SIMULATION MODEL FOR EXILLIRIOUS SAFARI

TECHNICAL REPORT

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1. INTRODUCTION AND PROBLEM DEFINITION

This report provides an overview of the technical aspects of the simulation model created for '**Exillirious Safari'**, an open-air entertainment park in the UK. The park comprises of three major attractions (African Village Trail, Penguin Cove, and Dinosaur World), a restaurant, a playground, two shops, and two kiosks. Visitors are guided through a one-way system, and the estimated data for arrivals and facility usage during weekends was utilized in creating the simulation model. This information was provided by the park manager based on her best guess.

The model was developed with the objective of addressing the concerns of the management team before the park's opening on May 10th, 2023. The primary concerns revolve around visitor experience and reducing queuing times. With the expected surge in visitor numbers during the summer, the queuing time for any attraction should not exceed 10 minutes. Additionally, the maximum number of visitors allowed in the park per day is also a key consideration.

The simulation model runs for one day, from 9 am to 5 pm, which corresponds to the park's operating hours. It simulates the current system and three experimental scenarios that highlight potential areas for improvement to reduce queuing times and accommodate the increasing number of visitors.

All the tables, diagrams, and results obtained from the simulation model are provided in the Appendix of this report. The appendix presents a comprehensive view of the data gathered from the simulation runs, including the parameters used, statistical analyses, and graphical representations of the results. However, some of the important figures have been included in the main body for easy reference and readability.

2. CONCEPTUAL MODEL

The objectives, Inputs, Assumptions, simplifications, and Key Performance indicators (KPIs), of the model are detailed in this section. A communicative model is also presented for easy visualisation.

2.1 Objectives

As mentioned in the introduction, the main objective of the model is for the management team to get an idea of how the park performs on any given day with the current Layout of the park along with staff numbers before the actual opening date. This is essential as necessary changes need to be made to opening times, staffs, and outlets according to the results which were obtained to ensure smooth operations of the park.

2.2 Inputs

The park has visitors that come in 3 groups, namely, families, friends, and couples. Families are usually parents with any combination of children, couples are in numbers of 2 and friends are groups are 4 people. Each of their arrival rates for 3 time slots, morning, afternoon, and evening are shown in (**Table 1)** of the Appendix.

The **Inputs** for the Facilities and Attractions are in (**Table 2 & 3)** respectively.

2.3 Communicative model

To aid in the visualization and understanding of the simulation model, a communicative model has been developed. The model depicts the flow of visitors through the park, the queuing times, and the average usage times at each attraction. The **model** is shown below –

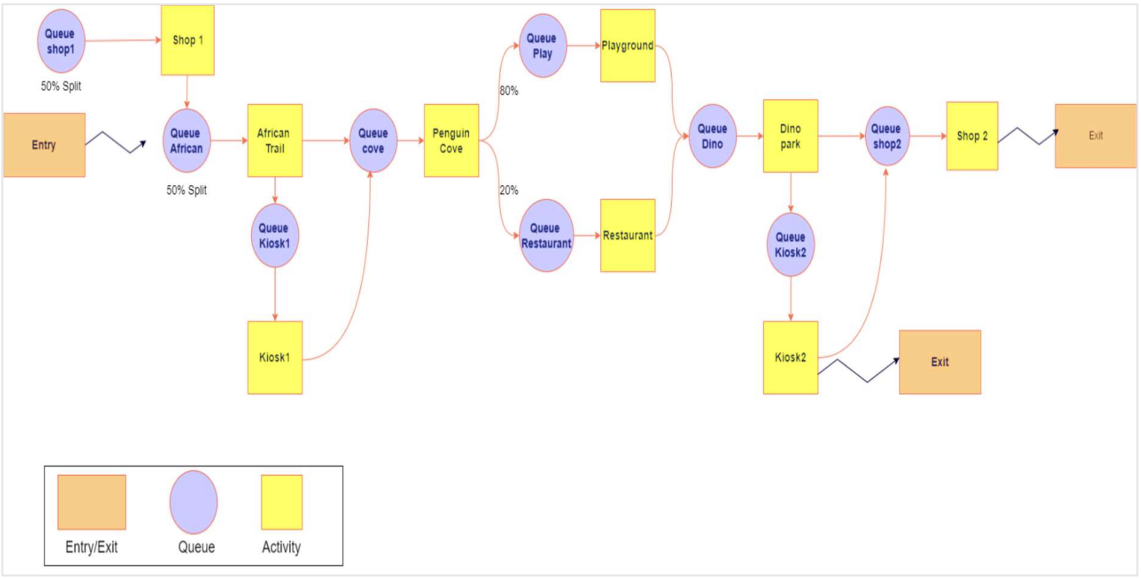

Figure 1: Model of flow of visitors

2.4 Assumptions

It is assumed that the visitors arrive and depart from the park at the same rate, and there are no external factors affecting their arrival or departure. They are also assumed to spend a fixed amount of time at each attraction, and this does not vary depending on the number of people visiting the attraction. Other numerical assumptions made are listed below –

a. The capacity for Browsing at the shops were assumed to be 80. This was chosen as it seems like an ideal amount of people a gift shop can accommodate.
b. The capacity of open-air activities was set to 1000 as they have unlimited capacity.
c. The split of visitors using Kiosk 1, Kiosk 2. Both were assumed to be 40%, 40% and 19% respectively which adds to a total of 99%. The remaining 1% did not use either kiosk.
d. The cleaning time for restaurants which is 5 minutes has been set to every 50 work items.

2.5 Simplifications

Everything was incorporated into model as per the information given. The only thing which was not added were the toilet blocks and the sanitary facilities as there was no information provided regarding usage and capacities.

2.6 Key performance Indicators

The KPIs that were used to evaluate the performance of the simulation model include **queuing times, average usage times, the number of people exiting the simulation and staff utilisation percentage**. The queuing time is the amount of time visitors spend waiting in line for an attraction. The average usage time is the time that visitors spend at each attraction.

3. MODEL CODING & BASELINE MODEL

The base model developed using Simul8 is shown below in **(Figure 2).** Notable differences between this model and the communicative model include the incorporation of distinct activities for shop payment and browsing, an open-air activity after each kiosk, and the introduction of two dummy variables. The first dummy variable is leveraged at the entry point to channel all three arrival groups

to Shop 1 and African Village, while the second dummy variable is used at the exit to route visitors to Shop 2 and the exit.

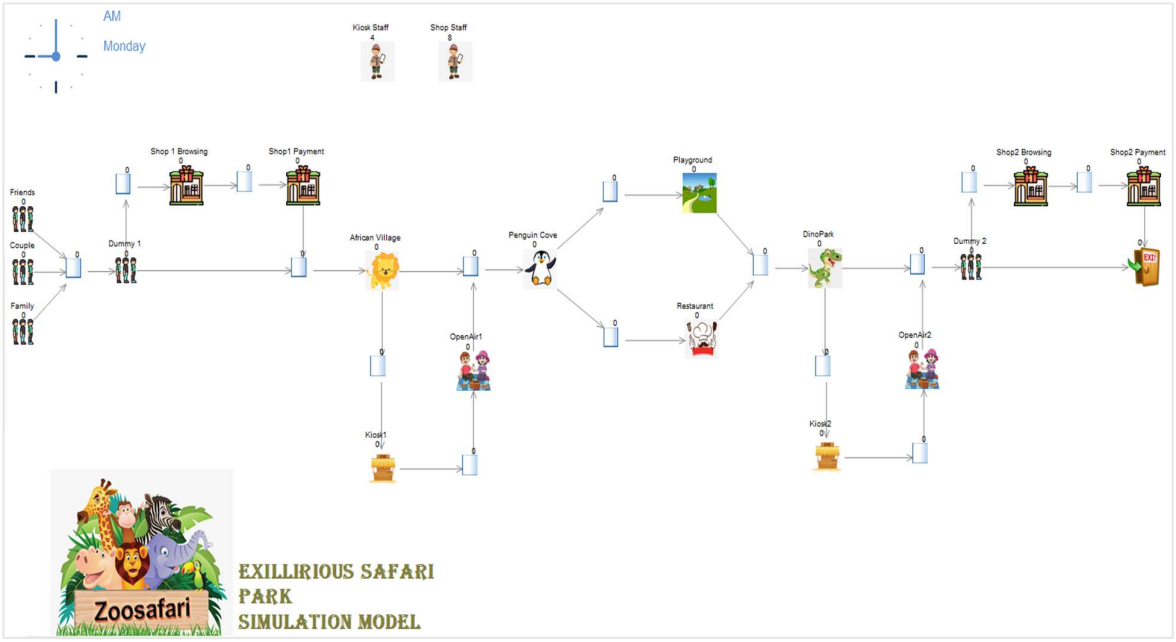

Figure 2: Base model using Simul8

3.1 Distributions

1. Inter-arrival times -

The inter-arrival times are calculated by the duration of the period divided by the arrival rate in that period. **(Table 4).** An **Average distribution** was used to model these. This was chosen as an average distribution is often used when there is no clear indication of what distribution to use, or when the data does not fit well into a specific distribution. In this case, the arrival rates were given for specific time periods, but there was no information on the variability or pattern of arrivals within those periods. Therefore, it was a reasonable choice, as it assumes a uniform distribution of arrivals within each period, which is a reasonable approximation for this scenario. Additionally, it is easy to implement and interpret, making it a common choice in simulation modelling.

To model the arrival rates of each visitor group, an average distribution was attached to a time-dependent distribution based on the time slot for each group (as indicated in **Table 4**). Furthermore, a fixed distribution with an inter-arrival time of 200 was utilized to prevent visitors from entering the park after 4 PM.

2. Shops, Kiosks, Open Airs and Attractions -

All these activities use an **Average distribution** as the data provided indicated the average time spent by visitors at these locations **(Table 2 & 3)**

3. Restaurant and Playground –

These activities use a **Uniform distribution** as there is a lower limit and an upper limit of the usage for these facilities given in the data.

4. Dummy Variables –

These dummies had a **fixed time of 0** as their sole purpose was to make the routings easier.

3.2. Labels

Different Labels were used to identify the visitors' using the shops, kiosks, and restaurants. Each of them were given a probability profile value according to the inputs, shown in **(Table 5).**

3.3 Routing out

1. **From Dummy 1 –**

   Routing out from here was accomplished by using the Shop label 1. 50% of visitors were routed to the queue of Shop1, while the other 50% were directed to the African Village trail.

2. **From African Village Trail –**

   A "By Condition" routing option was utilized from this activity. Kiosk Labels 1 or 3 were routed to Kiosk 1, while the default route was used for the Penguin Cove.

3. **From Penguin Cove –**

   The restaurant label was used to direct the visitors to the restaurant, while the default route led them to the playground. However, it was important to consider that the restaurant is only open from 11am to 3pm. To account for this, an AND condition was incorporated into the routing out process. Value 1 was only routed to the restaurant between simulation time 120 and 360, which correspond to the opening and closing times of the restaurant. This ensured that visitors were only directed to the restaurant during the hours it was open, and not outside of those hours.

4. **From Dino Park –**

   Kiosk Labels 2 OR 3 were routed to Kiosk 2 and Kiosk Labels 1 OR 4 were routed to dummy 2 as they do not utilise Kiosk 2.

5. **From Dummy 2 –**

   Shop Label 2 was used to route to the shop 2 and Shop label 1 was routed to the Exit.

3.4 Resources

Two resources were created for both the kiosk and shop staffs. The kiosks were staffed with 2 employees each, resulting in a total of 4 kiosk staff. Each kiosk was then replicated twice to simulate the real-world situation, bringing the total number of kiosks to 4. Similarly, each shop was equipped with four tills, and each shop was replicated four times to simulate the real-world scenario. A total of 8 staff members were then added to the Shop resource to ensure adequate staffing.

4. Calibration, Validation and Verification

4.1 Calibration

To calibrate the model and establish its accuracy, the key performance indicators (KPIs) were fed into the Trial calculator, which recommended 41 simulations for implementation. The outcomes, which include the average for each KPI, and their respective 95% confidence intervals are in **(Table 6).**

4.2 Validation

For the validation process, the simulation model can be checked with the real-world system to see how accurate the representation is. The simulation results can be compared with the actual data collected to identify any discrepancies. This step ensures that the model accurately reflects the system's behaviour and dynamics. Validation can be performed through statistical methods, graphical comparison, and sensitivity analysis.

A peer review can also be done. This is an essential step in the model development. It involves subjecting the simulation model and its documentation to critical evaluation by domain experts and other stakeholders. The peer review process helps to identify any potential errors, validate the model's assumptions, and ensure that the model is suitable for the intended purpose.

4.3 Verification

Verification is the process of ensuring that the simulation model's implementation is correct and free of errors. In the verification phase, various checks were performed to ensure that the simulation model accurately represented the real system being modelled. These checks included verifying that all the input parameters were correctly specified. Specifically, the labels and distributions of all input data were checked to ensure that they matched the real-world system being modelled. Any discrepancies were addressed and corrected.

Overall, a rigorous Validation & Verification process can be conducted to ensure the accuracy and validity of the simulation model. This process includes multiple rounds of review and testing and will involve input from various subject matter experts and stakeholders. The goal is to produce a robust and reliable model that accurately represents the real system being studied.

5. Results and Experimentation

The baseline simulation model revealed significant queue build-ups at both kiosks, which was expected given the low staff-to-visitor ratio. The simulation results are presented in **(Table 6).**

- A total of 953 individuals entered the system, but the number of people who exited was only 340, which indicates a low throughput rate.

To address these issues, 3 experimental scenarios were run by changing several parameters to achieve lower queueing times and higher throughput rates. Detailed summary of all scenario results is in **(Table 7).**

5.1 Scenario 1: [Staff Changes along with an alteration in the Kiosk Probability Profile]

To cope with the high volume of visitors at the kiosks, it was decided to increase the number of tills at each kiosk from **2 to 8**. However, the baseline model showed that the shop staff were being underutilized **(Table 7).** To address this issue, 3 out of the 8-shop staff were relocated to the kiosk resource. Despite this adjustment, the queue times at the kiosks were still not acceptable, which led to a decision to further increase the number of kiosk staff to 15. The kiosk label probabilities were changed as shown (**Table 8).**

These changes resulted in the number of visitors exiting from 336 to an average of 871. Queuing times drastically decreased as well as shown in **(Table 7).**

5.2 Scenario 2: [Variation in staff change, Kiosk Probability Profile and opening hours]

To further optimize the system, additional changes were implemented. The park's operating hours were extended by one hour, with no entry permitted after 4pm. To address bottlenecks at the shops, an additional till was added to Shop 2, bringing the total to 5. Number of staff was

maintained at 5. The shop label probability profile was changed to 45% (*value 1*) and 55% (*value2*) **(Table 5).**

The number of kiosk tills remained unchanged at 8, while the number of kiosk staff was reduced to 12. The Probability profile was altered as shown in **(Table 8).**

These modifications led to a significant improvement in system performance, with the total number of visitors exiting the park increasing to 919. Other key metrics such as average waiting times and queue lengths showed marked improvement, except for a slight decrease in average queuing time at Kiosk 2.

5.3 Scenario 3: [Changes made to accommodate increased visitor traffic]

The model was further modified to account for an anticipated increase in visitor numbers during the next summer season. The arrival rate for each group was adjusted according to **(Table 9)**, resulting in a total input of 1522 visitors.

To better manage the increased traffic, several changes were made. The park's opening times were extended to 8am-7pm, and visitors were denied entry from 5pm onwards by adjusting the fixed distribution time. The browsing area of Shop 1 was expanded from 80 to 90 to accommodate the increased traffic, and an extra till was added to each shop, bringing the total to 5 tills per shop. Shop staff were also increased to 7.

The Kiosk distribution was adjusted (**Table 8)** and Kiosk staff were increased to 16. The number of tills at Kiosks 1 and 2 were increased to 12 and 13 respectively.

30% of visitors now utilized the restaurant and 70% went to playground.

These changes resulted in an average of 1484 visitors exiting the system and all KPIs falling within the desirable range.

6. CONCLUSIONS

In conclusion, based on the simulation models, it is evident that certain staff changes and increased capacity in kiosks are necessary to reduce queuing times and improve key performance indicators. However, it is important to note that these are experimental models, and an ideal model can be created by working closely with the park manager to discuss scalability and other factors.

Despite this, the simulation models demonstrate that with the right changes, the park's operations can run smoothly and efficiently. These models provide a valuable tool for park managers to analyse and improve their operations, allowing them to make informed decisions about staffing, capacity, and other factors that impact the visitor experience.

APPENDIX

Table 1: Visitors Arrival Timing

Group Arrivals	Time Window: 9am and 11am	Time Window: 11am and 2pm	Time Window: 2pm and 4pm
Families	300 arrivals	120 arrivals	40 arrivals
Couples	200 arrivals	100 arrivals	5 arrivals
Friends	100 arrivals	50 arrivals	30 arrivals

Table 2: Inputs for Facilities

Facility	Usage	Time/ Activity	Capacity/ Staff
Gift Shop (All day)	50% - use gift shop 1 Rest 50% - use gift shop 2	5 minutes - browsing 2 minutes - paying	4 tills at each shop
Kiosks (All day)	99% visitors - use at least 1 of the kiosks Rest 1% - use neither	5 minutes - choosing & paying 10 minutes - consumption in open air with unlimited capacity	2 staff at each kiosk
Restaurant (Open 11am-3pm)	20% of visitors use it	20 to 40 minutes. 5 minutes to clear tables.	100 tables
Playground (All day)	80% of visitors use it	30 to 60 minutes	500 groups

Table 3: Inputs for Attractions

Attraction	Capacity	Time (Average)
African Village Trail	500 Groups	20 minutes
Penguin Cove	100 groups	10 minutes
Dino Park	300 groups	60 minutes

Table 4: Inter-arrival times

Group Arrivals	Morning (9-11 hours)	Afternoon (11-14 hours)	Evening (14-17 hours)
Families	0.4	1.5	3
Couples	0.6	1.8	24
Friends	1.2	3.6	4

Table 5: Probability distribution for Labels

Type of Label	Probability profile values
Shop Label	Value 1 – queue for shop 1 – 50% Value 2 – queue for shop 2 – 50%
Kiosk Label	Value 1 – Kiosk 1 users – 40% Value 2 – Kiosk 2 users – 40% Value 3 – Both Kiosk Users – 19% Value 4 – Neither Kiosks – 1%
Restaurant Label	Value 1 – Restaurant users – 20% Value 2 – Playground users – 80%

Table 6: Baseline Model Results

Simulation Object	Performance Measure	-95%	Average	95%
Queue for Shop1 Payment	% Queued Less Than Time Limit	52.50809	55.2153	52.5081
Queue for Shop2 Payment	% Queued Less Than Time Limit	100	100	100
Queue for Kiosk1	Average Queuing Time	187.63949	188.70711	189.775
	% Queued Less Than Time Limit	4.22367	4.44113	4.65859
Queue for Kiosk2	Average Queuing Time	103.28143	104.67148	106.062
	% Queued Less Than Time Limit	9.81107	10.32186	10.8327
Shop Staff	Utilization %	32.51383	33.09677	33.6797
Kiosk Staff	Utilization %	84.64402	85.50272	86.3614
End 2	Average Time in System	218.46427	219.55177	220.639
End 2	Number Completed	335.62	336	346.946

Table 7: Results of Scenarios

Simulation Object	Performance Measure	Scenario 1	Scenario 2	Scenario 3
Queue for Shop1 Payment	% Queued Less Than Time Limit	52.85066	76.12764	61.89192
Queue for Shop2 Payment	% Queued Less Than Time Limit	94.09717	78.56265	63.20352
Queue for Kiosk1	Average Queuing Time	31.15633	13.14481	10.52025
	% Queued Less Than Time Limit	23.72358	49.32542	63.70396
Queue for Kiosk2	Average Queuing Time	15.13101	17.07383	14.48087
	% Queued Less Than Time Limit	41.05941	41.42772	48.81314
Shop Staff	Utilization %	75.79662	69.03223	65.4257
Kiosk Staff	Utilization %	68.61711	61.34014	64.53145
End 2	Average Time in System	195.4896	176.36111	179.7829
End 2	Number Completed	871.5	919.68235	1484.953

Table 8: Updated Kiosk Distributions for Scenarios

Kiosk Label Value	Scenario 1	Scenario 2	Scenario 3
Label 1 – Kiosk 1 only	45%	37%	43%
Label 2 – Kiosk 2 only	45%	38%	37%
Label 3 – Both Kiosks	9%	5%	5%
Label 4 – Neither Kiosk	1%	20%	15%

Table 9: Scenario 3 – Increased Arrival Rate

Group Arrivals	Time Window: 9am and 11am	Time Window: 11am and 2pm	Time Window: 2pm and 4pm
Families	320 arrivals	140 arrivals	60 arrivals
Couples	210 arrivals	110 arrivals	15 arrivals
Friends	130 arrivals	80 arrivals	60 arrivals