Final Project

March 14, 2025

[1299]:
```
using DataFrames #for data wrangling
using StatsPlots #for plotting
using Turing #for MCMC
using CSV #CSV import
using Random #data generation (if required)
using Distributions
using LogExpFunctions #for logistic function
```

Import Data

[1300]:
```
#this is a local document, but i've also saved a slightly cleaned up version in␣
↪github with the same "valveTestRaw" title
valveData = CSV.read("./Results of New Valve Tests.csv", DataFrame)
```

	Vendor	Population	Rejected	High Pop	% Over Set	% Over Limit	Set Pressure	
	String1	Int64	Int64	Int64	String7	String7	Int64?	
1	a	9	2	1	10.00%	4.30%	35	...
2	b	13	0	0	0.00%	0.00%	*missing*	...
3	c	85	1	1	13.00%	9.70%	175	...
4	d	108	21	4	4.50%	1.50%	350	...
5	e	1	0	0	0.00%	0.00%	*missing*	...
6	f	55	9	2	5.50%	2.50%	400	...
7	g	41	5	2	6.70%	3.30%	165	...
8	h	2	0	0	0.00%	0.00%	*missing*	...
9	z	40	6	1	24.00%	20.00%	165	...
10	k	1	0	0	0.00%	0.00%	*missing*	...
11	y	66	4	4	6.00%	3.00%	100	...
12	m	54	6	1	27.00%	24.00%	75	...
13	m	14	7	3	10.00%	3.00%	80	...
14	n	1	0	0	0.00%	0.00%	*missing*	...
15	o	3	0	0	0.00%	0.00%	*missing*	...
16	p	3	0	0	0.00%	0.00%	*missing*	...
17	r	38	7	1	6.80%	4.00%	250	...
18	s	8	0	0	0.00%	0.00%	*missing*	...
19	x	18	2	1	6.30%	1.20%	175	...

Collect Number of Trials & Separate into Service Mediums

[1301]:
```
serviceMediums = ["steam", "air", "liquid", "air/liquid", "na"]
mediumDF = Dict()
vendorDF = Dict()

for medium in serviceMediums
    mediumDF = merge(Dict(medium => filter(:Service => ==(medium), valveData)),␣
 ↪mediumDF)
    vendorDF = merge(Dict(medium => mediumDF[medium][:, 1]), vendorDF)
end

vendorDF["steam"]
```

```
6-element Vector{String1}:
 "a"
 "c"
 "g"
 "z"
 "k"
 "m"
```

Set Up Model

[1302]:
```
@model function valveTesting(Vendors, Population, rejects) # highpops␣
 ↪serviceMedium)
    #additional functionality can be added to this, especially when considering␣
 ↪that the probability of failing (p-1) is the sum of the probability of␣
 ↪failing on a low pop (less dangerous) & a high pop (more dangerous)



    #hyper prior
     _bar ~ Normal(-2, 2) #best first guess is that most valves are unlikely to␣
 ↪fail, possibly with large spread
      ~ Exponential(1) #allow possibility of large std dev in data

     = Vector{Real}(undef, length(Vendors))

    for i in 1:length(Vendors)
         [i] ~ Normal( _bar,  ) #assume that the logit(probability) is␣
 ↪distributed normally for each vendor
    end

    for i in 1:length(Vendors)

        #prior
        n = Population[i] #number of trials for binomial function
        p = logistic( [i]) #force p (probability of failure) to be 0<p<1
        #distribution of values failing given fail probability p and n trials
```

```
        rejects[i] ~ Binomial(n, p) #binomial distribution used (most␣
↪appropriate since measuring probability of failure given trial data)
    end
end
```

```
valveTesting (generic function with 2 methods)
```

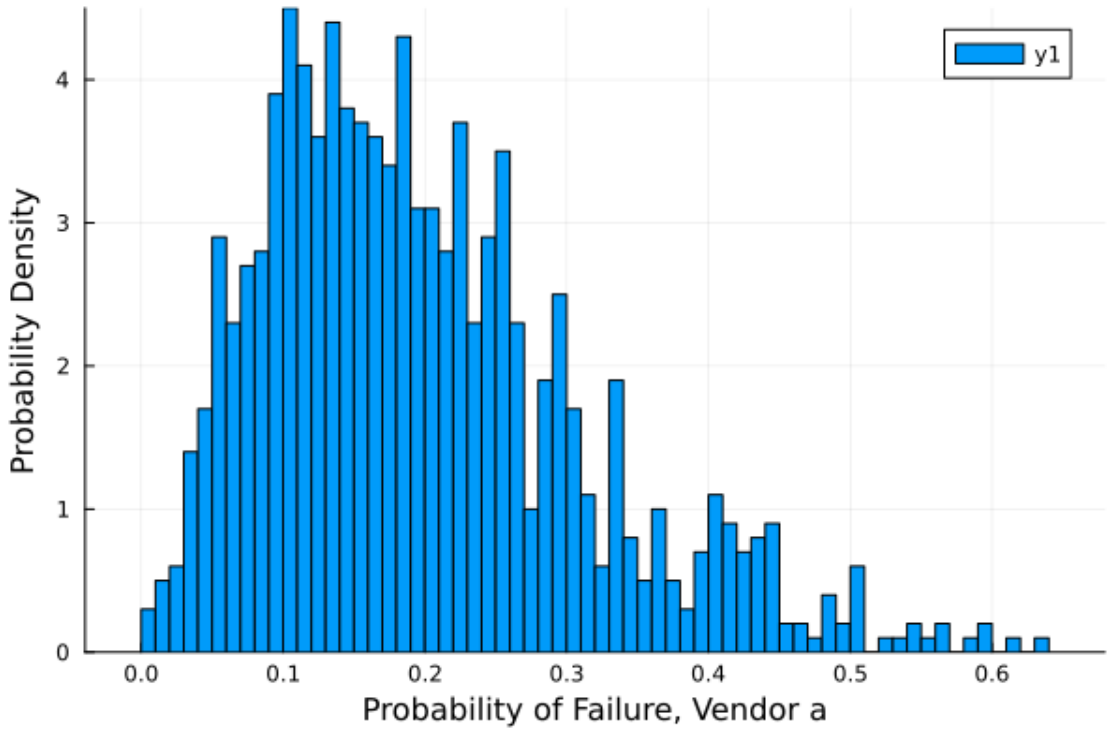
Implement Model

[1303]:
```
model = Dict()
posterior = Dict()
posteriorDF = Dict()
for medium in serviceMediums
  model = merge(Dict(medium => valveTesting(mediumDF[medium][:,1],␣
↪mediumDF[medium][:,2], mediumDF[medium][:,3])), model)
  posterior = merge(Dict(medium => sample(model[medium], NUTS(), 1000)),␣
↪posterior)
  posteriorDF = merge(Dict(medium => DataFrame(posterior[medium])), posteriorDF)
end
```

Process Data

[ ]:
```
dataProcessed = Dict()
plots = Dict()
for medium in serviceMediums
    vendorProcessed = Dict()
    vendorPlots = Dict()
    for i in 1:length(vendorDF[medium])
        #recover probability of a valve from this vendor & service medium␣
↪failing an initial pop test
        vendorLog = zeros(nrow(posteriorDF[medium]))
        for j in 1:nrow(posteriorDF[medium])
            vendorLog[j] = logistic(posteriorDF[medium][j, " [$i]"])
        end
        vendorProcessed = merge(Dict(vendorDF[medium][i] => vendorLog),␣
↪vendorProcessed)
        vendorPlot = histogram(vendorProcessed[vendorDF[medium][i]][:], xlab =␣
↪"Probability of Failure, Vendor " * vendorDF[medium][i], ylab = "Probability␣
↪Density", normalize=:pdf, bins=101)
        vendorPlots = merge(Dict(vendorDF[medium][i] => vendorPlot),␣
↪vendorPlots)
    end
    dataProcessed = merge(Dict(medium => vendorProcessed), dataProcessed)
    plots = merge(Dict(medium => vendorPlots), plots)
end
```

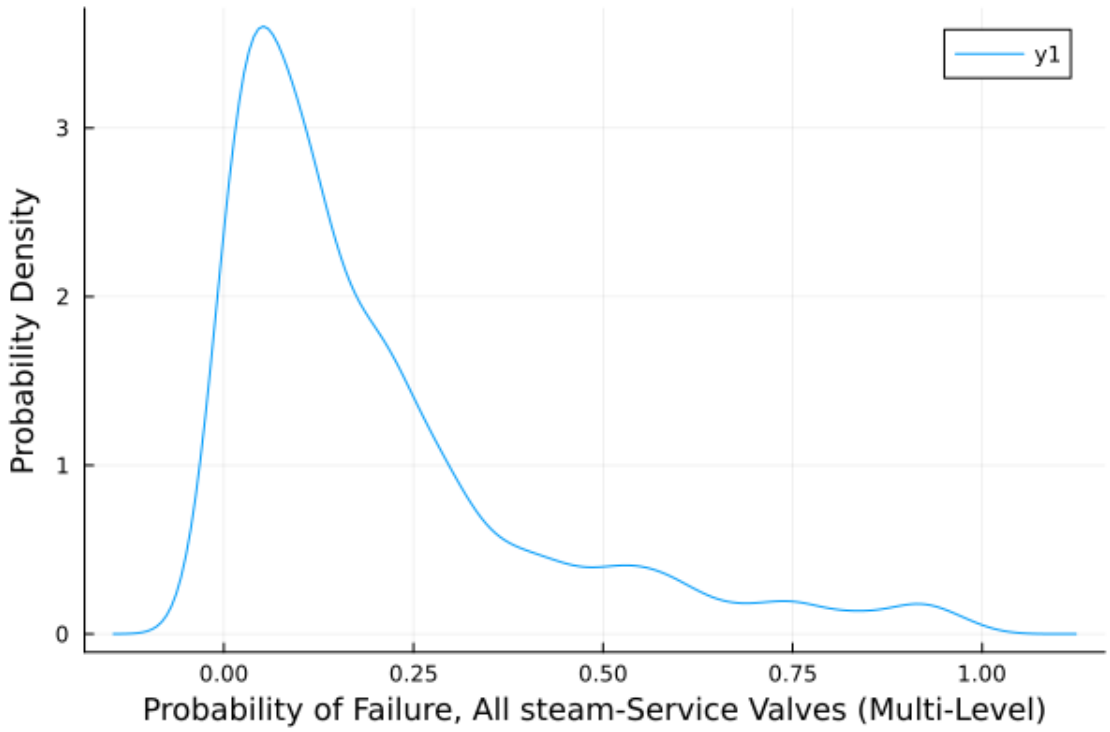
```
#histogram(dataProcessed["steam"][vendorDF["steam"][1]], xlab = "Probability of␣
 ↪Failure, Vendor " * vendorDF["steam"][1], ylab = "Probability Density",␣
 ↪normalize=:pdf, bins=101)
plot(plots["steam"]["a"])
```



Predict Valve Failure

[1305]:
```
mediumPDF = Dict()
for medium in serviceMediums
  mediumLogodds = rand.(Normal.(posteriorDF[medium]._bar[1:1000],␣
 ↪posteriorDF[medium].[1:1000]))
  mediumPDF = merge(Dict(medium => logistic.(mediumLogodds)), mediumPDF)
end

predict_plot = plot(xlab="Probability of Failure, All " * serviceMediums[1] *␣
 ↪"-Service Valves (Multi-Level)", ylab="Probability Density")
density!(mediumPDF["steam"])
```


y1
Probability Density
0
1
2
3
0.00
0.25
0.50
0.75
1.00
Probability of Failure, All steam-Service Valves (Multi-Level)