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Safelife

Autonomous Vehicles Insurance Development Report

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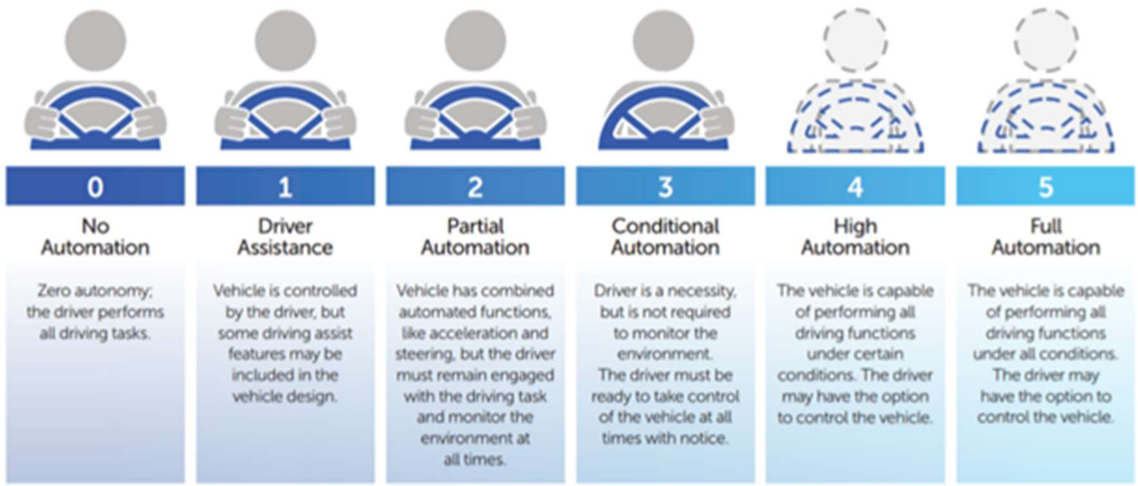
Executive Summary

As a leading automobile insurance company in Carbia, Safelife has a great opportunity in the market for autonomous vehicle insurance. In this report, we first summarize the definition and market of autonomous vehicles. After that, we introduce our pricing model and show some significant results from our data analysis. At last, we state some regulation and model limitations.

Purpose and Background

2.1 What are Autonomous Vehicles?

Nowadays, autonomous vehicle (AV) technologies provide a safer mode of transportation. By transferring human in complete control of driving to some level of self-driving capability, autonomous vehicles have the potential advantages of reducing car accidents and increasing accessibility. The U.S. Department of Transportation defines autonomous vehicles in six different levels:



Source: U.S. Department of Transportation, *Automated Driving Systems 2.0, A Vision for Safety*

2.2 Why do we Need Autonomous Vehicle Insurance?

In recent decades, a significant number of car manufactures and technology companies, like Tesla, Audi, General Motor, and Google, are developing, testing and selling their AVs to the market. Many studies show a potential trend of AV adoption, which has a different set of risks in comparison to vehicles without any automation. Safelife, being one of the top auto insurance company in Carbia, has a great opportunity to launch an autonomous vehicle insurance policy.

From the Transition to Self-driving Vehicles and Autonomous Vehicle Penetration graph, we can tell the estimate ratio for personal and commercial vehicles at each level. The level-0 in the market will significantly decline after 2020 and the higher levels will gradually grow starting from 2023. The relationship between each level are not straight, but curves gently, while still increasing or decreasing steadily over time.

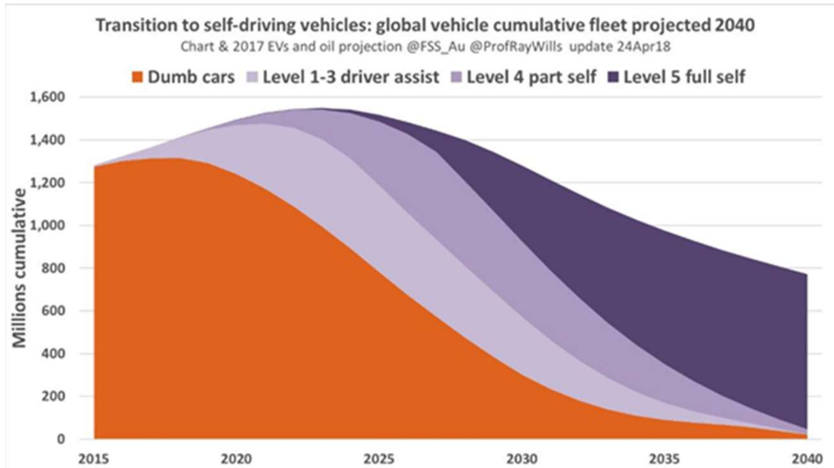


*Figure 2.1 *[9]*

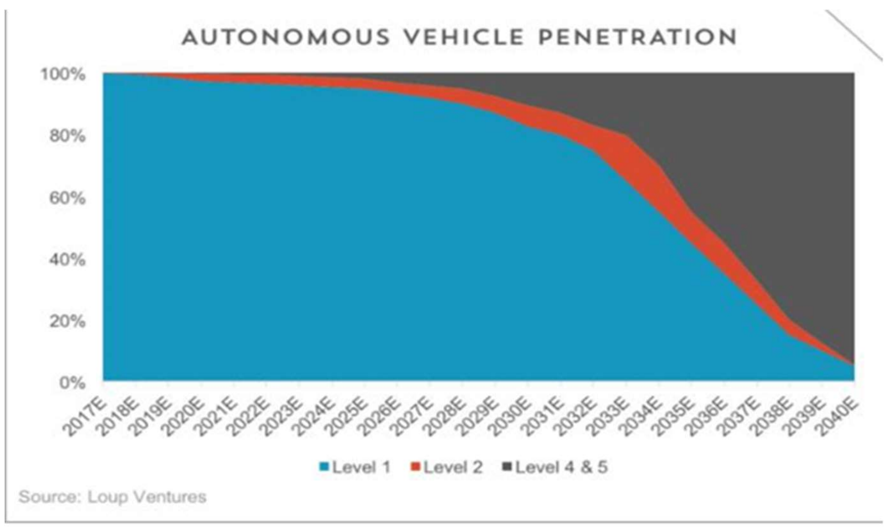


*Figure 2.2 *[1]*

We expect an increasing market share of AVs with higher levels in the following years, which makes the business opportunities available to the insurance industry. Being the first company to launch an autonomous vehicle insurance in the country will not only give Safelife a first-mover advantage, but also provide a complete coverage for customers adopting the AV trend.

Risks and Coverage

Self-driving vehicles have impact on the traditional auto insurance product in variety of ways, as a result of the utilization of AI sensors and the introduction of web control system. The three major risk categories involved in measuring pure premium for autonomous vehicles include:

- Cybersecurity
- Software algorithm
- Public infrastructure.

Several situations that we will cover and include in the policy regarding the new risk categories are:

- Loss or damage to your car caused by hacking or attempted hacking of its operating system or other software—Cybersecurity.
- Updates and patches to your car's operating system, firewall, and mapping and navigation systems that have not been successfully installed within 24 hours of you being notified by the manufacturer—Software algorithm.
- Failure of the manufacturer's software or failure of any other authorized in-car software—Software algorithm.
- Loss or damage caused by the AV when manual override to avoid this problem is possible (software or mechanical failures).—Software algorithm.
- Satellite failure or outages that affect your car's navigation systems—Public infrastructure.

We will leave the five-coverage policy unchanged, with more circumstances added under certain coverage categories.

Pricing Model

4.1 Launch Dates

The launch date of the SafeLife's new policy depends on the launch date of each levels vehicle for carmarkers. The following are carmakers' on-the-record timing for their automated products.

- Year 2020
  - Audi will build level-4 vehicle
  - Daimler will release Level 4 taxis in select cities "by the beginning of the next decade."
  - Honda vehicles will have Level 3 capability for highway use.
  - Hyundai will sell vehicles with Level 3 highway capability.
  - Nissan ProPilot will offer Level 4 city driving.
  - Toyota's Highway Teammate will deliver Level 3 capability.
- Year 2021
  - BMW will release its fully automated flagship model, iNext.
  - Ford will produce Level 4 vehicles without steering wheels or pedals for ride-hailing services.
  - Volvo will offer Level 4 cars for sale.
- Year 2025
  - Honda will offer Level 4 capability for use in most driving situations.
  - Nissan will introduce Level 5 driverless vehicles.
- Year 2030
  - Kia will put fully automated vehicles on the road.

At the end of December 2018, Waymo, the self-driving car company owned by Alphabet Inc., has officially launched the world's first driverless service -- Waymo One in Phoenix, Arizona, Ford is planning to launch fully self-driving car in commercial operation by 2021, and announced its partnership with Lyft. Volvo plans to launch the XC90 SUVs as level 4 autonomy by 2021.

According to the market of personal and commercial autonomous vehicles, we decided to launch our new policy for personal vehicles in 2020 and commercial vehicles in 2022.

4.2 Pure Premium Model

4.2.1 Introduction of the Model

For autonomous vehicle insurance policy, we don't change the limit, deductible, and coverage categories. By the definition of autonomous vehicles, automation level should be an additional risk class. Our new policy is designed for vehicles with automation levels from 1 to 5; while the traditional policy will be kept for level 0 automation. In order to make the data analyzable, we separated commercial and personal data and transferred quarterly data into annual because premiums for automobile insurance are always annually based.

Since we have already chosen launch dates, the first step is to use multivariate regression to predict exposure, frequency, and severity to launch dates without adding any new classes. Based on the Chow test result, classes of age and driver experience don't affect response variables for commercial vehicle insurance. Therefore, our model only kept the vehicle size class for the traditional commercial vehicle policy. In our model, we classified risks according to the categories:

Commercial Risk Classes	
Vehicle Size	Automation Level
Small	1
Medium	2
Large	3
	4
	5

Personal Risk Classes			
Vehicle Size	Driver Age	Driver Risk	Automation Level
Small	**Y**oung	**L**ow	1
Medium	**M**iddle	**A**verage	2
Large	**S**enior	**H**igh	3
			4
			5

Table 4.1

Taking large commercial vehicles as an example, Figure 4.1 shows projected frequencies for each coverage without considering new risks.

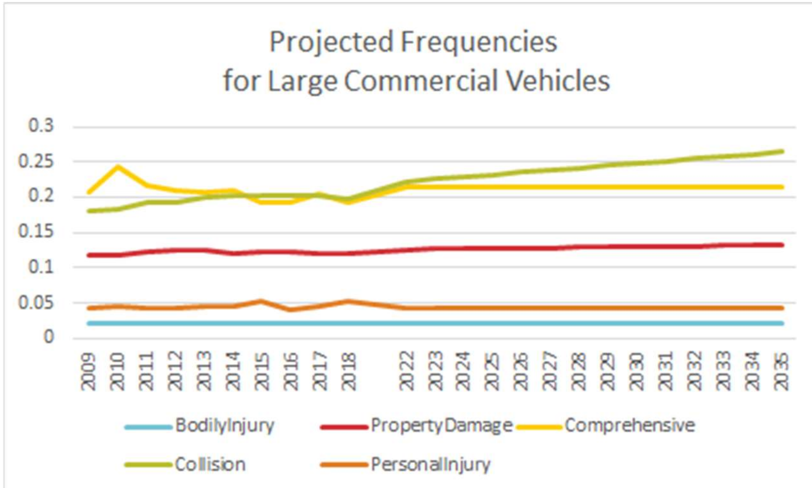


Figure 4.1

Our basic approach is to adjust projected frequencies with additional risks and new accident rates for different levels of autonomous vehicles. Severity remains the same as projected values. Exposures are distributed to new classes by the market share of levels of automation on the road. We take steps below to calculate pure premium and total premium for each class:

- Calculate frequency for each coverage after taking new risks and market share into consideration. Since the comprehensive coverage covers loss other than collision, there is no need to adjust the frequency for this coverage. For other coverages,
  $Frequency_{ik}=Traditional\ Frequency \times New\ Risks\ Factor \times Accident\ Rate\ Factor_{adj}$
  where i indicates the class and k indicates the coverage. Factors will be described in the next session.
- According to the KPMG report, *Will Autonomous Vehicles Put the Brakes on the Collision Parts Business*, projected repair cost will be increasing for driverless cars, but the increasing rate is lower than projected rate of our regression. Keeping severities the same as projected severities is already a conservative approach and automation level does not affect severities.
- We can calculate pure premium as
  $Pure\ Premium_i=\Sigma_k\ Frequency_{ik} \times Severity_{ik}$
- In order to find the influence of launching new policy to the whole business, we find expected exposures and total premiums as
  $Expected\ Exposures_i=Traditional\ Exposure_i \times Market\ Share\ Factor \times Sales\ Rate$
  $Total\ Premium=Expected\ Exposures_i \times Pure\ Premium_i$

4.2.2 Factors

Market share factor shows the percentage of different automation vehicles on the road in the following 15 years. We assume the distribution of customers in the company has the same distribution as in the market. Those numbers are based on the Figure 2.2 and the percentage of personal and commercial vehicles.

Personal	Level	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2035
level0	0	62.260%	39.450%	22.730%	15.040%	4.740%	0.415%	0.167%	0.086%	0.005%	0.000%	0.000%	0.000%	0.000%
level1	1	33.590%	50.780%	63.290%	62.600%	64.175%	59.180%	55.700%	50.005%	45.767%	38.423%	32.631%	26.840%	15.000%
level2	2	3.774%	8.465%	11.510%	13.410%	18.210%	15.310%	17.960%	19.010%	21.127%	22.440%	22.054%	23.769%	24.750%
level3	3	0.377%	1.305%	2.400%	8.661%	12.380%	24.100%	25.040%	29.059%	30.933%	35.827%	39.315%	42.699%	41.460%
level4	4	0.0%	0.0%	0.077%	0.289%	0.495%	0.995%	1.133%	1.840%	2.168%	3.310%	4.100%	4.731%	16.490%
level5	5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.900%	1.960%	2.300%

Commercial	Level	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2035
level0	0	18.002%	16.146%	15.000%	12.500%	9.800%	7.233%	4.633%	2.033%	0.670%	0.0%	0.0%	0.0%	0.0%
level1	1	75.078%	71.580%	68.490%	63.530%	61.970%	57.350%	53.000%	42.360%	42.100%	38.000%	30.000%	22.000%	4.050%
level2	2	5.992%	10.538%	13.740%	20.970%	24.040%	30.350%	31.780%	34.390%	34.270%	32.190%	29.850%	27.510%	11.000%
level3	3	0.878%	1.575%	2.460%	2.680%	3.680%	4.450%	9.300%	15.790%	17.430%	22.750%	26.000%	30.550%	49.800%
level4	4	0.050%	0.162%	0.310%	0.322%	0.513%	0.619%	1.240%	3.540%	3.630%	5.000%	12.040%	16.290%	30.500%
level5	5	0.00%	0.00%	0.0%	0.0%	0.0%	0.0%	0.048%	1.890%	1.900%	2.060%	2.110%	3.650%	4.650%

Table 4.2 Market Share Factors

New risks factor shows the expected frequencies once we expand our cyber coverage for autonomous vehicle insurance policy. This factor is calculated from accident rate assuming all cars on the road are in corresponding levels and frequencies of each new risk. Those rates are in Appendix A.

New Risks Factors		
Level	**Risk Factor(Personal)**	**Risk Factor(Commercial)**
0	1	1
1	1.027629885	1.03040648
2	1.036935551	1.040645695
3	1.1516321	1.157702916
4	1.210910966	1.219254822
5	1.241019034	1.250541986

Table 4.3

Accident rate factor$_{adj}$ reflects ratio of accident rate of autonomous vehicles with that of traditional vehicles considering market share of different levels on vehicles on road. No matter what car you are driving, the more vehicles of higher level of automation on road, the less chance you will be hit by another vehicle.

Accident Rate Factor_adj														
Level	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	...	2035
0	92.5417%	91.0580%	89.9529%	88.8050%	87.7034%	86.4718%	85.4930%	83.3662%	82.9325%	81.7360%	79.6892%	77.7941%		72.0422%
1	80.8668%	79.3737%	78.2596%	77.1022%	75.9914%	74.7504%	73.7622%	71.6262%	71.1830%	69.9772%	67.9211%	66.0166%		60.2275%
2	75.0293%	73.5315%	72.4129%	71.2508%	70.1354%	68.8897%	67.8968%	65.7562%	65.3082%	64.0977%	62.0370%	60.1279%		54.3201%
3	63.3543%	61.8472%	60.7195%	59.5479%	58.4233%	57.1683%	56.1660%	54.0163%	53.5587%	52.3389%	50.2689%	48.3504%		42.5054%
4	51.6794%	50.1629%	49.0261%	47.8451%	46.7113%	45.4469%	44.4352%	42.2763%	41.8092%	40.5800%	38.5008%	36.5730%		30.6907%
5	45.8419%	44.3207%	43.1794%	41.9937%	40.8552%	39.5862%	38.5698%	36.4063%	35.9344%	34.7006%	32.6167%	30.6842%		24.7833%

Table 4.4

Sales rate means the additional increasing rate of exposures of new policies because being the first company to launch autonomous vehicle insurance policy can attract more customers. We also use this rate as the additional decreasing rate of exposures of old policies if we do not launch the new one. This is because we could lose our own customers if other insurance companies start to realize the business opportunity of autonomous vehicle insurance. In our model, the sales rate is 10%, but we also show the sensitive analysis of this rate in later sections.

4.2.3 Commercial Autonomous Vehicle Insurance Policy Pure Premium

Commercial Pure Premium in 2022								
NewClass	Pure Premium	Total Premium	NewClass	Pure Premium	Total Premium	NewClass	Pure Premium	Total Premium
L1	1599.606027	201043992.6	M1	1657.323988	216035079.8	S1	1485.336372	158228532.6
L2	1518.12743	38277702.48	M2	1572.064041	41109922.86	S2	1411.344067	30161466.44
L3	1440.072804	6500854.686	M3	1490.38697	6977885.634	S3	1340.461137	5128875.45
L4	1277.828512	726917.5772	M4	1320.613064	779160.5904	S4	1193.123926	575281.0482
L5	1188.721417	0	M5	1227.370588	0	S5	1112.204033	0

Table 4.5

4.2.4 Personal Autonomous Vehicle Insurance Policy Pure Premium

Personal Pure Premium in 2020								
New Class	PurePremium	Total Premium	New Class	PurePremium	Total Premium	New Class	PurePremium	Total Premium
LMA1	1575.323415	67161293.14	LSA1	1737.360341	52943967.21	LYA1	1781.641025	29495454.54
LMA2	1487.153201	7123557.329	LSA2	1638.854666	5611240.863	LYA2	1680.310924	3125477.895
LMA3	1406.649861	673794.1269	LSA3	1548.914589	530329.6877	LYA3	1587.792019	295338.725
LMA4	1233.958596	0	LSA4	1355.980162	0	LYA4	1389.325637	0
LMA5	1139.336242	0	LSA5	1250.266015	0	LYA5	1280.580378	0
LMH1	2103.710157	74671950.78	LSH1	2294.754189	53549974.66	LYH1	2298.277932	21643438.68
LMH2	1987.043161	7924480.225	LSH2	2165.901525	5678762.389	LYH2	2169.200507	2295172.355
LMH3	1880.520986	749966.1638	LSH3	2048.253291	537030.129	LYH3	2051.347057	217047.4809
LMH4	1652.015571	0	LSH4	1795.880876	0	LYH4	1798.534423	0
LMH5	1526.81109	0	LSH5	1657.599001	0	LYH5	1660.01134	0
LML1	1270.463282	44399568.08	LSL1	1414.620763	32236381.36	LYL1	1475.358084	13085573.96
LML2	1206.712176	4738187.19	LSL2	1341.674629	3435147.234	LYL2	1398.537844	1393674.81
LML3	1148.50457	450963.3492	LSL3	1275.071553	326462.0514	LYL3	1328.397536	132377.8395
LML4	1023.640869	0	LSL4	1132.198356	0	LYL4	1177.936468	0
LML5	955.2245695	0	LSL5	1053.914153	0	LYL5	1095.494657	0

Personal Pure Premium in 2020								
New Class	PurePremium	Total Premium	New Class	PurePremium	Total Premium	New Class	PurePremium	Total Premium
MMA1	1539.15865	74236461.72	MSA1	1694.573986	61127191.78	MYA1	1689.025255	37418203.01
MMA2	1453.295192	7875526.653	MSA2	1598.797422	6479764.776	MYA2	1593.602615	3966602.755
MMA3	1374.898022	745068.5918	MSA3	1511.349145	612534.5722	MYA3	1506.477485	374974.1427
MMA4	1206.724797	0	MSA4	1323.759988	0	MYA4	1319.581528	0
MMA5	1114.578002	0	MSA5	1220.974663	0	MYA5	1217.176027	0
MMH1	2017.454829	82905025.29	MSH1	2201.877271	63709844.61	MYH1	2155.571599	32367525.11
MMH2	1906.289595	8801522.547	MSH2	2078.948724	6758481.156	MYH2	2035.596641	3434240.127
MMH3	1804.790774	833289.2723	MSH3	1966.709474	639360.1133	MYH3	1926.05415	324943.1795
MMH4	1587.061178	0	MSH4	1725.940109	0	MYH4	1691.069721	0
MMH5	1467.761068	0	MSH5	1594.015867	0	MYH5	1562.315207	0
MML1	1262.450523	51187382.16	MSL1	1399.986414	39740729.97	MYL1	1410.894321	20412721.81
MML2	1199.210508	5463058.736	MSL2	1327.973726	4235389.87	MYL2	1338.185876	2175277.99
MML3	1141.469551	520001.7147	MSL3	1262.222928	402568.6726	MYL3	1271.799821	206736.4637
MML4	1017.606878	0	MSL4	1121.177991	0	MYL4	1129.392167	0
MML5	949.7390699	0	MSL5	1043.895541	0	MYL5	1051.363046	0

Personal Pure Premium in 2020								
New Class	PurePremium	Total Premium	New Class	PurePremium	Total Premium	New Class	PurePremium	Total Premium
SMA1	1608.844757	62598114.99	SSA1	1767.473741	47278502.34	SYA1	1748.836936	22438655.87
SMA2	1518.536398	6638412.176	SSA2	1667.047295	5010147.983	SYA2	1649.599231	2378032.898
SMA3	1436.080836	627795.0609	SSA3	1575.353467	473457.1131	SYA3	1558.990777	224741.3364
SMA4	1259.201773	0	SSA4	1378.656994	0	SYA4	1364.622587	0
SMA5	1162.284807	0	SSA5	1270.881517	0	SYA5	1258.122842	0
SMH1	2080.889197	66111430.51	SSH1	2268.525286	44488550.04	SYH1	2209.13154	12575791.97
SMH2	1965.677826	7016682.568	SSH2	2141.345622	4718275.425	SYH2	2085.740282	1334030.9
SMH3	1860.484703	664118.5248	SSH3	2025.224912	446241.3183	SYH3	1973.078557	126197.2924
SMH4	1634.830295	0	SSH4	1776.129256	0	SYH4	1731.402921	0
SMH5	1511.187959	0	SSH5	1639.642808	0	SYH5	1598.982108	0
SML1	1330.343543	41537237.06	SSL1	1471.093081	28044037.89	SYL1	1468.912914	7557294.478
SML2	1262.772998	4429869.963	SSL2	1394.544883	2986928.182	SYL2	1392.503776	804930.8451
SML3	1201.078075	421344.1129	SSL3	1324.652961	283722.9055	SYL3	1322.738823	76460.35128
SML4	1068.733574	0	SSL4	1174.724716	0	SYL4	1173.082946	0
SML5	996.2183353	0	SSL5	1092.574855	0	SYL5	1091.082322	0

Table 4.6

10 Year Forecast

5.1 Exposures of New Policy vs. Traditional Policy

We expect gradual shift of Safelife's traditional vehicle market to autonomous vehicle market. Based on our 10-year forecast, we will have an increasing amount of autonomous vehicles insurance clients, from 814,500 exposures in 2020 to 4,244,000 exposures in 2029. In respect of traditional vehicles, we predict exposures will be a decreasing condition. It starts at 1,279,000 exposures in 2020 and drops to 0 exposure in 2029 if we launch the new policy.

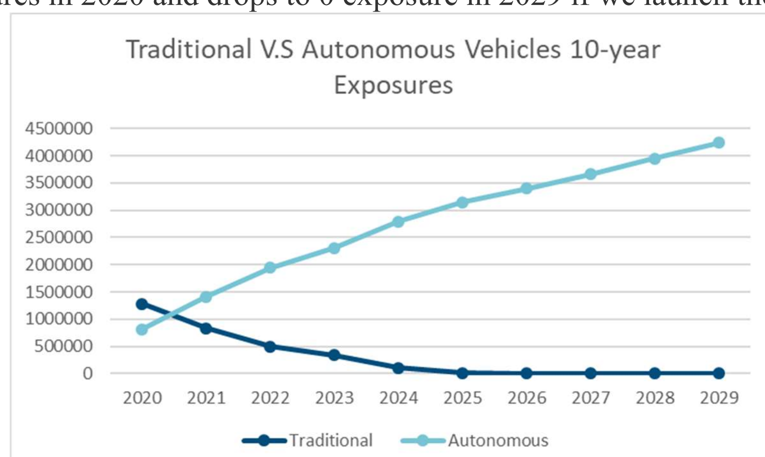


Figure 5.1

5.2 Pure Premium Forecast

By the huge number of risk classes shares the same trend of pure premium, we can choose one class as an example. The figure below is the pure premium trend over 10 years for commercial medium sized vehicles. As expected, autonomous vehicles have lower pure premium that increases at a slower rate compared to traditional vehicles.

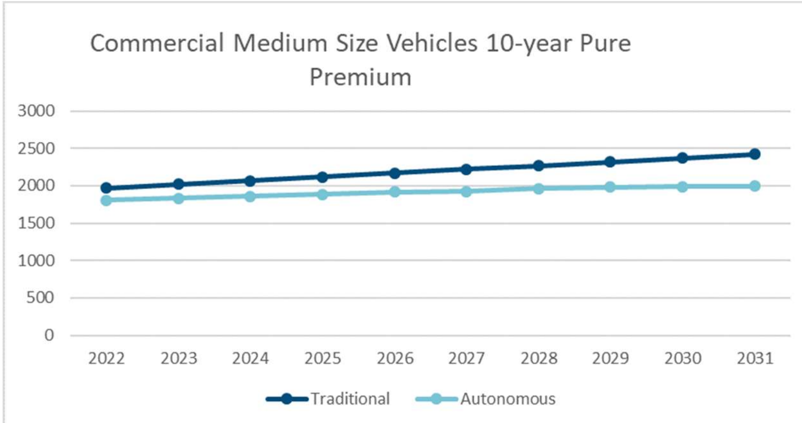
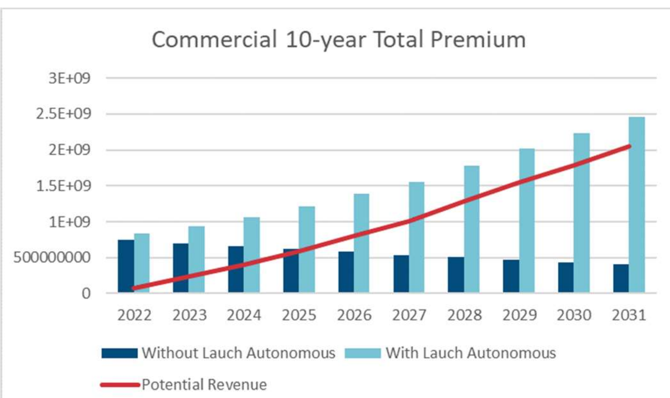


Figure 5.2

5.3 Total Premium Forecast

Without launching autonomous vehicle insurance policy, the company might retain the previous clients but in decreasing manor. When other insurance companies launch this profitable policy, we might expect a huge loss of our own customers. By launching the new policy, we can retain our own clients and attract other customers at the same time. The significant amount of potential revenue exists once we launch the new policy.



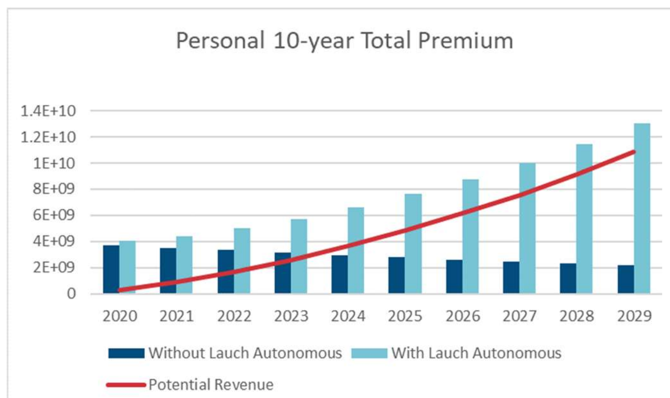


Figure 5.3

Sensitive Analysis

6.1 Change of Market Share Prediction

The new policy account achieves to 20 to 25 percent of overall business is our management's goal by 2030. According to our previous analysis for market trend, we will exceed our expectations for the market share prediction. To be conservative, we can change our business distribution by changing market share assumption, because we assume our client distribution is the same as market share. From the histogram below, we can tell that there is a positive correlation between the market share and the total premium. However, lowering the number of autonomous vehicles on road, there is a huge decrease on the total premium. By summing up pure premiums of different classes, we can see that the pure premium is weakly affected by adjusting the autonomous vehicle ratio to 25% for both personal and commercial vehicles. There are only 2% difference for pure premiums.

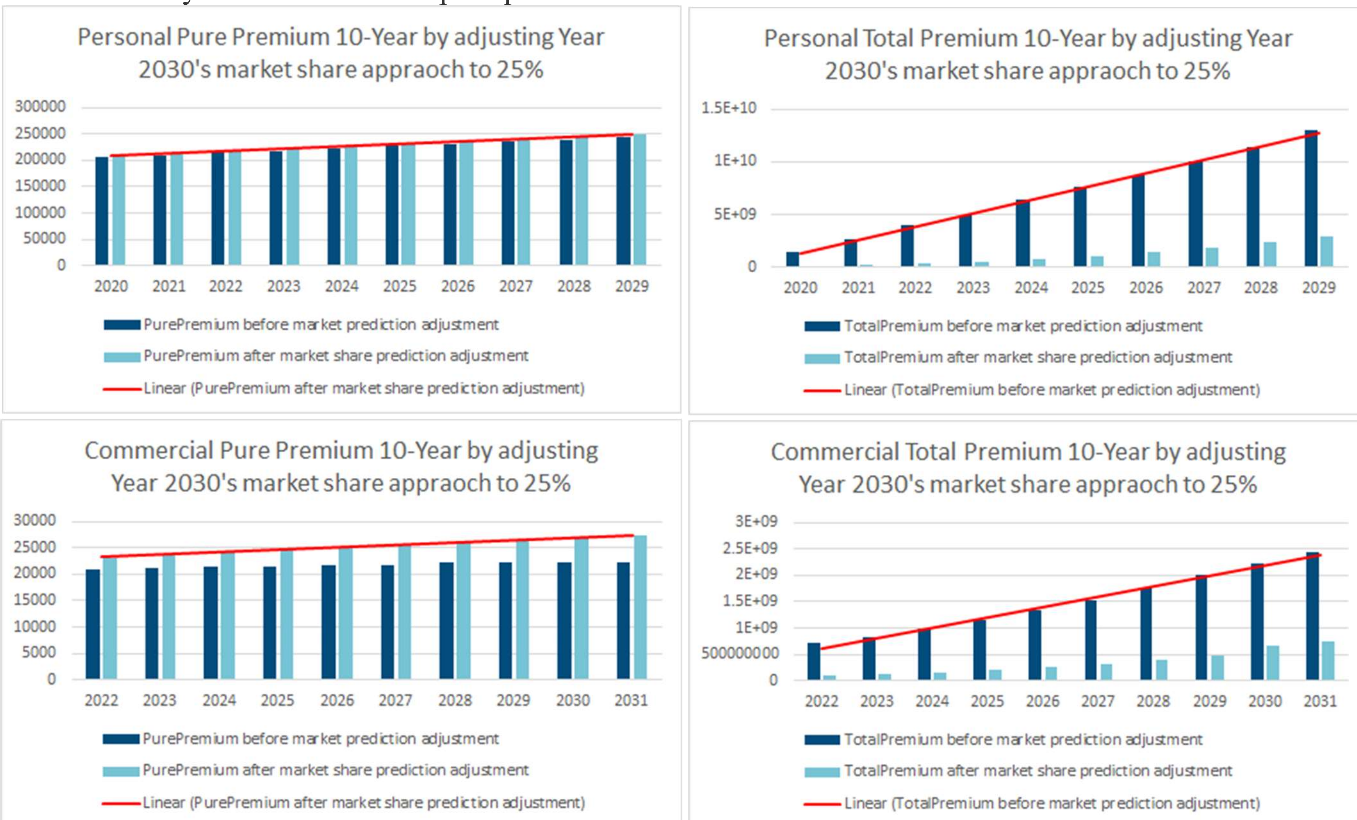
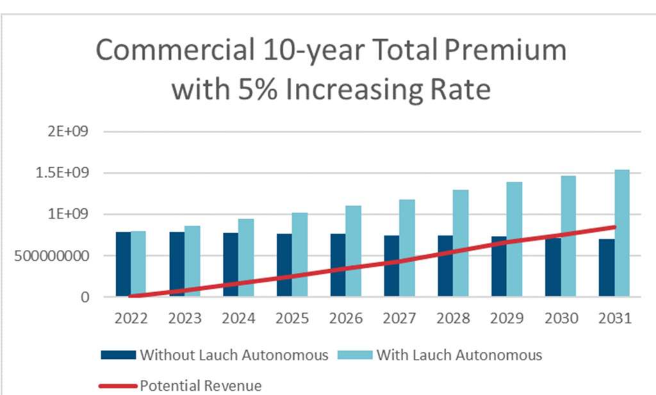
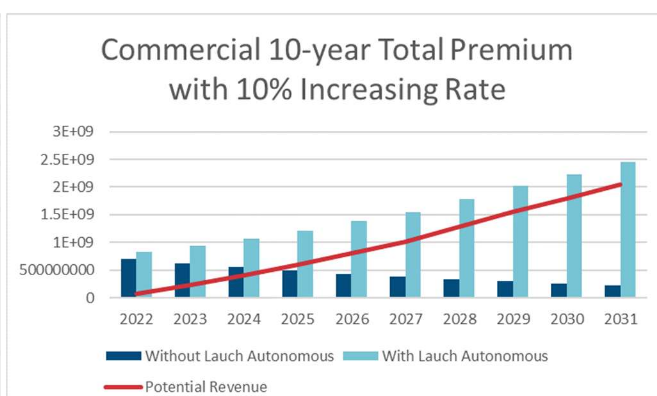


Figure 6.1

6.2 Increasing Rate Variation

By changing the company's predictive Autonomous Vehicles increasing rates, we can see a positive relationship between potential revenue and the increasing rates from both personal and commercial usage of vehicles. For example, if we change the AV increasing rate of 10% to 5%, we can see a decreasing potential revenue from the commercial total premium plot compared to the 10% increasing rate plot. The same pattern applies to the personal vehicles as well, we can see from the following plots.





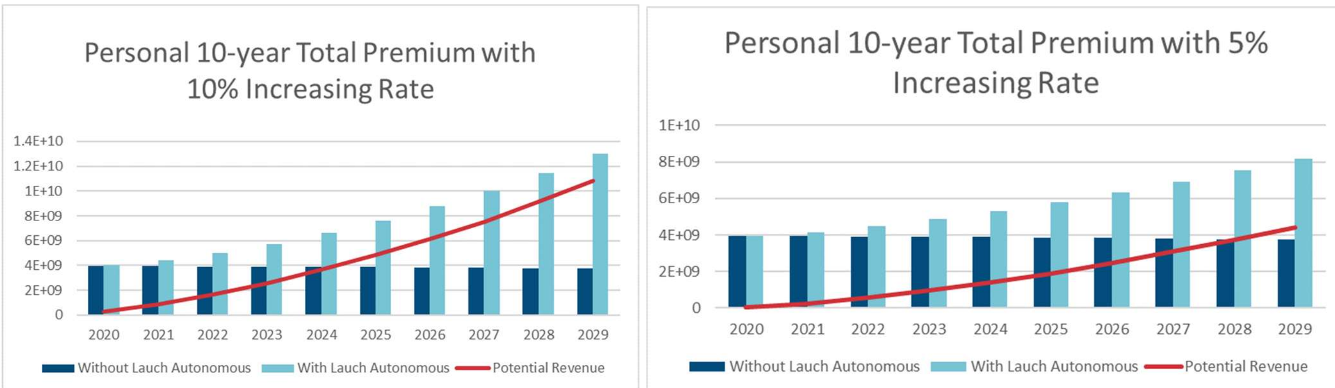


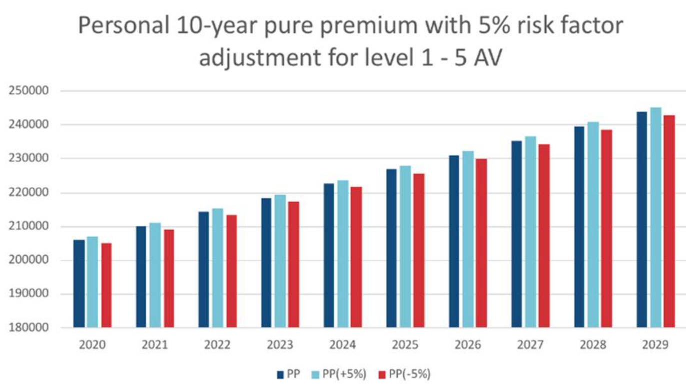
Figure 6.2

6.3 Change of accident rate and new risk factors

We test the effect of accident rates on the pure premium by assuming that those rates of level 1 - 5 are underestimated. We first increase the accident rates by 10%. After that, we test the scenario when the actual rates are lower by dropping them by 10%. We conclude that there is a positive correlation between the accident rate and the pure premium. Increasing of accident results in 5% increase of pure premium of personal vehicles and 6% increase of pure premium of commercial vehicles. Result charts are given below.

Figure 6.3

We also test the effect of accident rates on pure premium by increasing each new risk factor by 5% and dropping it by 5%. We end up with the same conclusion as changing accident rates. A positive correlation can describe the effect of risk factors on pure premium. We expect a 0.5% change on pure premium if we change 5% of accident rates.



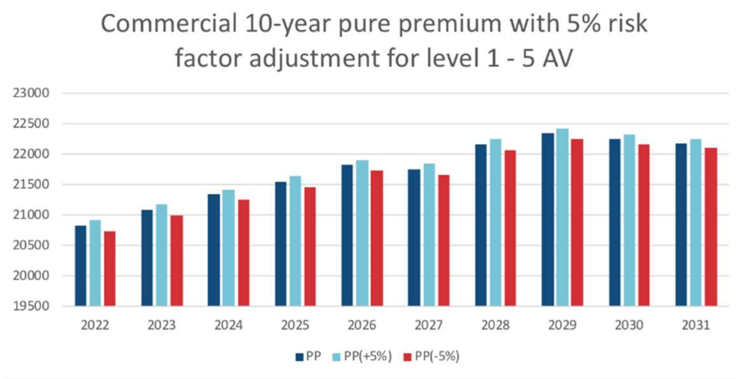


Figure 6.4

Limitations

7.1 Laws and Regulation Limitations

In a car crashes involving autonomous vehicles, a plaintiff may have three options to pursue:

- Company that created the finished autonomous vehicle: The original manufacturer of a vehicle converted by a third party into an AV is not liable for injury due to an alleged vehicle defect caused by the conversion of the vehicle, or by equipment installed by the converter, unless the alleged defect was present in the vehicle as originally manufactured.
- Operator of the vehicle: An operator is defined as a person who causes the autonomous technology to engage, regardless of whether the person is in vehicle. The viability of a claim against operator will be determined based on the level of autonomy. For instance, if the autonomous technology allows the passenger to cede full control of the vehicle, then the passenger will likely not be found to be at fault for a crash caused by the technology.
- Car manufacturer: with this option, a plaintiff will need to determine whether the manufacturer had a part in installing autonomous technology into the vehicle. States such as Florida, however, are providing protection by limiting product liability for manufacturers.

7.2 Model Limitations

Since the autonomous vehicle insurance policy is lacking in the market, calculations are based on our assumptions. We assume that there is no historical data about autonomous vehicles; the penetration of autonomous vehicles may not be as fast as we expected; or autonomous vehicles will be much safer than traditional vehicles, etc. Therefore, it is the responsibility of the actuarial department to adjust assumptions according to the actual sales and market conditions in each year.

Due to the need of 10-year prediction and huge number of risk classes, the regression method can effectively obtain the predicted values. If we have enough time, we will be able to use the loss trend to come up with the pure premium, and to adjust the estimated pure premium with credibility.

According to the current regulations of the insurance industry, the manufacturer is not responsible for any losses caused by the technical problem in the self-driving mode. Therefore, the insurance company needs to cover all responsibilities. The future legal provisions may have a more comprehensive interpretation of the self-driving cars; hence, our model may change in the future depending on the policy changes.

Conclusion

With all the reach and analysis done above, in order to improve our model and adjust to the changing market in the future, we came up with a few suggestions to the CEO:

1. Consider developing a new type of insurance product for manufacturers of autonomous vehicles to protect them against lawsuit of accident resulting from causes like vehicle software dysfunction. It is easier for insurance companies to define the party at fault if it is specified in the future regulations.
2. Consider transferring our existing customers to new autonomous vehicle policy once the product is launched, and return any excess premiums to them.

Despite public doubts and fears toward autonomous vehicles, self-driving cars are imminent. The new technology may not end the traditional auto insurance, but rather change it into a different form.

Appendix

Appendix A-Other Factors

New Risks Frequency			
	Personal	**Commercial (110%)**	
A	0.29150000	0.29150000	*hacking or attempted hacking of its operating system or other software*
B	0.0001	0.0001	*Updates and patches failure*
C	0.00072401	0.000796408	*Satellite failure or outages*
D	0.08225806	0.090483871	*Failure of the manufacturer's software*
E	0.008225806	0.009048387	*failing when able to use manual override to avoid an accident*

Accident Rate (Assume All Cars on the Road in Corresponding Level)			
Level	Fatalities	Driver	System
0	100%	100%	0%
1	77.50%	75%	25%
2	66.25%	62.50%	37.50%
3	43.75%	37.50%	62.50%
4	21.25%	12.50%	87.50%
5	10%	0%	100%

Appendix B-Code

B-1 Season Analysis

```
Season.Number <- read.delim("C:/Users/Vanora/Desktop/SOA Challenge/Season-Number.txt")
library(ggplot2)
ggplot(Season.Number,aes(x=Time,y=Bodily.Injury,group=1))+geom_line(color = "#00AFBB",
size = 2)


Class=rep(c("LMA","LMH","LML","LSA","LSH","LSL","LYA","LYH","LYL","MMA","MM
H","MML","MSA","MSH","MSL",
        "MYA","MYH","MYL","SMA","SMH","SML","SSA","SSH","SSL","SYA","SYH","S
YL"),each=5)
Level=rep(c(1,2,3,4,5),times=27)
autonomousframe=data.frame(Class,Level)
write_csv(autonomousframe, path = "C:/Users/Vanora/Desktop/SOA
Challenge/Autonomous_frame.csv")
```

B-2 Commercial using vehicle size

```
Commercial_VSize <- read.delim("C:/Users/Vanora/Desktop/SOA
Challenge/Commercial_VSize.txt")
CommercialModel=lm(Exposures ~ Year + Vsize,data = Commercial_VSize)
summary(CommercialModel)
CommercialModel1<- lm(BodilyInjury1 ~ Year + Vsize,data = Commercial_VSize)
summary(CommercialModel1)
CommercialModel2<- lm(PropertyDamage1 ~ Year + Vsize,data = Commercial_VSize)
summary(CommercialModel2)
CommercialModel3<- lm(Comprehensive1 ~ Year + Vsize,data = Commercial_VSize)
summary(CommercialModel3)
##R-square is small. Then let comprehensive as average.
CommercialModel4<- lm(Collision1 ~ Year + Vsize,data = Commercial_VSize)
summary(CommercialModel4)
CommercialModel5<- lm(PersonalInjury1 ~ Year + Vsize ,data = Commercial_VSize)
summary(CommercialModel5)
##Year and VSize are not significant here. Average as well.


CommercialModel6<- lm(BodilyInjury2 ~ Year + Vsize,data = Commercial_VSize)
summary(CommercialModel6)
CommercialModel7<- lm(PropertyDamage2 ~ Year + Vsize,data = Commercial_VSize)
summary(CommercialModel7)
CommercialModel8<- lm(Comprehensive2 ~ Year+Vsize,data = Commercial_VSize)
summary(CommercialModel8)
##But we see a inceasing trend of severity in recent 5 years. Then we only use recend five year
data to analyze.
Comprehensive=Commercial_VSize[c(16:30),]
```

```
CommercialModel8<- lm(Comprehensive2 ~ Year,data = Comprehensive)
summary(CommercialModel8)

CommercialModel9<- lm(Collision2 ~ Year + Vsize,data = Commercial_VSize)
summary(CommercialModel9)
CommercialModel10<- lm(PersonalInjury2 ~ Year + Vsize,data = Commercial_VSize)
summary(CommercialModel10)

Year=rep(2022:2035,each=3)
Vsize=rep(c("L","M","S"),times=14)
prediction_frame=data.frame(Year,Vsize)
prediction_frame$Exposures=predict(CommercialModel,prediction_frame)
prediction_frame$BodilyInjury1=predict(CommercialModel1,prediction_frame)
prediction_frame$PropertyDamage1=predict(CommercialModel2,prediction_frame)
prediction_frame$Comprehensive1=predict(CommercialModel3,prediction_frame)
prediction_frame$Collision1=predict(CommercialModel4,prediction_frame)
prediction_frame$PersonalInjury1=predict(CommercialModel5,prediction_frame)

prediction_frame$BodilyInjury2=predict(CommercialModel6,prediction_frame)
prediction_frame$PropertyDamage2=predict(CommercialModel7,prediction_frame)
prediction_frame$Comprehensive2=predict(CommercialModel8,prediction_frame)
prediction_frame$Collision2=predict(CommercialModel9,prediction_frame)
prediction_frame$PersonalInjury2=predict(CommercialModel10,prediction_frame)

library("readr")
write_csv(prediction_frame, path = "C:/Users/Vanora/Desktop/SOA
Challenge/Commercial_prediction_Vsize.csv")
```

B-3 Fit market Share of Commercial and Personal

```
ComPer <- read.delim("C:/Users/Vanora/Desktop/SOA Challenge/Com_VS_Per.txt")
ComPerModel1=lm(Vehicles_n~Year,data=ComPer)
summary(ComPerModel1)

ComPerModel2=lm(Com_Share~Year,data=ComPer)
summary(ComPerModel2)
ComPerModel3=lm(Per_Share~Year,data=ComPer)
summary(ComPerModel3)
Year=rep(2020:2035)
ShareFrame=data.frame(Year)
ShareFrame$Com_Share=predict(ComPerModel2,ShareFrame)
ShareFrame$Per_Share=predict(ComPerModel3,ShareFrame)
library("readr")
write_csv(ShareFrame, path = "C:/Users/Vanora/Desktop/SOA Challenge/Share.csv")
```

B-4 Analyze Personal Data

```
POrig <- read.delim("C:/Users/Vanora/Desktop/SOA Challenge/Personal_Orig.txt")


Per_exp=lm(Exposures ~ Year + Vsize+Age+RiskL,data = POrig)
summary(Per_exp)
per1<- lm(BodilyInjury1 ~ Vsize+Age+RiskL,data = POrig)
summary(per1)
per2<- lm(PropertyDamage1 ~ Vsize+Age+RiskL,data = POrig)
summary(per2)
per3<- lm(Comprehensive1 ~ RiskL,data = POrig)
summary(per3)
##Didn't find one model good for predicting the comprehensive frequency, we will use last year's frequency as a prediction.
per4<- lm(Collision1 ~  Year+Vsize+RiskL,data = POrig)
summary(per4)
per5<- lm(PersonalInjury1 ~ Vsize,data = POrig)
summary(per5)
##Didn't find one model good for predicting the comprehensive frequency, we will use last year's frequency as a prediction.


per6<- lm(BodilyInjury2 ~ Year + Vsize+Age,data = POrig)
summary(per6)
per7<- lm(PropertyDamage2 ~ Year+RiskL,data = POrig)
summary(per7)
per8<- lm(Comprehensive2 ~ Year+RiskL,data = POrig)
summary(per8)
per9<- lm(Collision2 ~  Year+Age+RiskL,data = POrig)
summary(per9)
per10<- lm(PersonalInjury2 ~ Year + Vsize+RiskL,data = POrig)
summary(per10)


Year=rep(2020:2035,each=27)
Vsize=rep(c("L","M","S"),each=9,times=16)
Age=rep(c("M","S","Y"),each=3,times=48)
RiskL=rep(c("A","H","L"),times=144)
p_frame=data.frame(Year,Vsize,Age,RiskL)
p_frame$Exposures=predict(Per_exp,p_frame)
p_frame$BodilyInjury1=predict(per1,p_frame)
p_frame$PropertyDamage1=predict(per2,p_frame)
p_frame$Comprehensive1=predict(per3,p_frame)
p_frame$Collision1=predict(per4,p_frame)
p_frame$PersonalInjury1=predict(per5,p_frame)
p_frame$BodilyInjury2=predict(per6,p_frame)
```

```
p_frame$PropertyDamage2=predict(per7,p_frame)
p_frame$Comprehensive2=predict(per8,p_frame)
p_frame$Collision2=predict(per9,p_frame)
p_frame$PersonalInjury2=predict(per10,p_frame)
library("readr")
write_csv(p_frame, path = "C:/Users/Vanora/Desktop/SOA Challenge/PersonalPre.csv")
```

B-5 New Personal in 2022

```
Year=rep(2020:2035,each=135)
Vsize=rep(c("L","M","S"),each=45,times=16)
Age=rep(c("M","S","Y"),each=15,times=48)
RiskL=rep(c("A","H","L"),each=5,times=144)
Level=rep(1:5,times=432)
p_frame=data.frame(Year,Vsize,Age,RiskL,Level)
library("readr")
write_csv(p_frame, path = "C:/Users/Vanora/Desktop/SOA Challenge/Personal2022.csv")
```

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