



# Optimization of Emergency Egress Doors in Road Tunnels



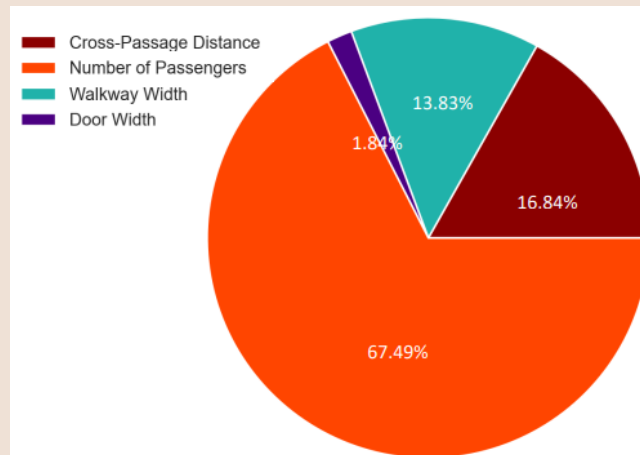
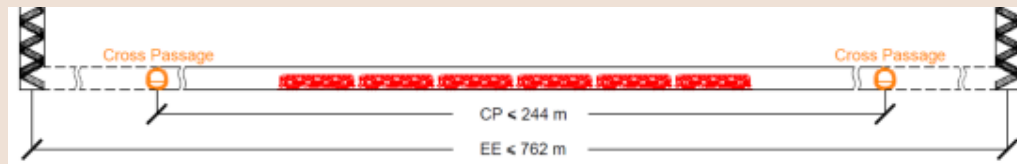
Basar Bulut, Leading Specialist | MIFireE

# AGENDA

- BACKGROUND STUDY
- MOTIVATION AND AIM OF THE STUDY
- MODEL SET-UP AND ASSUMPTIONS
- RESULTS
- DISCUSSION

# BACKGROUND STUDY

Where cross-passages are utilized in lieu of exits, cross-passages shall not be farther than 244m (800ft) [NFPA 130 - 6.3.1.6 (1)]



Evacuation Time

$$= 614.16 + (1.23 \cdot \text{dist\_CP}) + (-9.88 \cdot \text{ww}) + (-2.29 \cdot \text{dw}) + (1.40 \cdot \text{no\_ppl})$$

# MOTIVATION AND AIM OF THE STUDY

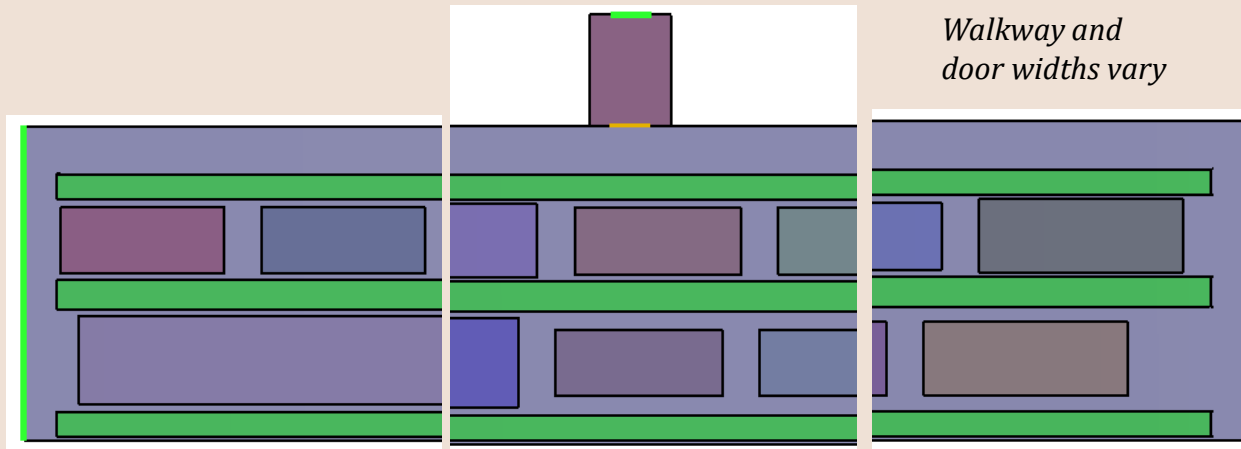
- Analyze the relation and importance of the variables.
- Analyze the effects of variables on evacuation time.
- Formulate evacuation time with the variables.
- Possible adjustments to the exit distances.

# Model Set-up

- Tunnel length: 1200 m
- Lane width: 3.7 m
- Variables:
  - 3 different tunnel model: 2, 3, 4-lane tunnel
  - distance between Cross-Passages: 300 m / 240 m / 200 m / 150 m / 120 m
  - walkway width: 1.2 m / 1.4 m / 1.6 m
  - width of exit door: 1.0 m / 1.1 m / 1.2 m
  - number of motorists: 1750 - 3250

# 2-Lane Tunnel

*3, 4, 5, 7, 9 cross-passages  
spread between portals*



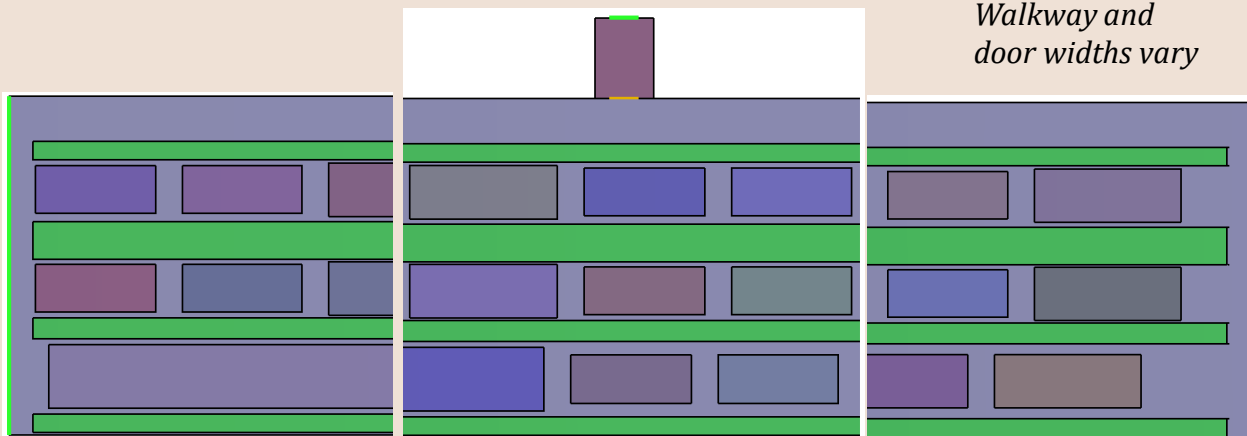
*Width of tunnel varies  
between 8.6 m – 9 m*

*Exit portal, for highly congested  
traffic condition is usable.*

2-LANE ROAD TUNNEL			
	Total number	Motorists per vehicle	Total number of motorists
Passenger vehicle	238	1,4	334
SUV	136	1,4	191
HGV	34	1	34
Bus	34	40	1360
TOTAL			1919

# 3-Lane Tunnel

*3, 4, 5, 7, 9 cross-passages  
spread between portals*



*Width of tunnel varies  
between 8.6 m – 9 m*

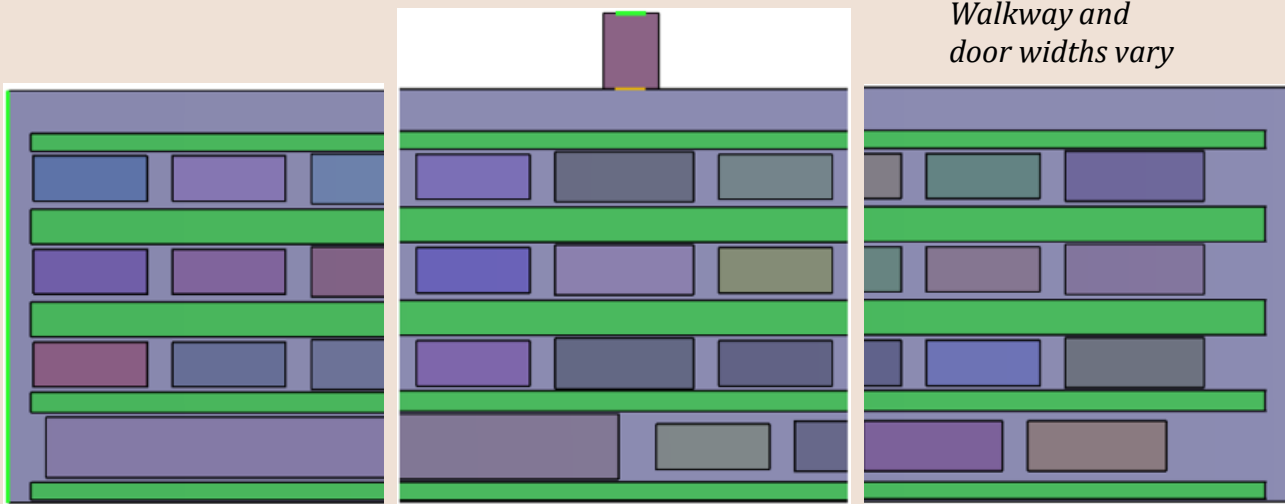
*Walkway and  
door widths vary*

*Exit portal, for flowing traffic  
condition is not usable.*

3-LANE ROAD TUNNEL			
	Total number	Motorists per vehicle	Total number of motorists
Passenger vehicle	476	1,4	667
SUV	272	1,4	381
HGV	34	1	34
Bus	34	40	1360
TOTAL			2442

# 4-Lane Tunnel

*3, 4, 5, 7, 9 cross-passages  
spread between portals*



*Width of tunnel varies  
between 16 m – 16.4 m*

*Walkway and  
door widths vary*

*Exit portal, for flowing traffic  
condition is not usable.*

**4-LANE ROAD TUNNEL**

	Total number	Motorists per vehicle	Total number of motorists
Passenger vehicle	714	1,4	1000
SUV	408	1,4	572
HGV	34	1	34
Bus	34	40	1360
TOTAL			2966



# Assumptions

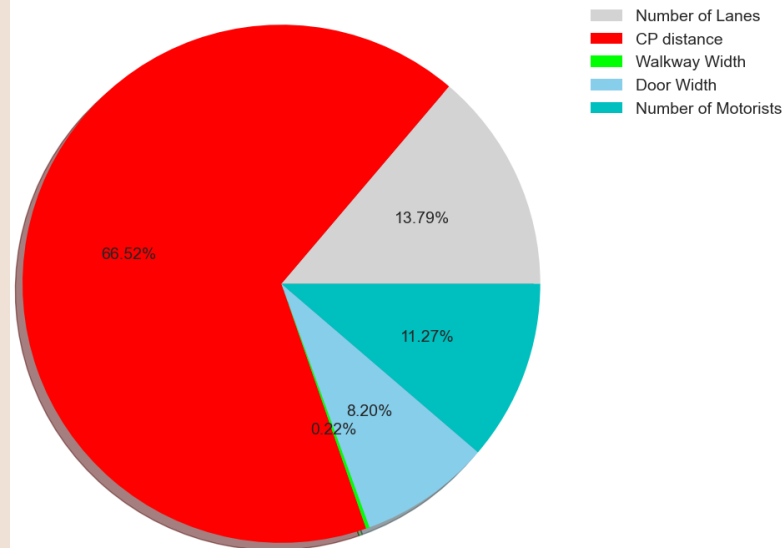
- Both portals can be used for Highly congested (almost stopped) traffic condition
- Exit portal can not be used for Flowing traffic condition
- Motorists walking speed not to exceed 0.62 m/s (37.7 m/min)
- Space between vehicles (0.5 m – 1 m)
- No pre-movement time is considered.
- 135 simulation for one case.

Number of Simulations				
	Number of lanes	Distance between cross-passages	walkway width	exit door width
	2	300	1,2	1
	3	240	1,4	1,1
	4	200	1,6	1,2
		150		
		120		
Number of variables	3	5	3	3

# Results – highly congested traffic

Data Analysis	SIMULATION DATA for highly congested traffic						Machine Learning Model
	no_lane	dist_CP	width_ww	width_ED	no_ppl	evac_time	
100% Values for Data Analysis	2	300	1,2	1	1962	834,7	67% / 70% / 80% Values for Train Dataset
	2	300	1,2	1,1	1817	676,5	
	2	300	1,2	1,2	2123	695,1	
	2	300	1,4	1	1949	887	
	2	300	1,4	1,1	2002	763,9	
	.	.	.	.	.	.	
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	.	.	.	.	.	.	
	3	240	1,6	1	2274	784,7	
	3	240	1,6	1,1	2387	735,9	
	3	240	1,6	1,2	2469	690,2	
	3	200	1,2	1	2433	740,9	33% / 30% / 20% Values for Test Dataset
	3	200	1,2	1,1	2637	655,6	
	3	200	1,2	1,2	2559	628,9	
	.	.	.	.	.	.	
	.	.	.	.	.	.	
	.	.	.	.	.	.	
	4	120	1,4	1,1	2965	492,3	
	4	120	1,4	1,2	3052	446,3	
	4	120	1,6	1	2779	518,8	
	4	120	1,6	1,1	2907	476,4	
	4	120	1,6	1,2	2999	427,2	

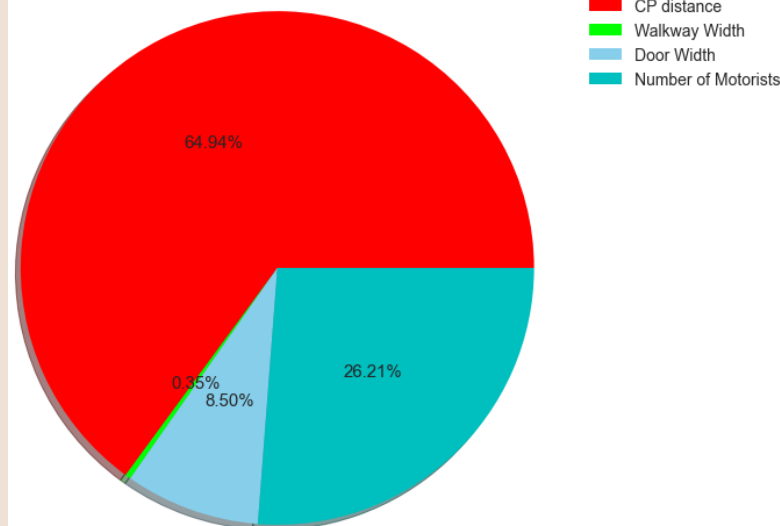
Importance Percentage of Variables for highly congested traffic



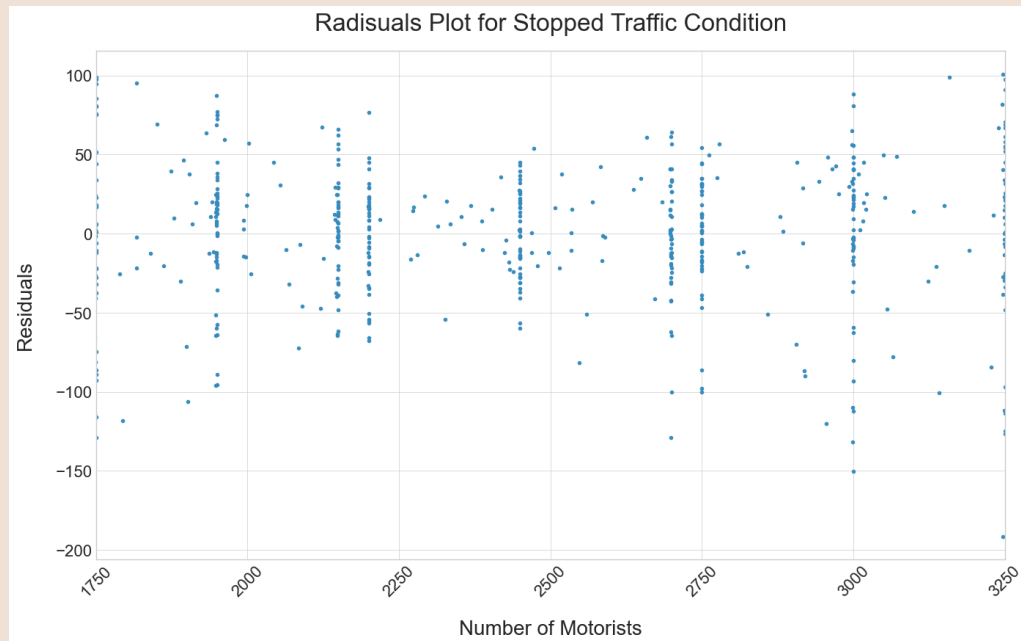
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Importance Percentage of Variables for highly congested traffic



# Results – highly congested traffic



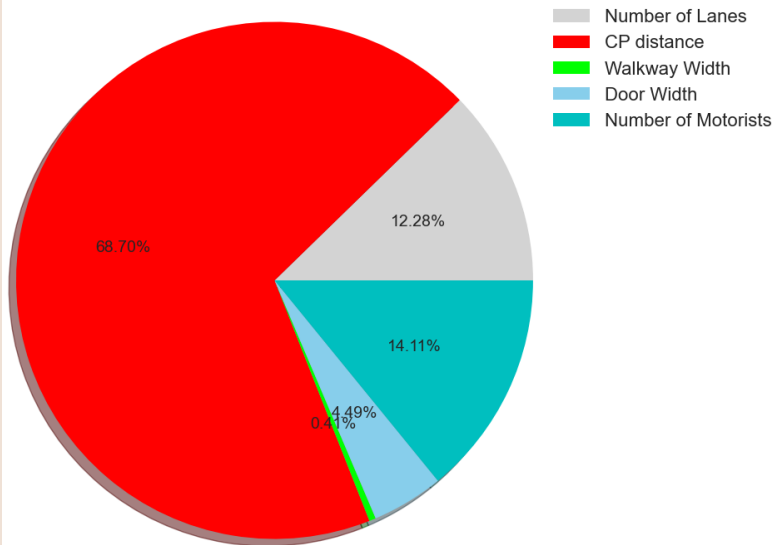
	coef	std err	R-squared:	0.965
Intercept	364.3563	32.585	Adj. R-squared:	0.965
dist_cp	2.9379	0.030	F-statistic:	3680.
width_ww	14.1543	11.673	Prob (F-statistic):	0.00
width_door	-860.1854	23.349	Log-Likelihood:	-2810.8
no_ppl	0.2505	0.004	AIC:	5632.
			BIC:	5653.

***Evacuation Time***<sub>highly congested traffic</sub>  
$$= 365.36 + (2.94 \cdot \text{dist\_CP}) + (14.15 \cdot \text{ww}) \\ + (-860.19 \cdot \text{dw}) + (0.25 \cdot \text{no\_ppl})$$

# Results – flowing traffic

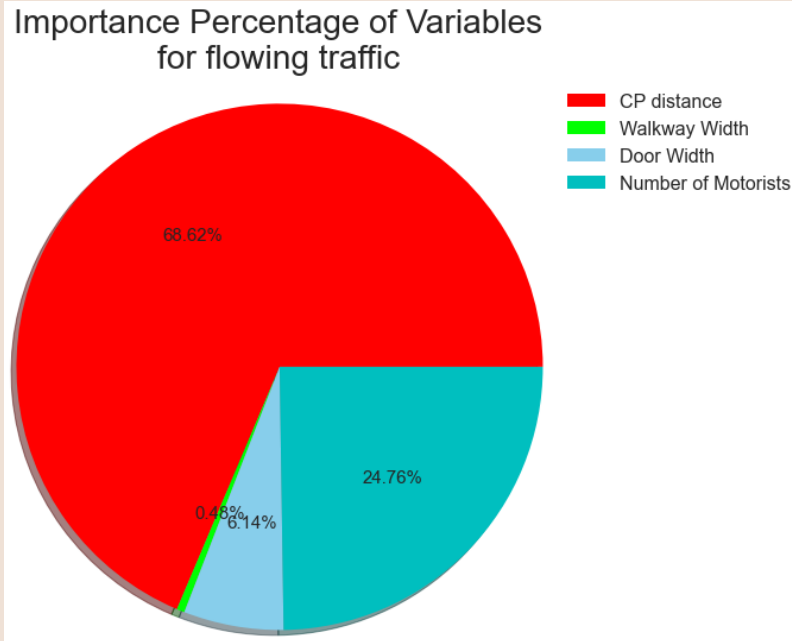
Data Analysis	SIMULATION DATA for flowing traffic						Machine Learning Model
	no_lane	dist_CP	width_ww	width_ED	no_ppl	evac_time	
100% Values for Data Analysis	2	300	1,2	1	1961	1283,8	67% / 70% / 80% Values for Train Dataset
	2	300	1,2	1,1	1817	991,8	
	2	300	1,2	1,2	2123	1034,3	
	2	300	1,4	1	1949	1224,6	
	2	300	1,4	1,1	2001	1119,1	
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	.	.	.	.	.	.	
	3	240	1,6	1	2423	1224,4	
	3	240	1,6	1,1	2418	1056,4	33% / 30% / 20% Values for Test Dataset
	3	240	1,6	1,2	2458	938,6	
	3	200	1,2	1	2509	1090,5	
	3	200	1,2	1,1	2596	994,6	
	3	200	1,2	1,2	2642	901,1	
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	4	120	1,4	1,1	2975	668,6	
	4	120	1,4	1,2	3022	607,3	
	4	120	1,6	1	3106	786,9	
	4	120	1,6	1,1	3189	712,4	
	4	120	1,6	1,2	3237	649,2	

Importance Percentage of Variables  
for flowing traffic

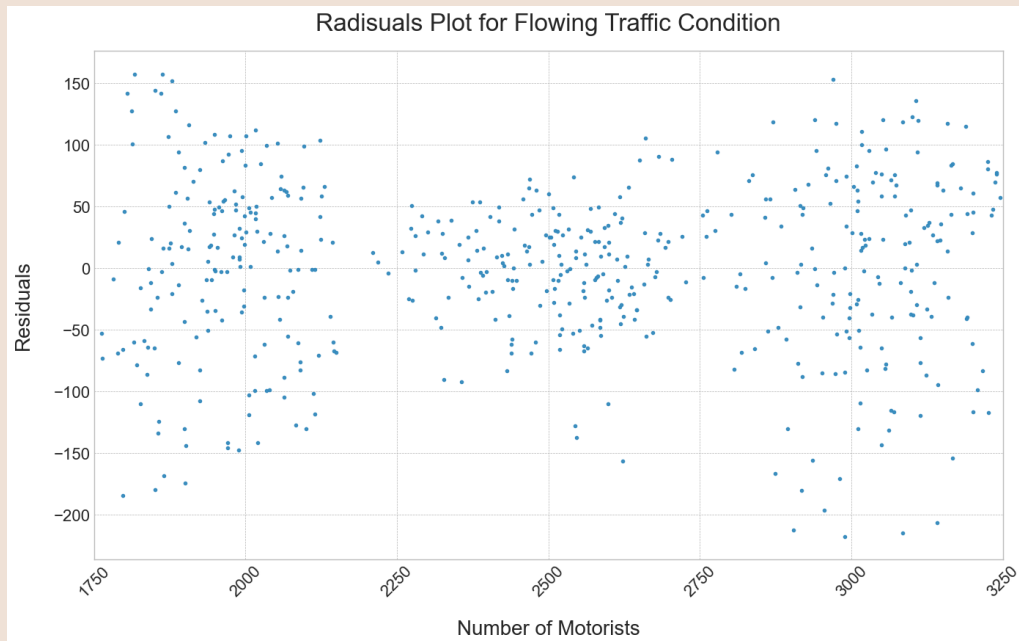


# Results – flowing traffic

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	4	120	1,4	1,2	3022	607,3	
	4	120	1,6	1	3106	786,9	
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# Results – flowing traffic

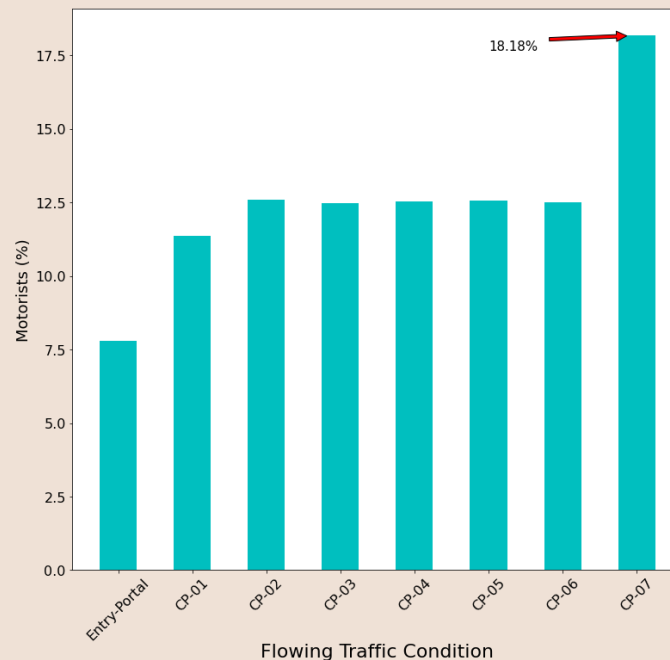
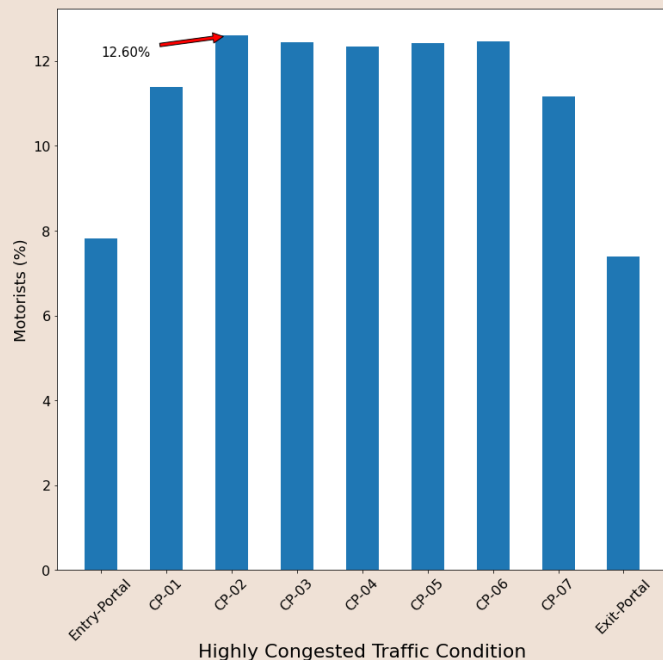


	coef	std err	R-squared:	0.965
Intercept	386.2012	49.606	Adj. R-squared:	0.965
no_CP	4.7489	0.046	F-statistic:	3683.
width_ww	37.0773	18.068	Prob (F-statistic):	0.00
door_width	-1266.0099	36.292	Log-Likelihood:	-3046.6
no_ppl	0.3778	0.007	AIC:	6103.
			BIC:	6125.

$$\begin{aligned} \text{Evacuation Time}_{\text{flowing traffic}} &= 386.2 + (4.75 \cdot \text{dist\_CP}) + (37.08 \cdot \text{ww}) \\ &+ (-1266.01 \cdot \text{dw}) + (0.38 \cdot \text{no\_ppl}) \end{aligned}$$

# Results – flowing traffic

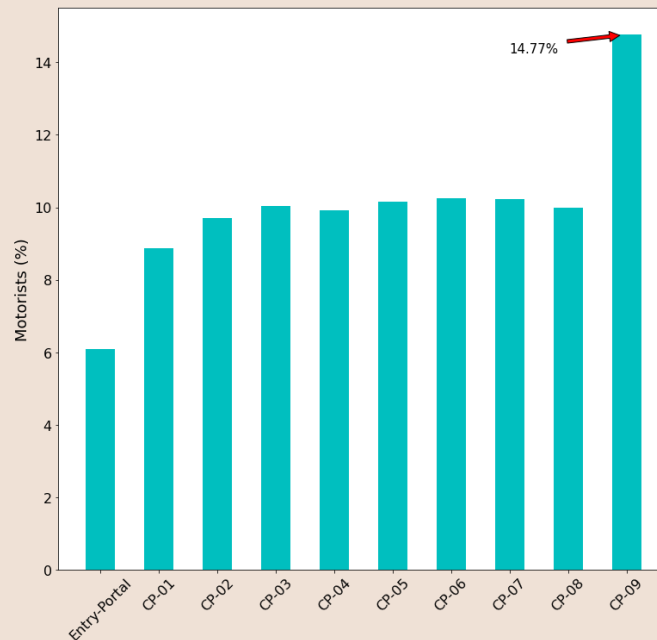
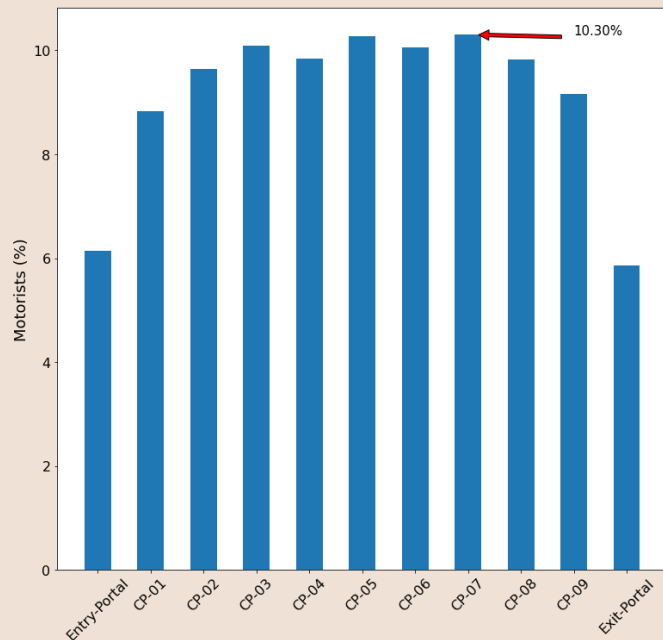
4-Lane Tunnels with 7 Cross Passages





# Results – flowing traffic

4-Lane Tunnels with 9 Cross Passages

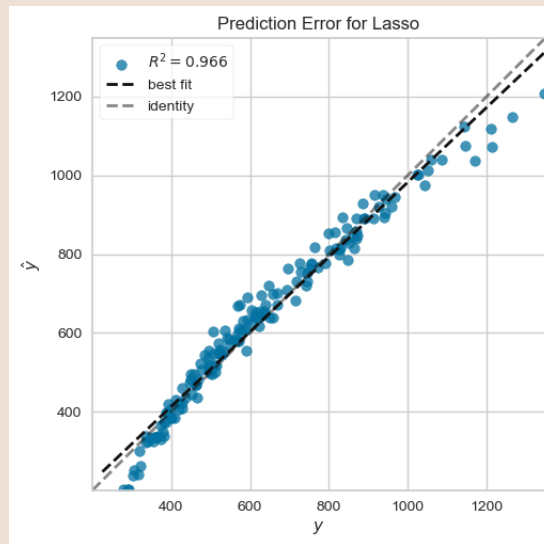
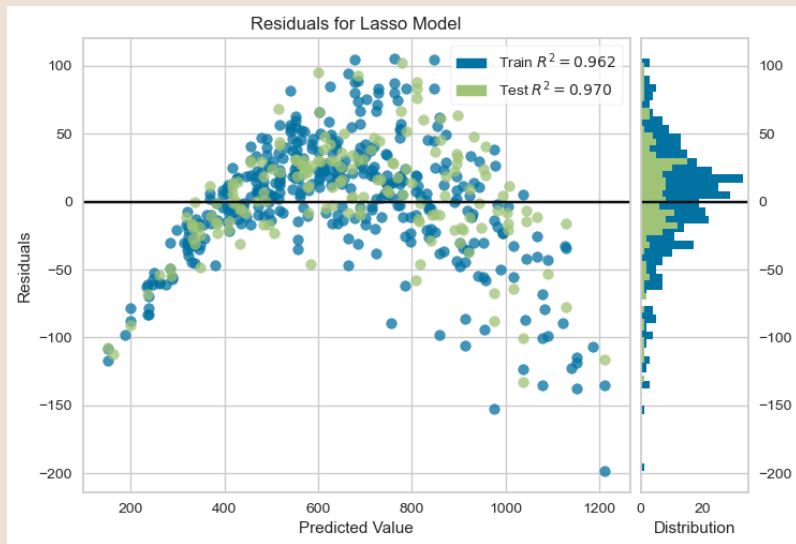


# Discussion & Conclusion

- Distance between Cross-Passages is the most effective variable.
- Number of motorists effect is:
  - 40 % of that of the distance between CP for highly congested traffic condition.
  - 36 % of that of the distance between CP for flowing traffic condition.
- Effect of door width is:
  - 9% of that of the distance between CP for highly congested traffic condition.
  - 13% of that of the distance between CP for highly congested traffic condition.
- Width of walkway is observed to be almost negligible.

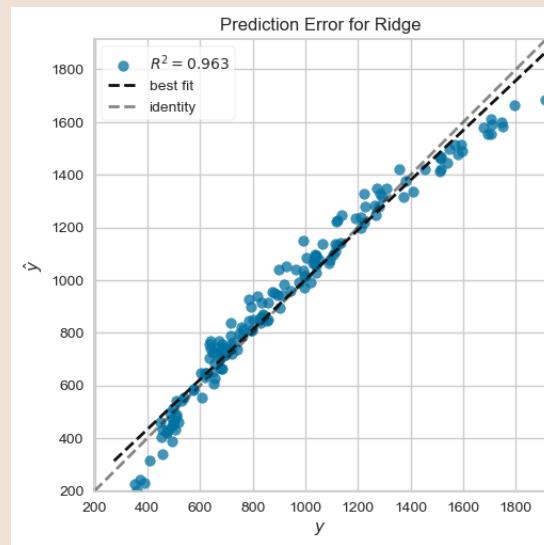
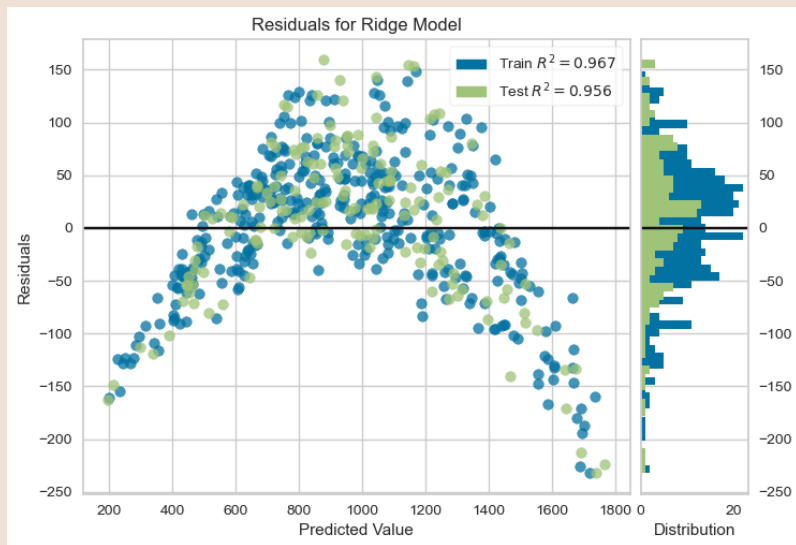
# Discussion & Conclusion

- train / test data with other ML methods (*highly congested traffic*)



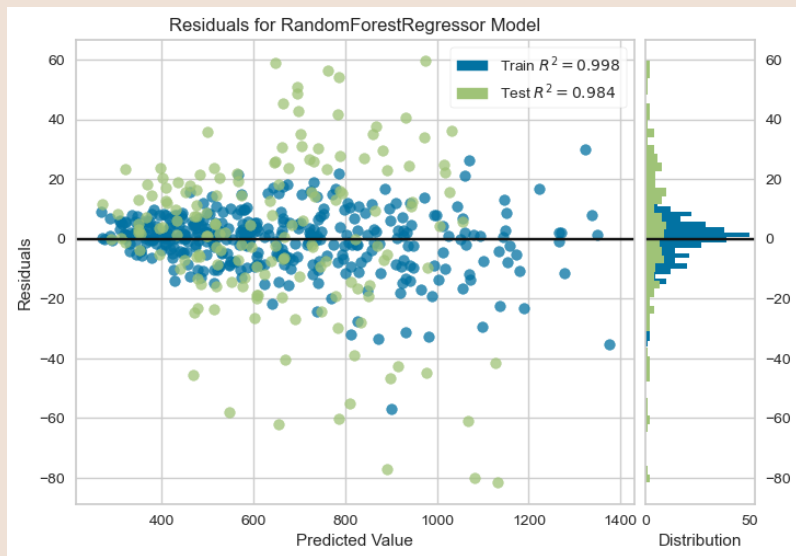
# Discussion & Conclusion

- train / test data with other ML methods (*flowing traffic*)

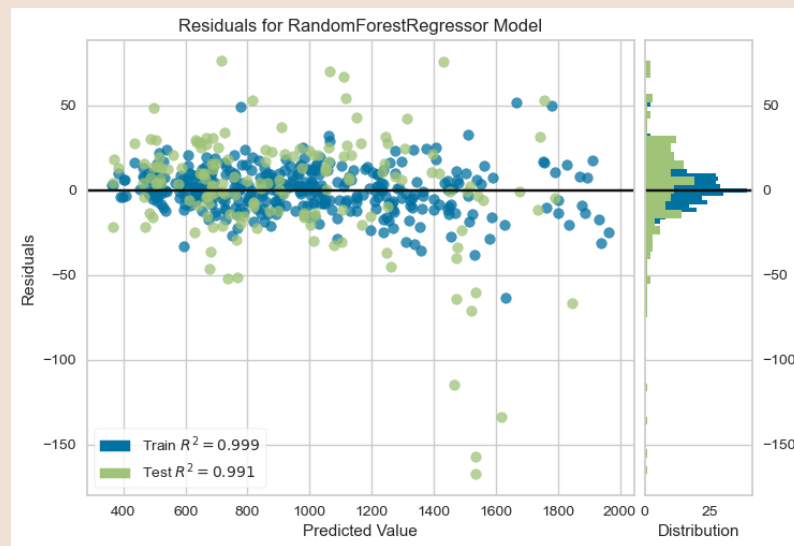


# Discussion & Conclusion

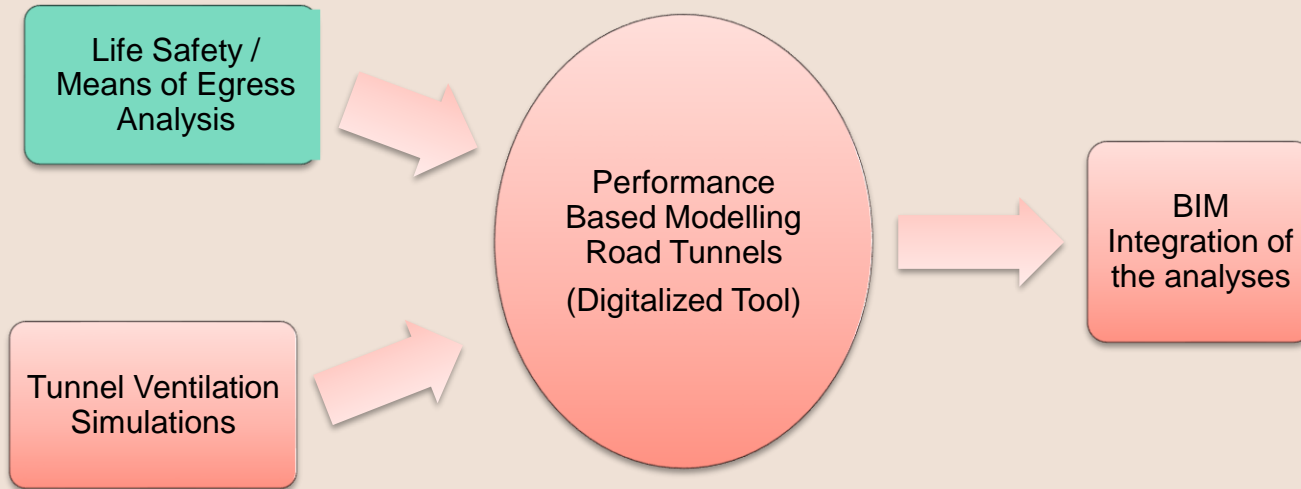
- Highly congested traffic



- Flowing traffic



# Discussion & Conclusion



**THANK YOU**  
**QUESTIONS?**