**Question 12.1**

**Describe a situation or problem from your job, everyday life, current events, etc., for which a design of experiments approach would be appropriate.**

Answer: My spouse works in a truck manufacturing company. They are launching a new program called the preventive maintenance program. This program involves selling maintenance services required for a given number of years. Two different formats were made for the same program. The first one includes selling the number of maintenances for a given time and mileage and the second one selling number of services for given period of time. These two formats were tested out with 30 different dealership out of the available 500 dealership. Each dealership would receive only one of the two formats and sales data was collected from the dealership for this program. All these dealerships had similar customer base and almost same number of customers. All these dealers were also ‘Elite Support’ which means they are all highly skilled salesman and technicians. Based on the sales information collected it was found that format number 2 which was number of services in a given period of time was far more popular than the format number 1.

**Question 12.2**

**To determine the value of 10 different yes/no features to the market value of a house (large yard, solar roof, etc.), a real estate agent plans to survey 50 potential buyers, showing a fictitious house with different combinations of features. To reduce the survey size, the agent wants to show just 16 fictitious houses. Use R’s FrF2 function (in the FrF2 package) to find a fractional factorial design for this experiment: what set of features should each of the 16 fictitious houses have? Note: the output of FrF2 is “1” (include) or “-1” (don’t include) for each feature.**

Answer:

Code:

*rm(list = ls())*

*set.seed(1)*

*install.packages("kableExtra")*

*install.packages("FrF2")*

*library(FrF2)*

*library(kableExtra)*

*FirstDesign <- FrF2(nruns = 16, nfactors = 10)*

*kable(FirstDesign)*

Output:

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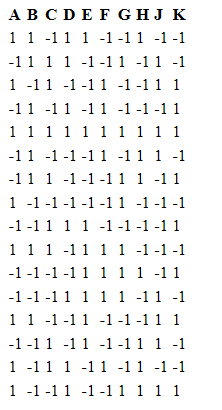
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Converting the above output into an HTML view





Let’s rename the columns to more understandable factor names – home features that have binary (-1 or 1) categorical values.

Code:

*knitr::kable(FirstDesign,*

*col.names = c("A"="Media Room",*

*"B"="Jacuzi",*

*"C"="Campfire Place",*

*"D"="Garrage BBQ",*

*"E"="Garden Sprinklers",*

*"F"="Property Tax",*

*"G"="Lawn",*

*"H"="Terrace",*

*"J"="Petrolium",*

*"K"="Solar Panels"))*

Output:

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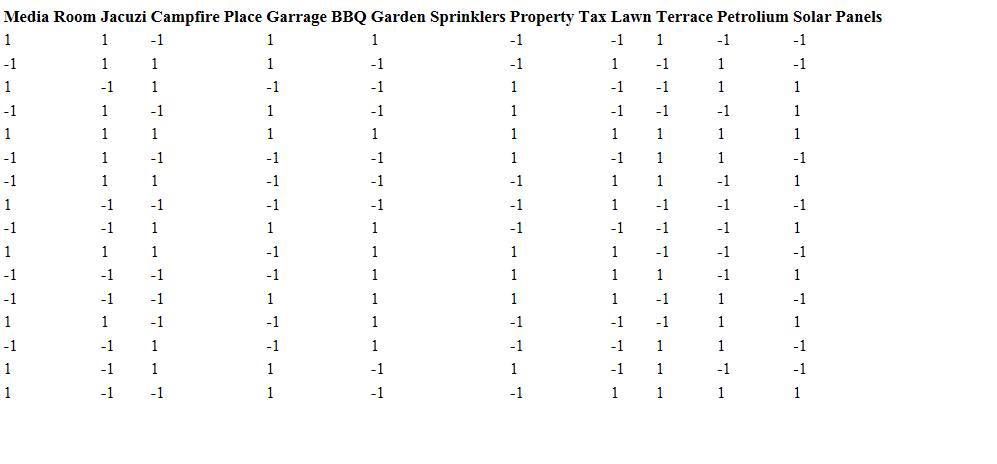
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Let’s try with a different seed

Code:

*set.seed(40)*

*SecondDesign <- FrF2(nruns = 16, nfactors = 10)*

*knitr::kable(SecondDesign,*

*col.names = c("A"="Media Room",*

*"B"="Jacuzi",*

*"C"="Campfire Place",*

*"D"="Garrage BBQ",*

*"E"="Garden Sprinklers",*

*"F"="Property Tax",*

*"G"="Lawn",*

*"H"="Terrace",*

*"J"="Petrolium",*

*"K"="Solar Panels"))*

Output:

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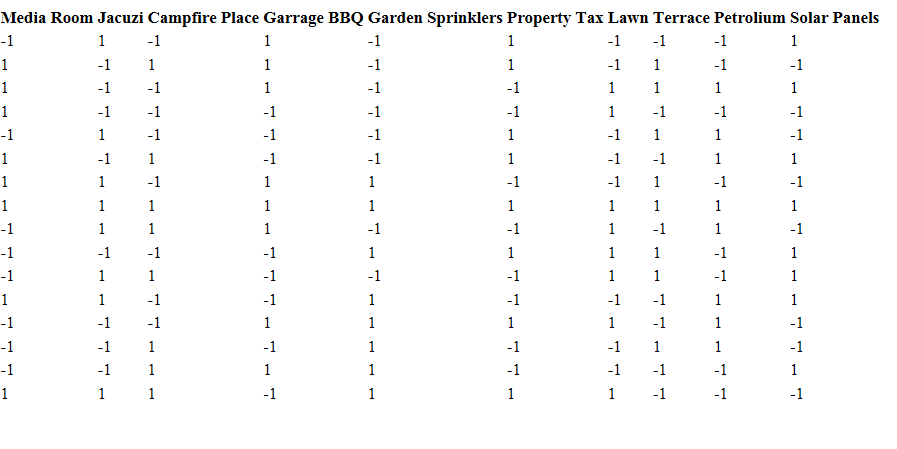
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If we were to look at every possible combination of each of the factors n=10  we would have ‘2 to the power n’ = ‘2 to the power 10’ = 1024 possible combinations, which demonstrates the significance of Design Of Experiments.

**Question 13.1**

**For each of the following distributions, give an example of data that you would expect to follow this distribution (besides the examples already discussed in class).**

**a. Binomial**

**b. Geometric**

**c. Poisson**

**d. Exponential**

**e. Weibull**

Answer:

**Binomial**: In genetic studies the existence of a particular mutation of a chromosome follows binomial distribution. (Yes or No).

**Geometric**: H-1B visa lottery in United States of America follows Geometric distribution. A candidate is eligible for a lottery till he/she wins it.

**Poisson**: Total number of migrants from rural areas to urban areas might follow Poissons distribution.

**Exponential**: Total number of customers arriving at a bank in the interval of 1-minute.

**Weibull:** Weibull distribution is often used in Engine reliability analysis. The analysts use the early life failures of the engines of a particular population (for instance engines manufactured in year 2018) to predict what percentage of engines will experience a failure at a certain point in their life. So using Weibull distribution can help predict what percentage of engines made in 2018 will fail by June 2020.

**Question 13.2**

In this problem you, can simulate a simplified airport security system at a busy airport. Passengers arrive according to a Poisson distribution with λ1 = 5 per minute (i.e., mean interarrival rate 1 = 0.2 minutes) to the ID/boarding-pass check queue, where there are several servers who each have exponential service time with mean rate 2 = 0.75 minutes. [Hint: model them as one block that has more than one resource.] After that, the passengers are assigned to the shortest of the several personal-check queues, where they go through the personal scanner (time is uniformly distributed between 0.5 minutes and 1 minute).

Use the Arena software (PC users) or Python with SimPy (PC or Mac users) to build a simulation of the system, and then vary the number of ID/boarding-pass checkers and personal-check queues to determine how many are needed to keep average wait times below 15 minutes. [If you’re using SimPy, or if you have access to a non-student version of Arena, you can use λ1 = 50 to simulate a busier airport.]

Answer: Given below is the solution using SimPy in python

Code:





*import random*

*import simpy*

*from statistics import mean*

*Total\_Checkers = 4*

*Total\_Scanners = 4*

*Traffic = 5*

*RateOfChecking = 0.75*

*MinimumTimeToScan = 0.5*

*MaximumTimeToScan = 1.0*

*RunTime = 600*

*total\_duration=0*

*total\_passengers=0*

*total\_passenger\_arrived = 0*

*Avg\_Checking\_Time = dict()*

*Avg\_Scanning\_Time = dict()*

*mean\_of\_time = dict()*

*###########*

*class AirportSimulation(object):*

*def \_\_init\_\_(self, envmt, Total\_Checkers , Total\_Scanners ):*

*self.envmt = envmt*

*self.checker = simpy.Resource(envmt, Total\_Checkers )*

*self.scanner = simpy.Resource(envmt, Total\_Scanners )*

*def check\_process(self, passenger):*

*check\_process\_duration=random.expovariate(1/RateOfChecking)*

*yield self.envmt.timeout(check\_process\_duration)*

*def scan\_process(self, passenger):*

*scan\_duration=random.uniform( MinimumTimeToScan , MaximumTimeToScan )*

*yield self.envmt.timeout(scan\_duration)*

*def Passenger\_Info( envmt, passenger\_number, ap ):*

*global total\_passengers*

*global total\_passenger\_arrived*

*Arrivaltime = envmt.now*

*print('Passenger # %s arrival time is %.2f.' % (passenger\_number, Arrivaltime ))*

*total\_passenger\_arrived = max(total\_passenger\_arrived, passenger\_number)*

*with ap.checker.request() as request:*

*yield request*

*yield envmt.process(ap.check\_process(passenger\_number))*

*Check\_time = envmt.now*

*print('Passenger # %s Check-in time is at %.2f.' % (passenger\_number, Check\_time ))*

*with ap.scanner.request() as request:*

*yield request*

*yield envmt.process(ap.scan\_process(passenger\_number))*

*Endtime = envmt.now*

*print('Passenger # %s scanning time is %.2f.' % (passenger\_number, Endtime ))*

*passage\_time = Endtime - Arrivaltime*

*checking\_time = Check\_time - Arrivaltime*

*scanning\_time = Endtime - Check\_time*

*Avg\_Checking\_Time[passenger\_number] = checking\_time*

*Avg\_Scanning\_Time[passenger\_number] = scanning\_time*

*mean\_of\_time[passenger\_number] = passage\_time*

*total\_passengers = total\_passengers+1*

*def setup(envmt, ap ):*

*i=0*

*while True:*

*time\_between\_arrivals=random.expovariate(Traffic)*

*yield envmt.timeout(time\_between\_arrivals)*

*i =i+ 1*

*envmt.process(Passenger(envmt, i , ap) )*

*random.seed(40)*

*envmt = simpy.Environment()*

*print('Define airport instance')*

*airport = AirportSimulation(envmt, Total\_Checkers, Total\_Scanners)*

*envmt.process(setup(envmt, airport ))*

*envmt.run(until=RunTime)*

*print('\n')*

*print("------------------------------")*

*print('Summary')*

*print("Total Number of Checkers : {}".format(Total\_Checkers))*

*print("Total Number of Scanners : {}".format(Total\_Scanners))*

*print("Total Number of Pessenger per Minute: {} ".format(Traffic))*

*print("Total Time Taken to Simulate : {}".format(RunTime))*

*print("Number of Passengers arrived : {} ".format(total\_passenger\_arrived) )*

*print("Passengers Covered : {}".format(total\_passengers))*

*print("Passenters Waiting : {}".format(total\_passenger\_arrived - total\_passengers))*

*print("Average Checking Time (minutes) : {}".format(round(mean(Avg\_Checking\_Time.values()),3)))*

*print("Average Scanning Time (minutes): {}".format(round(mean(Avg\_Scanning\_Time.values()),3)))*

*print("Average total time spent (minutes): {}".format(round(mean(mean\_of\_time.values()),3)))*

*print("Maximum time spent (minutes): {}".format(round(max(mean\_of\_time.values()),2)))*

*print("Minimum time spent (minutes): {}".format(round(min(mean\_of\_time.values()),2)))*

Output

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Passenger # 2978 arrival time is 591.45.

Passenger # 2976 Check-in time is at 591.54.

Passenger # 2977 Check-in time is at 591.60.

Passenger # 2979 arrival time is 591.66.

Passenger # 2980 arrival time is 591.72.

Passenger # 2975 Check-in time is at 591.72.

Passenger # 2980 Check-in time is at 591.82.

Passenger # 2970 Check-in time is at 591.88.

Passenger # 2981 arrival time is 591.89.

Passenger # 2974 scanning time is 591.92.

Passenger # 2967 scanning time is 591.95.

Passenger # 2982 arrival time is 591.99.

Passenger # 2968 scanning time is 592.10.

Passenger # 2983 arrival time is 592.14.

Passenger # 2978 Check-in time is at 592.18.

Passenger # 2984 arrival time is 592.27.

Passenger # 2973 scanning time is 592.28.

Passenger # 2985 arrival time is 592.38.

Passenger # 2986 arrival time is 592.53.

Passenger # 2972 scanning time is 592.56.

Passenger # 2976 scanning time is 592.68.

Passenger # 2977 scanning time is 592.70.

Passenger # 2987 arrival time is 592.74.

Passenger # 2988 arrival time is 592.78.

Passenger # 2975 scanning time is 592.80.

Passenger # 2989 arrival time is 592.87.

Passenger # 2981 Check-in time is at 593.05.

Passenger # 2990 arrival time is 593.08.

Passenger # 2984 Check-in time is at 593.09.

Passenger # 2982 Check-in time is at 593.15.

Passenger # 2980 scanning time is 593.22.

Passenger # 2983 Check-in time is at 593.36.

Passenger # 2991 arrival time is 593.38.

Passenger # 2978 scanning time is 593.46.

Passenger # 2970 scanning time is 593.49.

Passenger # 2981 scanning time is 593.66.

Passenger # 2979 Check-in time is at 593.70.

Passenger # 2988 Check-in time is at 593.77.

Passenger # 2992 arrival time is 593.81.

Passenger # 2986 Check-in time is at 594.09.

Passenger # 2983 scanning time is 594.12.

Passenger # 2982 scanning time is 594.17.

Passenger # 2984 scanning time is 594.17.

Passenger # 2993 arrival time is 594.25.

Passenger # 2987 Check-in time is at 594.43.

Passenger # 2979 scanning time is 594.44.

Passenger # 2994 arrival time is 594.49.

Passenger # 2989 Check-in time is at 594.52.

Passenger # 2995 arrival time is 594.53.

Passenger # 2988 scanning time is 594.71.

Passenger # 2996 arrival time is 594.79.

Passenger # 2987 scanning time is 594.94.

Passenger # 2991 Check-in time is at 595.02.

Passenger # 2986 scanning time is 595.08.

Passenger # 2997 arrival time is 595.13.

Passenger # 2985 Check-in time is at 595.21.

Passenger # 2990 Check-in time is at 595.30.

Passenger # 2998 arrival time is 595.31.

Passenger # 2999 arrival time is 595.32.

Passenger # 2989 scanning time is 595.32.

Passenger # 3000 arrival time is 595.50.

Passenger # 3001 arrival time is 595.54.

Passenger # 2991 scanning time is 595.73.

Passenger # 2985 scanning time is 595.90.

Passenger # 2993 Check-in time is at 595.94.

Passenger # 3002 arrival time is 596.00.

Passenger # 3003 arrival time is 596.03.

Passenger # 3004 arrival time is 596.06.

Passenger # 3005 arrival time is 596.20.

Passenger # 2990 scanning time is 596.25.

Passenger # 3006 arrival time is 596.37.

Passenger # 2993 scanning time is 596.59.

Passenger # 2996 Check-in time is at 596.61.

Passenger # 2992 Check-in time is at 596.64.

Passenger # 2994 Check-in time is at 596.77.

Passenger # 2995 Check-in time is at 596.86.

Passenger # 2997 Check-in time is at 596.86.

Passenger # 3007 arrival time is 597.03.

Passenger # 2999 Check-in time is at 597.04.

Passenger # 3001 Check-in time is at 597.05.

Passenger # 3008 arrival time is 597.11.

Passenger # 3002 Check-in time is at 597.12.

Passenger # 2996 scanning time is 597.21.

Passenger # 2998 Check-in time is at 597.54.

Passenger # 2994 scanning time is 597.55.

Passenger # 3003 Check-in time is at 597.58.

Passenger # 2992 scanning time is 597.59.

Passenger # 3006 Check-in time is at 597.60.

Passenger # 3009 arrival time is 597.62.

Passenger # 2995 scanning time is 597.69.

Passenger # 2997 scanning time is 597.73.

Passenger # 3000 Check-in time is at 597.92.

Passenger # 3005 Check-in time is at 598.10.

Passenger # 3008 Check-in time is at 598.11.

Passenger # 3010 arrival time is 598.13.

Passenger # 2999 scanning time is 598.22.

Passenger # 3001 scanning time is 598.33.

Passenger # 3011 arrival time is 598.48.

Passenger # 3002 scanning time is 598.51.

Passenger # 3010 Check-in time is at 598.60.

Passenger # 2998 scanning time is 598.61.

Passenger # 3004 Check-in time is at 598.77.

Passenger # 3012 arrival time is 598.83.

Passenger # 3003 scanning time is 598.84.

Passenger # 3007 Check-in time is at 598.93.

Passenger # 3006 scanning time is 598.93.

Passenger # 3009 Check-in time is at 599.14.

Passenger # 3000 scanning time is 599.21.

Passenger # 3013 arrival time is 599.48.

Passenger # 3013 Check-in time is at 599.48.

Passenger # 3008 scanning time is 599.50.

Passenger # 3014 arrival time is 599.53.

Passenger # 3005 scanning time is 599.53.

Passenger # 3011 Check-in time is at 599.64.

Passenger # 3010 scanning time is 599.70.

Passenger # 3012 Check-in time is at 599.73.

Passenger # 3014 Check-in time is at 599.78.

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Summary

Total Number of Checkers : 4

Total Number of Scanners : 4

Total Number of Pessenger per Minute: 5

Total Time Taken to Simulate : 600

Number of Passengers arrived : 3014

Passengers Covered : 3007

Passenters Waiting : 7

Average Checking Time (minutes) : 2.727

Average Scanning Time (minutes): 2.271

Average total time spent (minutes): 4.997

Maximum time spent (minutes): 12.64

Minimum time spent (minutes): 0.61

The dictionaries Avg\_Checking\_Time, Avg\_Scanning\_Time and mean\_of\_time will have the data as explained below

Avg\_Checking\_Time= Average Checking time for boarding-pass

Avg\_Scanning\_Time= Average scanning time per passenger

Mean\_of\_time= Average of Total time ( waiting + checking + scanning)

It can be observed that using 4 checkers and 4 scanners the average wait time comes to 12.64 minutes. It varies between 12-15 minutes.