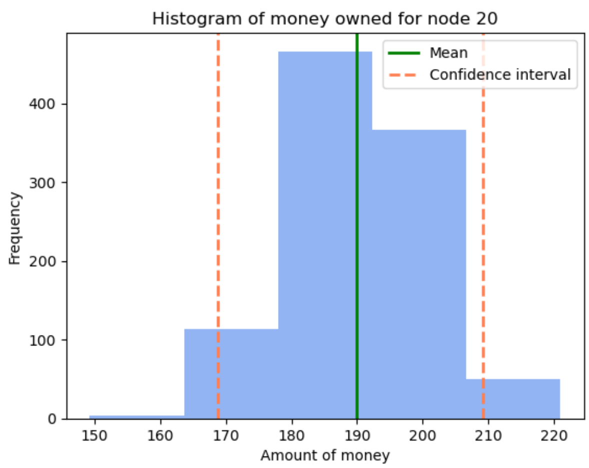
Confidence intervals

How confident are we that this unclear correlation pattern and this emergent property emerge? As we generate the 95% confidence interval for the number of tickets and the amount of money owned, we notice that this analysis may not be useful, considering we already assume that the total number of tickets generated by the system is fixed. It would therefore be expected for the average to remain the same across all trials. The report thus takes a look at node #20 and examines their confidence interval: their high number of tickets and high amount of money left shows that they "never go out of style."

Figure 6.
The histograms show the distribution of node 20's node degree, number of tickets, and amount of money owned. Observations show that the confidence intervals for the number of tickets owned and the amount of money remaining are very large.







The histogram of the node degree shows that after the simulation, node 20 becomes a very well-connected node. The large confidence intervals of the number of tickets (understandably a discrete variable) and the amount of money owned show that we cannot be too confident about our observed patterns. The correlation between these two quantities still remains relatively unpredictable. Just like how Taylor Swift herself is unpredictable with her album schedules, the emerging patterns between our resulting number of metrics become a mystery, very much a “Question…?”

Future directions

The report recommends the following future directions for extensions of this project which address some assumptions and shortcomings.

- An agent-based model that consists of many other attributes for the agents, such as socio-economic status, political ideals, demographics, and number of hours dedicated to camping on site before the show (which could end up at 6 months)

- Having a different distribution for the amount of money spent and the price of the resale tickets
- Using a different type of random network to initialize the simulation, such as the Barabási-Albert Scale-Free Network model instead of the Watts-Strogatz model. In this scenario, preferential attachment to popular nodes and the evolution of these networks can be examined. For you Swifties out there, yes, that is StubHub, who charge us $1000 for a ticket.

Regardless, it is known throughout the world that we are dedicated fans, and the report shows no exception. May we continue “making friendship bracelets,” “taking the moment and taste it,” and using more modeling to make a difference in the world.

References

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Appendix: AI Statement

The report utilizes ChatGPT 4 to help with complicated tasks of advanced data visualization. I took the main intellectual and creative direction and instructed ChatGPT to help me draw out the animations for my first data visualization network, as well as generating a data visualization of the networks using the colormaps available in the matplotlib library, which I am not familiar with. ChatGPT 4 also assisted with debugging my code for the update() methods of both the classes for the Eras Tour, both basic and Buenos Aires, as well as helped me complete the observe() method which shows data visualization for the simulations. I took full control of the creative and intellectual direction as well as the analysis involved for all the complex systems analysis in the assignment.