Project 3 - **Quick Checkout**

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Objectives

Compare the **Mean Waiting Time** and **Mean Response Time** under a varying workload.

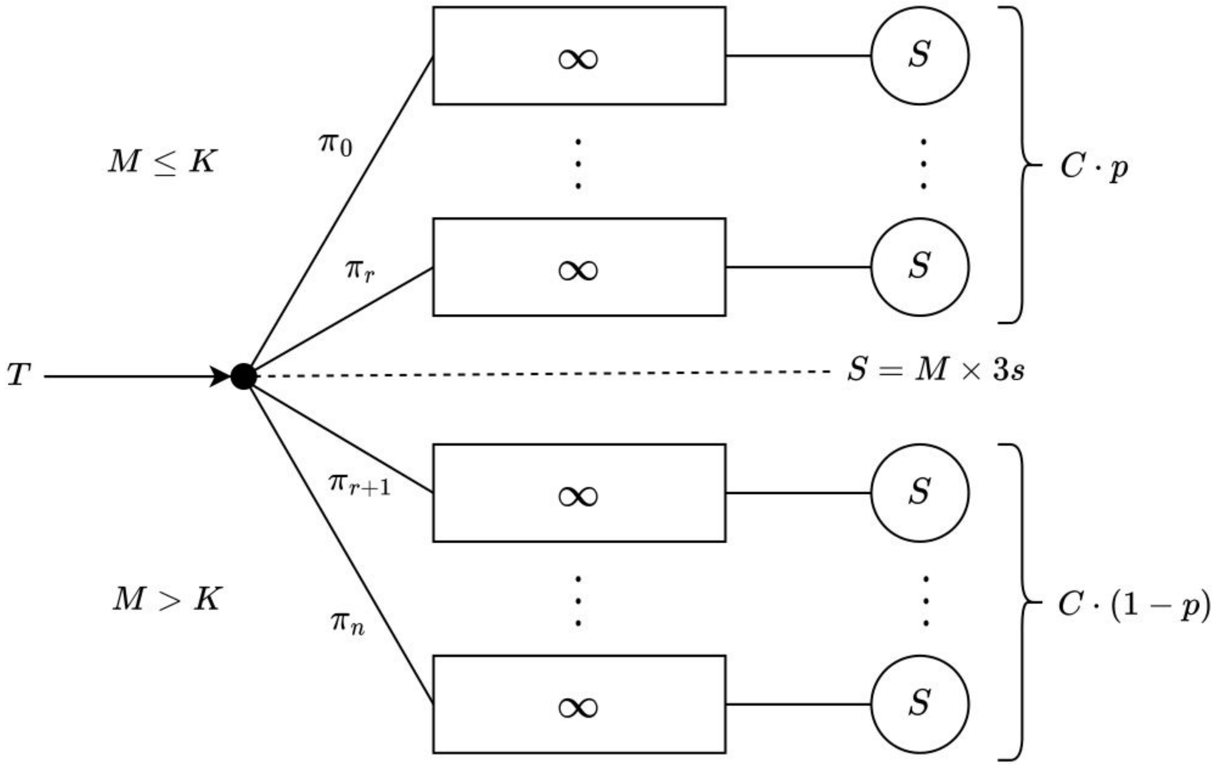
Key Performance Indices

Mean Waiting Time

Average Queue Size

Mean Service Time

Model



$M \leq K$
π_0
π_r
∞
∞
S
S
$C \cdot p$
T
$S = M \times 3s$
π_{r+1}
π_n
∞
∞
S
S
$M > K$
$C \cdot (1 - p)$

Factors

The percentage of **quick checkout tills** p

The **maximum number of items** that a customer can have in their cart to access to the quick checkout subsystem K

Parameters

The **total number of checkout tills** C

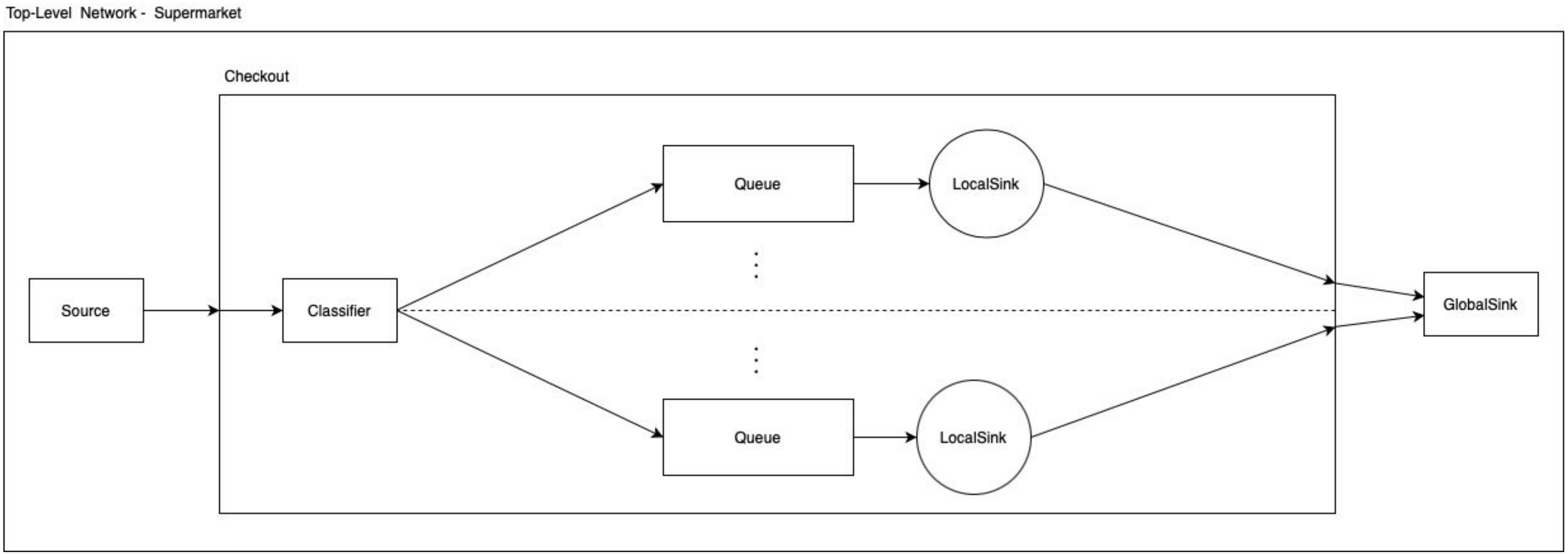
Distribution of the **inter-arrival time** of customers

$$exp(\lambda_T)$$

Distribution of the **number of items** in a customer's cart

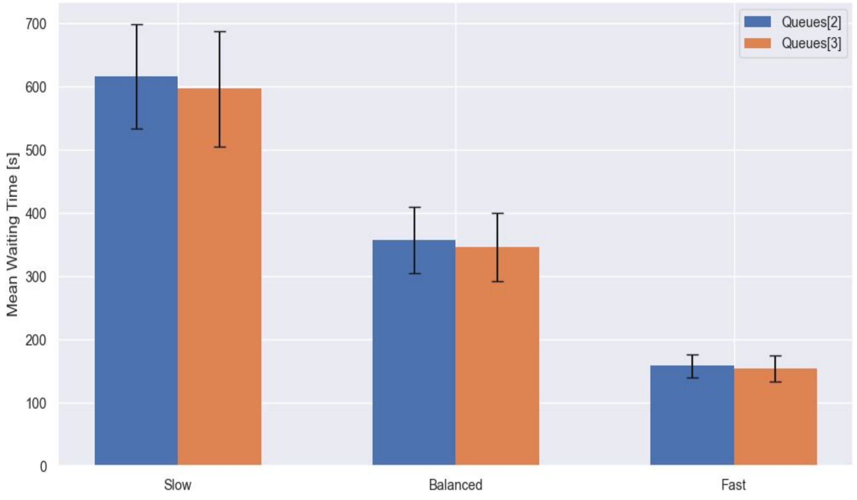
$$exp(\lambda_M) \qquad lognormal(\mu, \sigma^2)$$

Implementation



Verification - Consistency

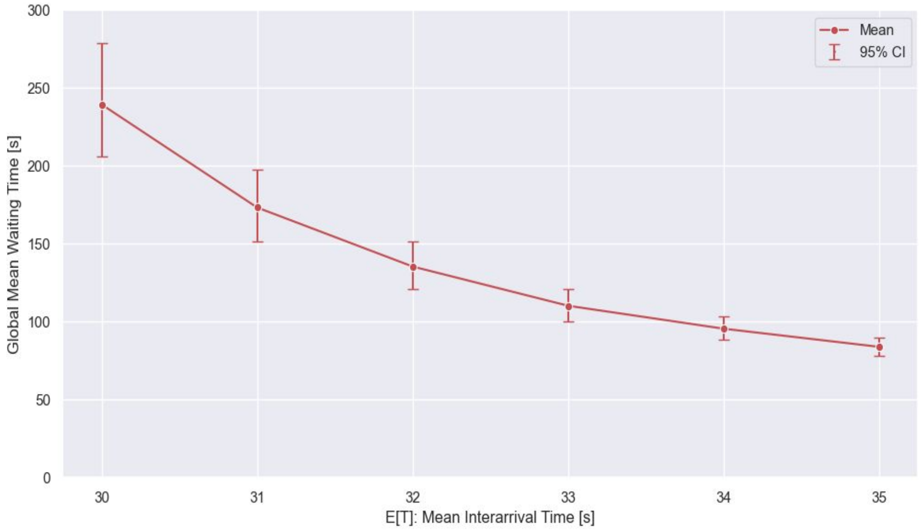
Expected Behaviour: **halving** both the **inter-arrival time** and the **mean number of items,** then **the Mean Waiting Time will halve**.



Normal Tills

Verification - Continuity

Expected Behaviour: **increasing** the **inter-arrival time**, the **Total Waiting Time decreases**.



Verification - Degeneracy

Unreachable quick tills
E[Nq], **K = 0** and **p = 0.5**

	Q[0]	Q[1]	Q[2]	Q[3]
Mean	0.0	0.0	18.2632	17.7777
Max	0.0	0.0	36.9281	36.3864

Verification - Theoretical Model

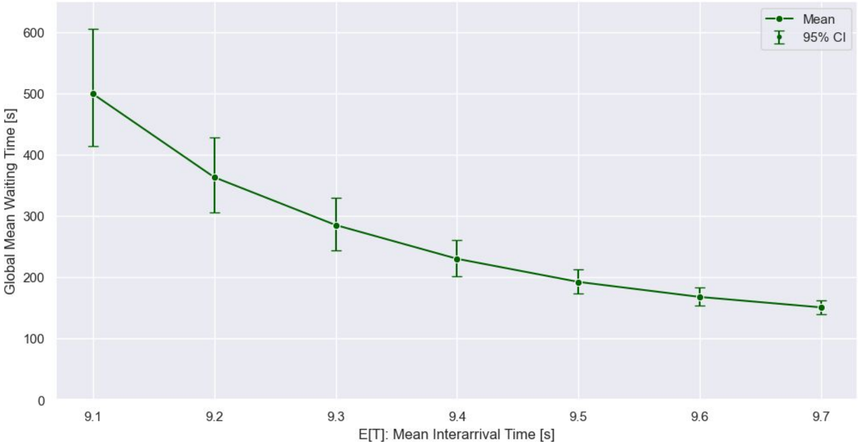
Utilization - CI 95%

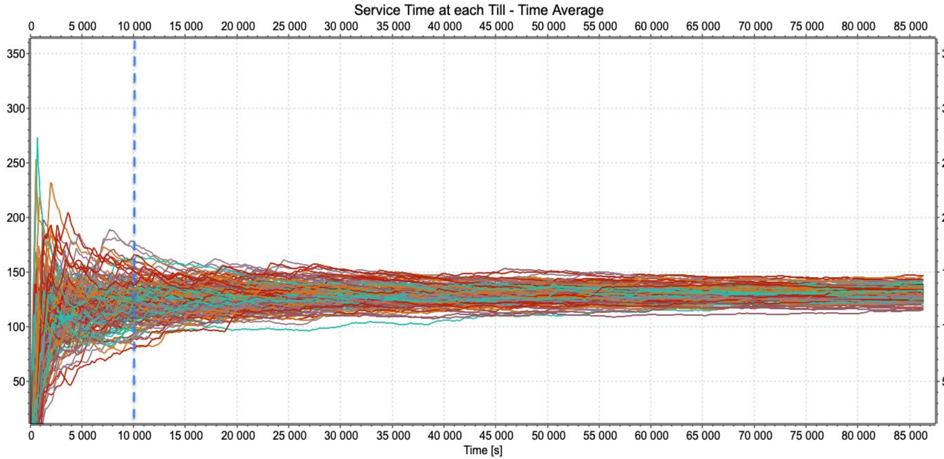
Queue	Theoretical	Mean	CI - LB	CI - UB	
Queues[0]	0.068452	0.068394	0.067328	0.069459	✓
Queues[1]	0.068452	0.068459	0.066834	0.070084	✓
Queues[2]	0.493988	0.492145	0.485497	0.498793	✓
Queues[3]	0.493988	0.496031	0.486992	0.505071	✓

$$E[N_i] = \rho_i + \frac{\rho_i^2 + \lambda_{T_i}^2 \cdot Var(t_{S_i})}{2 \cdot (1 - \rho_i)}$$

Factors Calibration

Warmup Period





"In 20 out of 25 major U.S. cities, the ***mean waiting time*** *at grocery stores is* ***under 5 minutes****."*

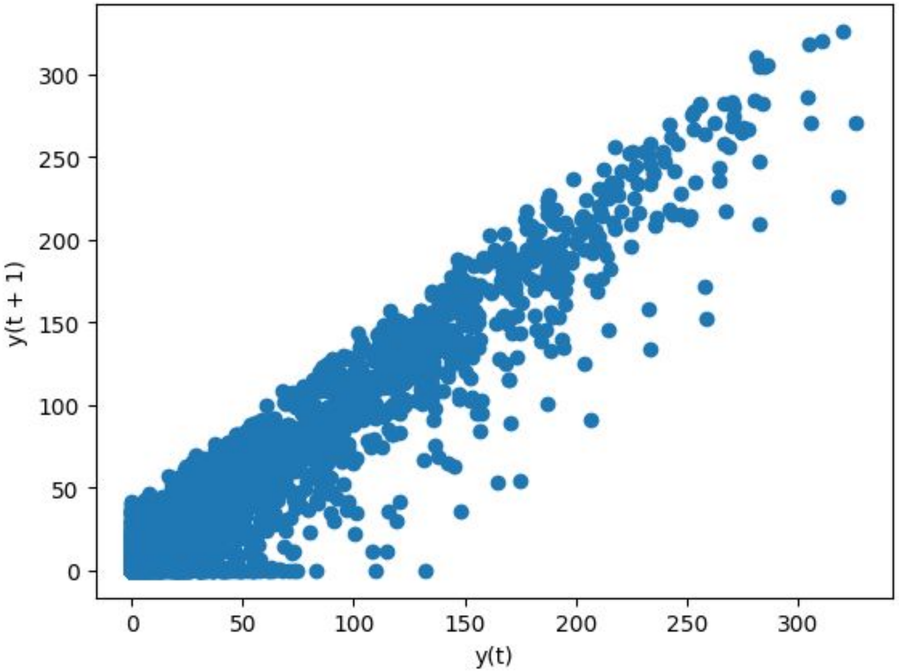
E[W] = 5 m = **300s** ⇒ E[T] = **9.3s**

Warmup Time: **~3h** (10.000s)

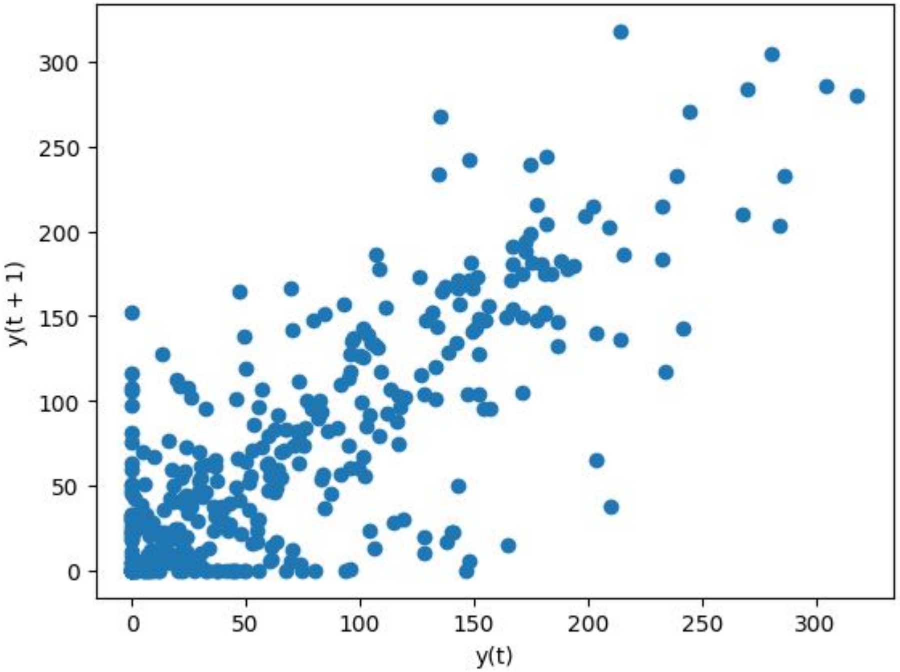
Simulation Time: **16h**

Subsampling (Quick Till Waiting Times)

Lag Plot **before** Subsampling
p = 0.1 K = 14 C = 10

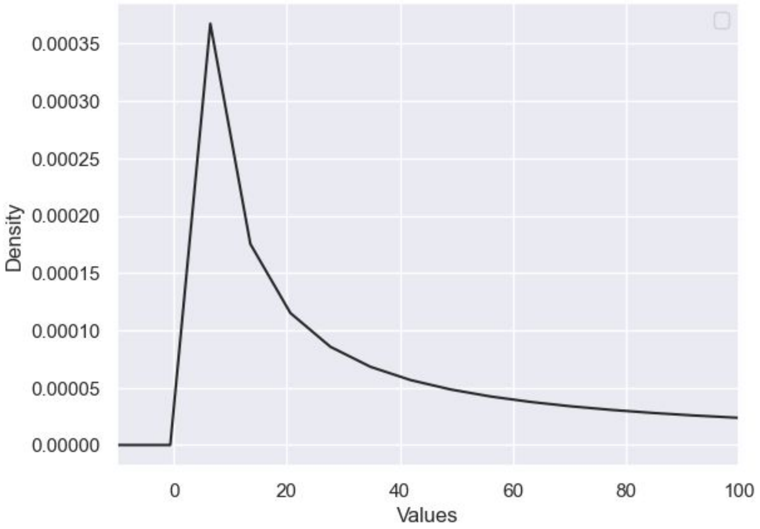


Lag Plot **after** 30% Subsampling
p = 0.1 K = 14 C = 10

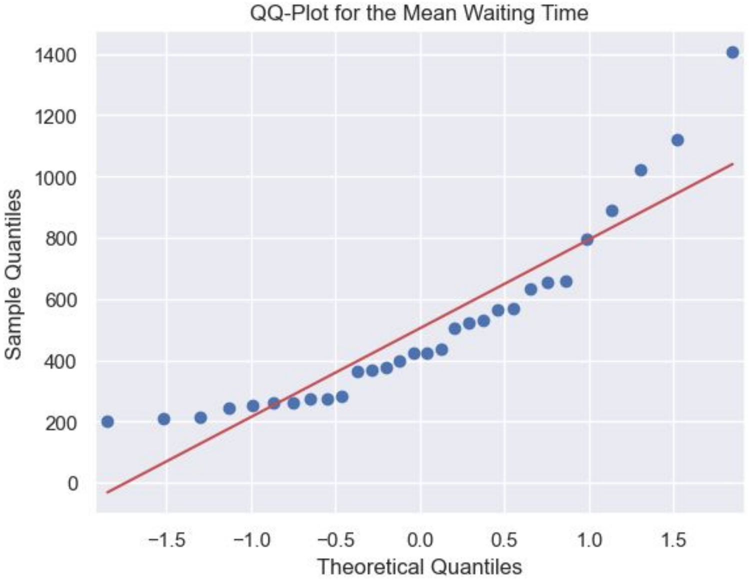


Waiting Time behaves as a Lognormal

Waiting Times in a simulation

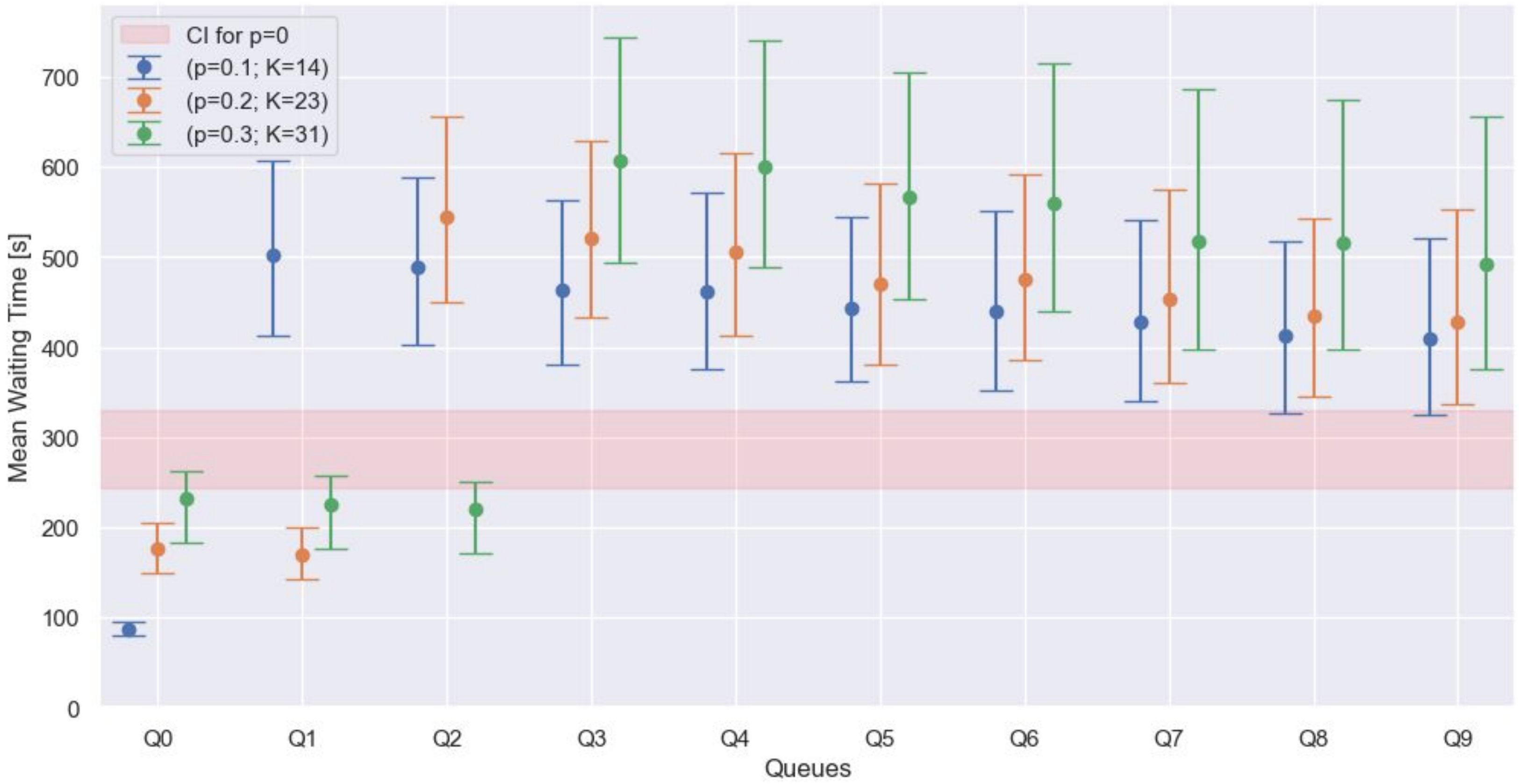


QQ Plot Mean Waiting Time
p = 0.1 K = 14

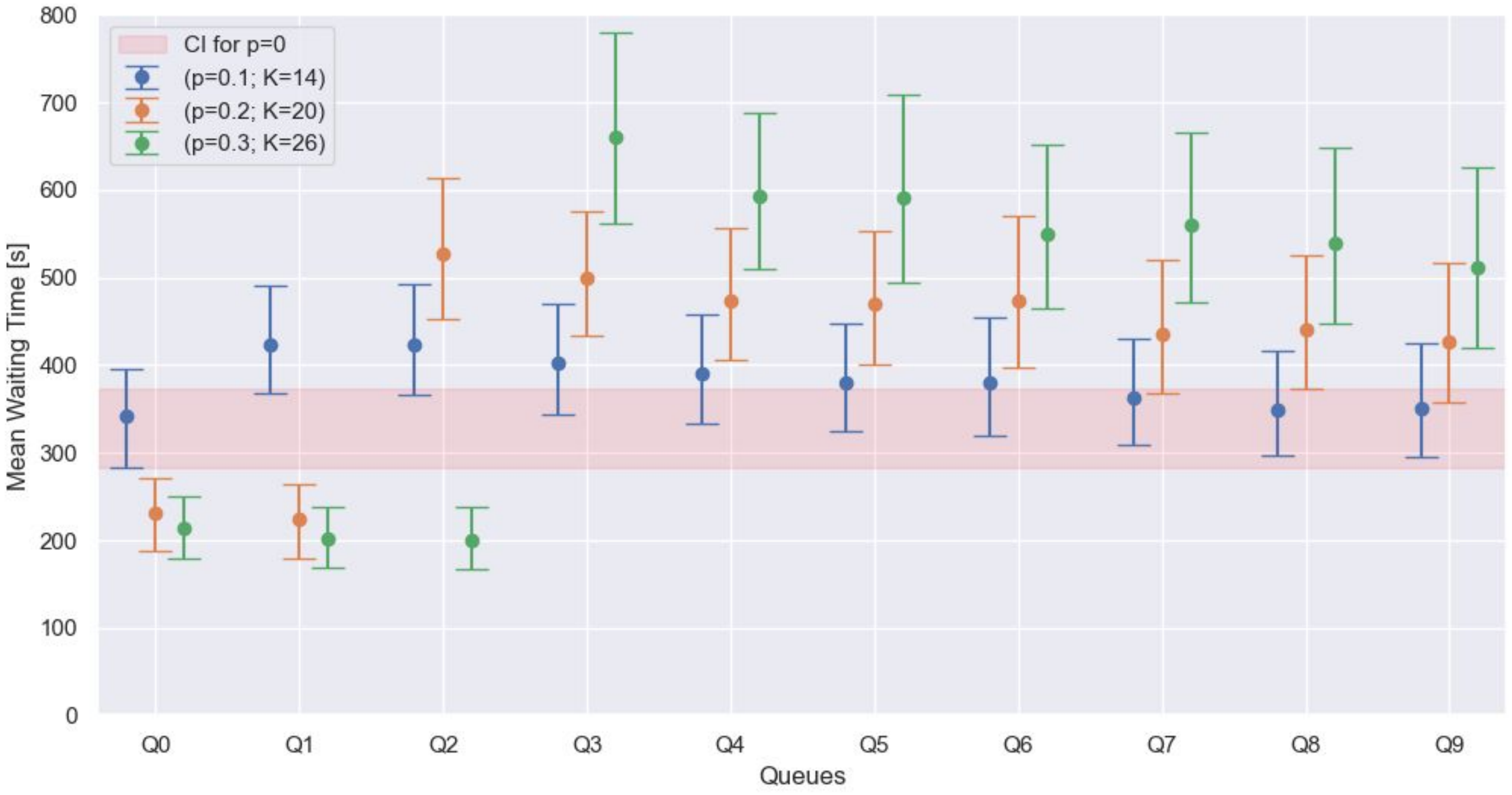


Cox Method for computing
the CIs

Exponential Experiment - Mean Waiting Time



Lognormal Experiment - Mean Waiting Time



Conclusion

The optimal configuration in the **exponential** case is:
p = 0.1 K = 14

There is **no optimal configuration** in the **lognormal** case

It is important to evaluate the **distribution of the items** in a customer's cart before introducing quick tills