Master Thesis Round Four

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# FLOW Vs SPEED + DENSITY

# Sunday March 27th 2022

Masters\_Research\_Final\_for\_Modelling =   
 read\_excel("Masters Research Final for Modelling.xls",   
 sheet = "Only\_Data")  
  
LOS\_A = subset(Masters\_Research\_Final\_for\_Modelling,  
 subset = (LOS == "A") )  
  
  
summary(flow\_model <-   
 lm(data = LOS\_A,   
 formula = log(Flow) ~   
 0 + log(Speed) + log(Density) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed) + log(Density), data = LOS\_A)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -5.4152 -0.2565 0.3354 0.5969 1.1138   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed) 0.43660 0.01307 33.413 <2e-16 \*\*\*  
## log(Density) 0.12082 0.04870 2.481 0.0133 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.9189 on 812 degrees of freedom  
## Multiple R-squared: 0.8298, Adjusted R-squared: 0.8293   
## F-statistic: 1979 on 2 and 812 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_A,   
 formula = log(Flow) ~   
 0 + log(Speed^(-1)) + log( Density^(-1) ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^(-1)) + log(Density^(-1)),   
## data = LOS\_A)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -5.4152 -0.2565 0.3354 0.5969 1.1138   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^(-1)) -0.43660 0.01307 -33.413 <2e-16 \*\*\*  
## log(Density^(-1)) -0.12082 0.04870 -2.481 0.0133 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.9189 on 812 degrees of freedom  
## Multiple R-squared: 0.8298, Adjusted R-squared: 0.8293   
## F-statistic: 1979 on 2 and 812 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_A,   
 formula = log(Flow) ~   
 0 + log(Speed^2) + log( Density^2 ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^2) + log(Density^2), data = LOS\_A)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -5.4152 -0.2565 0.3354 0.5969 1.1138   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^2) 0.218298 0.006533 33.413 <2e-16 \*\*\*  
## log(Density^2) 0.060412 0.024350 2.481 0.0133 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.9189 on 812 degrees of freedom  
## Multiple R-squared: 0.8298, Adjusted R-squared: 0.8293   
## F-statistic: 1979 on 2 and 812 DF, p-value: < 2.2e-16

LOS\_B = subset(Masters\_Research\_Final\_for\_Modelling,  
 subset = (LOS == "B") )  
  
  
summary(flow\_model <-   
 lm(data = LOS\_B,   
 formula = log(Flow) ~   
 0 + log(Speed) + log(Density) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed) + log(Density), data = LOS\_B)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.32787 -0.08753 0.00278 0.09487 0.55277   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed) 0.638710 0.002152 296.86 <2e-16 \*\*\*  
## log(Density) 0.193500 0.007808 24.78 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1273 on 980 degrees of freedom  
## Multiple R-squared: 0.9982, Adjusted R-squared: 0.9982   
## F-statistic: 2.685e+05 on 2 and 980 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_B,   
 formula = log(Flow) ~   
 0 + log(Speed^(-1)) + log( Density^(-1) ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^(-1)) + log(Density^(-1)),   
## data = LOS\_B)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.32787 -0.08753 0.00278 0.09487 0.55277   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^(-1)) -0.638710 0.002152 -296.86 <2e-16 \*\*\*  
## log(Density^(-1)) -0.193500 0.007808 -24.78 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1273 on 980 degrees of freedom  
## Multiple R-squared: 0.9982, Adjusted R-squared: 0.9982   
## F-statistic: 2.685e+05 on 2 and 980 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_B,   
 formula = log(Flow) ~   
 0 + log(Speed^2) + log( Density^2 ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^2) + log(Density^2), data = LOS\_B)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.32787 -0.08753 0.00278 0.09487 0.55277   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^2) 0.319355 0.001076 296.86 <2e-16 \*\*\*  
## log(Density^2) 0.096750 0.003904 24.78 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1273 on 980 degrees of freedom  
## Multiple R-squared: 0.9982, Adjusted R-squared: 0.9982   
## F-statistic: 2.685e+05 on 2 and 980 DF, p-value: < 2.2e-16

LOS\_C = subset(Masters\_Research\_Final\_for\_Modelling,  
 subset = (LOS == "C") )  
  
  
summary(flow\_model <-   
 lm(data = LOS\_C,   
 formula = log(Flow) ~   
 0 + log(Speed) + log(Density) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed) + log(Density), data = LOS\_C)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.36281 -0.08837 0.00353 0.09593 0.80893   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed) 0.723906 0.001373 527.3 <2e-16 \*\*\*  
## log(Density) 0.180601 0.004921 36.7 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1304 on 2301 degrees of freedom  
## Multiple R-squared: 0.9985, Adjusted R-squared: 0.9985   
## F-statistic: 7.528e+05 on 2 and 2301 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_C,   
 formula = log(Flow) ~   
 0 + log(Speed^(-1)) + log( Density^(-1) ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^(-1)) + log(Density^(-1)),   
## data = LOS\_C)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.36281 -0.08837 0.00353 0.09593 0.80893   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^(-1)) -0.723906 0.001373 -527.3 <2e-16 \*\*\*  
## log(Density^(-1)) -0.180601 0.004921 -36.7 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1304 on 2301 degrees of freedom  
## Multiple R-squared: 0.9985, Adjusted R-squared: 0.9985   
## F-statistic: 7.528e+05 on 2 and 2301 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_C,   
 formula = log(Flow) ~   
 0 + log(Speed^2) + log( Density^2 ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^2) + log(Density^2), data = LOS\_C)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.36281 -0.08837 0.00353 0.09593 0.80893   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^2) 0.3619530 0.0006864 527.3 <2e-16 \*\*\*  
## log(Density^2) 0.0903007 0.0024605 36.7 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1304 on 2301 degrees of freedom  
## Multiple R-squared: 0.9985, Adjusted R-squared: 0.9985   
## F-statistic: 7.528e+05 on 2 and 2301 DF, p-value: < 2.2e-16

LOS\_D = subset(Masters\_Research\_Final\_for\_Modelling,  
 subset = (LOS == "D") )  
  
  
summary(flow\_model <-   
 lm(data = LOS\_D,   
 formula = log(Flow) ~   
 0 + log(Speed) + log(Density) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed) + log(Density), data = LOS\_D)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.40416 -0.10115 0.00344 0.10031 0.59147   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed) 0.794091 0.001240 640.34 <2e-16 \*\*\*  
## log(Density) 0.228102 0.004389 51.97 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1382 on 3679 degrees of freedom  
## Multiple R-squared: 0.9986, Adjusted R-squared: 0.9986   
## F-statistic: 1.315e+06 on 2 and 3679 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_D,   
 formula = log(Flow) ~   
 0 + log(Speed^(-1)) + log( Density^(-1) ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^(-1)) + log(Density^(-1)),   
## data = LOS\_D)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.40416 -0.10115 0.00344 0.10031 0.59147   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^(-1)) -0.794091 0.001240 -640.34 <2e-16 \*\*\*  
## log(Density^(-1)) -0.228102 0.004389 -51.97 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1382 on 3679 degrees of freedom  
## Multiple R-squared: 0.9986, Adjusted R-squared: 0.9986   
## F-statistic: 1.315e+06 on 2 and 3679 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_D,   
 formula = log(Flow) ~   
 0 + log(Speed^2) + log( Density^2 ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^2) + log(Density^2), data = LOS\_D)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.40416 -0.10115 0.00344 0.10031 0.59147   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^2) 0.3970455 0.0006201 640.34 <2e-16 \*\*\*  
## log(Density^2) 0.1140510 0.0021944 51.97 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1382 on 3679 degrees of freedom  
## Multiple R-squared: 0.9986, Adjusted R-squared: 0.9986   
## F-statistic: 1.315e+06 on 2 and 3679 DF, p-value: < 2.2e-16

LOS\_E = subset(Masters\_Research\_Final\_for\_Modelling,  
 subset = (LOS == "E") )  
  
  
summary(flow\_model <-   
 lm(data = LOS\_E,   
 formula = log(Flow) ~   
 0 + log(Speed) + log(Density) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed) + log(Density), data = LOS\_E)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.31854 -0.10226 -0.01443 0.09951 0.90090   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed) 0.884396 0.001516 583.35 <2e-16 \*\*\*  
## log(Density) 0.190563 0.004893 38.95 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1436 on 2093 degrees of freedom  
## Multiple R-squared: 0.9987, Adjusted R-squared: 0.9987   
## F-statistic: 8.293e+05 on 2 and 2093 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_E,   
 formula = log(Flow) ~   
 0 + log(Speed^(-1)) + log( Density^(-1) ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^(-1)) + log(Density^(-1)),   
## data = LOS\_E)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.31854 -0.10226 -0.01443 0.09951 0.90090   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^(-1)) -0.884396 0.001516 -583.35 <2e-16 \*\*\*  
## log(Density^(-1)) -0.190563 0.004893 -38.95 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1436 on 2093 degrees of freedom  
## Multiple R-squared: 0.9987, Adjusted R-squared: 0.9987   
## F-statistic: 8.293e+05 on 2 and 2093 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_E,   
 formula = log(Flow) ~   
 0 + log(Speed^2) + log( Density^2 ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^2) + log(Density^2), data = LOS\_E)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.31854 -0.10226 -0.01443 0.09951 0.90090   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^2) 0.442198 0.000758 583.35 <2e-16 \*\*\*  
## log(Density^2) 0.095281 0.002446 38.95 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1436 on 2093 degrees of freedom  
## Multiple R-squared: 0.9987, Adjusted R-squared: 0.9987   
## F-statistic: 8.293e+05 on 2 and 2093 DF, p-value: < 2.2e-16

LOS\_F = subset(Masters\_Research\_Final\_for\_Modelling,  
 subset = (LOS == "F") )  
  
  
summary(flow\_model <-   
 lm(data = LOS\_F,   
 formula = log(Flow) ~   
 0 + log(Speed) + log(Density) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed) + log(Density), data = LOS\_F)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.27429 -0.08946 0.00480 0.10601 0.39052   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed) 0.952154 0.005897 161.46 <2e-16 \*\*\*  
## log(Density) 0.256514 0.018960 13.53 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.13 on 120 degrees of freedom  
## Multiple R-squared: 0.9991, Adjusted R-squared: 0.9991   
## F-statistic: 6.943e+04 on 2 and 120 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_F,   
 formula = log(Flow) ~   
 0 + log(Speed^(-1)) + log( Density^(-1) ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^(-1)) + log(Density^(-1)),   
## data = LOS\_F)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.27429 -0.08946 0.00480 0.10601 0.39052   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^(-1)) -0.952154 0.005897 -161.46 <2e-16 \*\*\*  
## log(Density^(-1)) -0.256514 0.018960 -13.53 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.13 on 120 degrees of freedom  
## Multiple R-squared: 0.9991, Adjusted R-squared: 0.9991   
## F-statistic: 6.943e+04 on 2 and 120 DF, p-value: < 2.2e-16

summary(flow\_model <-   
 lm(data = LOS\_F,   
 formula = log(Flow) ~   
 0 + log(Speed^2) + log( Density^2 ) ) )

##   
## Call:  
## lm(formula = log(Flow) ~ 0 + log(Speed^2) + log(Density^2), data = LOS\_F)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.27429 -0.08946 0.00480 0.10601 0.39052   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## log(Speed^2) 0.476077 0.002949 161.46 <2e-16 \*\*\*  
## log(Density^2) 0.128257 0.009480 13.53 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.13 on 120 degrees of freedom  
## Multiple R-squared: 0.9991, Adjusted R-squared: 0.9991   
## F-statistic: 6.943e+04 on 2 and 120 DF, p-value: < 2.2e-16