Assignment 2B: Bycicle Rental System in a Theme Park

Group 4:

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1.0 Problem Description and Model Development

At the SIM Theme Park tourists can rent and return bicycles at four attractions. The rental system has 80 bicycles in each station, and tourists can only rent or reteurn bicycles if there are available bicycles or empty docks. The distance between the attractions ranges from 1 km to 3 km, and we assume that tourists visit at least two attractions before leaving the park. The system operates 24 hours a day, and tourists have different speeds while riding bicycles. The task is to analyze the reliability and efficiency of the current system and propose improvements, such as calculating the average waiting time for renting or returning a bicycle at each station and optimizing the number of docks at each station to ensure tourist satisfaction while minimizing costs.

To create a simulation model of the Bike rental system at SIM Theme Park, we need to consider the following:

- Bike station layout: There are 4 stations, each with a certain number of bicycles and docks.
- Tourist behavior: Tourists will arrive randomly at any station, rent bicycles, visit the attractions, return bicycles to the station, and possibly rent bicycles again to travel to the next attraction.
- Bike availability: The availability of bicycles and docks will depend on the number of tourists at each station and the time they spend at each attraction.
- Bike speed: Different tourists have different speeds, affecting the travel time between attractions. A tourist's speed is constant throughout their visit.
- Bike rental and return time: The time a tourist takes to rent or return a bike will depend on the availability of bicycles and docks and the number of tourists waiting.

Assumptions:

- Weather is clear, no rain that stops movement between attractions. We don't simulate delays for rain.
- No bicycles were damaged or lost.
- Tourists don't skip attractions, they follow the sequence of A->B->C->D, however, they may not visit all attractions.
- For simplicity's sake, statistics of those who haven't left the park by the end of the simulation will be ignored.
- The cost of building a dock and acquiring a new bike are the same. Therefore, optimizations will not emphasize on either docks or bikes.

Based on these factors, we can create a simulation model Arena as shown in Figure 1.0.1.

To understand if the model developed was suitable, we started by building a submodel considering just two attractions available at the park. Once verified that it could work, we just duplicated the general structure for all the other attractions. We could generally divide our model in two main parts: the generation of tourists, and the change of attraction.

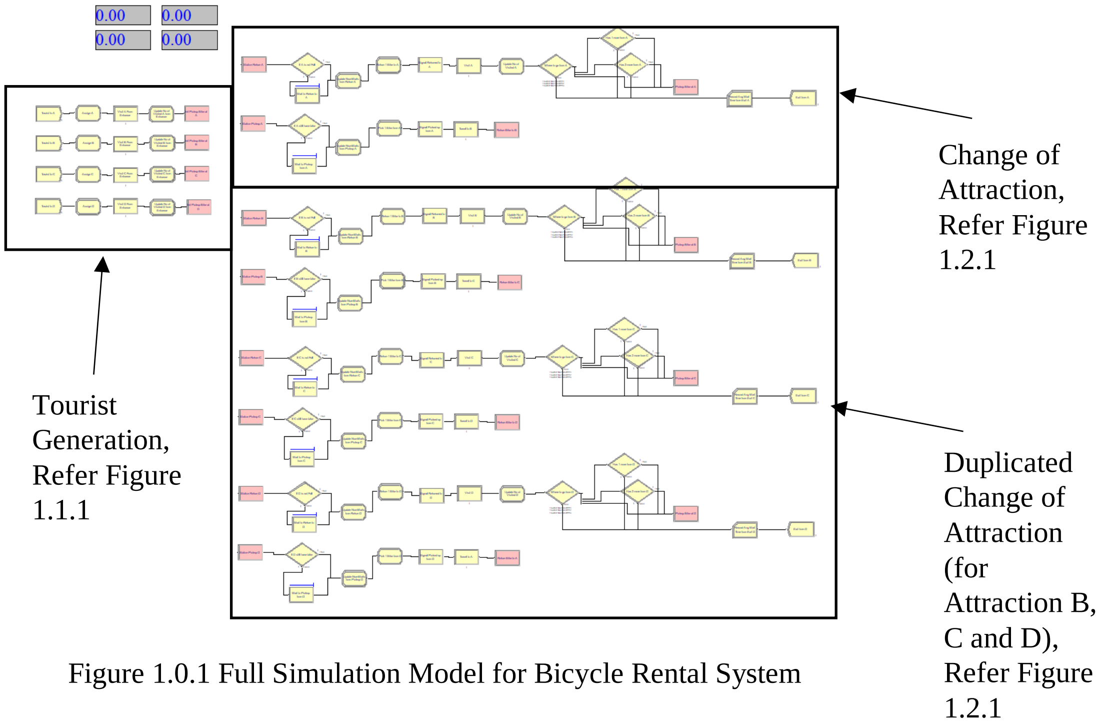

Figure 1.0.1 Full Simulation Model for Bicycle Rental System

1.1 Tourists Generation

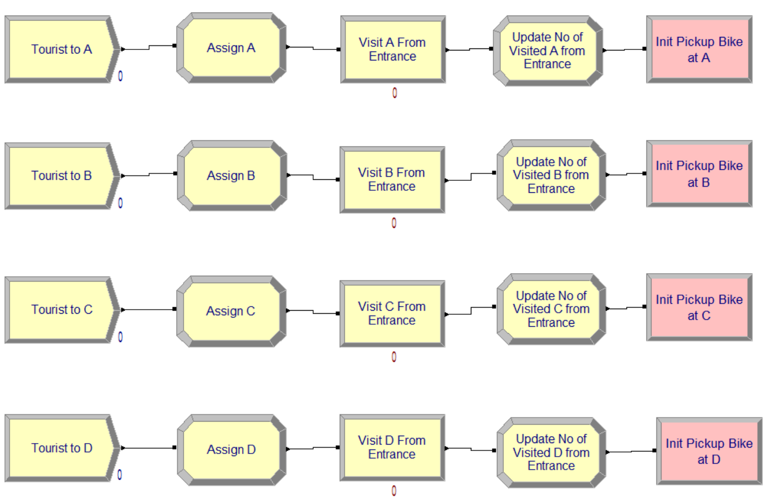

Figure 1.1.1 Tourist Generation Model Section

This part consists of four repetitions of the same line of blocks, one for each attraction. A tourist is randomly generated in one of the four Create blocks based on different distributions for every station to represent better a real-world scenario in which some attractions might be visited more than others, in particular, we've used the following distributions, based on input analysis which will be discussed in Section 2:

1. For attraction A: Exponential distribution with mean of 10.7;

2. For attraction B: Weibull distribution alpha 11 and beta 0.906;
3. For attraction C: Weibull distribution alpha 11.5 and beta 1.03;
4. For attraction D: Beta distribution with alpha 0.662 and beta 3.02.

The second block assigns values to the tourists entering the attraction, such as speed based on a triangular distribution. Then there is a Delay block to simulate the tourist visit at the specific attraction, after which the number of visited attractions is updated, and the tourist is sent to the bike pickup to reach the next attraction. Note that the Delay time is not included in the wait time of the tourist.

1.2 Change of attraction:

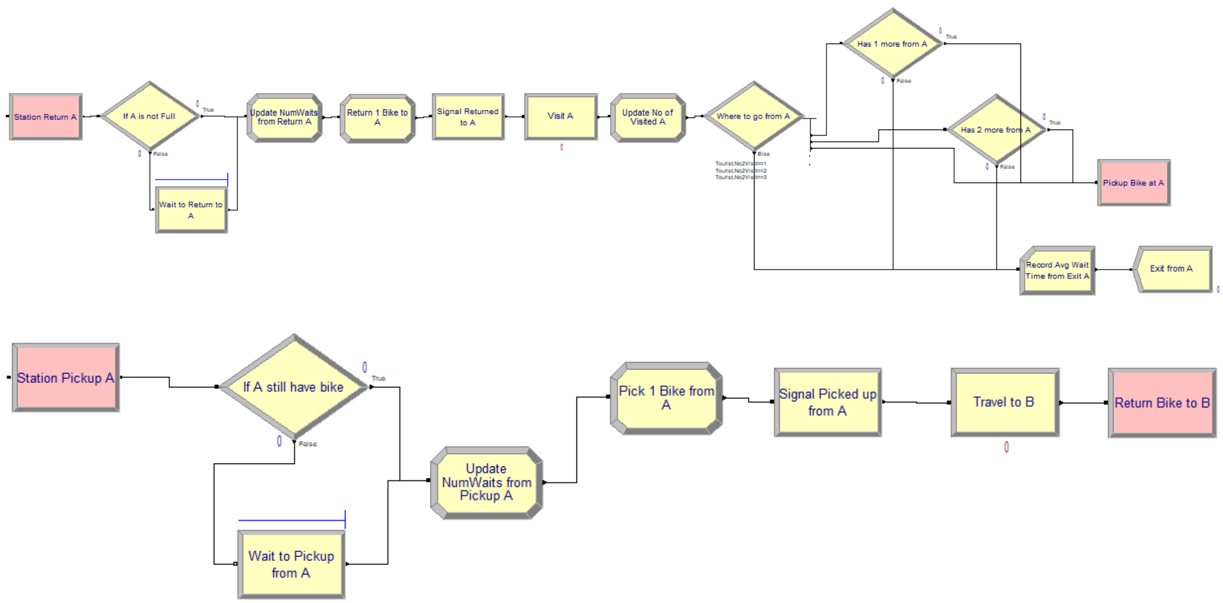

Figure 1.2.1 Change of Attraction Model Section

This part is structurally the same for each station, and for this reason, repeated 4 times. From the tourist generation part, the tourists are sent to the bike pickup block; at this point is verified if there are any available bikes, and in case there are not, the tourist is sent to a queue where he waits until a bike is available. The number of times the tourist had to wait increases, even though the tourist didn't have to wait in line, because it we have supposed useful, for the calculation of the average waiting time, also to count the people that didn't wait at all. The number of available bikes on that specific station is decreased, and a signal is sent to the return part in case there is a queue for returning bikes. At this point, a delay to indicate the time to travel to the next station is simulated and calculated by dividing the km of distance by the tourist speed.

Once arrived at the return station the tourist starts the procedure of parking the bike, and in case no docks are available he stands on the queue waiting for one to get free. Consequently, the counters of the number of times the tourist had to wait, and parked bikes, are increased by one, and a signal for an available bike is sent in case another tourist is standing in line to get one. Another delay of a random amount of time is set to represent the time the tourist has spent on the specific attraction, and after that the number of times the attraction has been visited is increased. At this point the tourist has already visited at least 2 attractions; therefore 3 scenarios are possible:

- The tourist hasn't visited 2 attractions: there's a 50% chance he's either going to visit the next attraction, or leave the SIM Theme Park;
- The tourist hasn't visited 1 attraction: there's a 25% chance he's going to visit the next attraction, or instead, he's going to leave the SIM Theme Park;
- The tourist has visited all the attractions available: the tourist is 100% going to leave the park.

In case the tourist is going to continue to the next attraction, he's sent to the pickup station to get a bike, and the process previously described is repeated. On the other hand, in case the tourist decides to leave the park, his statistics, such as the number the number of times he has entered in a queue, the number of attractions he has visited, the total and average time he had to wait, and if these values are good or bad according to our study.

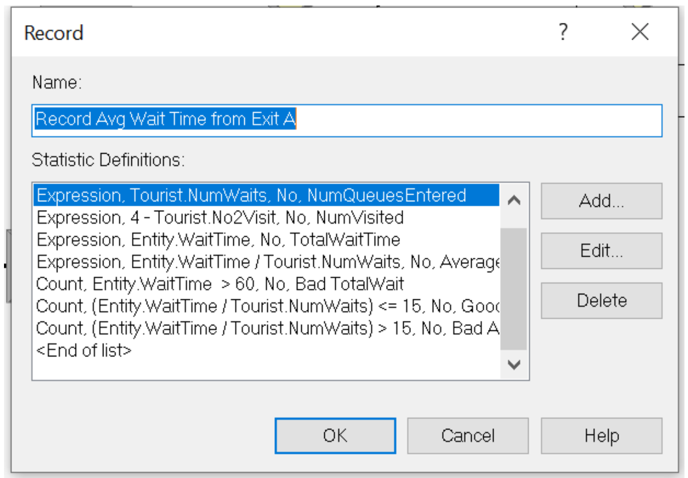

Figure 1.2.2 Record Module Configuration

The formulas are quantified as follows:

Statistics Collected	Type	Formulas Used
Good TotalWait	Count	Entity.WaitTime <= 60
Bad TotalWait	Count	Entity.WaitTime > 60
Good AvgWait	Count	(Entity.WaitTime / Tourist.NumWaits) <= 15
Bad AvgWait	Count	(Entity.WaitTime / Tourist.NumWaits) > 15
NumQueuesEntered	Expression	Tourist.NumWaits
NumVisited	Expression	4 – Tourist.No2Visit
Total WaitTime	Expression	Entity.WaitTime
Average WaitTime	Expression	Entity.WaitTime /Tourist.NumWaits

2.0 Input Analysis

In this section, we will discuss the analysis on these input variables which includes identifying the distribution, parameter estimation and goodness-of-fit tests. In ARENA, the 'Input Analyzer' function under 'Tools' is used to identify the best distribution that represents the data provided.

2.1 Tourists' Interarrival Times

Tourists' arrival times were provided for each attraction in the theme park. Figure 2.1.1 shows the distribution plots for tourists' interarrival times at attractions and Table 2.1.1 shows the best fitted distributions for tourists' interarrival times at all attractions in the theme park.

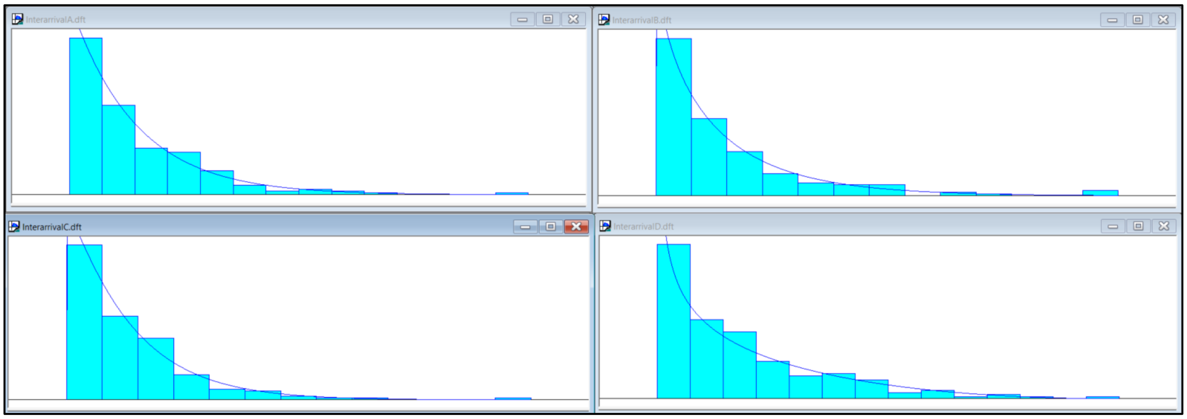

Figure 2.1.2 Distribution Plots for Time Spent in Attractions (Top left: Interarrival at A, Top right: Interarrival at B, Bottom left: Interarrival at C, Bottom right: Interarrival at D)

Table 2.1.1 Tourists' Interarrival Times Distributions and Goodness of Fit Summary

Attractions	Distribution (Best Fit)	Chi-Square P-val	Kolmogorov-Smirnov P-val*
A	EXPO(10.7)	0.382	> 0.15
B	WEIB(11, 0.906)	0.71	> 0.15
C	WEIB(11.5, 1.03)	0.317	> 0.15
D	60 * BETA(0.662, 3.02)	0.585	> 0.15

**Note: KS Test in the input analyzer does not give actual p-value but provides a rough estimation of the p-value*

An interesting observation on the best fitted distribution is that attraction B, C and D does not follow the assumption of the exponential distribution. This can be attributed to the differing arrival patterns for attractions B, C, D if they are not near the main entrance of the theme park. Next, the goodness of fit measure which can be evaluated based on Chi-square and Kolmogorov-Smirnov tests shows that the best fitted distributions have p-value that is > 0.05. For the goodness of fits test, the null and alternate hypothesis are as follows (using Attraction A as an example):

Ho = The random variable is an exponential distribution
H1 = The random variable is not an exponential distribution

The random variable here, refers to the interarrival times. For a p-value that is > 0.05, we fail to reject the null hypothesis, and therefore agree that the interarrival time follows a exponential distribution.

2.2 Time Spent in Attractions

The same procedure that was used for tourists' interarrival times was conducted for time spent in attractions. Figure 2.2.1 shows the distribution plots for time spent in attractions and Table 2.2.1 shows the best fitted distributions for time spent in attractions in the theme park.

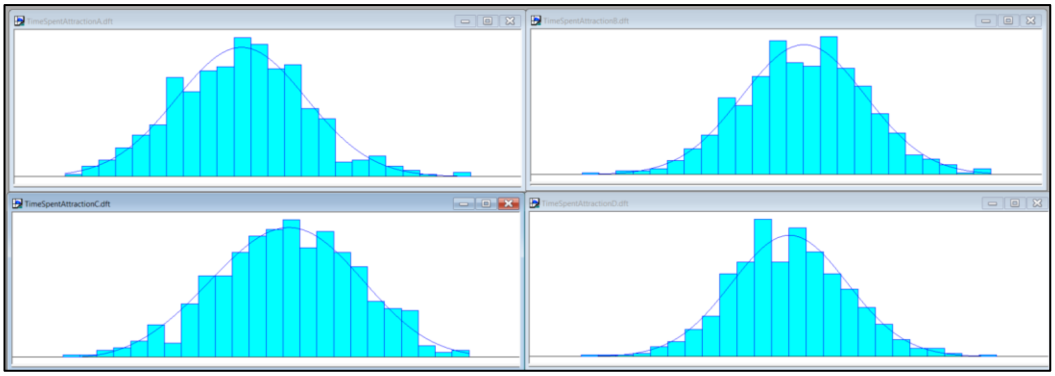

Figure 2.2.1 Distribution Plots for Time Spent in Attractions (Top left: Time Spent at A, Top right: Time Spent at B, Bottom left: Time Spent at C, Bottom right: Time Spent at D)

Table 2.2.1 Tourists' Time Spent in Attractions and Goodness of Fit Summary

Attractions	Distribution (Best Fit)	Chi-Square P-val	Kolmogorov-Smirnov P-val*
A	NORM(29.9, 5.11)	0.109	>0.15
B	NORM(30, 5.29)	0.694	>0.15
C	14 + WEIB(17.7, 3.54)	0.185	>0.15
D	NORM(30, 5.01)	0.51	>0.15

Time spent in attraction A, B and D assumes a normal distribution whereas for attraction C, it is a Weibull distribution. When observing the distributions plots, the time spent distribution at Attraction C is similar to that of the normal distribution plot. The p-val for Chi-squared and Kolmogorov-Smirnov tests are > 0.05 which means we fail to reject the null hypothesis of the said distributions.

2.3 Bike Speed

The bike speed is assigned to tourist as they arrive at any attraction in the theme park. As the tourists are randomly assigned, there is only a single input data file for bike speed. Figure 2.3.1 demonstrates the distribution of bike speed and Table 2.3.1 demonstrates the best fitted distributions for tourists' bike speeds in the theme park.

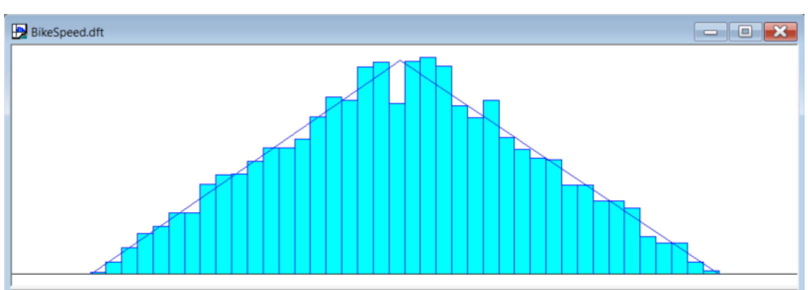

Figure 2.3.1 Distribution Plots for Bike Speed

Table 2.2.1 Tourists' Bike Speed in Theme Park and Goodness of Fit Summary

Attractions	Distribution (Best Fit)	Chi-Square P-val	Kolmogorov-Smirnov P-val*
Any	TRIA(10, 19.8, 30)	0.202	>0.15

The bike speed of tourist' in any attractions at the theme park follows a triangular distribution. The p-val for Chi-squared and Kolmogorov-Smirnov tests are > 0.05 which means we fail to reject the null hypothesis of the triangular distributions. In the context of a bike rental system, the speed of the bike may follow the triangular distributions as, there is uphill and downhill sections in the theme park; the level of traffic in the theme park; tourists will slowdown and stop for taking pictures or tourists rushing to the next attractions. The bike speed data will also be used to estimate the travelling time from one attraction to another. Since the distances between attractions were provided, the travelling time from one attraction to another will merely be the following formula:

$$Travelling\ Time\ between\ Attraction = \frac{Distances\ between\ Attractions}{Bike\ Speed\ (\frac{km}{hr})}$$

3.0 Verification and Validation

To verify our model, it is necessary to ensure that the programmed processes are functioning correctly. Upon visual inspection of the model, we can observe that it is well-structured and easily understandable, as it is segmented into sections for each attraction. This enables us to track the path of each tourist and understand the corresponding processes associated with each part. Further, we have conducted a review of the code and found no errors that could potentially affect the overall performance of the model.

We have also rigorously tested the model with a range of different inputs, to assess its outputs. Our findings indicate that altering the inputs can indeed affect the outputs, specifically regarding arrival times and time spent at each attraction, which in turn, can impact the result in expected ways. For instance, we observed that if the inter-arrival time is short, then the waiting time will increase as shown in Table 3.0.1, increase bike speed increase waiting time, increases time spent per arrival increases wait time, and having more docks would result in a reduced waiting time as shown in Table 3.0.4. These observations validate the performance of the model and give us confidence that it can accurately simulate the system being modeled.

Table 3.0.1 Wait Time Changes between different Interarrival Modes

Configurations (Right)	Baseline	Reduce Interarrival Times
Performance Metrics (Bottom)	**Interarrival Time @ Attraction A EXPO(10.7)**	**Interarrival Time @ Attraction A EXPO(8.2)**
Average Total WaitTime	190.57 mins	569.57 mins
Average Avg WaitTime	58.73 mins	181.45 mins

Table 3.0.2 Wait Time Changes between different Bike Speed Modes

Configurations (Right)	Baseline	Increase Bike Speed Time
Performance Metrics (Bottom)	**Bike Speed** TRIA(10, 19.8, 30)	**Bike Speed** TRIA(15, 19.8, 30)
Average Total WaitTime	190.57 mins	212.63 mins
Average Avg WaitTime	58.73 mins	65.72 mins

Table 3.0.3 Wait Time Changes between different Time Spent Modes

Configurations (Right)	Baseline	Increase Time Spent per Arrival
Performance Metrics (Bottom)	**Time Spent @ Attraction A** NORM(29.9, 5.11)	**Time Spent @ Attraction A** NORM(35, 5.11)
Average Total WaitTime	190.57 mins	219.68 mins
Average Avg WaitTime	58.73 mins	68.52 mins

Table 3.0.4 Wait Time Changes between different no. of Docks

Configurations (Right)	Baseline	Increase No. of Docks
Performance Metrics (Bottom)	**Docks = 80** **Bicycles = 80**	**Docks = 160** **Bicycles = 80**
Average Total WaitTime	190.57 mins	19.97 mins
Average Avg WaitTime	58.73 mins	6.18 mins

To validate our model, it was necessary to assess whether it provided a meaningful and accurate representation of the real system. To establish face validity, we carefully examined the model's structure and behavior and determined that it aligns well with our understanding of how the real-world bike rental process works. Furthermore, we conducted many tests to ensure that the model produced the expected outputs and behaved consistently with our assumptions. Additionally, we made certain assumptions in constructing the model, such as if tourists move through the system in a certain order. These assumptions appear reasonable given our understanding of the system and the available data. Finally, we compared the interarrival times, attraction times, and bike speeds generated by the model to historical data. We found that the model's output aligned closely with the given data, providing further evidence of its validity. By conducting these validation tests and comparing the model's performance to real-world data, we are confident that it provides a reliable representation of the bike rental process.

4.0 Output Analysis

The bike rental system simulated is a terminating simulation that follows a time-controlled termination. We consider this as a terminating system as we are evaluating it based on a one week's operation. In this section, we will discuss the simulation output which include the following:

- Determination of warm-up period
- Selection of no. of replications and replication length
- Is the current system feasible?
    - How many bike docks and bikes for all tourists to wait <= 1 hr in total?
    - How many bike docks and bikes for 80% of the tourists to be happy?

4.1 Warm-up Period Estimation

To determine the warm-up period, we will monitor the total no. of tourists and the run set up is assigned the initial conditions as mentioned in Table 4.1.1.

Table 4.1.1 Run Setup for Warm-up Period Determination

No. of Replications	Replication Length	Warm-up Period	Hours per Day
10	36 hours	0 hours	24

The total no. of tourists output is generated using the 'Statistics' module in ARENA, modelled as a time-persistent statistics type, with the following expression:

$$Total\ No.of\ Visitors = EntitiesWIP(Tourist)$$

Where 'Tourist' is an attribute modelled in the simulation setup. The collection period is over the entire replication and the no. of tourists vs. time plot is analyzed using the 'Output Analyzer' of ARENA as shown in Figure 4.1.1. From the plot, it is worth noting that the 6^{th} replication has a larger no. of tourists beyond the 16-hour mark. As most replications apart from the 6^{th} replication follows a similar pattern, the warm - up period is estimated when the no. of tourists reaches its steady state condition after the transient phase has been surpassed for all replications apart from the 6th replication. The warm-up period is roughly at the 14-hour mark. As the estimation of this period is prone to point estimator bias, we added a rough 20% of safety margin, the final warm-up period is 16-hour.

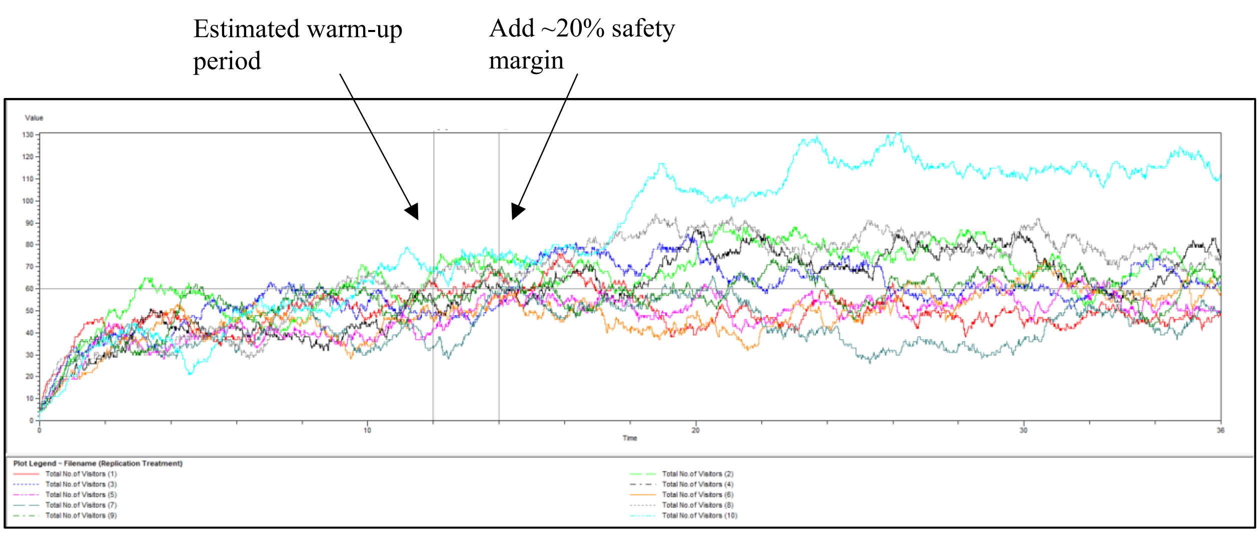

Figure 4.1.1 Warm-up Period Estimation

4.2 Replication Parameters Estimation

To estimate the total no. of replication, we use the point estimator of average total time spent. In this assignment, we assume that the average waiting time computed to be within +-5 minutes i.e. $\varepsilon = 5$, within probability of 0.90 i.e. 90% confidence interval. An initial sample of size $R_0 = 10$ is collected. We also noted from the warm-up estimation, that the 10^{th} replication results has the most different total no. of visitors, which is an outlier, and will be omitted from the calculation. By omitting the 10^{th} replication, an estimate of the population variance is, $S_0 = 9.7$ minutes for 9 replications. Therefore, the initial estimate for the replication with the following formula,

$$R \geq \left(\frac{Z_{\frac{\alpha}{2}} S_0}{\varepsilon}\right)^2 = \left(\frac{1.6449 \ \times 9.7}{5}\right)^2 = 10.18$$

Therefore the possible number of replications can be R(11, 12, 13,…)

Table 4.2.1 Replication Number Estimation

Replication, R	11	12	13
$\left(\frac{t_{\frac{\alpha}{2},R-1} S_0}{\varepsilon}\right)^2$	$\left(\frac{t_{0.05,10} S_0}{\varepsilon}\right)^2 = 12.36$	$\left(\frac{t_{0.05,11} S_0}{\varepsilon}\right)^2 = 12.14$	$\left(\frac{t_{0.05,12} S_0}{\varepsilon}\right)^2 = 11.95$
Difference	12.36-11 =1.36	**12.14-12=0.14**	13-11.95=1.05

The final selection of replication number is therefore 12 replications. The replication length is assumed to be a 7-day period as we assume the theme park operates for the full week. The resultant output analyzer results is shown in Figure 4.2.1. From Figure 4.2.1, it is shown that the total visitors for each replication is more stable as compared to the previous replication plot. Additionally, there is no longer obvious outlier trend as compared to the previous replication plot.

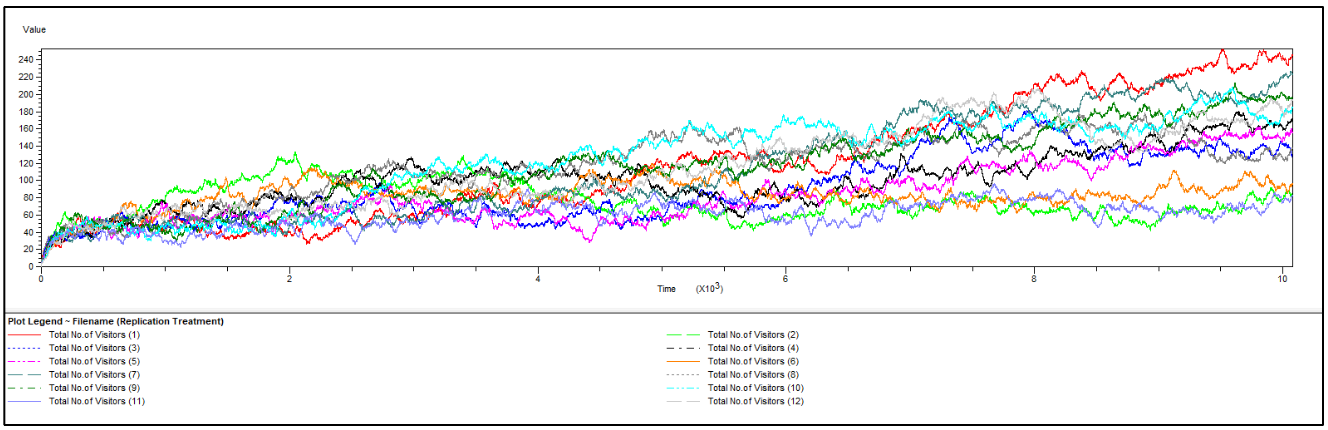

Figure 4.2.1 Total Visitors Plot After Replication Length Estimation

4.3 Feasibility Study of Existing Bike Rental System

In this section, we will discuss the performance of the current bicycle rental system and optimization of the no. of docks and bicycles.

4.3.1 Assessment of current bike rental system

The current configuration of the bike rental system is 80 docks and 80 bicycles. To assess the performance of the current bike rental system, the following metrics were developed:

- Metrics 1: 100% of tourists wait no longer than 1 hour in total.
- Metrics 2: At least 80% tourists wait no longer than 15 minutes in average.

Table 4.3.1.1 Current Bike Rental System Performance

Performance Metrics	Without Outlier	With Outlier

Tourist% wait no longer than 1 hour	39.1%	**34.2%**
Tourist% wait no longer than 15 mins	38.2%	**34.1%**

For output analysis, the replication with outliers will be considered to achieve a more conservative analysis. As only 34% of total tourists wait no longer than 1 hour and 34% of tourists wait no longer than 15 mins, therefore the current system is not feasible. There are two configurations to explore which is equal number of bicycles and docks or unequal number of bicycles and docks. A simple binary search algorithm will be used to explore the different configurations.

4.3.2 Optimizing docks and bicycles to ensure meet tourist's satisfactory metrics

As we will need to meet 100% of tourist's wait no longer than 1 hour, we will consider outlier statistics for this section. We define the rather conservative happiness statistics as:

$$Satisfactory\% = \frac{Min(Good\ TotalWait)}{Min(Good\ TotalWait) + Max(Bad\ TotalWait)}$$

Table 4.3.2.1 Equal and Inequal Configurations of Bike Rental System (With Outlier)

Configurations (Right)	**Baseline**	**Equal**	**Inequal**
Performance Metrics (Bottom)	**Docks = 80 Bicycles = 80**	**Docks = 160 Bicycles = 160**	**Docks = 160 Bicycles = 80**
Tourist% waited <= 1 hour i.e. Satisfactory%	34.1%	36.0%	78.5%
Average Total Wait Time	190.57 mins	194.14 mins	19.97 mins
Min Bad TotalWait	1373	1399	0
Max Bad TotalWait	2043	2124	674
Min Good TotalWait	1063	1192	2462
Max Good TotalWait	1846	1900	3329

**Bad Total Wait refers to the count of tourists waited 1 hour or more for both renting and returning and Good TotalWait refers to the count of tourists wait no longer than 1 hour*

For equal configuration of 160 docks for both docks and bicycles, it is observed that the Tourist% has improved only marginally by 1.8%, although the count is doubled for both docks and bicycles. As for the inequal configuration of 160 docks and 80 bicycles, the performance is significantly improved by 44.3%. This suggests that having inequal configuration is better than having equal configuration. Besides that, it is observed that the minimum average of tourist waited 1 hour or more (Min Bad TotalWait) is 0 for the inequal configuration. This indicates there are days when no tourist has to wait >1hr for both returning and renting the bicycle. Based on inequal configuration, we proceed to refine the counts of docks and bicycles to consider widening or closing the gap between dock counts and bicycle counts as well as performing an extreme test of using large count on both docks and bicycles to evaluate the performance of the system.

Table 4.3.2.2 Final Refinement for Meeting Satisfactory Requirements

Configurations (Right)	**Previous Optimized**	**Closing the Gap**	**Widening the Gap**	**Extreme Test**
Performance Metrics (Bottom)	**Docks = 160 Bicycles = 80**	**Docks = 160 Bicycles = 120**	**Docks = 240 Bicycles = 80**	**Docks = 450 Bicycles = 150**
Tourist% waited < 1 hour i.e. Satisfactory%	78.5%	45.3%	83.9%	100%

Configurations (Right)	Previous Optimized	Closing the Gap	Widening the Gap	Extreme Test
Performance Metrics (Bottom)	**Docks = 160 Bicycles = 80**	**Docks = 160 Bicycles = 120**	**Docks = 240 Bicycles = 80**	**Docks = 450 Bicycles = 150**
Average Total Wait Time	19.97 mins	61.15 mins	3.01 mins	0 mins
Min Bad TotalWait	0	168	0	0
Max Bad TotalWait	674	1692	533	0
Min Good TotalWait	2462	1402	2786	3120
Max Good TotalWait	3329	3094	3329	3346

**Bad Total Wait refers to the count of tourists waited longer than 1 hour for both renting and returning and Good TotalWait refers to the count of tourists wait no longer than 1 hour*

It is observed that closing the gap between bicycle and dock counts can worsen the performance of the system, from 78.5% waited <= 1hr to 45.3% waited <= 1hr, which is about 33.2% reduction. On the contrary, widening the gap result with significant improvements of 5.4% tourist waited <=1hr. However, to reach 100% satisfactory requirements, 240 dock counts and 80 bicycle counts is still short of 16.1%. An extreme test of using very large bicycle and dock counts i.e. 150 and 450 respectively is conducted, and was able to meet 100% satisfactory requirement. To further analyse this, the actual bicycle count statistics was collected and tabulated in Table 4.3.2.3. It is observed that the max average count of bicycles in the 4 attractions can reach up to 240 counts. This shows that with an assigned bicycle count of 150, the system will require at least 240 docks + 20% safety margins to achieve 100% tourist wait <=1hr. The system will become very expensive, and a larger space for hosting the docks is required.

Table 4.3.2.3 Actual Bicycle Count Statistics for Each Attraction

Attraction Location	Bicycle (Average Count)	Bicycle (Min Avg Count)	Bicycle (Max Avg Count)
A	128.65	82.97	168.21
B	186.37	100.02	238.52
C	154.86	87.27	229.91
D	126.26	75.07	161.08

4.3.3 Optimizing docks and bicycles to ensure 80% tourists' happiness

The second requirement is to ensure that at least 80% tourists are happy which means the average wait time should be <= 15 minutes. To compute this, we recorded the statistics of the tourist' as they exit each attraction to travel to the other attractions. We define the rather conservative happiness statistics as:

$$Happiness\% = \frac{Min(Good\ AvgWait)}{Min(Good\ AvgWait) + Max(Bad\ AvgWait)}$$

Table 4.3.3.1 Configuration Refinement for Tourists' Happiness

Configurations (Right)	Baseline	Previous Optimized	Increase docks	Final Optimized
Performance Metrics (Bottom)	**Docks = 80 Bicycles = 80**	**Docks = 160 Bicycles = 80**	**Docks = 180 Bicycles = 80**	**Docks = 175 Bicycles = 80**
Tourist% waited <= 15 mins i.e. Happiness%	34.1%	78.1%	82.9%	80.4%
Average Avg Wait Time	58.73 mins	6.18 mins	2.36 mins	2.47 mins
Min Bad AvgWait	1399	0	0	0
Max Bad AvgWait	2046	688	560	642

Configurations (Right)	Baseline	Previous Optimized	Increase docks	Final Optimized
Performance Metrics (Bottom)	**Docks = 80 Bicycles = 80**	**Docks = 160 Bicycles = 80**	**Docks = 180 Bicycles = 80**	**Docks = 175 Bicycles = 80**
Min Good AvgWait	1060	2448	2716	2640
Max Good AvgWait	1785	3329	3329	3329

**Bad AvgWait refers to the average count of tourists waited longer than 15 mins for both renting and returning and Good TotalWait refers to the average count of tourists wait no longer than 15 mins*

From previous experiment, we gathered that 80 bicycles and 160 docks result with about 6.18 mins average wait time. Recalculating the Tourist% waited <=15 mins, we see that the happiness statistics is 78.1%. We further refine the system by increase the dock counts to 180 and maintain the same number of bicycles, resulted with 82.9% happiness statistics. To fine tune this further, we reduce the dock count marginally to arrive at 80.4% happiness statistics with 175 docks and 80 bicycles. This number of docks and bicycles is sensible and reasonable for implementation.

5.0 Conclusion and Recommendations

Based on the analysis, we conclude the following points:

- The current bicycle rental system configuration with 80 docks and 80 bicycles is not feasible as it does not meet both satisfactory requirement nor tourist happiness statistics requirement.
- To meet 100% satisfactory requirement, we need at least 240 docks + 20% safety margin = 288 docks and 150 bicycles. This is not recommended for implementation as the cost of building can be high and more space is required for hosting the docks.
- To meet 80% tourists' happiness, the final optimized configuration is 175 docks and 80 bicycles. As it only requires expanding the docking areas without purchasing more bikes, it is a much more sensible investment, compared to above. Therefore, we will recommend this configuration for the bicycle rental system.