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BUSN9660: Simulation Modelling

Case Study: Exillirious Safari Simulation Modelling

Spring Term

Academic Year 2023/2024

1. Introduction

1.1 About Exillirious Safari

Exhillirous Safari is a popular outdoor park where visitors buy tickets digitally and enjoy free parking. The park is known for its extensive collection of exotic animals, housing the largest groups of certain species globally, supported by a dedicated team of animal researchers.

Visitors are guided through the park by a one-way system leading to various attractions such as Dinosaur World, Penguin Cove, Safari Theme Park Square, and an African animal trail. The park layout ensures guests typically see each exhibit once. Facilities include two souvenir shops, a restaurant, and kiosks offering snacks and drinks.

1.2 Objective

The safari park manager would like to improve visitors' experience by reducing queuing time within safari attractions. The safari indicates that the customer should not spend longer than 15 minutes in any attraction’s queue. The safari also predicts that the volume of visitors will increase in the summer of 2024.

Currently, the safari is developing some facilities and is expected to be opened on 8th May 2024. The safari management team is considering how many visitors they should receive daily and whether they need to adjust their operating time or outlets to accommodate them.

2. Conceptual Model

2.1 Inter-Arrival Time

The safari park normally operates from 09:00 to 17:00 every day. However, the safari's gates allow visitors to enter the park from 9:00 to 16:00 to clear people in the park before closing at 17:00. The safari manager finds that the visitors could be distinguished into 3 types and provides an approximate number of visitors arriving on the weekend based on her best guess in the following table.

Visitors Types	9:00 – 11:00	11:00 – 14:00	14:00 – 16:00
Families (Parents and children in any combination)	500 arrivals 0.24 Inter-arrival	200 arrivals 0.9 Inter-arrival	15 arrivals 8 Inter-arrivals
Couples (group of 2 people)	200 arrivals 0.6 Inter-arrival	50 arrivals 3.6 Inter-arrival	5 arrivals 24 Inter-arrivals
Friends (group of 4 people)	100 arrivals 1.2 Inter-arrivals	80 arrivals 2.25 Inter-arrivals	9 arrivals 13.33 Inter-arrivals

Table 1: Table of Inter-Arrival Time

To identify the batching number of family categories, the modeller uses triangular distribution based on the existing study, which finds that the minimum number of children per family in the UK is 1, and the mode number is 2. However, the maximum number is mentioned as 3 or more children instead[1]. Since the portion of 3 or more children is small, the modeller assumes the maximum number is 4 to avoid outliers and keep the data as realistic as possible.

[1] Office for National Statistics (UK). (2023). Number of families in the United Kingdom from 1996 to 2022, by number of dependent children (in 1,000s). *Statista*. Accessed: April 25, 2024. Available at: https://www.statista.com/statistics/734771/family-sizes-uk/

2.2 Distributions and Conditions

The safari manager provides the necessary information about each attraction, including capacity, volume of visitors, time consumption, resources, and location of each attraction. To demonstrate the above information, the table summary is provided below, where the sequence of each attraction in the table represents the sequence of attractions located in the safari park.

Seq.	Attraction/Facilities	Distributions of Time Consumption	Additional Information
1	Gift Shop 1	Average – 5 minutes for browsing the shop Average – 2 minnutes for paying	- 50% of visitors go to Gift Shop 1. - 4 Tills available - The shop is large
2	Dinosaur World	Average – 60 minutes for walking through	- Capacity 300 groups
3	Kiosk 1	Average – 5 minutes for choosing nad paying Rounded Uniform – 0-10 minutes for consuming foods and drinks	- 99% of visitors go to kiosk (1 or 2) at least once - No capacity of visitors consuming at Kiosk 1 - 2 Staffs work at Kiosk 1
4	Penguin Cove	Average – 10 minutes for watching penguins	- Capacity 100 groups
5	Restaurant (located in Theme Park Square)	Rounded Uniform – 20-50 minutes for consuming Average – 5 minutes for cleaning table before leaving (set in routing in - Change Over)	- 20% of visitors go to restaurant - Capacity 100 groups - Restaurant opens 11:00-15:00
6	Playground (located in Theme Park Square)	Rounded Uniform – 30-60 minutes for consuming	- 80% of visitors go to playground - Capacity 500 groups - If restaurant closes, visitors will use playground.
7	African Animal Village Trail	Average – 20 minutes for walking through	- Capacity 500 groups
8	Kiosk 2	Average – 5 minutes for choosing nad paying Rounded Uniform – 0-10 minutes for consuming foods and drinks	- 99% of visitors go to kiosk 1 or 2 at least once - No capacity of visitors consuming at Kiosk 1 - 2 Staffs work at Kiosk 2
9	Gift Shop 2	Average – 5 minutes for browsing the shop Average – 2 minnutes for paying	- Visitors will Visit Gift Shop 1 or 2 at least once and not twice - 4 Tills available - The shop is large

Table 2: Table of Distribution and Conditions of Each Attraction

According to the Gift Shop 1 and 2, the shop has no explicit capacity. The capacity for both Gift Shop should be identified to create an effective conceptual model. Regarding the existing information, the average area of a large store is 204 square meters[2]. Assume that 40% of the area, 81.6 square meters, is a storage and staff area, and the remaining 60%, 122.4 square meters, is a commercial area where the customer could browse the merchandise. To provide a comfortable shopping experience, the modeller assumes that 1 customer consumes 2 square meters. After calculating the above information, the maximum capacity of the Gift Shop is 61.2 persons, rounded up to 62 persons.

2.3 Communicative Model

The layout of the Exillirious Safari could be described in the following diagram.

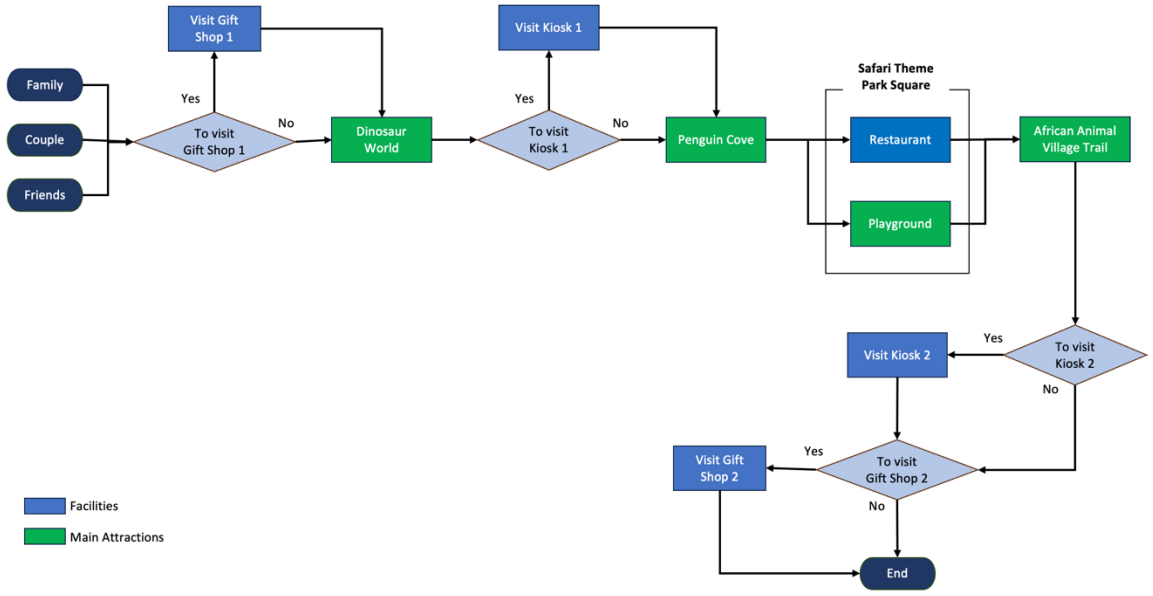

Figure 1: The Communicative Model of the Exillirious Safari

The diagram displays the Exillirious Safari's layout as a one-way system, where visitors must start at the entrance and follow the safari's route. No route avoids the main attractions, including Dinosaur World, Penguin Cove, Safari Theme Park Square, and African Animal Village Trail.

[2] Strutt and Parker. (2015). Does size matter? The changing shape of retail. *Strutt and Parker.* Accessed: 25 April, 2024. Available at: https://www.struttandparker.com/knowledge-and-research/does-size-matter-changing-shape-retail

3. Model Coding the Baseline Model

Regarding the information mentioned earlier, after gathering all information, conditions, and assumptions, the baseline model could be built up as shown below.

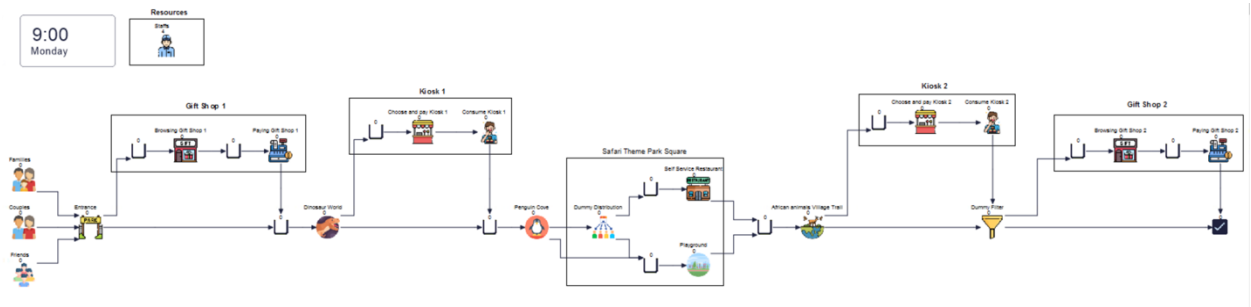

Figure 2: The Baseline Model of the Exillirious Safari

According to the recent figure, the baseline model starts with 3 types of visitors, including families, couples, and friends. All visitors must enter the entrance, which allocates 50% of the visitors to Gift Shop 1 and the rest to Dinosaur World. Visitors allocated to Gift Shop 1 will go to Dinosaur World after browsing the store and paying for the merchandise.

When the visitors exit the Dinosaur World, the kiosk, which provides ice cream, drinks and sweets, is located on the path between the Dinosaur World and the Penguin Cove. 99% of visitors purchase goods at kiosk 1 with 2 staff and consume the goods near the kiosk before entering Penguin Cove.

When visitors are done watching penguins at Penguin Cove, if the restaurant is opened, all visitors will be sent to the Dummy Distribution, which works as a distributor allocating 20% of visitors to the restaurant and 80% to the playground, both located in the Safari Theme Park Square. All visitors will be sent directly to the playground if the restaurant is closed.

Later, the visitors will head to the African Animal Village Trail, the last attraction. After the last attraction, the second kiosk has 2 staff, where 99% of visitors will buy a product the same as Kiosk 1. The Dummy Filter is located after the African Animal Village Trail and Kiosk 2 to filter those visitors who have visited Gift Shop 1 to the exit of safari and those who have not visited Gift Shop 1 to Gift Shop 2 before exiting the safari, according to the information mentioning that the visitors must visit Gift Shop at least once. The visitors will be filtered by the label stamped at Kiosk 1.

4. Validation, Verification and Calibration

4.1 Validation

Based on the information given by the safari manager, the average number of visitors combining families, couples, and friends is approximately 1,159 groups on a single day. Compared to the baseline average result of the simulation model simulated on a one-day basis, which has 1,178 visitors, combining 3 types of visitors. The difference between the given observations and the simulation model is 19 visitors, a 1.64% difference considered acceptance.

4.2 Verification

Referring to the baseline result of the simulation model, the requirements given by the safari manager are met, including the closing time of entrance, which is set to 16:00, the mandatory of visitors visiting Gift shops at least once and not twice, and the conditional distribution of the visitor traffic. However, the opening period of the restaurant, 11:00-15:00, seems unverified. Based on the realistic situation, when the restaurant closes, the visitors sitting inside the restaurant should be moved to the next attraction, but in the simulation model, the visitors will be stuck at the restaurant until the model finishes, which could be assumed as a backlog in the model.

4.3 Calibration

According to the given information, the modeller found that the capacity of Gift Shops and Kiosks should be assigned. Otherwise, the model would be incomplete and inefficient. The assumptions based on the existing study replace the missing Gift Shops' capacity. The missing Kiosks' capacity is fulfilled based on the assumption that one staff is supposed to be capable of serving one visitor at a time.

To ensure that the results of the simulation model are reliable, the random number of visitors is run based on the same number to avoid the bias and uncertainty of the model.

5. Experimentations

5.1 Baseline Model Result

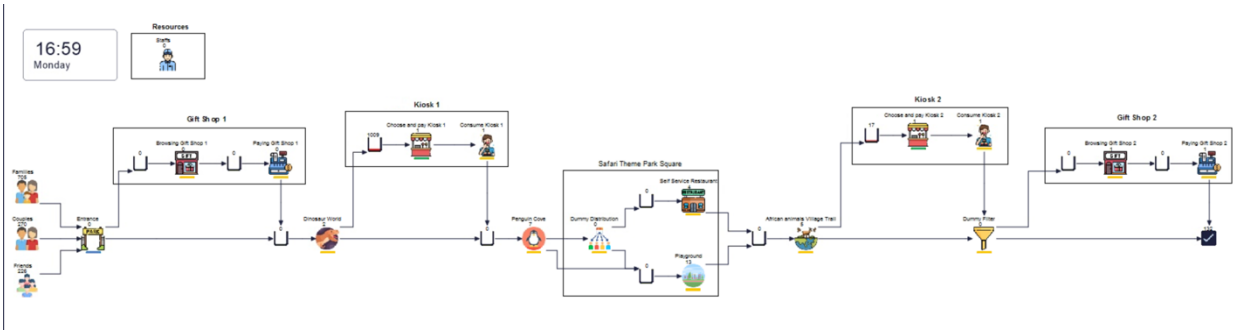

Figure 3: The Baseline Model

		Low 95% Range	Average Result	High 95% Range	Risk
Families	Number Entered	1561.67	1666.00	1770.33	
Couples	Number Entered	486.81	532.40	577.99	
Friends	Number Entered	697.94	797.60	897.26	
Entrance	Number Completed Jobs	1160.75	1177.80	1194.85	
Queue for Browsing Gift Shop 1	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Paying Gift Shop 1	% Queued Less Than Time Limit	20.51	27.33	34.14	
Queue for Dinosaur World	% Queued Less Than Time Limit	99.62	99.90	100.00	
Queue for Choose and pay Kiosk 1	% Queued Less Than Time Limit	5.83	7.41	9.00	
Queue for Penguin Cove	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Self Service Restaurant	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Playground	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for African animals Village Trail	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Choose and pay Kiosk 2	% Queued Less Than Time Limit	17.03	33.66	50.30	
Queue for Browsing Gift Shop 2	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Paying Gift Shop 2	% Queued Less Than Time Limit	100.00	100.00	100.00	
Exit	Average Time in System	291.85	294.50	297.14	
	Number Completed	127.59	133.00	138.41	
Staffs	Utilization %	80.30	81.01	81.72	
	Average Use	3.21	3.24	3.27	
	Maximum Use	4.00	4.00	4.00	

Figure 4: Results of the Baseline Model

Regarding the objectives the safari manager gave, the % queued less than the time limit, 15 minutes, in every attraction should be 100%. However, on the results, the queue at the Dinosaur World achieves 99.9% on average. Moreover, the percentages for Gift Shop 1, Kiosk 1, and Kiosk 2 are only 27.33%, 7.41%, and 33.66% respectively. Most importantly, there are 1,178 entries in the safari, but only 123 groups reach the end of the model. The results show that the average time visitors are on the safari is 294.47, around 5 hours. The utilisation of the resources, 4 staff working at both Kiosks, is 81.01%, where the average use is 3 persons, and the maximum use is 4 persons. Plus, the model also displays that many visitors are stuck in the queue of Kiosk 1.

5.2 Scenario 1 Result

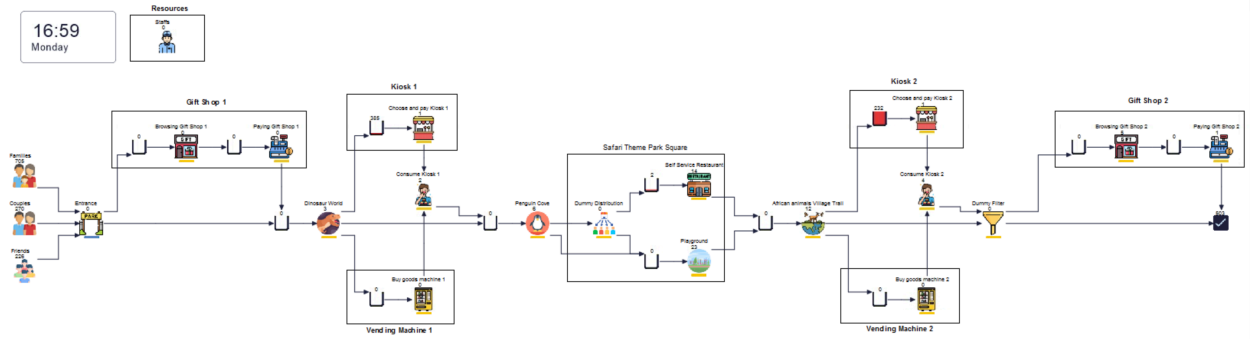

Figure 5: The Scenario 1 Simulation Model

In Scenario 1, to decrease the queue at the Gift Shop, the tills are added to 8 tills at both Gift Shops 1 and 2. The modeller assumes that after fixing the queuing problem at the Kiosks, Gift Shop 2 will face the same problem as Gift Shop 1 and Dinosaur World, in which the capacity is increased to 400. To reduce the queue at Kiosk, the modeller added 16 vending machines to the model to create an alternative to the Kiosk for visitors buying drinks and sweets, 8 machines are located at Kiosk1, and the rest are located at Kiosk 2, where visitors are assumed to use vending machines in minimum 1 minute, mode 3 minute, and maximum 5 minutes following the triangular distribution. The discipline of visitors going to kiosks, both 1 and 2, and vending machines are set equally, where 49.5% use kiosks, 49.5% use vending machines, and the remaining 1% directly go to the next attraction. The Kiosks are also increased to 6 kiosks, 3 after Dinosaur World and another 3 after African Animals. Along with resources, 8 staff are additionally hired due to increased kiosks.

		Low 95% Range	Average Result	High 95% Range	Risk
Families	Number Entered	1561.67	1666.00	1770.33	
Couples	Number Entered	486.81	532.40	577.99	
Friends	Number Entered	697.94	797.60	897.26	
Entrance	Number Completed Jobs	1160.75	1177.80	1194.85	
Queue for Browsing Gift Shop 1	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Paying Gift Shop 1	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Dinosaur World	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Choose and pay Kiosk 1	% Queued Less Than Time Limit	13.95	16.77	19.59	
Queue for Penguin Cove	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Self Service Restaurant	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Playground	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for African animals Village Trail	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Choose and pay Kiosk 2	% Queued Less Than Time Limit	8.63	10.40	12.16	
Queue for Browsing Gift Shop 2	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Paying Gift Shop 2	% Queued Less Than Time Limit	100.00	100.00	100.00	
Exit	Average Time in System	222.11	223.86	225.61	
	Number Completed	486.71	512.60	538.49	
Staffs	Utilization %	88.07	88.88	89.69	
	Average Use	10.57	10.67	10.76	
	Maximum Use	12.00	12.00	12.00	
Queue for Buy goods machine 1	% Queued Less Than Time Limit	58.15	74.60	91.06	
Queue for Buy goods machine 2	% Queued Less Than Time Limit	100.00	100.00	100.00	

Figure 6: The Results of Scenario 1

The results are better than the baseline model. The % queued less than the time limit at Gift Shop and Dinosaur World is now 100%. As well as, the performance of kiosks is slightly better, from approximately 7% to 16%. The utilsation of staff also climbs up to 88.88%. However, even though the number of visitors reaching the exit of the safari is higher than the baseline model, which is 513 exits, it is still too low to be acceptable.

5.3 Scenario 2 Result

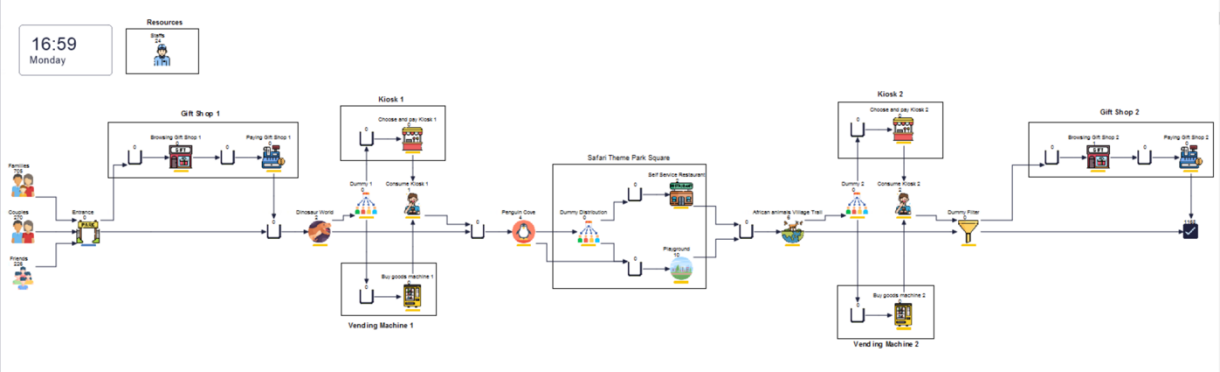

Figure 7: The Scenario 2 Simulation Model

For scenario 2, Dummy 1 and Dummy 2 are created to change visitors' discipline using kiosks and vending machines to the shortest queue discipline. In this scenario, 99% of visitors will buy drinks and sweets at kiosks or vending machines, and 1% will directly head to the next attraction. The kiosks were also added to be 8 in total, and the number of staff per kiosk increased to 3, 24 staff in total. The increased staff at the kiosk will reduce visitors' time consumption, which the modeller assumes to be 3 minutes on average.

		Low 95% Range	Average Result	High 95% Range	Risk
Families	Number Entered	1561.67	1666.00	1770.33	
Couples	Number Entered	486.81	532.40	577.99	
Friends	Number Entered	697.94	797.60	897.26	
Entrance	Number Completed Jobs	1160.75	1177.80	1194.85	
Queue for Browsing Gift Shop 1	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Paying Gift Shop 1	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Dinosaur World	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Choose and pay Kiosk 1	% Queued Less Than Time Limit	42.41	46.29	50.17	
Queue for Penguin Cove	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Self Service Restaurant	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Playground	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for African animals Village Trail	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Choose and pay Kiosk 2	% Queued Less Than Time Limit	37.26	42.89	48.52	
Queue for Browsing Gift Shop 2	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Paying Gift Shop 2	% Queued Less Than Time Limit	100.00	100.00	100.00	
Exit	Average Time in System	204.99	210.59	216.18	
	Number Completed	1124.81	1142.60	1160.39	
Staffs	Utilization %	80.06	81.05	82.04	
	Average Use	19.22	19.45	19.69	
	Maximum Use	24.00	24.00	24.00	
Queue for Buy goods machine 1	% Queued Less Than Time Limit	39.61	45.11	50.60	
Queue for Buy goods machine 2	% Queued Less Than Time Limit	97.89	99.44	100.00	

Figure 8: The Result of Scenario 2

Although staff utilisation slightly decreased to 81.05%, the overall results are much better than those in scenario 1; the % performance of kiosks increased to 45% average. More importantly, the number of visitors exiting the safari spikes up to 1,142 persons, which means only 35 visitors or 3% of visitors, are stuck on the safari.

5.4 Scenario 3 Result

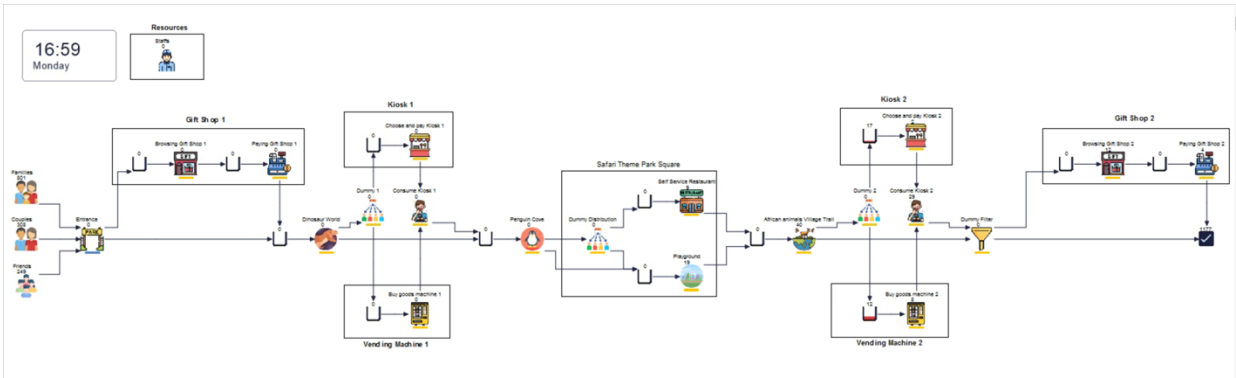

Figure 9: The Scenario 3 Simulation Model

Referring to the previous models, visitors' average time is 216.78, almost 2 and a half hours, but the entrance is closed 1 hour before the safari's closing time. It means that the visitors who enter after 14:00 tend to be stuck in the middle of the safari when closing at 17:00. To resolve this problem, the modeller decides to alter the entrance closing time from 16:00 to 14:00. Those visitors who come between 14:00-16:00 will be allocated to 11:00-14:00 instead. The modeller also increased the number of visitors by roughly 10%, aligning with the expectations of the safari's management. The inter-arrival time will be adjusted to the following table.

Visitors Types	9:00 – 11:00	11:00 – 14:00
Families (Parents and children in any combination)	570 arrivals 0.21 Inter-arrival	235 arrivals 0.76 Inter-arrival
Couples (group of 2 people)	220 arrivals 0.55 Inter-arrival	62 arrivals 2.9 Inter-arrival
Friends (group of 4 people)	110 arrivals 1.08 Inter-arrivals	100 arrivals 1.8 Inter-arrivals

Table 3: Table of Inter-Arrival Time in Scenario 3

		Low 95% Range	Average Result	High 95% Range	Risk
Families	Number Entered	1767.65	1881.40	1995.15	
Couples	Number Entered	546.45	602.40	658.35	
Friends	Number Entered	768.30	879.20	990.10	
Entrance	Number Completed Jobs	1296.76	1325.00	1353.24	
Queue for Browsing Gift Shop 1	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Paying Gift Shop 1	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Dinosaur World	% Queued Less Than Time Limit	93.77	98.35	100.00	
Queue for Choose and pay Kiosk 1	% Queued Less Than Time Limit	26.44	28.24	30.04	
Queue for Penguin Cove	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Self Service Restaurant	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Playground	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for African animals Village Trail	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Choose and pay Kiosk 2	% Queued Less Than Time Limit	25.42	33.58	41.75	
Queue for Browsing Gift Shop 2	% Queued Less Than Time Limit	100.00	100.00	100.00	
Queue for Paying Gift Shop 2	% Queued Less Than Time Limit	100.00	100.00	100.00	
Exit	Average Time in System	226.06	229.67	233.28	
	Number Completed	1221.65	1228.80	1235.95	
Staffs	Utilization %	86.73	87.55	88.36	
	Average Use	20.81	21.01	21.21	
	Maximum Use	24.00	24.00	24.00	
Queue for Buy goods machine 1	% Queued Less Than Time Limit	20.42	22.81	25.20	
Queue for Buy goods machine 2	% Queued Less Than Time Limit	97.35	99.24	100.00	

Figure 10: The Results of Scenario 3

The results show the falling queue performance at Kiosk 1, Kiosk 2, and Dinosaur World. The number of visitors reaching the exit of the safari is 1,229 from 1325 entries, with 96 visitors or 7.25% of visitors being stuck on the safari. The utilisation of staff increases to 87.55%.

6. Conclusion and Discussion

6.1 Conclusion

The findings of the experimentation show that the implementation of vending machines is key to the model development. It significantly mitigates the queue and time of visitors buying drinks and sweets. Besides, increasing the number of staff working at kiosks is crucial. It reduces the average time spent choosing and buying goods, which makes the simulation model run more fluently. Even though 3% of visitors are still stuck on the safari in scenario 2, it is acceptable for the safari to face a random residual in the operations.

Beyond those 2 vital adjustments, the additional kiosks, resources, tills at the Gift Shop and capacity at Dinosaur World are required. Otherwise, the number of visitors stuck on the safari will increase, alongside the drop in queue performance at Gift Shops, Dinosaur World and Kiosks, particularly in scenario 3, where visitors' arrival increased by around 10%. The results in scenario 3 show that the capacity at

Dinosaur World needs more expansion to reduce queuing time, as well as African Animal Village Trail's capacity to move all visitors out of attractions before closing at 17:00. In scenario 3, additional resources might be required at kiosk 2, vending machine 2, and Gift Shop 2 to finish serving visitors before closing the safari.

In conclusion, the results and model of scenario 3 are acceptable. It could accommodate the queue at the attraction, with an average of 99.67% of visitors waiting less than 15 minutes and a 10% increase in visitors. The daily capacity of the safari is approximately 1,250 visitors.

6.2 Discussion

Regarding the experimentations, the queue performance at kiosks seems low compared to other facilities. However, the only way to reduce the queue is by adding more kiosks or resources selling drinks and sweets, which the significance and additional cost should be further discussed.

Although the experimentation results are good and acceptable, the modeller would recommend that the safari manager conduct more research on cost analysis. The final developed model required many additional resources, including staff, kiosks, vending machines, tills, and a larger capacity at Dinosaur World, which might cause significant changes in the safari's finances.

Furthermore, the safari manager is also recommended to collect and verify the reliability of the data once again. Since there are some approximations and missing of the given data, including the capacity of the Gift Shop, the average time of choosing and paying at kiosks when there are 3 staff working, and the average time of using the vending machines, it is necessary to reconcile and collect the data from the real testing and operation at the safari to ensure the accuracy of the simulation model.