Optimization and Simulation Spring 2022 Project 2 - Restaurant Design

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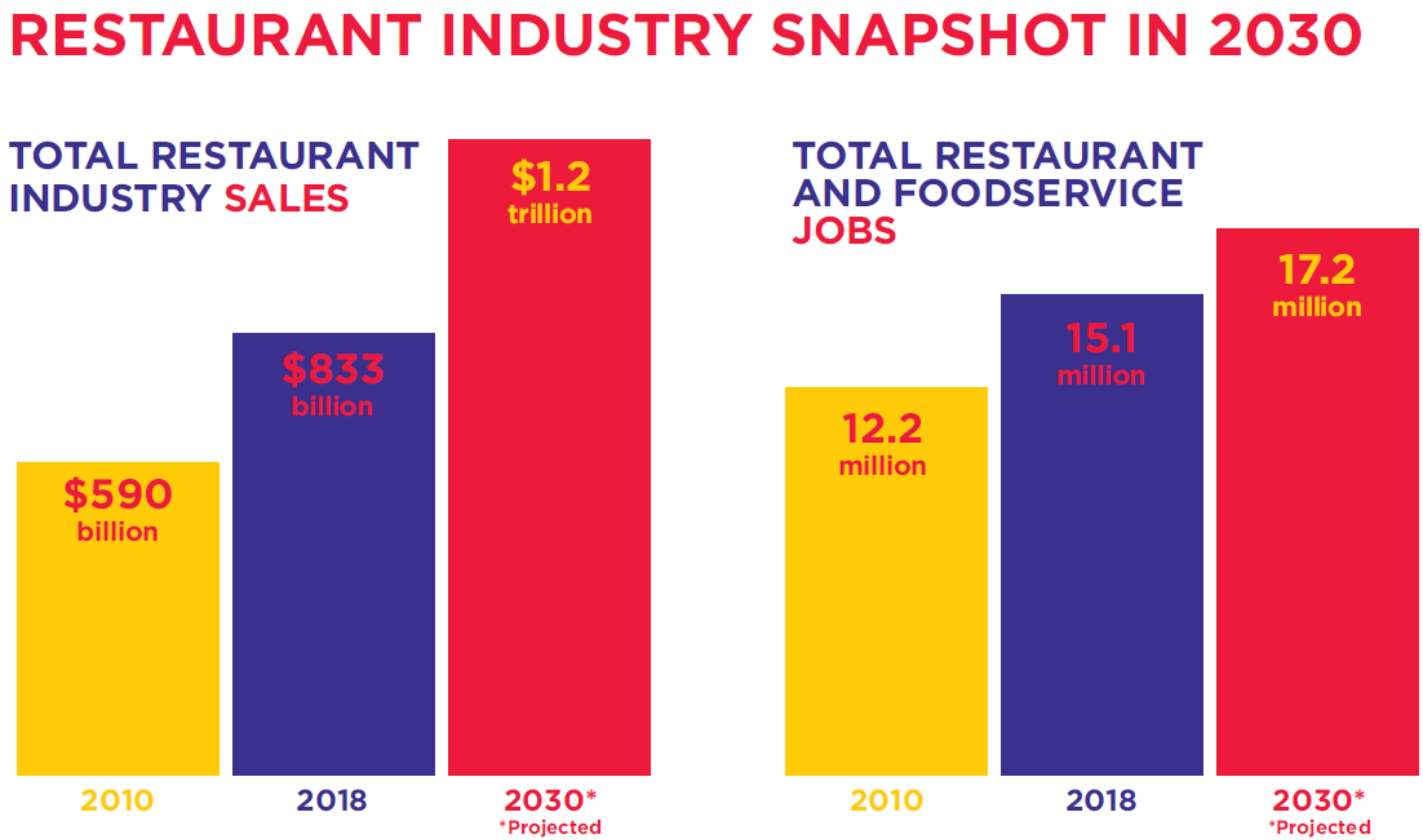

Source: Restaurant Industry 2030 (November 05, 2019), National Restaurant Association.

2030: THE DISRUPTORS

INFORMATION TECHNOLOGY WILL PERMEATE RESTAURANTS.

This will enable restaurants to interact in real time with an evolving digital ecosystem of apps, services and personal AI assistants (apps such as Siri (Apple) or Alexa (Amazon) that understand natural-language voice commands, complete tasks for the user, and over time "learn" their owners' preferences). All will deeply integrate into consumers' everyday decisions. It will be increasingly important for restaurants to provide accessible, detailed and accurate data. Restaurants will be able to use new data capabilities to develop dynamic menus with real-time pricing that can respond to supply-and-demand changes. Relevant data about restaurant operations will include details on nutrition, preparation methods, ingredients and supply-chain authentication.

WHY THIS COULD HAPPEN

- Near-universal smartphone adoption.
- AI as personal assistant and gatekeeper between a brand and consumer.
- The spread of the Internet of Things (IoT), physical objects embedded with electronics, software, sensors and network connectivity that enable the objects to collect, send and receive data.
- Growth of voice search, which allows users to search the Internet by verbally asking a question via smartphone, smart device or a computer.
- Growing demand for personalized diets (e.g., allergies, weight, religion, ethics).
- Consumer choices as an expression of social and political values.

WHY THIS MATTERS FOR RESTAURANTS

- A growing information ecosystem will require upgrades and integration of restaurant data collection and IT systems.
- Brands will market directly on virtual-assistant platforms and may find the platforms' algorithms to be highly responsive to small tweaks in restaurant pricing or other data.
- All aspects of restaurant operations will be more transparent, such as health inspections, safety training, staff certifications and food sourcing.
- Effective management of food allergens will grow in importance as consumers expect documentation of food preparation, ingredients and practices.

RESTAURANT INDUSTRY 2030 • NATIONAL RESTAURANT ASSOCIATION

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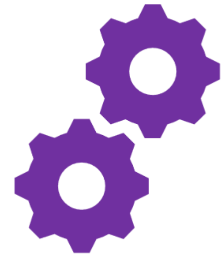
Source: Restaurant Industry 2030 (November 05, 2019), National Restaurant Association.

Restaurant design considerations

Maximize Your Space

Enhance An Ambiance

Improve Guest Comfort



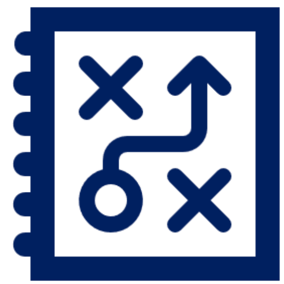
Optimizes Workflows

Reduce Wait Times

ROSS

Restaurant
Optimizer
and
Simulator
Software

Decisions



The table arrangement:

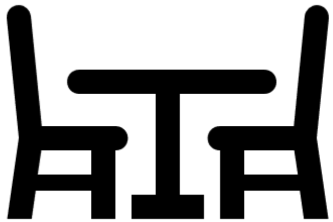
number and type of tables.

The seating policy:

the rules that you apply to allocate customers to tables.

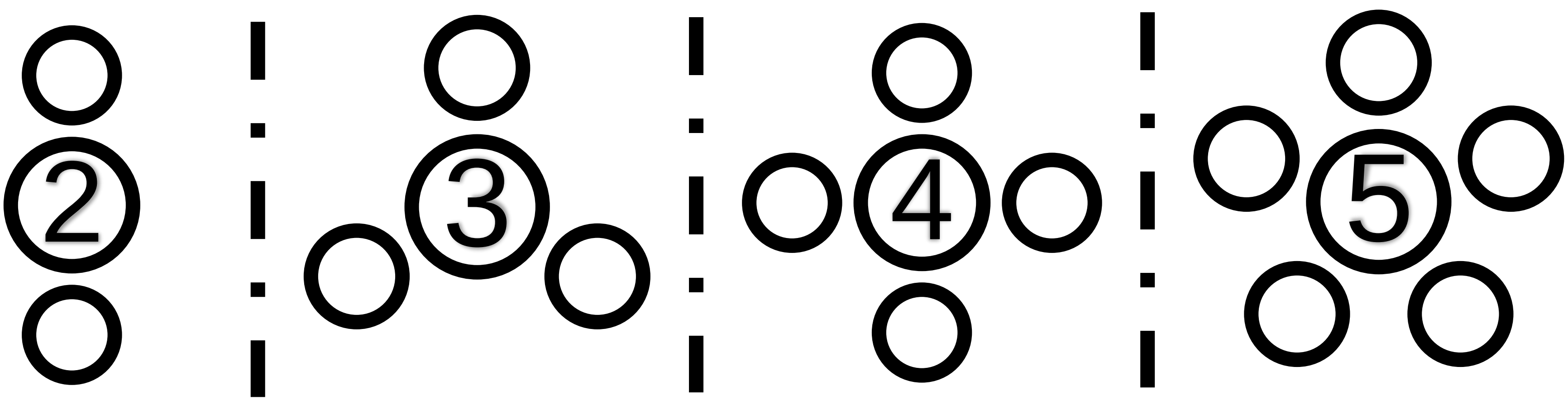
Setup – Space and Tables

No Split
No Merge
Sharing



Up to 400 seats

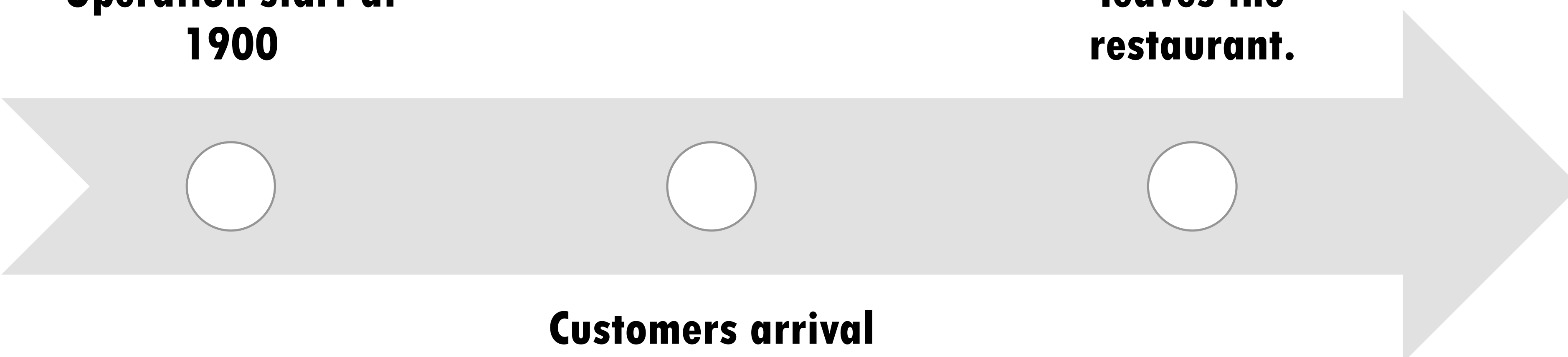
- **Table's sizes:**



Setup - Operation

Operation start at 1900

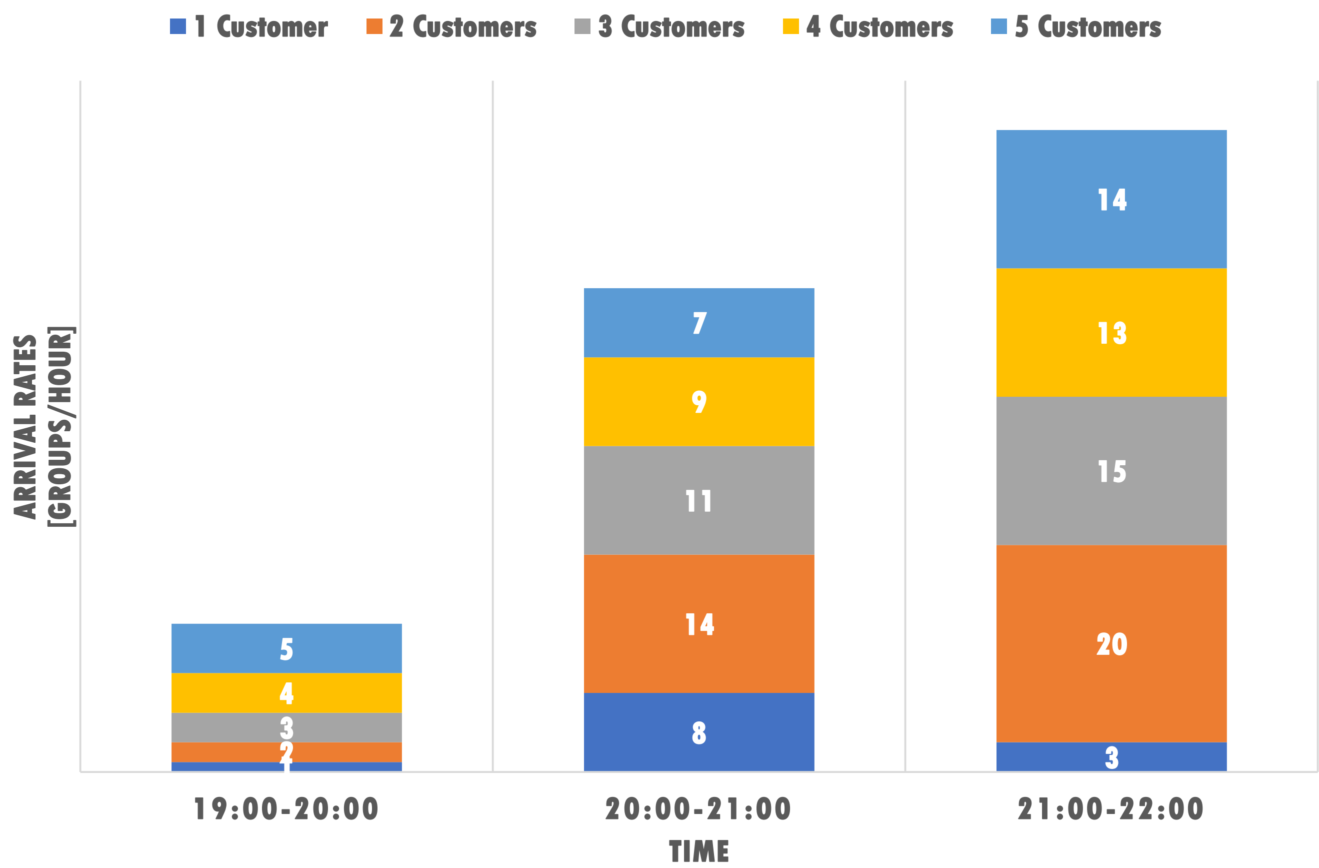
Operation ends when the last customer leaves the restaurant.



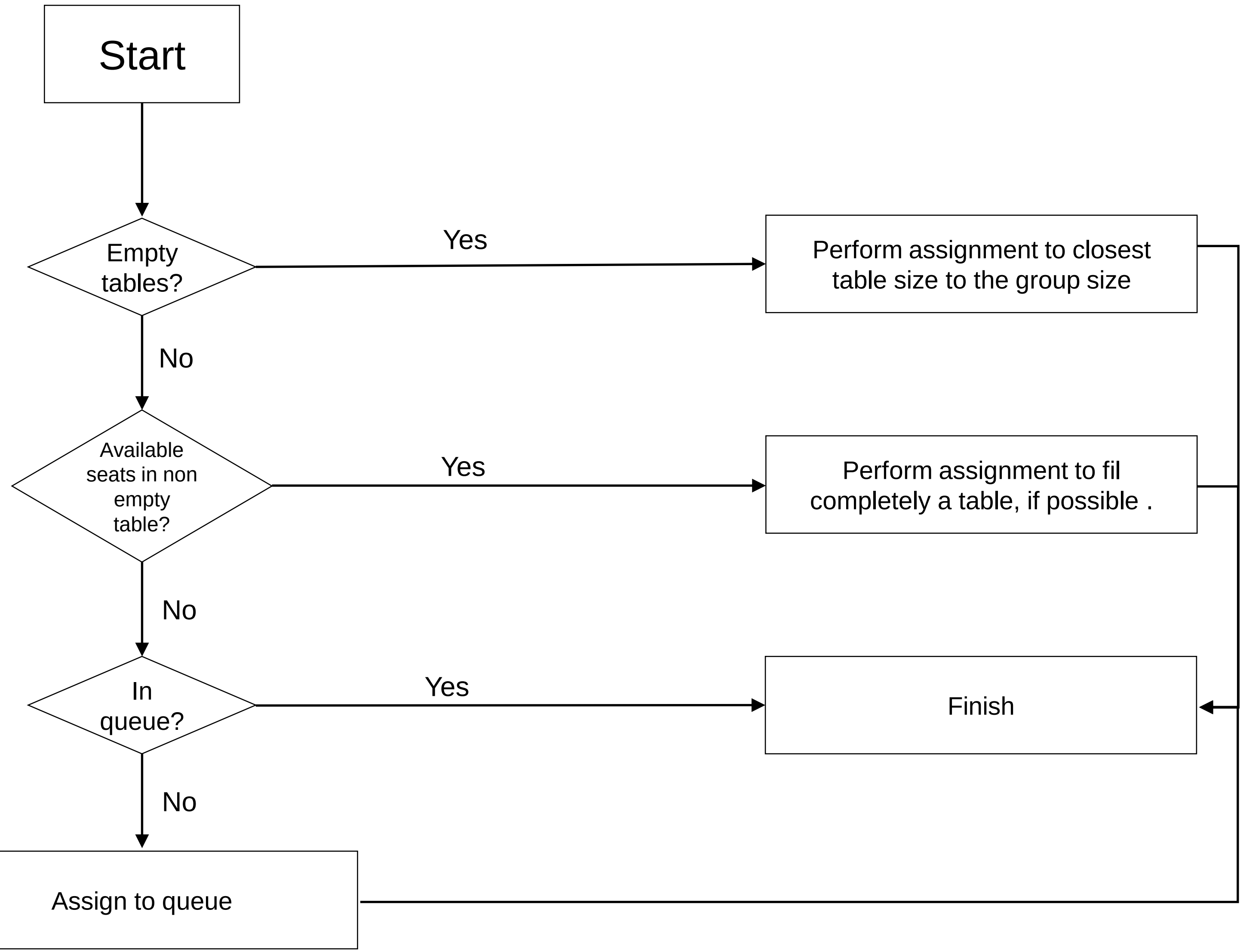
Customers arrival from 19:00-22:00

Setup – Customer Arrivals

- Customer arrivals are non-homogeneous and change among group sizes.



Setup – Seating Policy



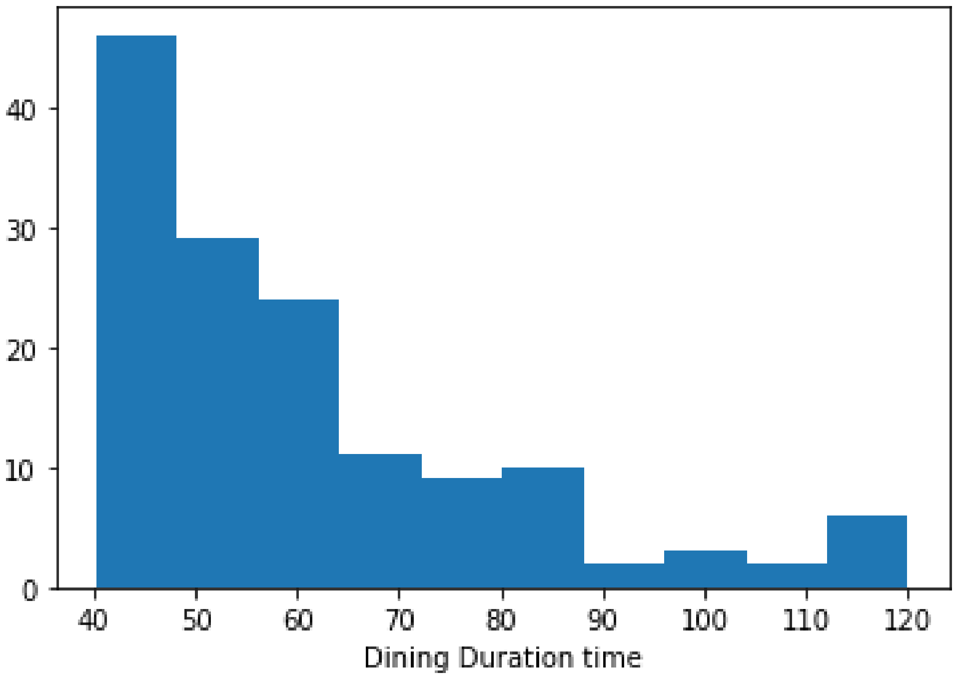
Setup – Abandon

Decision
Every five minutes

- Waiting time > 20 minutes
  Probability of leaving – 0.5
- Waiting time 10-20 minutes
  Probability of leaving – 0.4
- Waiting time 5-10 minutes
  Probability of leaving – 0.3
- Waiting time < 5 minutes
  Probability of leaving – 0.1
- No waiting time
  Probability of leaving – 0.0

Setup – Duration and Bill

- The duration of the dinner d :

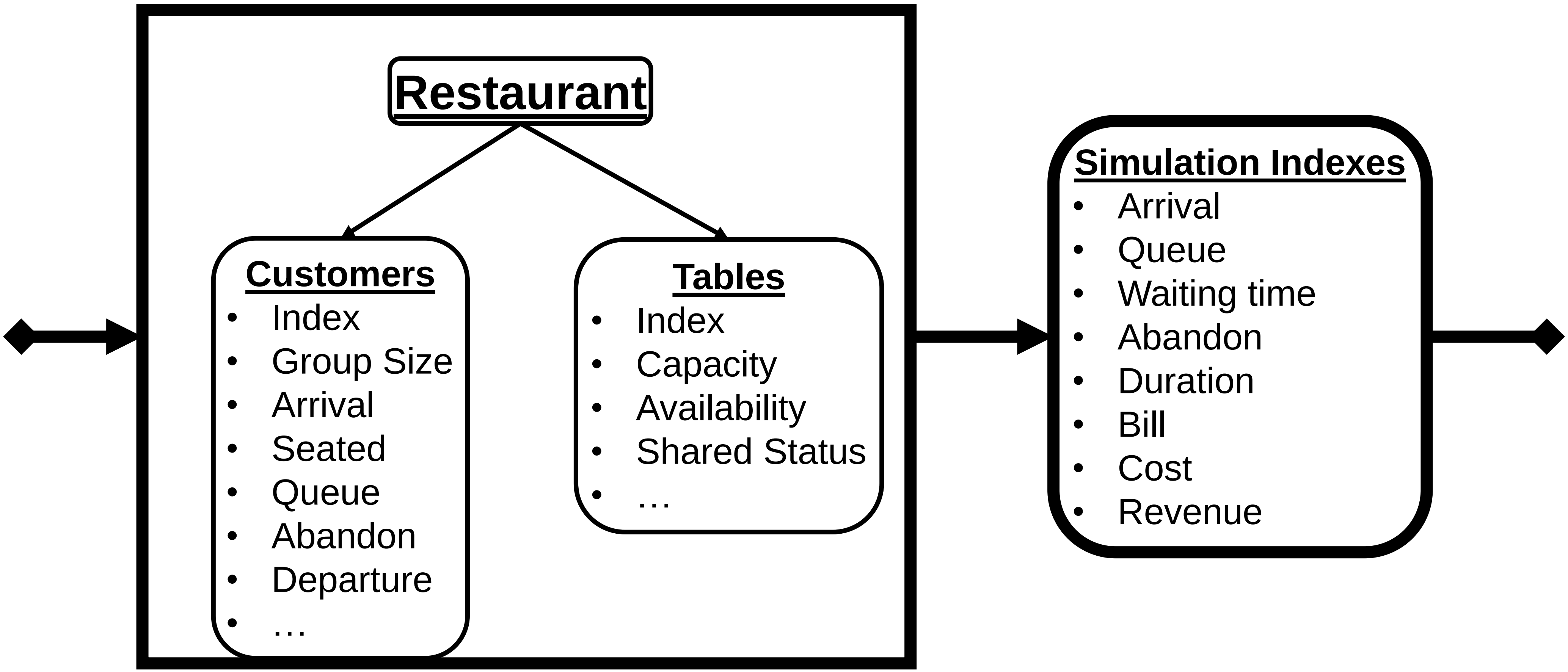


- The bill per person b can be calculated by multiplying a customer-specific consumption rate, defined by r, and the dinner duration d. The customer-specific consumption rate r is uniformly distributed between 0.5 €/minute and 1.2 €/minute.
- When a group sits together with another group at the same table, the remaining duration d decreases to d*0.5. Moreover, the consumption rate r also decreases to r*0.8.

Setup - Cost

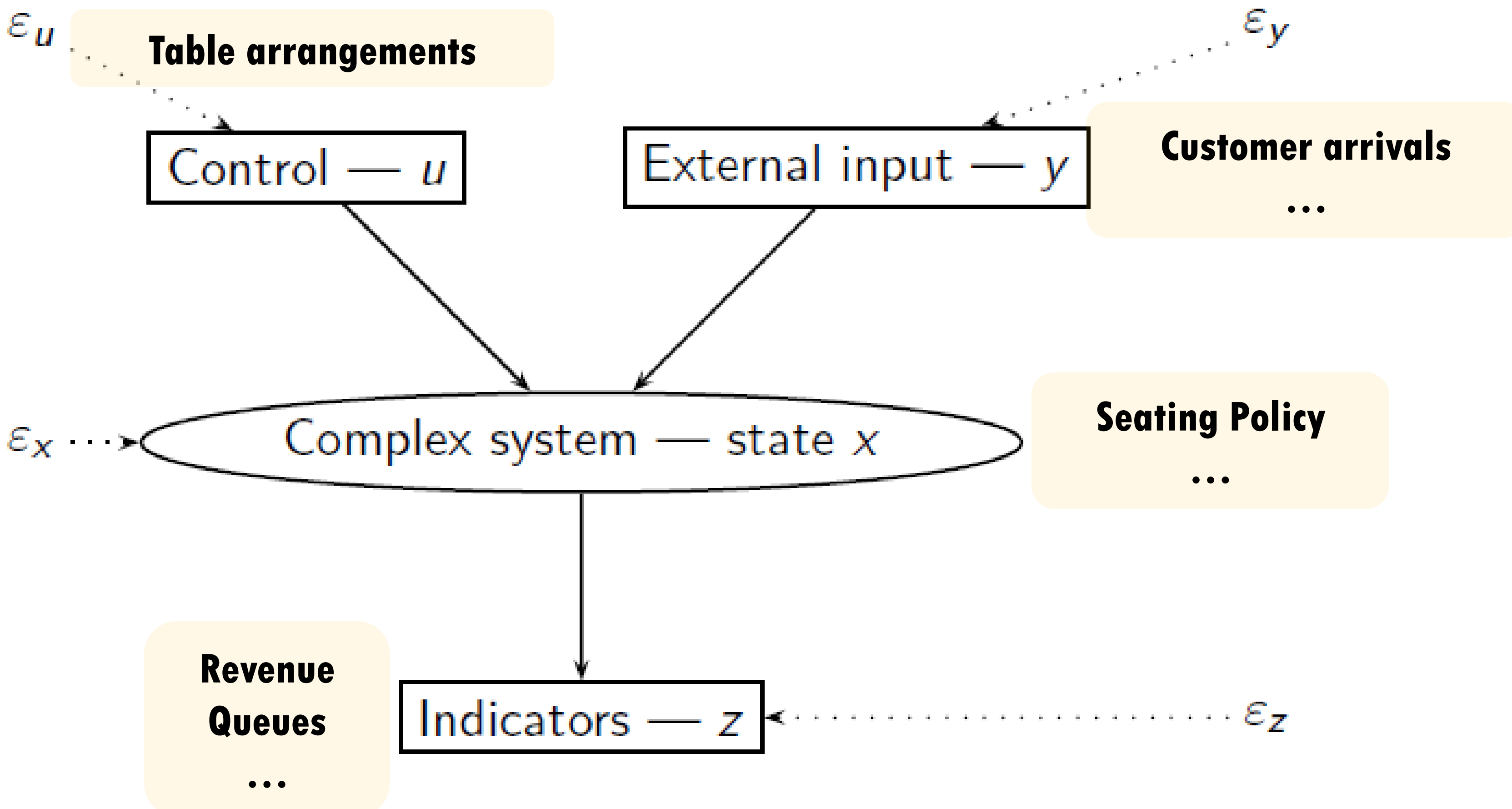
- Total Cost = $\mathrm{TC}\ [\mathrm{EUR}] = 0.1 \left[\frac{EUR}{min \cdot seat}\right] \cdot (\#seats)\ [seat]\ \cdot T_f\ [min]$

Simulation Setup



Simulation framework

$$Z = h(X, Y, U) + \varepsilon_z$$



Simulation Results

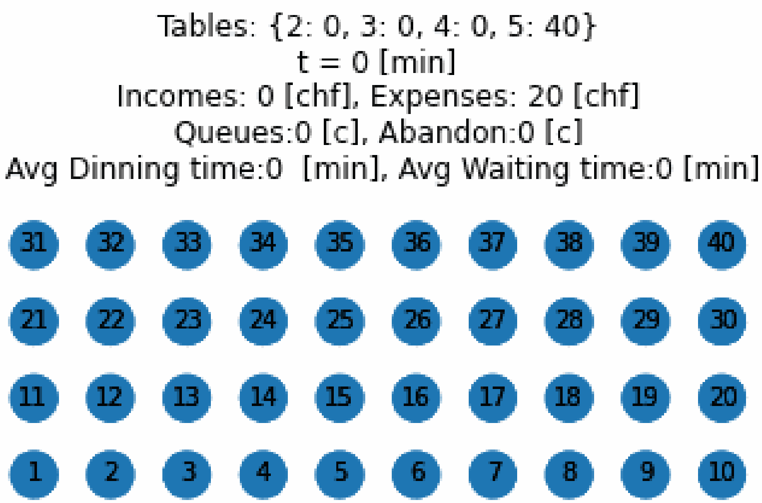
Op.1 - 40 tables for 5 | Op.2 - 50 tables for 2, 20 tables for 5

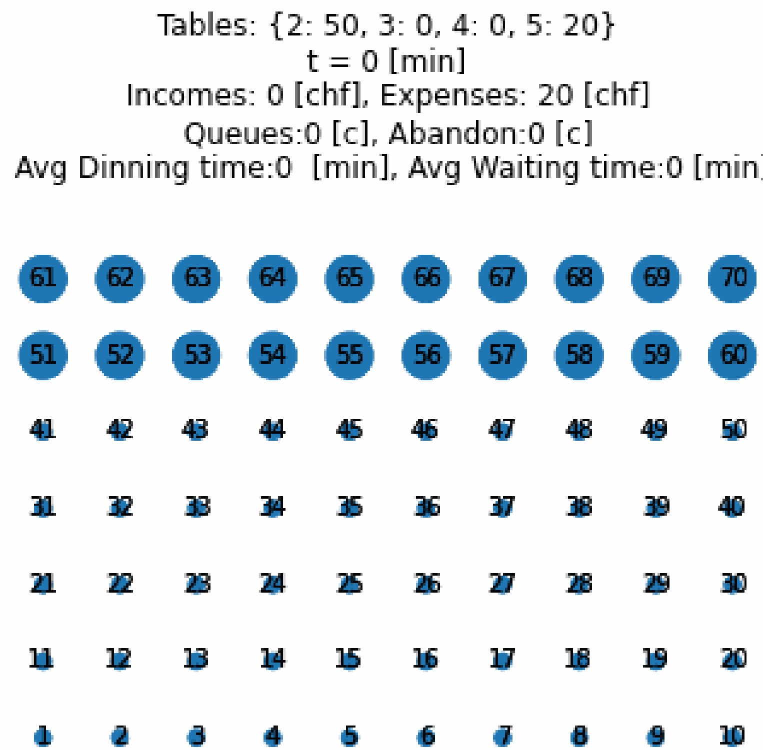
Two Policies – With and without Sharing tables

Results – Table arrangements

Op.1
40 tables for 5

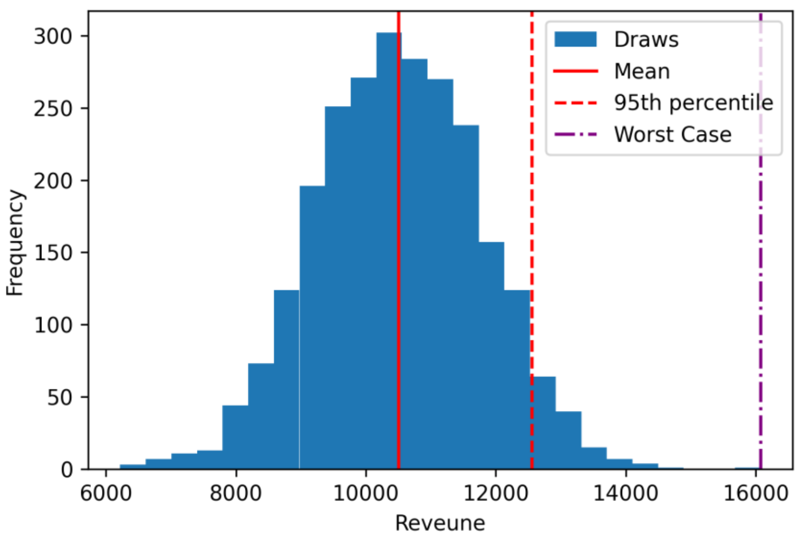
Op.2
50 tables for 2, 20 tables for 5



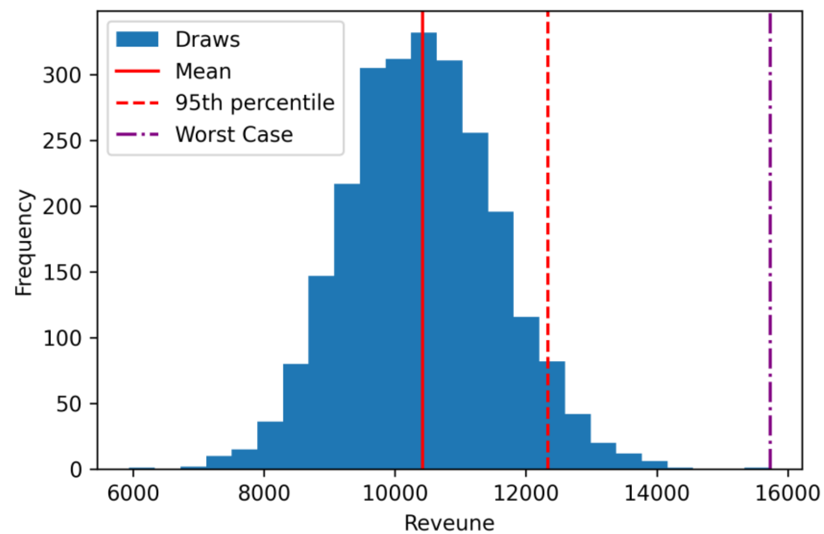


Results – Revenue (Op.1) (#n=5000)

Allow sharing tables

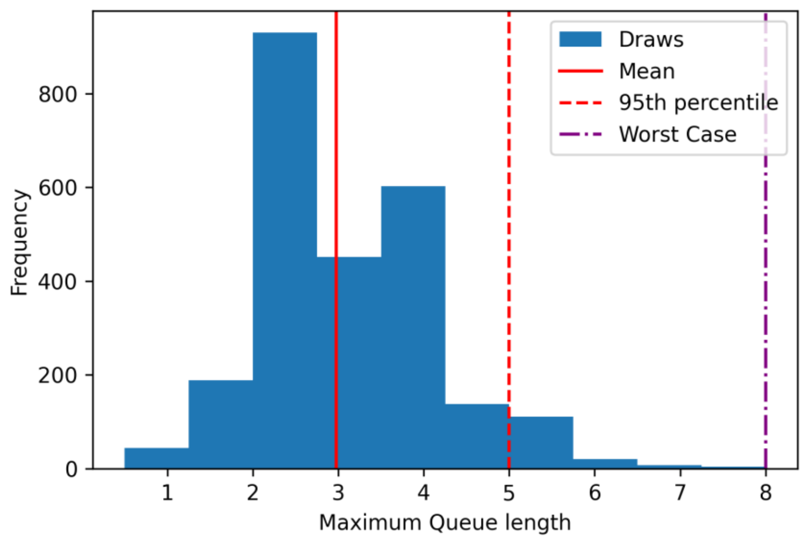


Not Allow sharing tables



Results – Queue (Op.1) (#n=5000)

Allow sharing tables



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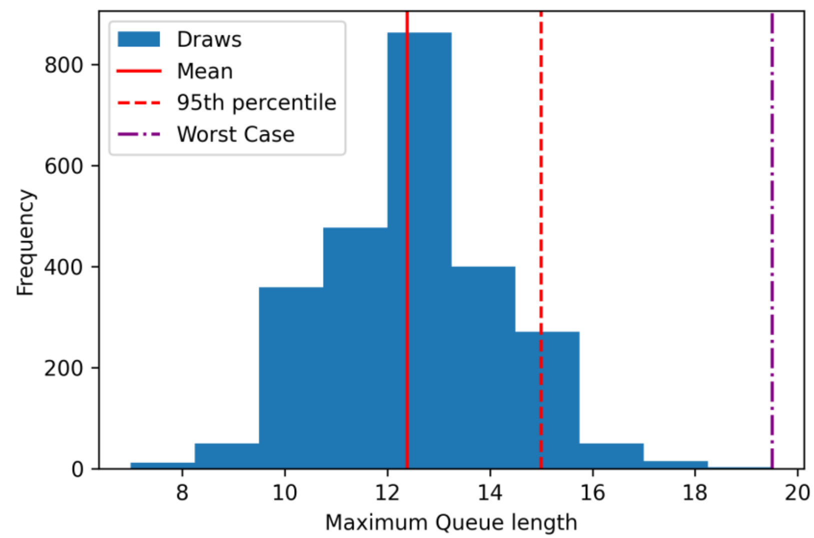
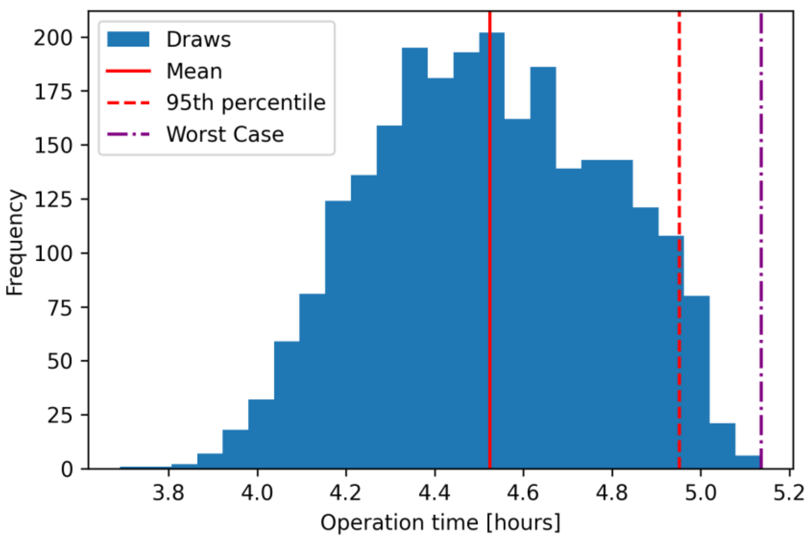


Results – Operation time (Op.1) (#n=5000)

Allow sharing tables



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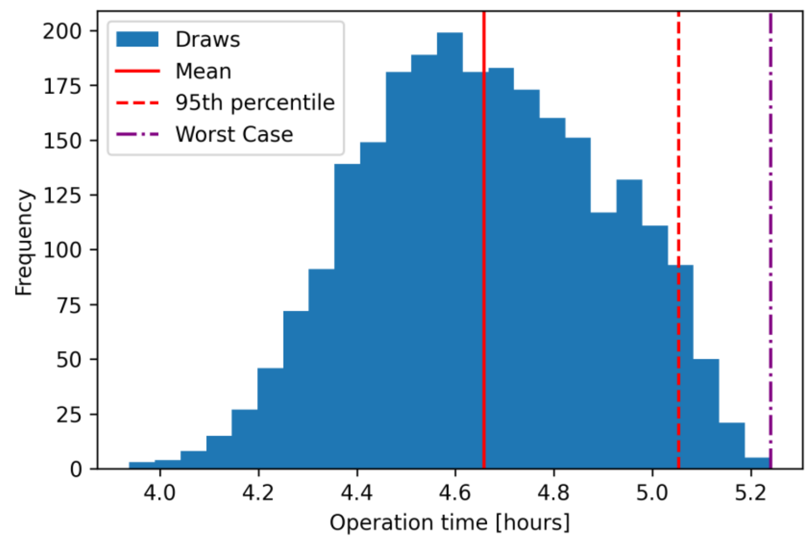
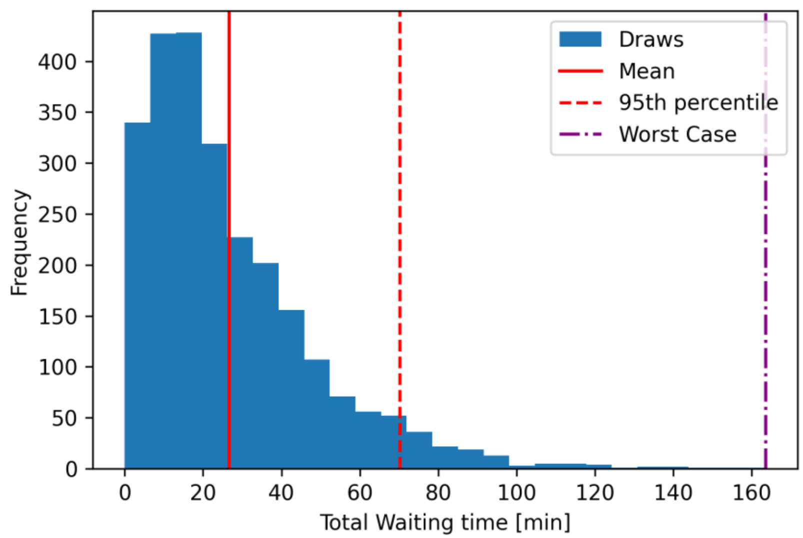


Results – Waiting time (Op.1) (#n=5000)

Allow sharing tables



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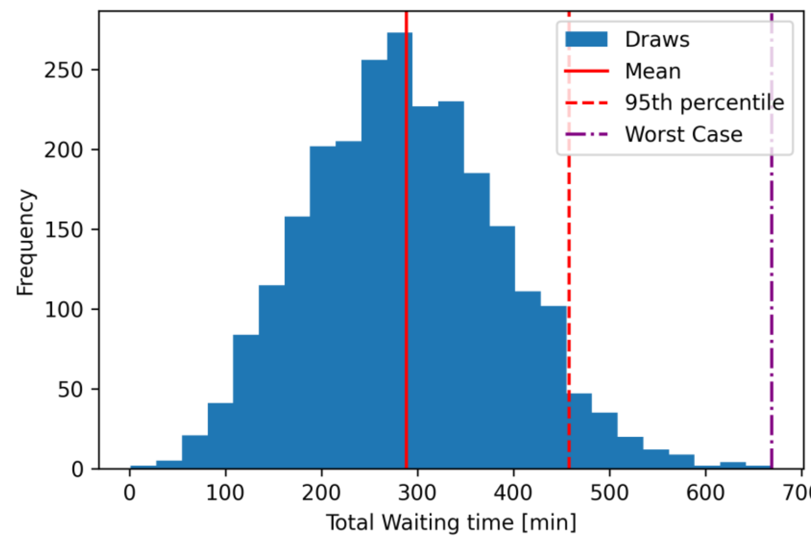
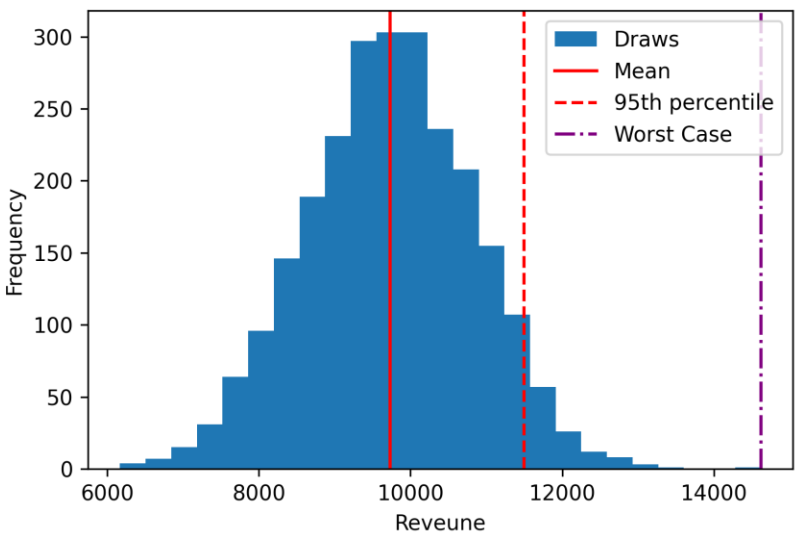


Results – Revenue (Op.2) (#n=5000)

Allow sharing tables



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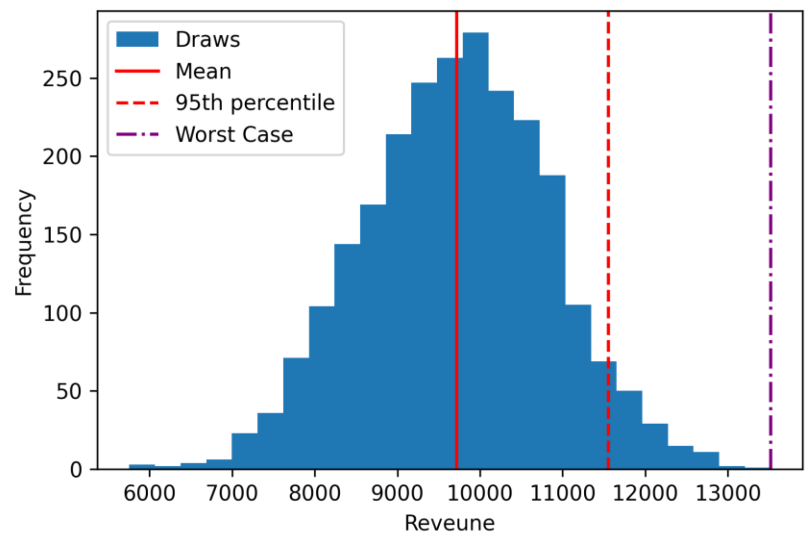
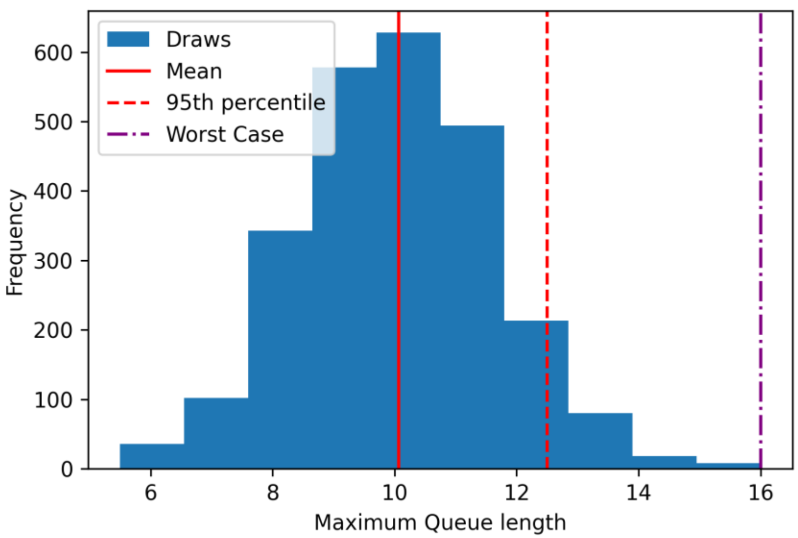


Results – Queue (Op.2) (#n=5000)

Allow sharing tables



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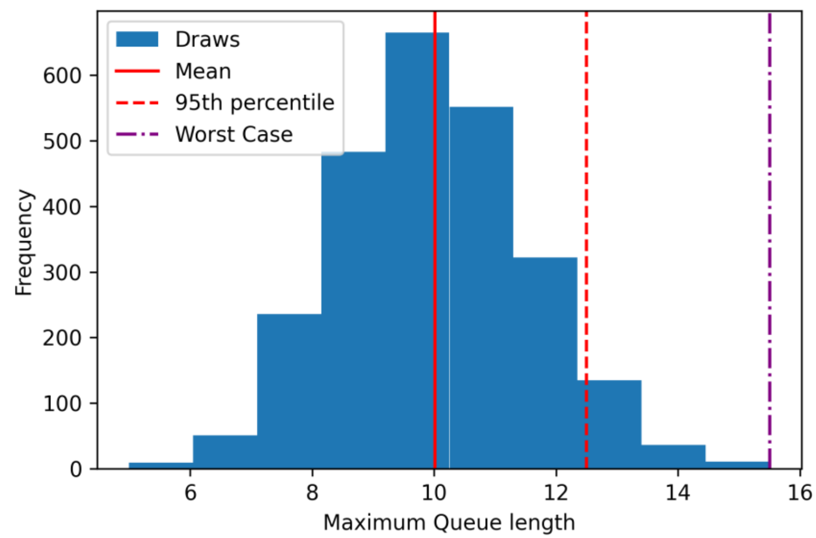
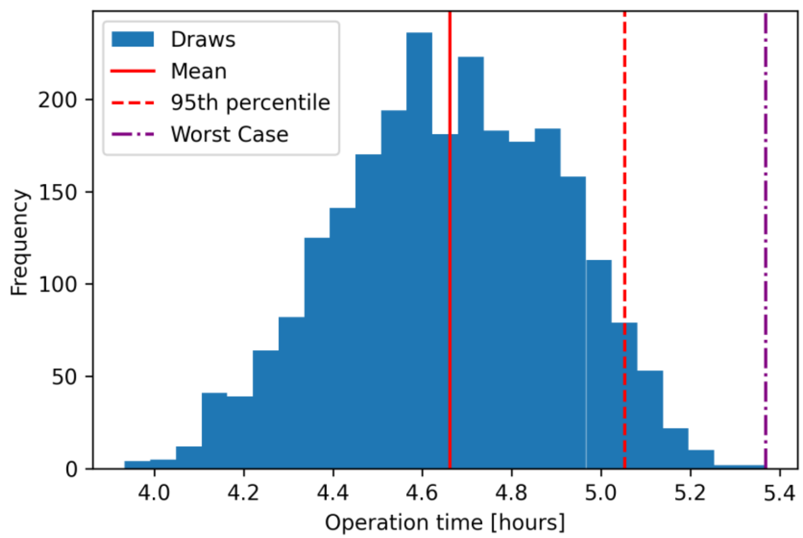


Results – Operation time (Op.2) (#n=5000)

Allow sharing tables



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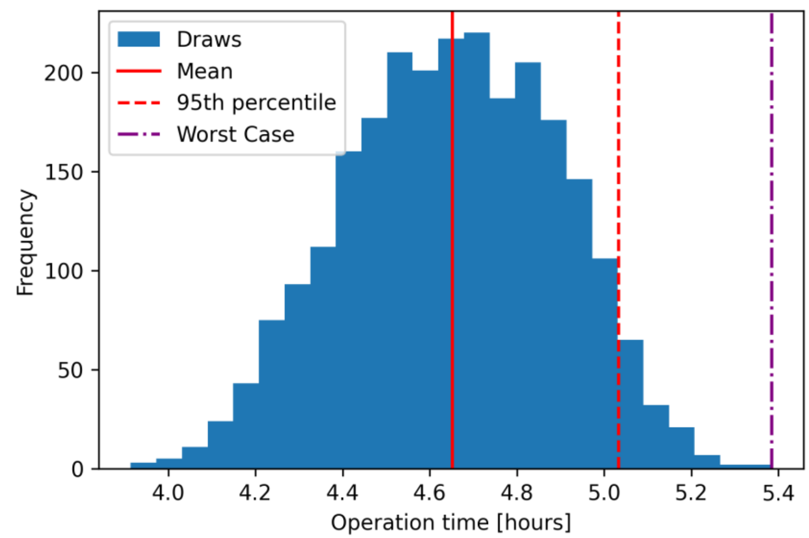
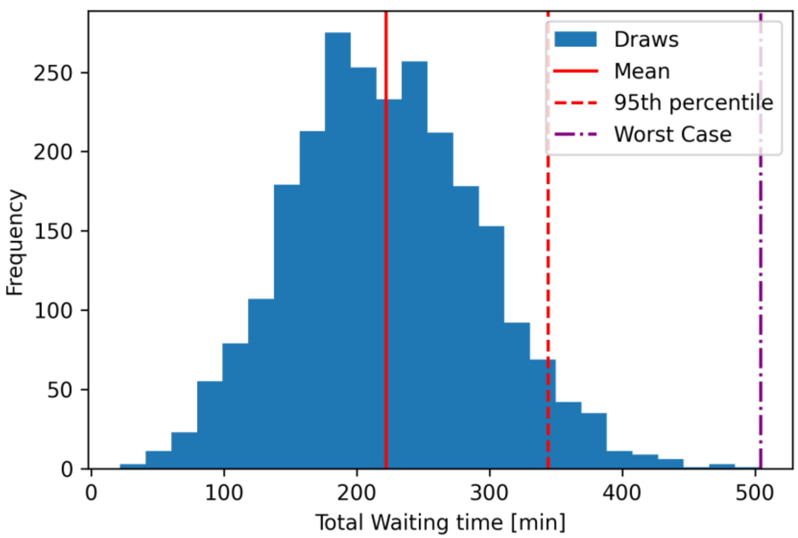
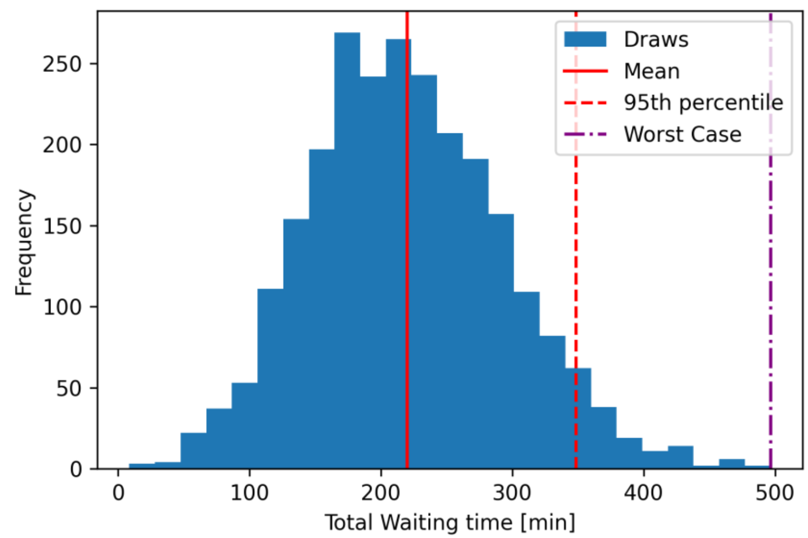


Results – Waiting time (Op.2) (#n=5000)

Allow sharing tables



Not Allow sharing tables



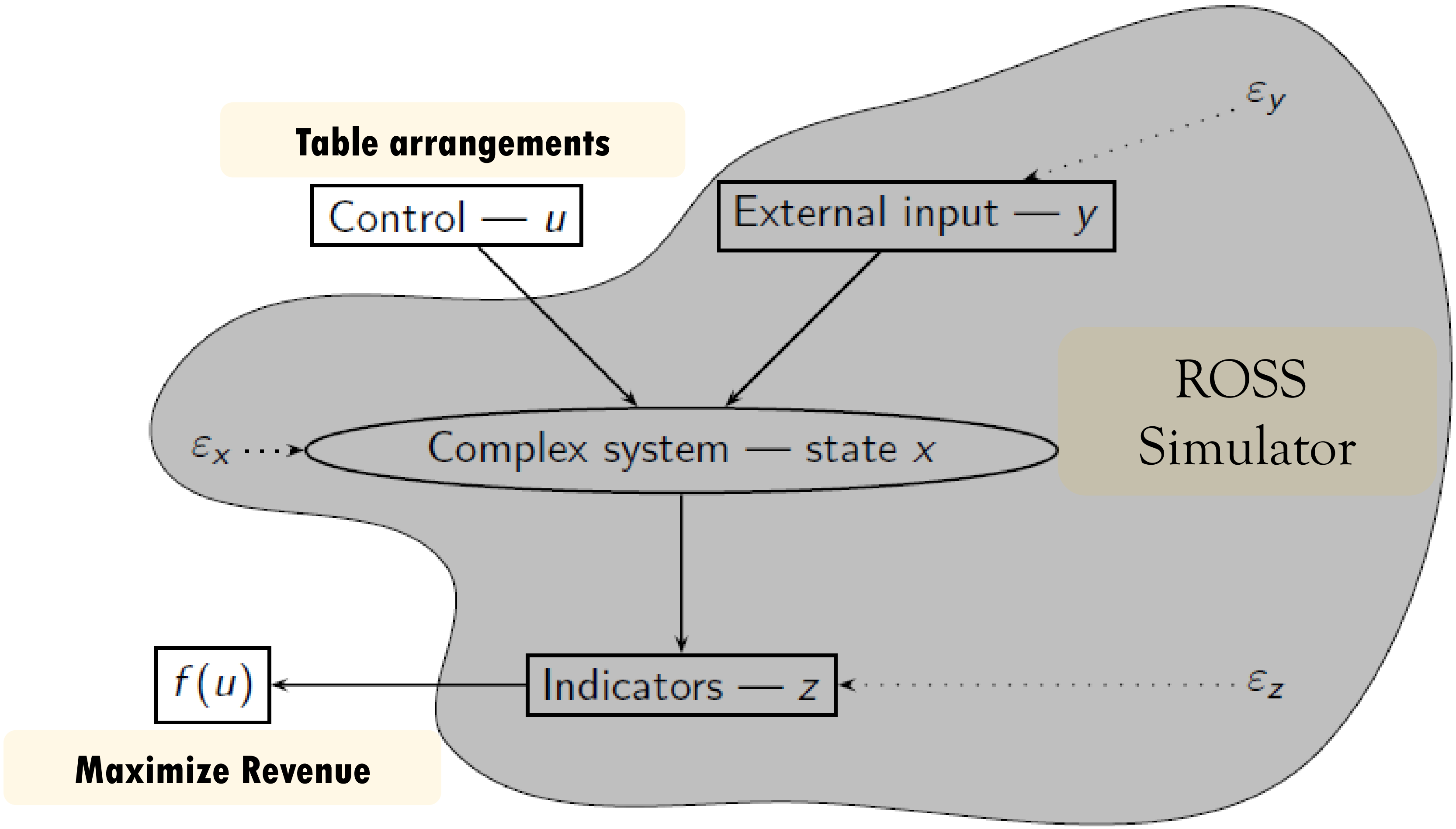
Summary

No Obvious Bias Observed.

- We can assume that, for better customer experience, the restaurant should not put different groups of customers together.
- This assumption is to be checked with further analysis.

Optimization

Optimization



Optimization

- Optimize over table arrangements, for maximized Revenue during open hours
- Method: Neighborhood search. Changing the number of tables of each size by 1, each arrangement would have at most 8 neighbors
- Algorithm: Simulated Annealing (Allows cost function to increase for searching larger area)

Optimization

Optimization

There are plans for a major renovation, after which the restaurant will be able to accommodate up to 400 seats. The owner is interested in knowing the best configuration of the seats as well the capacity of the restaurant. We disregard renovation costs and our only interest is the maximization of the daily revenue.

For the optimization project, you are requested to:

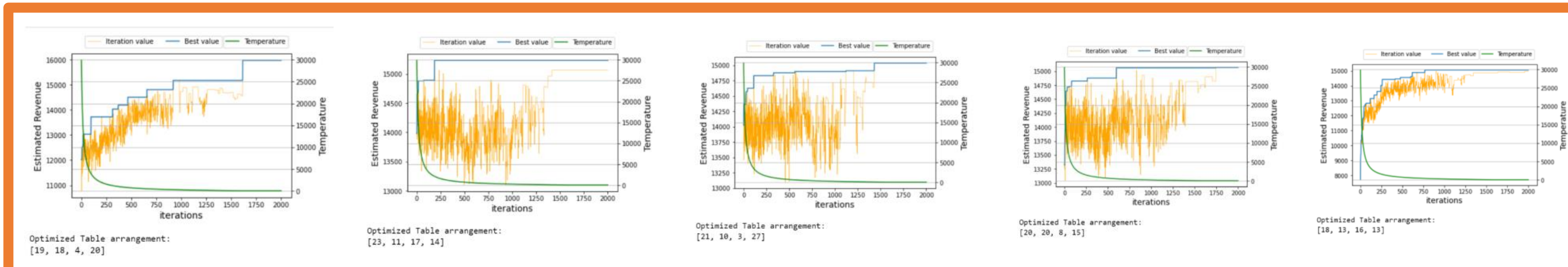
- Identify the decision variables of the problem.
- Define the objective function
- Design an optimization algorithm and apply it to solve the problem. The value of the objective function is evaluated by discrete event simulation.
- Like in the simulation project, the objective function can reflect various policies of the decision maker: whether they want to optimize over the average, best, worst, or certain percentile of the objective function distribution. Decide what your position is and justify it, or present results for several alternatives.
- Compare the result of your algorithm with the seating policies described in the simulation project.
- For the best configuration that you have found, use your creativity and design a new seating policy that would lead to a lower cost solution.

We decide to optimize over the average value of the Revenue because we already known the revenue almost follows normal distribution. And we believe it's a representative value to estimate the long-term performance of the restaurant,

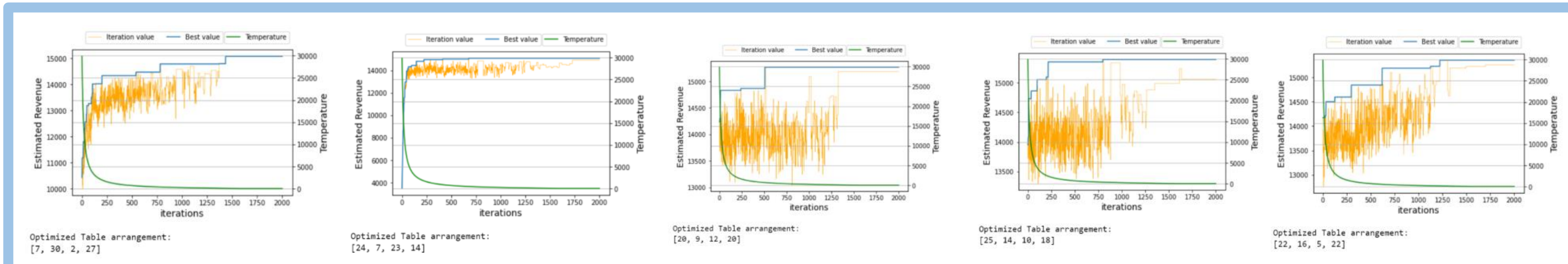
Optimization – Initial solutions

- Finding Initial solutions with multiple coarse optimization (#n=2000)
- No Variance Reduction applied, average of 10 runs used to estimate mean

SHARING

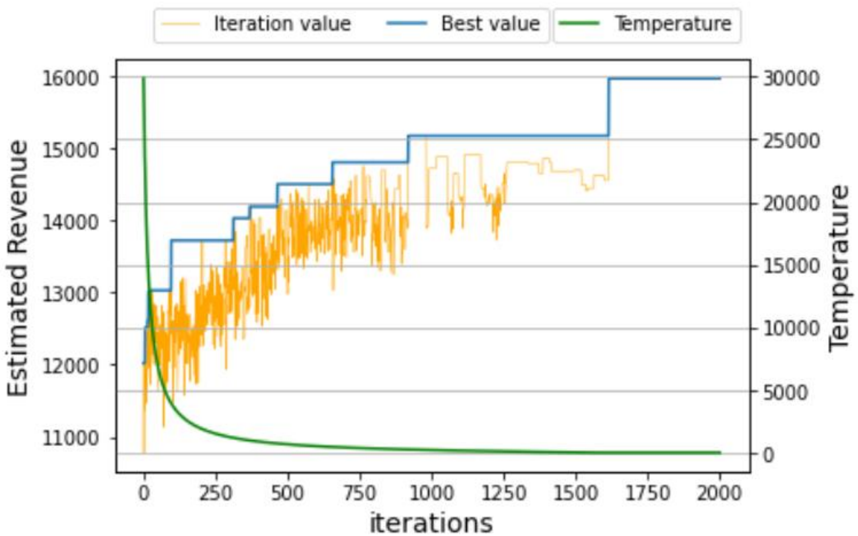


NO SHARING



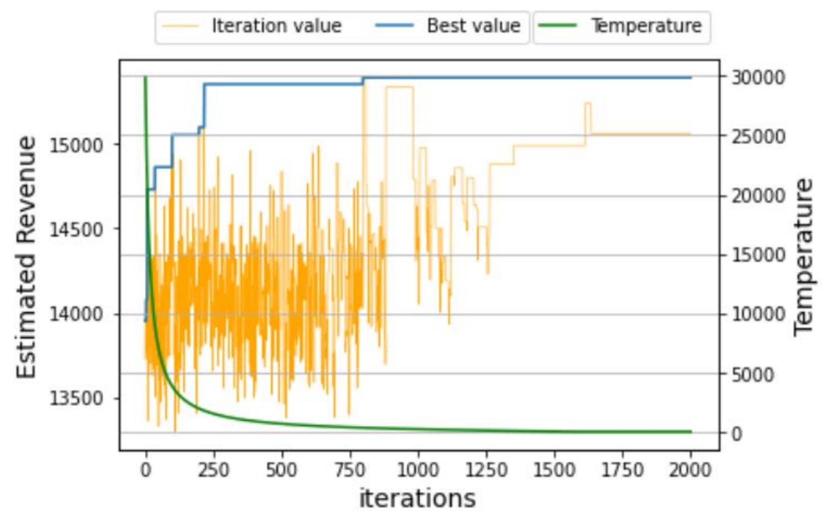
Optimal Initial solutions

Allow sharing tables




```
Optimized Table arrangement:
[19, 18, 4, 20]
```

Not Allow sharing tables




```
Optimized Table arrangement:
[25, 14, 10, 18]
```

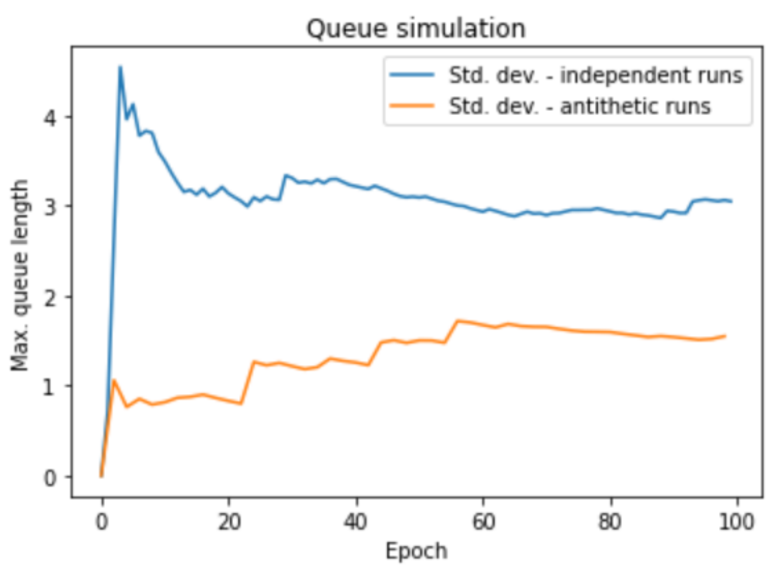
These solutions are only for reference

- Because an average of 10 runs is not a good estimate of the real mean value

- It is also observed that the optimized table arrangements are quite different, but the optimized revenue is almost constant around 15000.

Apply Variance Reduction to the simulator

- With a hoped accuracy of 0.5, the standard deviations are reduced:
- (Example u0=[19,18,4,20], allow sharing)
- We choose runtime = 124 instead 100 for better error tolerance



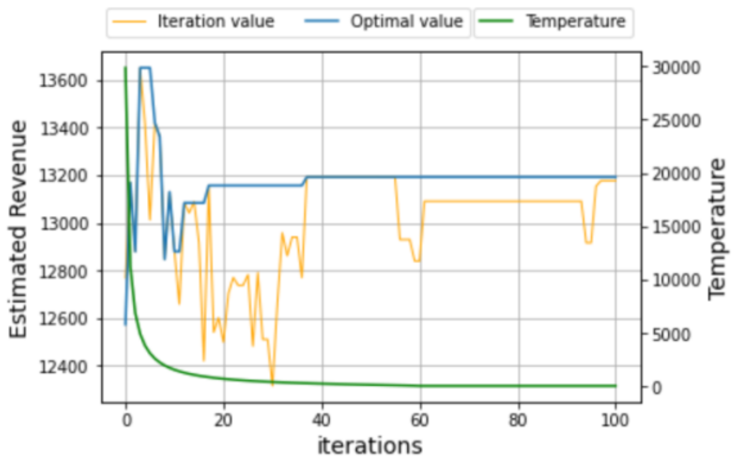
Multi-Objective Optimization

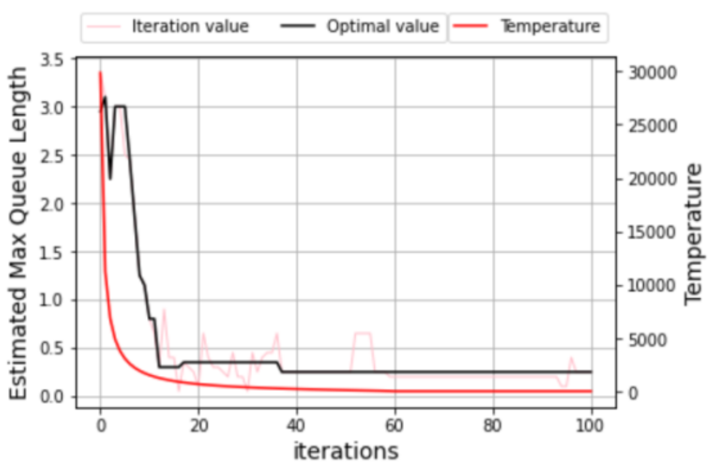
- We might want to minimize the length of waiting queue of our restaurant, at a cost of Revenue, for better customer experience and staff well-being

- Add weight*maximum queue length as an evaluation term to the cost function. The weight value indicates how much revenue are we willing to give up for optimizing the queue length by 1 people. Here we chose 1000(CHF)

```
def cost_function(max_queue_mean,Rev_mean,queue_weight=1000):
    return -1*Rev_mean+max_queue_mean*queue_weight
```

Multi-Objective Optimization example



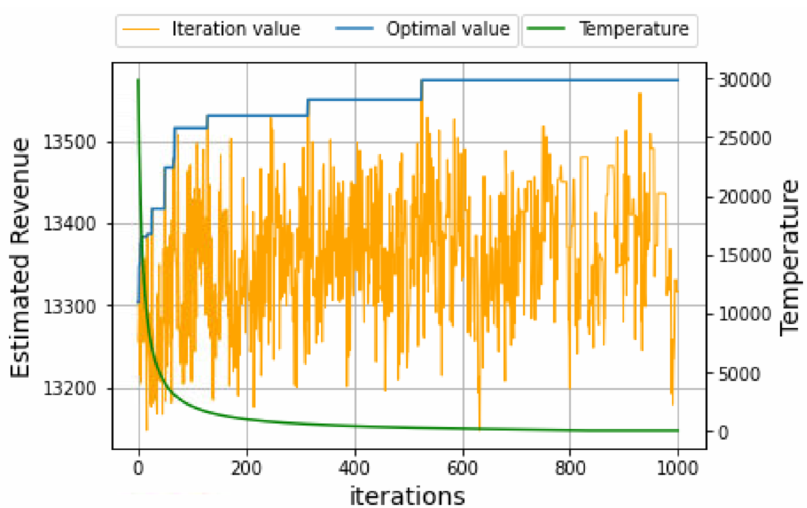


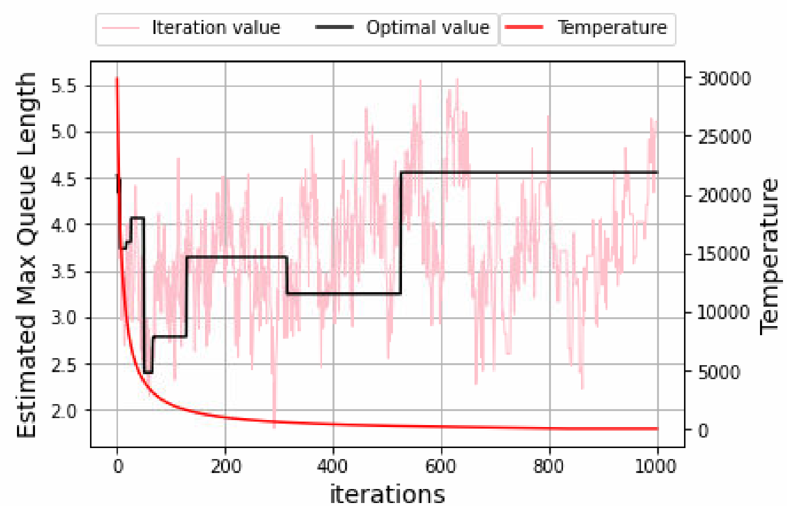

```
Optimized Table arrangement:[19, 19, 5, 29]
Corresponding Revenue:13191.57CHF
Corresponding max queue length:0.25
Running time:214.69 seconds
```

- This very coarse optimization example shows how our multi-objective optimizer accepts lower revenue to shorten the queue

Results – Case 1

- Allow sharing, with Variance reduction, Optimize only Revenue
- U0=[19,18,4,20]

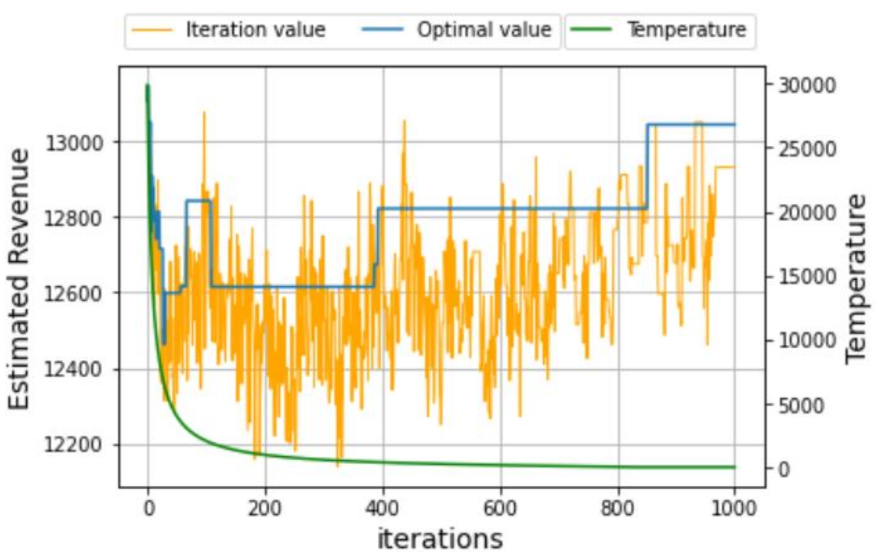


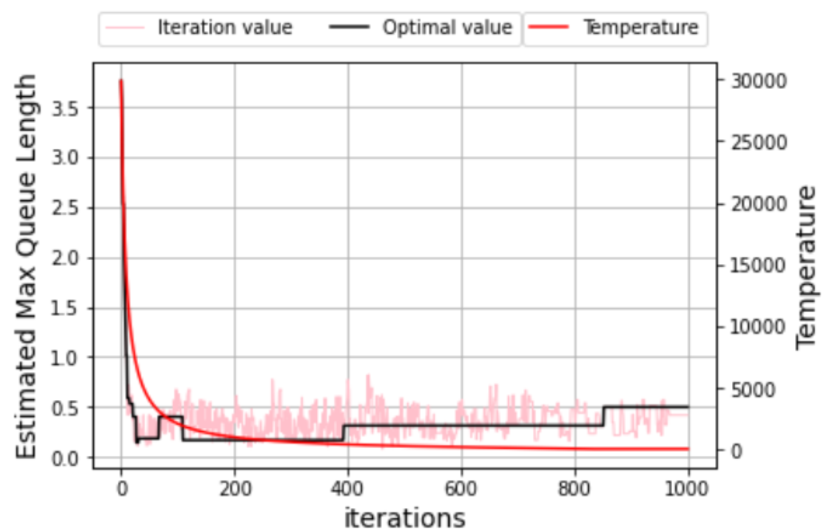



```
Optimized Table arrangement:[26, 14, 10, 14]
Corresponding Revenue:13574.28CHF
Corresponding max queue length:4.556451612903226
Running time:7356.40 seconds
```

Results – Case 2

- Allow sharing, with Variance reduction, Optimize both Revenue and Queue
- U0=[19,18,4,20]

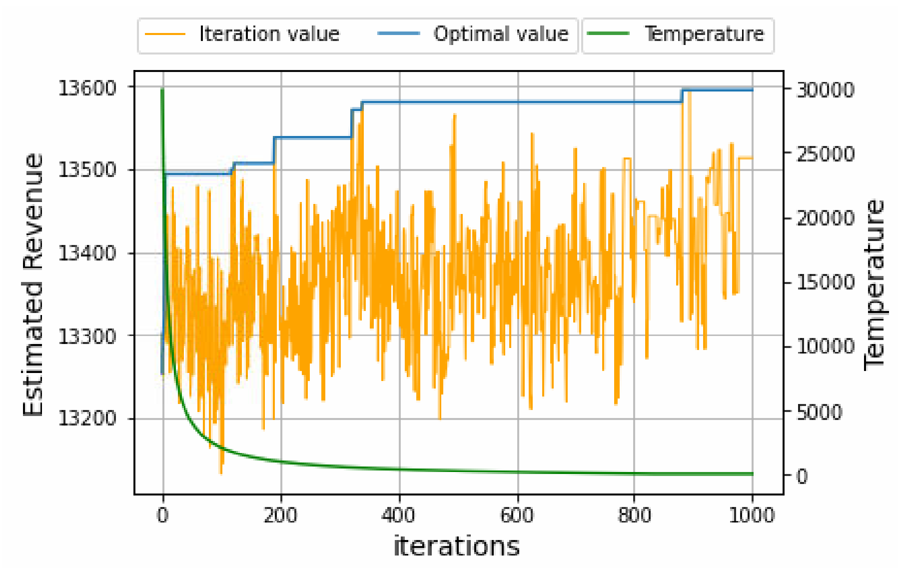


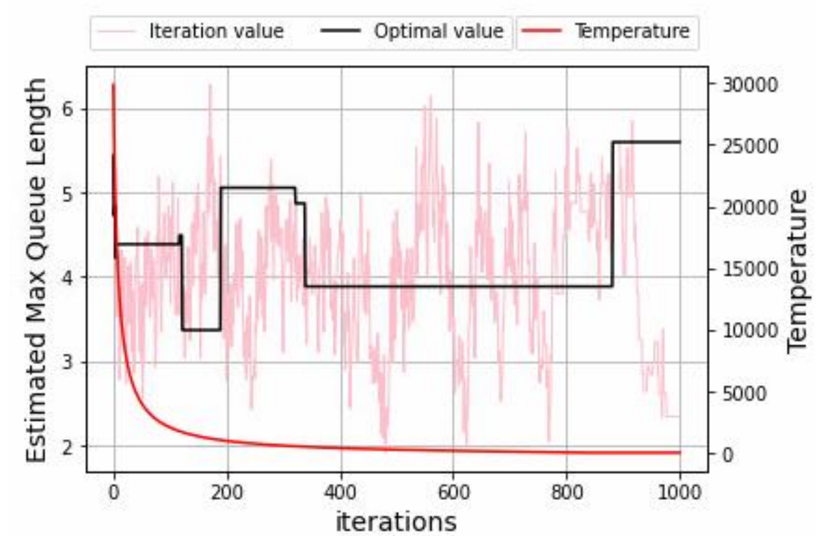



```
Optimized Table arrangement:[25, 17, 16, 19]
Corresponding Revenue:13044.90CHF
Corresponding max queue length:0.5
Running time:14927.99 seconds
```

Results – Case 3

- No sharing, with Variance reduction, Optimize only Revenue
- U0=[25,14,10,18]

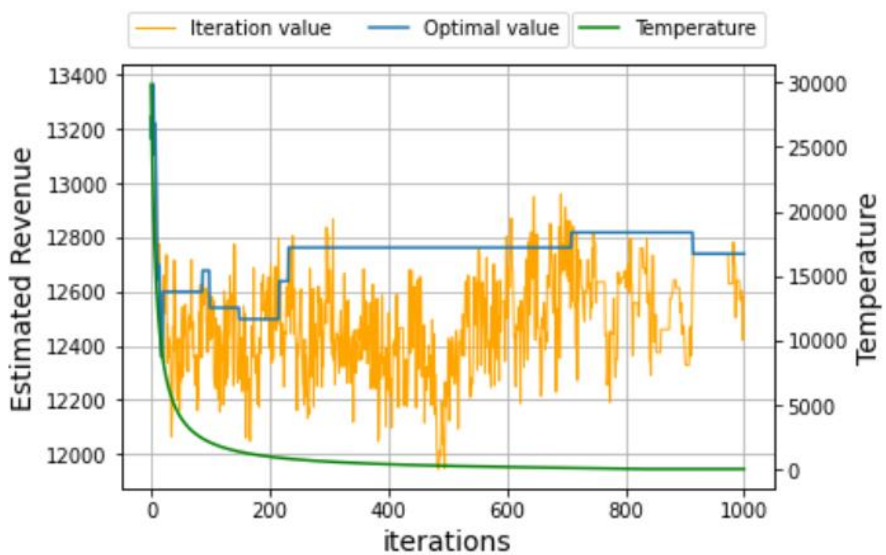


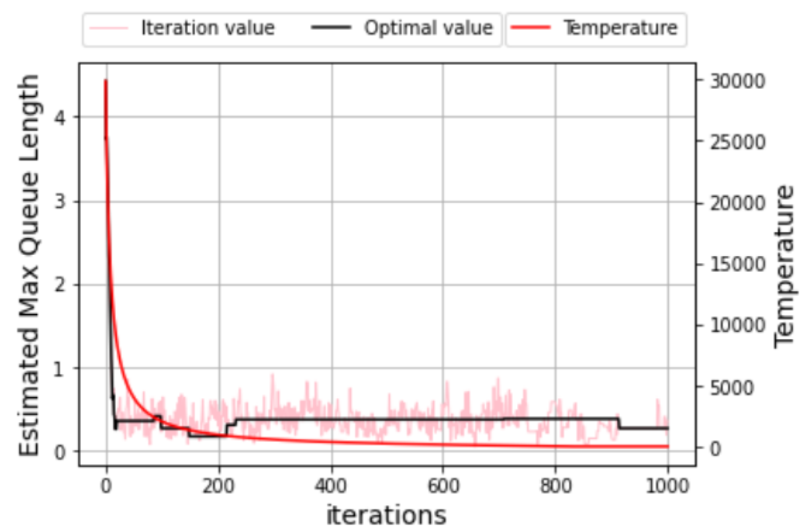



```
Optimized Table arrangement:[23, 13, 10, 16]
Corresponding Revenue:13595.30CHF
Corresponding max queue length:5.596774193548386
Running time:7215.58 seconds
```

Results – Case 4

- No sharing, with Variance reduction, Optimize both Revenue and Queue
- U0=[25,14,10,18]



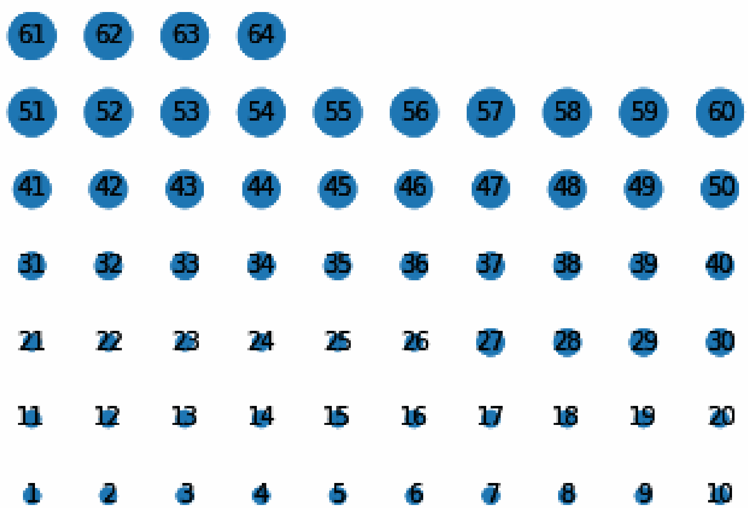



```
Optimized Table arrangement:[21, 21, 14, 22]
Corresponding Revenue:12739.68CHF
Corresponding max queue length:0.27419354838709675
Running time:13050.71 seconds
```

Results

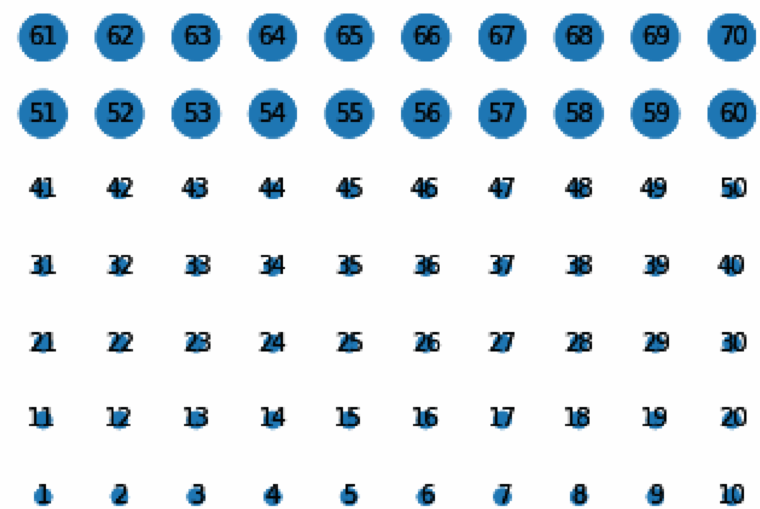
Optimized

Tables: {2: 26, 3: 14, 4: 10, 5: 14}
t = 0 [min]
Incomes: 0 [chf], Expenses: 20 [chf]
Queues:0 [c], Abandon:0 [c]
Avg Dinning time:0 [min], Avg Waiting time:0 [min]



Given

Tables: {2: 50, 3: 0, 4: 0, 5: 20}
t = 0 [min]
Incomes: 0 [chf], Expenses: 20 [chf]
Queues:0 [c], Abandon:0 [c]
Avg Dinning time:0 [min], Avg Waiting time:0 [min]



EMPTY TAKEN SHARED

Summary

- Optimization of restaurant operation is needed.
- Simulation framework for restaurant design is achieved.
- Utilization of multi-objective optimization can increase revenue and reduce queues.

THANK YOU!

ROSS

Restaurant
Optimizer
and
Simulator
Software

TEAM:
Michael Bombile
Ismail Nejjar
Yazan Safadi
Shuhang Zhang