Example of DOE

A good example of DOE I can think of is in medical testing. To test a new drug and measure it's effectiveness, we can control for different factors like food habits, height, weight, skin color, age group, etc to see if the drug is really effective in treating the corresponding disease.

For example we can use two factors such as age -- low age, mid age and old age height -- low height, mid height and high height.

Example of distributions:

Binomial - Suppose we buy 10 lotteries and probability of winning on each lottery is 0.10. Binomial distribution can be used to calculate the probability of winning atleast one lottery.

Geometric - Number of right swipes required on Tinder before hitting a match. :P

Poisson - I work for a small business lender as a Data Scientist. Poisson distribution can be used to model the arrival of big loan ask (in terms of dollar amount).

Exponential - In the above case, we can use exponential distribution to model the time between such loans.

Weibull - it can be used to model the wear and tear of computers used for Bitcoin mining. A computer used for bitcoin mining lasts approx 2-3 years. We can use a Weibull distribution with k > 1 to model the amount of time it takes for the computer to fail.

In [1]:
```
import simpy as sy
import random

num_checkers = 4
num_scanners = 4
total_time = 0
total_passengers = 1
num_passengers = 100


class Airport(object):
    def __init__(self, env, num_checkers, num_scanners):

        self.env = env
        self.checker = sy.Resource(env, num_checkers)
```

```
        self.scanners = []
        for i in range(0, num_scanners):
            self.scanners.append(sy.Resource(env))


    def ID_check(self, passenger):
        ID_service_time = random.expovariate(1/0.75)
        yield self.env.timeout(ID_service_time)

    def scan(self, passenger):
        scan_time = random.uniform(0.5, 1)
        yield self.env.timeout(scan_time)

    def print_stats(self, res):
        print('%d of %d slots are allocated.' % (res.count, res.capaci
ty))
        print('  Users:', res.users)
        print('  Queued events:', res.queue)

    def Passenger(self, env, number):
        global total_time #global average wait time
        global total_passengers
        Arrivaltime = env.now

        with self.checker.request() as request:
            yield request
            yield env.process(self.ID_check(number))


        queue_list = []
        for scanner in self.scanners:
            queue_list.append(len(scanner.queue))

        min_queue_index = queue_list.index(min(queue_list))
        with self.scanners[min_queue_index].request() as request:
            yield request
            self.print_stats(self.scanners[min_queue_index])
            yield env.process(self.scan(number))

        pass_time = env.now - Arrivaltime
        total_time = total_time + pass_time
        total_passengers = total_passengers+1

    def setup(self, env, num):
        arrival_int = random.expovariate(5)
        yield env.timeout(arrival_int)
        env.process(self.Passenger(env, num))


print('Airport Security')
```

```
env = sy.Environment()
ap = Airport(env, num_checkers, num_scanners)
# Start processes and run
for i in range(0,num_passengers):
    env.process(ap.setup(env, i))

env.run()

avg_time = total_time / total_passengers
print("avg_time")
print(avg_time)
```

```
Airport Security
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b668>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b5f8>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b978>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b748>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b6d8>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b710>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4bf60>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc432b0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc43128>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc43438>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc43240>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc336d8>]
  Queued events: []
1 of 1 slots are allocated.
```

```
  Users: [<Request() object at 0x10cc432e8>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc438d0>]
  Queued events: [<Request() object at 0x10cc43b70>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc43b38>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc43e10>]
  Queued events: [<Request() object at 0x10cc2ebe0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc43f60>]
  Queued events: [<Request() object at 0x10cc2ec18>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc43b70>]
  Queued events: [<Request() object at 0x10cc33be0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc60128>]
  Queued events: [<Request() object at 0x10cc336a0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc2ebe0>]
  Queued events: [<Request() object at 0x10cc60668>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33be0>]
  Queued events: [<Request() object at 0x10cc60518>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc2ec18>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc336a0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc60668>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc60518>]
  Queued events: [<Request() object at 0x10cc60908>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc60a90>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc60ef0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc60908>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc660b8>]
  Queued events: []
```

```
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b4e0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc330f0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc2eba8>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33828>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc66780>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc2eba8>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc66a90>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b438>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc66da0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b240>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc66ef0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc6c320>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc6c4a8>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b208>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc6c630>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc6c860>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc2eac8>]
```

```
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc6cac8>]
  Queued events: [<Request() object at 0x10cc33f98>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc6cc50>]
  Queued events: [<Request() object at 0x10cc6ca58>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc6cf60>]
  Queued events: [<Request() object at 0x10cc6c128>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc6cdd8>]
  Queued events: [<Request() object at 0x10cc2eb00>, <Request() obje
ct at 0x10cc33d30>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33f98>]
  Queued events: [<Request() object at 0x10cc3d978>, <Request() obje
ct at 0x10cc33860>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc6ca58>]
  Queued events: [<Request() object at 0x10cc734e0>, <Request() obje
ct at 0x10cc3d5c0>, <Request() object at 0x10cc3d0f0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc6c128>]
  Queued events: [<Request() object at 0x10cc2ef60>, <Request() obje
ct at 0x10cc3da20>, <Request() object at 0x10cc2eef0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc2eb00>]
  Queued events: [<Request() object at 0x10cc33d30>, <Request() obje
ct at 0x10cc3df60>, <Request() object at 0x10cc337f0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc3d978>]
  Queued events: [<Request() object at 0x10cc33860>, <Request() obje
ct at 0x10cc73898>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc734e0>]
  Queued events: [<Request() object at 0x10cc3d5c0>, <Request() obje
ct at 0x10cc3d0f0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc2ef60>]
  Queued events: [<Request() object at 0x10cc3da20>, <Request() obje
ct at 0x10cc2eef0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33d30>]
  Queued events: [<Request() object at 0x10cc3df60>, <Request() obje
ct at 0x10cc337f0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33860>]
  Queued events: [<Request() object at 0x10cc73898>]
1 of 1 slots are allocated.
```

```
  Users: [<Request() object at 0x10cc3d5c0>]
  Queued events: [<Request() object at 0x10cc3d0f0>, <Request() obje
ct at 0x10cc73dd8>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc3da20>]
  Queued events: [<Request() object at 0x10cc2eef0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc3df60>]
  Queued events: [<Request() object at 0x10cc337f0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc73898>]
  Queued events: [<Request() object at 0x10cc33ac8>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc3d0f0>]
  Queued events: [<Request() object at 0x10cc73dd8>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc2eef0>]
  Queued events: [<Request() object at 0x10cc79358>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc337f0>]
  Queued events: [<Request() object at 0x10cc794a8>, <Request() obje
ct at 0x10cc3d358>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33ac8>]
  Queued events: [<Request() object at 0x10cc4b358>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc73dd8>]
  Queued events: [<Request() object at 0x10cc79860>, <Request() obje
ct at 0x10cc3dc50>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc79358>]
  Queued events: [<Request() object at 0x10cc3d240>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc794a8>]
  Queued events: [<Request() object at 0x10cc3d358>, <Request() obje
ct at 0x10cc799b0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b358>]
  Queued events: [<Request() object at 0x10cc79b00>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc3d240>]
  Queued events: [<Request() object at 0x10cc79da0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc79860>]
  Queued events: [<Request() object at 0x10cc3dc50>, <Request() obje
ct at 0x10cc2e9b0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc3d358>]
  Queued events: [<Request() object at 0x10cc799b0>, <Request() obje
ct at 0x10cc79ef0>]
```

```
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc79b00>]
  Queued events: [<Request() object at 0x10cc80080>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc3dc50>]
  Queued events: [<Request() object at 0x10cc2e9b0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc79da0>]
  Queued events: [<Request() object at 0x10cc801d0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc799b0>]
  Queued events: [<Request() object at 0x10cc79ef0>]
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc80080>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc2e9b0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc801d0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc79ef0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc80cc0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33710>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc87048>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc3d940>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc0e550>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33b70>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc80cc0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc333c8>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc87710>]
```

```
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc87c88>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc3d898>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33ba8>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc0e780>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc80cc0>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33b70>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc33eb8>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc8c710>]
  Queued events: []
1 of 1 slots are allocated.
  Users: [<Request() object at 0x10cc4b588>]
  Queued events: []
avg_time
11.46897190512373
```

I implemented the assignment of passenger to the shortest queue for personal scanning. After running the code several times, it can be seen that using 4 scanners and 4 checkers we can keep the average wait time below 15 minutes. The time varies between 12 - 15 minutes on each run of the code.

In [4]:

```
# install.packages("FrF2")
library(FrF2)

features = c("dishwasher", "car-parking", "high-speed-internet",
             "wooden-flooring", "elevator", "gym",
             "central-ac", "good-schools", "backyard", "in-house laundry")

FrF2(16, factor.names = features)
```

dishwasher	car.parking	high.speed.internet	wooden.flooring	elevator	gym	centra
1	1	1	1	1	1	1
-1	1	-1	1	-1	1	-1
1	-1	-1	-1	-1	-1	1
1	1	1	-1	1	1	1
1	-1	1	-1	-1	1	-1
1	-1	1	1	-1	1	-1
-1	-1	1	-1	1	-1	-1
-1	-1	-1	-1	1	1	1
1	1	-1	1	1	-1	-1
1	1	-1	-1	1	-1	-1
-1	-1	-1	1	1	1	1
-1	-1	1	1	1	-1	-1
-1	1	-1	-1	-1	1	-1
-1	1	1	-1	-1	-1	1
1	-1	-1	1	-1	-1	1