Autonomous Vehicles Insurance Policy Report

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I. Executive Summary

The autonomous car industry is the leader in car industry development. Now, we are testing the performance of the autonomous car on the road. We expect that in the short future the autonomous vehicle will enter the market formally.

With the increase in public adoption of autonomous vehicles in the future, there will be a shift from traditional cars to autonomous cars, same as insurance. As a leading insurance company in Carbia, Safelife needs to develop an autonomous insurance plan which requires to execute in the future to secure its leading position. The critical question we need to consider is what the insurance policy should cover? What's the premium level we should set.

In this report, we will focus on these two points, considering the factors we need to think about when we design the autonomous insurance policy. We will also predict the exposure of autonomous cars and the premium of the autonomous insurance policy.

II. Background

(i) Public Attitudes Toward Autonomous Vehicles

Autonomous Vehicles are expected to be safer than traditional ones due to the reduction in human-caused error accidents. However, the public expresses strong concerns about its actual effectiveness. A Pew Research Center Survey showed that public attitudes towards the influence of driverless car in the number of traffic accidents are entirely different. In total, 61% of participants say driverless cars cannot reduce traffic death, with 30% of participants think some traffic deaths will even increase under the extensive use of driverless cars.

Other than the safety issue, according to the research of Public Views Toward Automated Cars, over half of respondents are strongly worried about "equipment or system failures," "higher vehicle purchasing cost," "risk of vehicle security from hackers," and "legal liability in case of the accident."

Even though there are many potential concerns, the development of autonomous cars is still attractive to the public. According to the research of Public Views Toward Automated Cars, over half of respondents are very interested in benefits like "increased mobility for the elderly, disable and others," "reduced fuel consumptions and emissions," or "lower insurance rates." Besides, "automatically navigate through a road network" is also an appealing benefit that 53% of respondents are moderately attractive to it.

With consideration of all related benefits and concerns, 60% of respondents would like to use automated cars if they are available in the future, with 44% of respondents would love to own one for private use, and 16% of respondents would like to use it through car sharing or pooling.

(ii) Autonomous Cars' Price and How Many People Can Afford It?

Speaking of autonomous cars' price and how many people can afford them, according to the National Dealers Association (2018), the average American spends around $30,000 on a new car or light truck. However, the price of the automated vehicle is approximately $250,000 per vehicle.

Therefore, in 2018, attitudes around self-driving technology have reversed with nearly half of consumers responding they would never buy a Level 5 vehicle. One of the main reasons is the price of the high-level autonomous car.

However, according to a recent study, IHS Automotive forecasts that the price for the self-driving technology will add between $7,000 and $10,000 to a car's sticker price in 2025,a figure that will drop to around $5,000 in 2030 and about $3,000 in 2035, the year when the report says most self-driving vehicles will be operated completely independent from a human occupant's control. The incremental decreases in cost are projected based on the adoption of the technology (i.e., projected increases in sales of cars with SDC technology). IHS predicts that annual sales between 2025 and 2035 will jump from 230,000 to 11.8 million. That's about 9% of all the world's auto sales in 2035. Seven million of those 11.8 million vehicles will rely on a mix of driver input and autonomous control, with the remaining 4.8 million vehicles relying entirely on computers to get around.

In summary, in short future, the small percentage of people will accept and afford automated cars, but as the technology matures in the following ten years, the cost will gradually decrease, and more and more people will rely heavily on automated vehicles.

(iii) Attitude Towards Autonomous Cars:

Public attitude has always been highly skeptical towards autonomous cars even though there are more and more successful experiments on autonomous cars conducted by companies like Tesla. The public concern comes more from the morality rather than technology side. People care more about who should be responsible in case of accidents associated with autonomous cars. However, this does not and probably never will come to a certain conclusion as to who should be responsible for how much of an accident. As a result, without a complete legislation specifying these proportions, the public and insurance companies are reluctant to get involved with autonomous cars because of the potential uncertainty of risk.

Comparatively, governmental attitude towards autonomous cars are much better. Introducing autonomous cars to the public will gradually reduce the cost on medical insurance due to car accidents because statistically, technology performs much better than human. So, the concern from the governments comes more from what will happen in the long transition from few autonomous cars to fully autonomous environment. The collapse of traditional cars and traditional driving habit with new autonomous cars and new driving "culture" will definitely overwhelm the benefit that autonomous cars could bring in the short run. Besides, even though hypothetically autonomous cars could reduce the cost on medical treatment, autonomous industry undoubtedly require much more inspection and related process cost which could be much more than the cost autonomous cars could ever possibly save.

However, even though the public and the governmental attitudes have never been very supportive. There is barely any huge obstruction to autonomous industry except for technological difficulty. Because autonomous cars don't directly affect the benefits of either party. Therefore, autonomous industry is gradually developing with

lack of both support and obstruction. Under the current circumstance, it is anticipated that there will be 3.5 million self-driving vehicles on U.S. roads by 2025, and 4.5 million by 2030. However, the institute cautioned that these vehicles would not be fully autonomous but would operate autonomously under certain conditions."

Currently, governmental attitude towards small autonomous cars is much better than that towards big autonomous cars because bigger cars carry more risk. And with autonomous technology, that part of the additional risk is extremely hard to predict and thus bad to the overall industry. And for companies, even the unpredictable risk with small cars are not good for their budgeting and thus commercial lines for autonomous cars will develop much slowly than the personal line side. As a result, the transition from traditional car industry to the autonomous car industry will most likely focus on small cars for families and individuals.

Even though there is not general support to incoming autonomous car industry. Some countries and regions are working on policies that will benefit the families and individuals who would like to buy autonomous cars in order to support this incoming industry and bring more profits in the long run. Some countries are also testing the combination of telematics and autonomous cars and try to add traditional human driving behavior to the programs of autonomous cars to better deal with the transition period from few autonomous cars to fully autonomous culture.

(iv) The Most Likely Market for The Adoption of The Autonomous Vehicles.

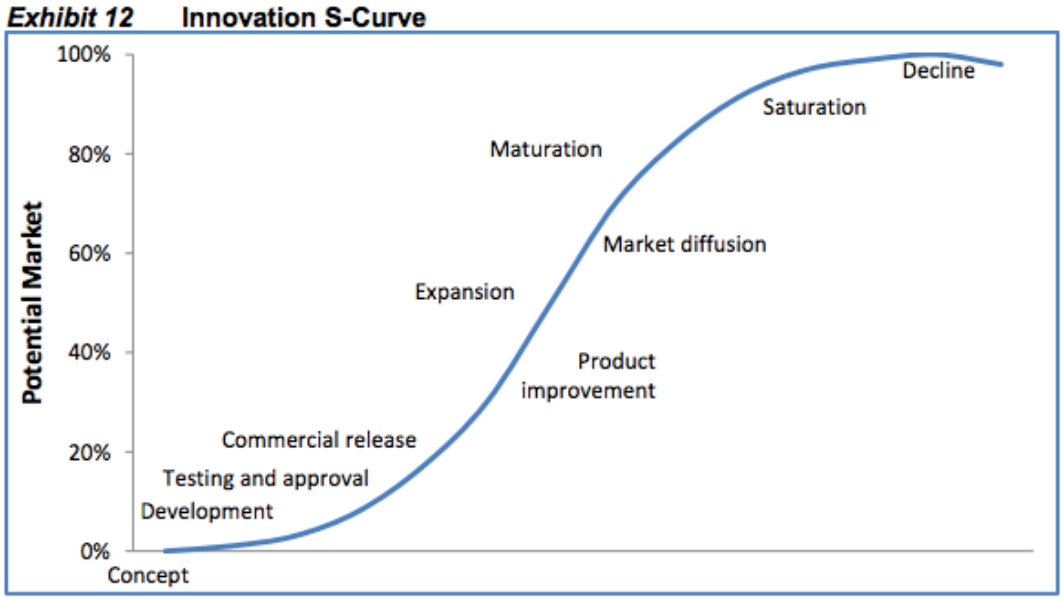
The adoption of the autonomous vehicles depends on the level of how much the human can operate the vehicles. In the study "2018 Cox Automotive Evolution Mobility Study: Autonomous Vehicles", it finds out that 84 percent of the consumers are more willing to operate the vehicles somehow by themselves even in a self-

driving vehicle and the remaining 16 percent would like to the drive the autonomous vehicles without the control over them. For the semi-autonomous vehicles, 54 percent of people mentioned being able to take the control over the self-driving vehicles would make them become better drivers, as they could operate the vehicles with collision warning and avoidance systems.

According to the study from Kelly Blue Book, 49 percent of the consumers states that they would not buy a level-5 vehicle, which is the fully autonomous vehicle, while only 48 percent of the groups aged within 12 and 22 years old and only 39 percent of the aged between 23 and 36 years old say they would never accept the level-5 vehicles. Therefore, comparing the rates of adoption for the autonomous vehicles in different groups of consumers, we find that people with the ages between 23 and 36 years old are more likely to adopt the autonomous vehicles in Carbia.

In addition, one of the factors that would affect the adoption of autonomous vehicles could be the environmental setting. According to Miralles-Guasch and Domene, the closed environments, including the college campus, airports, retirement villages, parks and golf courses, would be more desired settings for the adoption of autonomous vehicles.

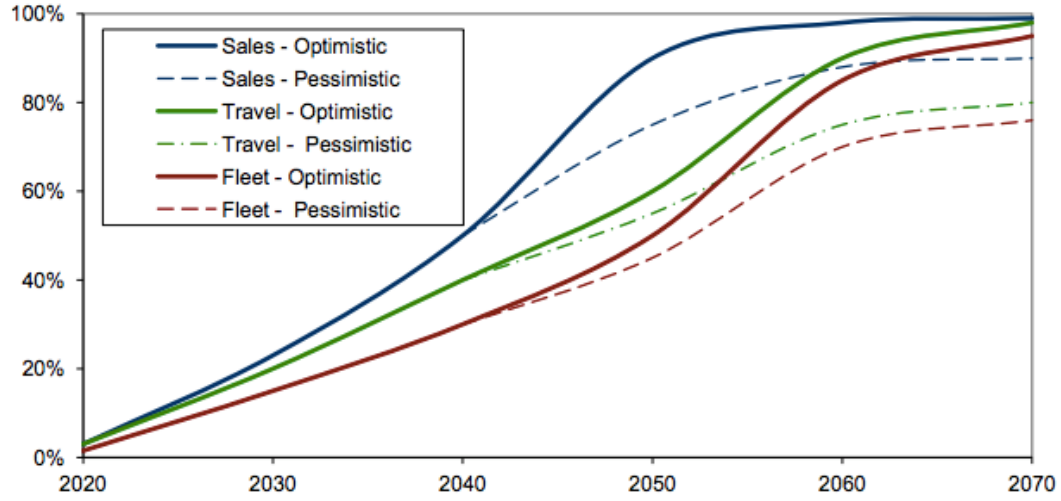
(v) The Timeline for the Adoption of the Autonomous Vehicles.



Most of the innovated products would follow the S-curve deployment curve, with the stages of development, testing, approval, commercial release, product improvement and others showed in the chart above. Therefore, we assume the innovation of the autonomous vehicles would generally follow this pattern.

Although we cannot accurately predict the date that the autonomous vehicles would be fully accepted by the market, we could make estimations about how quick the shift from the traditional vehicles to the self-driving ones will be.

Exhibit 14 **Autonomous Vehicle Sales, Fleet and Travel Projections** (Based on Exhibit 13)



When we look at the distribution of the deployment of the autonomous vehicle sales in the first ten years after 2020, we could find the line is almost linear. At time of 2030, the deployed rate of the autonomous vehicles would probably be 20%. And the adoption rate would be very high and close to 100% in 2055.

(vi) The Change in Extents That the New Policy Should Cover and The Liability Assigned in Case of Accidents.

As the driverless cars would significantly reduce the risks associated with human, the premium of the new policy would be decreased, but not would disappear. As long as there are some uncontrollable and unpredictable situations happen, such as car theft, softballs that hit the windshields, the animals that rush into the road, the insurance would remain as necessary as ever.

However, there would be a large shift of the coverage from the traditional insurance policy to the new policy. When we determine the policy premium, the factors that we should consider are changed from the human driving behavior, human errors and human foibles, to machines-related risks like cyber security, product liability, and infrastructure system.

- Cyber Security. Once the autonomous vehicles are placed on the market, one of the most concerned issue is the security of the information. Cyber data theft, digital attacks, and leakage of personal information are the most risks that should be focused on. More and more hardware and software would be incorporated, insuring against the risks related to cyber could create as much as $12 billion in annual premium.

- Product liability. The expensive sensors and chips of the autonomous vehicles and the failures due to the software defects, memory leaks, the algorithmic flaws, and the resulting responsibilities are the risks that the manufacturers would face, insuring against this is a $2.5 billion annual opportunity.

- Infrastructure Insurance. The cloud server system, GPS repository, signals, real-time alert and other safeguards, which are used to protect the drivers and riders, would be a major problem associated with the infrastructure. Insuring against this would generate as much as $500 million in the annual premium for the property and casualty insurers

On the other hand, although autonomous vehicles could decline the accidents rate, it doesn't mean everything is predictable and controllable. In case of accidents, the parties that the liabilities assigned to would change. For the partially auto-cars, which could be operated by human, the assigning responsibilities would rely on which party made the decisions and actions. Therefore, it could be human and the manufacturers as well. For the fully autonomous vehicles, there are many parties, who are going to take or share the liability, including software and hardware producer, manufacturers, services center, and the vehicles owners. If the accidents happened, the liability would likely assign to the manufactures due to the design faults, assign to the software producer due to system defects, assign to service center due to deficient services to the vehicles, or assign to the owner due to lately updated system.

III. Key Variables Estimating

(i) 95% Prediction Interval for Total Number of Exposures of Traditional Cars in the Future

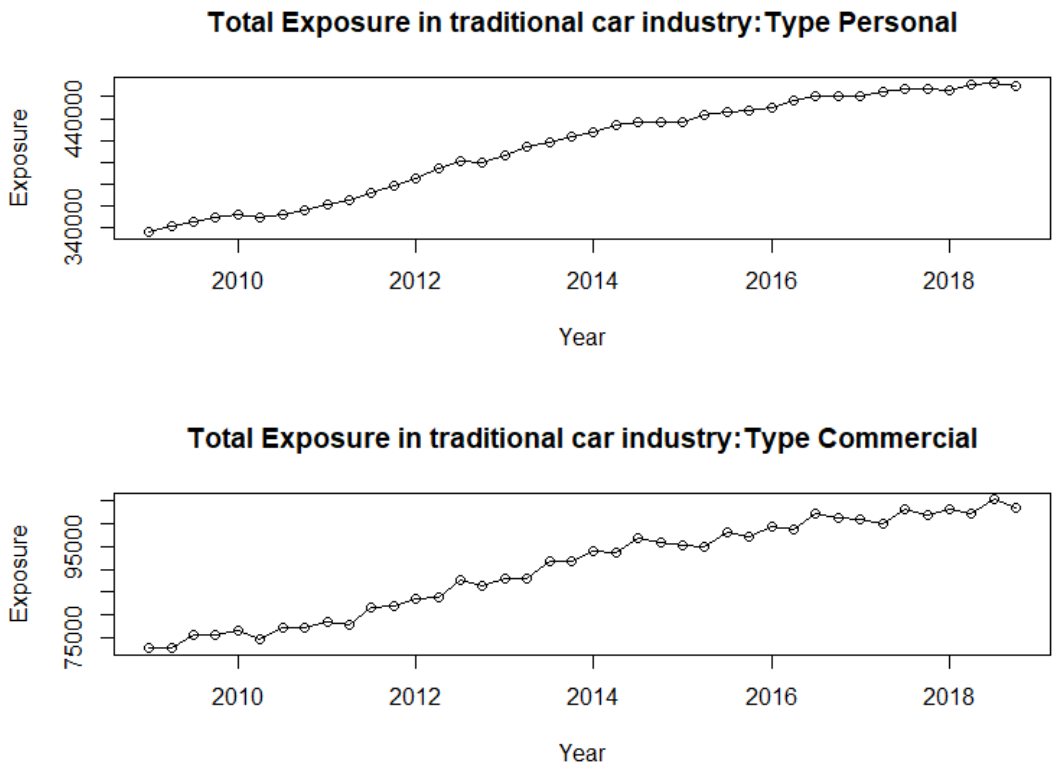


figure 4 1

From the figure 4-1, the exposure rate in the traditional car industry is increasing through time. But in the recent year, it seems that the rate of increasing number of exposures is diminishing. In the future, we expect the exposure in the traditional car industry continuously increase in decreasing rate.

Figure 4-2 shows the 95% prediction interval of total number of exposures of traditional car for each type. We are 95% confident that our prediction interval will capture the actual number of exposures in traditional car industry until 2030.

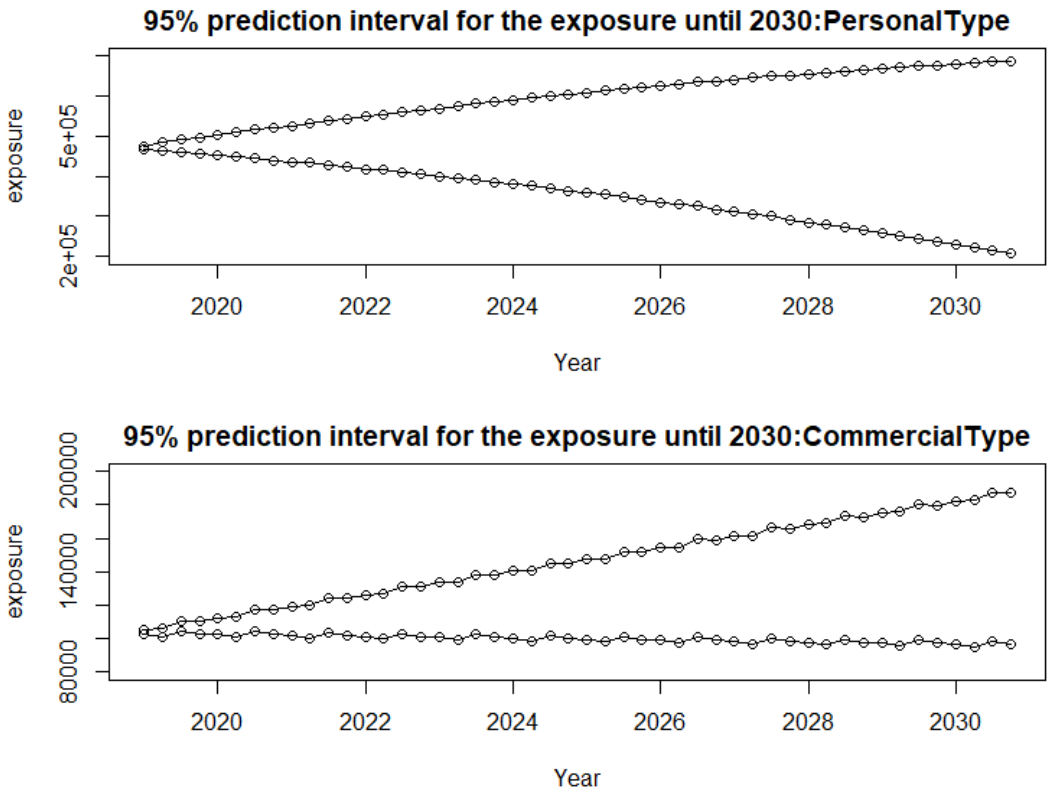


figure 4 2

(ii) Estimation of the 95% Prediction Interval for Total Number of Exposures of Autonomous Cars in the Future

Carbian law requires that all automobile owners purchase automobile insurance. We assume each person owns only 1 car. So, the number of cars sold equals to the number of exposures. Further, we can get the following relationship:

$$\frac{number\ of\ exposures\ of\ traditional\ car}{number\ of\ exposures\ of\ autonomous\ car} = \frac{number\ of\ traditional\ car\ sold}{number\ of\ autonomous\ car\ sold}$$

According to our research, we find out that in the next 10 years, the sales of autonomous car increase in constant rate. Sofia expect new policy account for 20 to 25 percent of overall business by the year 2030. We assume the autonomous car will enter the car industry at 2020 and occupy 2-5% of car industry's market share at end of 2020. By 2030, autonomous car will occupy 20% - 25% of car industry. We expect development rate of sales of autonomous car market increasing in constant rate. The

result shown in figure 4-3.

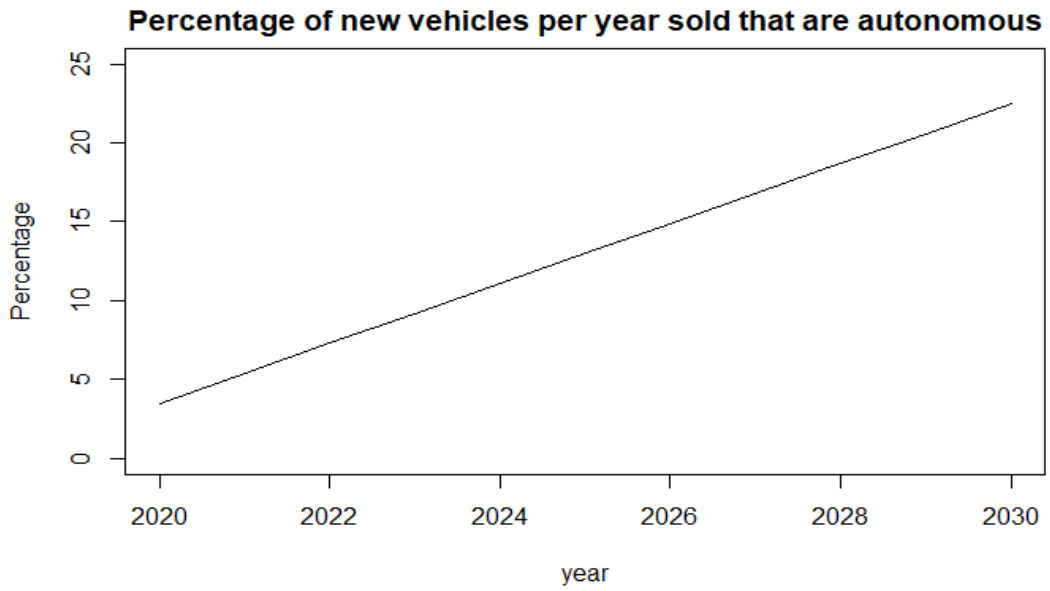


figure 4 3

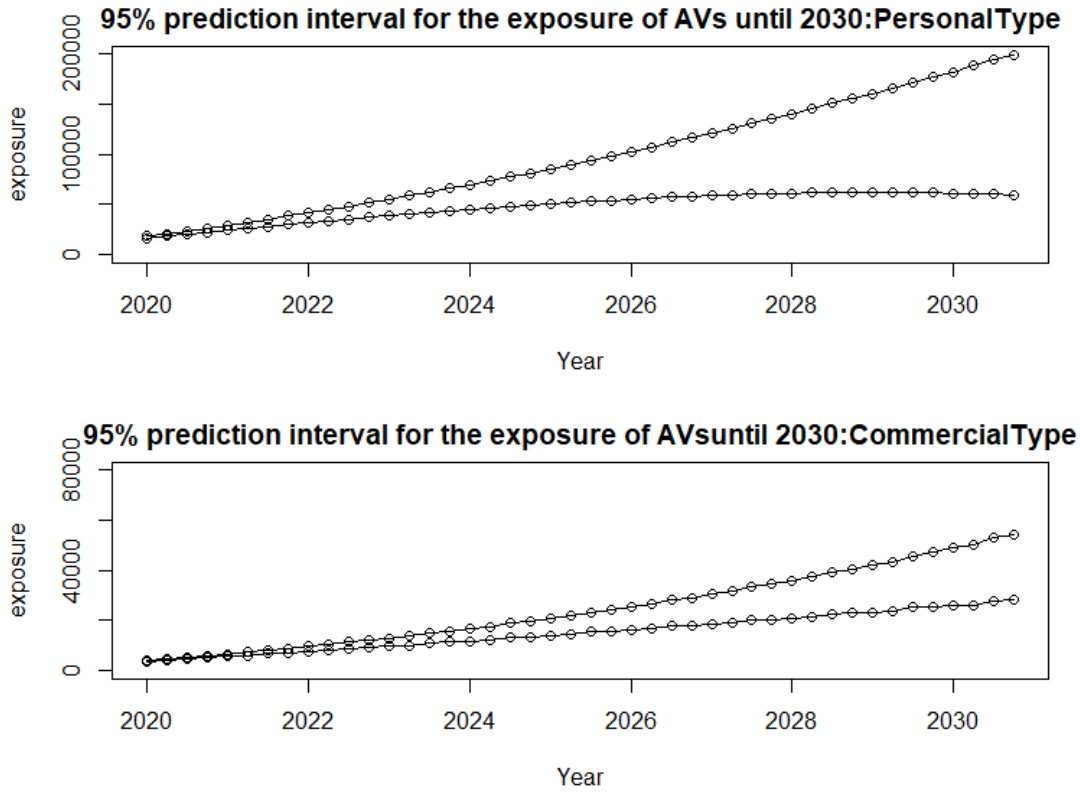


figure 4 4

Since we know the exposure rate of car in traditional car market, we can estimate the 95% prediction interval for the exposures of autonomous car during 2020-2030.

(iii) Frequency and Severity in Traditional Car Industry

We define the frequency and severity in the following way

$$frequency = \frac{Number\ of\ Claims\ incurred}{Policy\ counts}$$

$$severity = \frac{Amount\ of\ Loss\ incurred}{Number\ of\ Claims\ incurred}$$

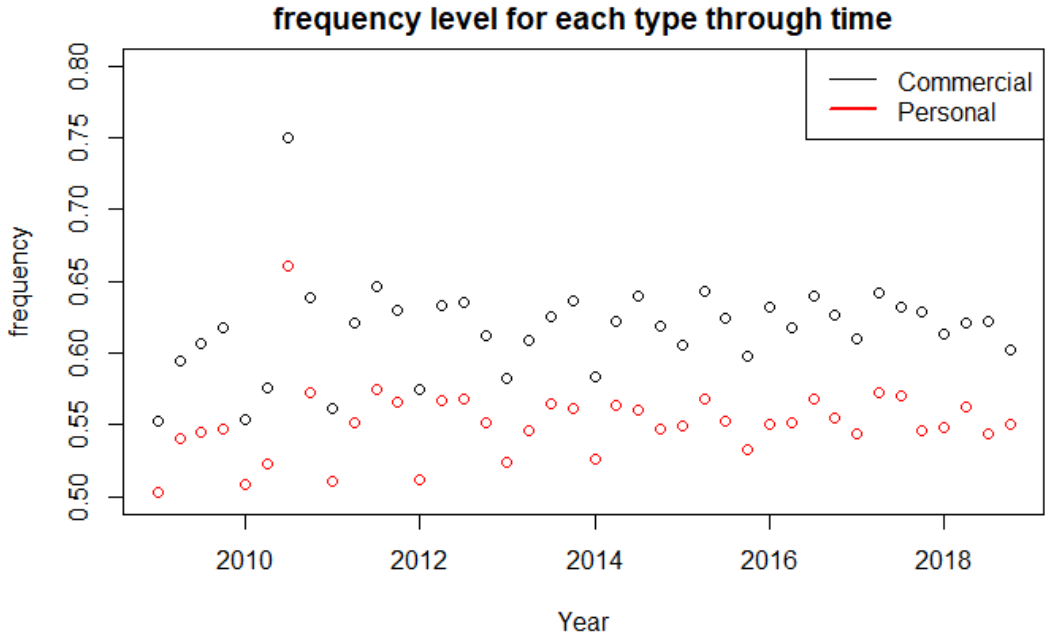


figure 4 5

From the figure 4-5, we find out that the frequency level tends to stay in constant level. There is no obvious increasing or decreasing trend from the chart. Thus, for simplicity we will use the average frequency level as an estimated frequency level at time t.

From the figure 4-6, the severity level shows some increasing trend. As time goes by, the severity level is increasing exponentially. We expect this trend will continuously forward through 2019-2030.

(iv) Frequency in Autonomous Car Industry

Autonomous car industry is a new market which we have no data to calculate the frequency and severity. However, we expect there is relationship between the

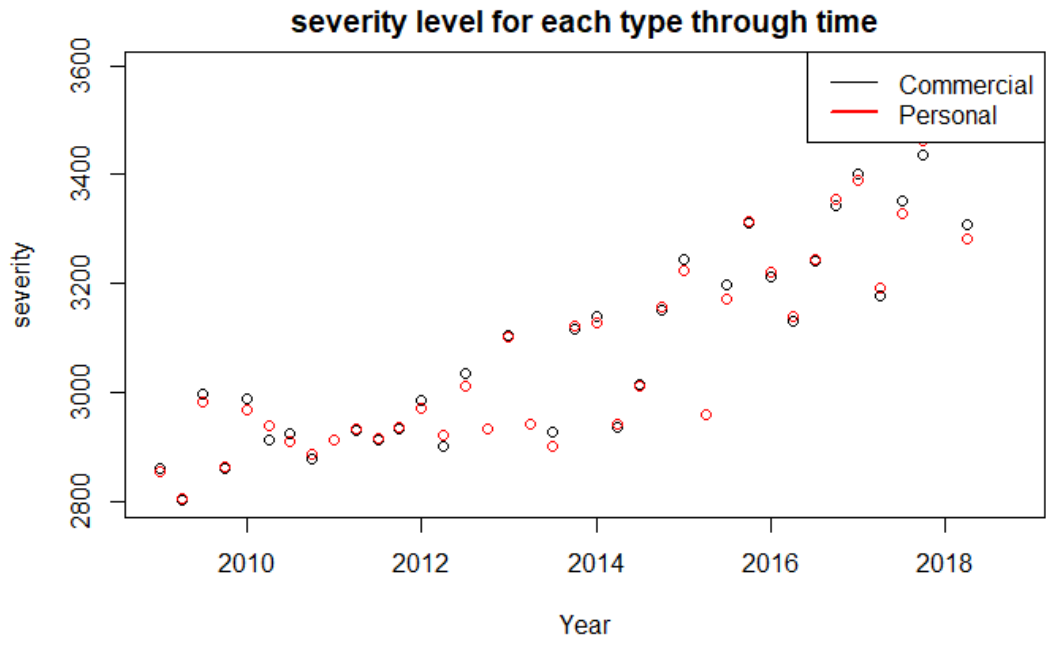


figure 4 6

traditional car's frequency and autonomous car's frequency.

In general, we assume the autonomous car's frequency can be calculated as

$$Freq_{Avs} = Freq_{traditional} * TransitionalRatio$$

Transitional ratio is different for different risk level. We can calculate each ratio by using the following formula.

$$Freq_{Avs\ type:u} = \left(\sum weight_{ijku} * Freq_{ijku} * T_b * \sum (F * R)\right)$$

- i stands for the vehicle size, $i \in \{Small, Medium, Large\}$
- j stands for the driver age, $j \in \{Young, Middle, Senior\}$
- k stands for the driver risk, $k \in \{Low, Average, High\}$
- u stands for the type of policy holder, $u \in \{Personal, Commercial\}$

- weight is the percentage of exposure of specified risk class in total exposure

- $Freq_{ijk}$ is the frequency of specified risk class

- $Severity_{ijku}$ is severity of specified risk class

-T_b: $the\ base\ transitional\ ratio$. In general, we assume the base transitional ratio is 90%. The frequency of autonomous car's frequency will be 90% of traditional car's frequency in general.

- $\sum(F * R)$: represent transitional ratio for specified risk class. F represent risk variable, including three types which are driver risk, driver age and vehicle size. And R is transitional ratio for each risk variable.

Through our research, we get the following transition table.

Transitional Ratio Table for Autonomous Car Industry

	Frequency	Severity
Base transitional ratio	0.9	1.2
F		
type	Ratio	
Car size	0.55	
Driver age	0.15	
Driver risk	0.3	
R		
Car Size	Frequency	Severity
Small	0.6	0.7
Middle	0.7	0.75
Large	0.8	0.85
Age		
young	0.6	0.65
middle	0.85	0.9
senior	0.75	0.8
Driver Risk		
low	0.9	0.9
average	0.8	0.85
high	0.65	0.75

- After calculating, we get the estimated frequency for autonomous car is

  - personal: 0.365910916

- commercial: 0.410385853

IV Results

(i) Average Pure Premium for Autonomous Cars

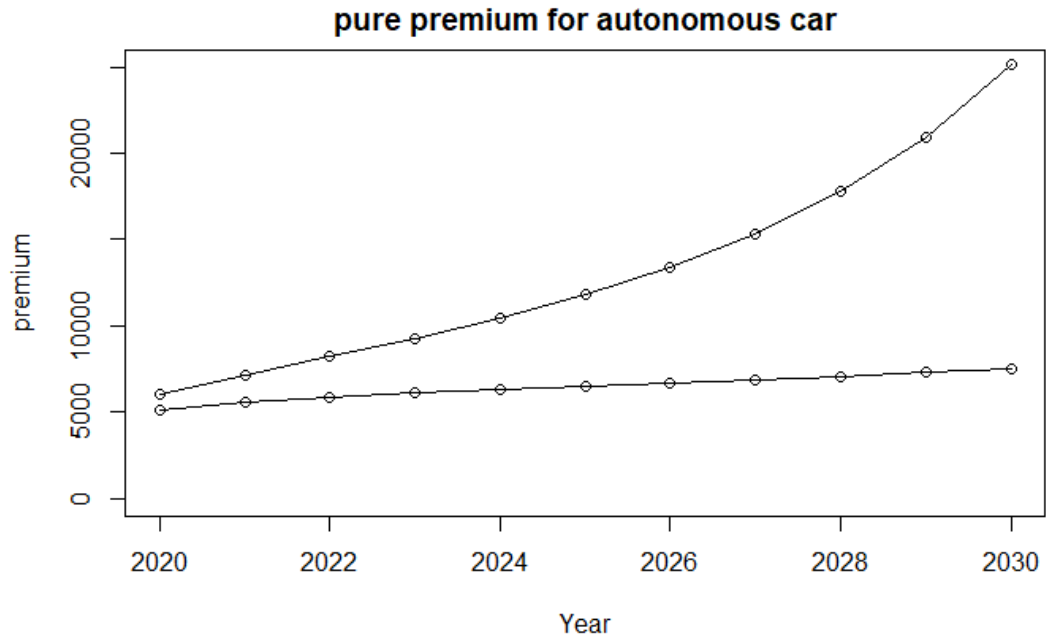


Figure 5 1

The pure premium we need to set is shown in figure 5-1. The pure premium for the autonomous car should set somewhere between two bounds. We recommend Safelife can try to set the price high to avoid the unpredictable risk.

(ii) Policy Coverage

The policy should cover bodily injury liability, personal injury, property damage, collision and comprehensive liability. Except these five liabilities, the new policy should also cover the liability caused by cyber security, product liability and Infrastructure liability.

V Data Limitation and validation requirement

- Since autonomous car industry is a new market. Currently, there is no actual data

related to the market of autonomous car. So, it’s important for Safelife to get the data about the market of autonomous car.

- the frequency and severity for autonomous car are still unknown. Although some research report make prediction about how the frequency and severity will change, it’s still not very credible because autonomous car is high-tech product, and still in development. Safelife need to do some collect the data related to the data from the autonomous manufacturer, knowing how the frequency of autonomous incur malfunction.

Appendix

A. Calculating process

A1. total number of exposures in traditional car industry

Setting following parameter

- $E_p(T)$: total number of exposures in traditional car industry for personal type

- $E_c(T)$: total number of exposures in traditional car industry for commercial type

Personal Type Model

- Setting variable D_{T-1} as $D_{T-1} = E_p(T) - E_p(T-1)$, where D_{T-1} represent the difference of exposure between t and t-1.

- $D_{T-1} = \beta_0 + \beta_1(T-1) + \beta_2 * Q_1 + \beta_2 * Q_2 + \beta_3 * Q_3 + \beta_4 * Q4$ where, for example, $Q_1 = 1$ if T-1 is in quarter 1,otherwise, $Q_1 = 0$

```
Call:
lm(formula = D ~ time(D) + M + 0)

Residuals:
    Min      1Q  Median      3Q     Max
-8662.0 -1196.1   247.8  1607.9  3591.4

Coefficients:
        Estimate Std. Error t value Pr(>|t|)
time(D)   -89.56      36.39  -2.461 0.019102 *
M1       6751.77    1062.96   6.352 3.02e-07 ***
M2       5740.23    1086.98   5.281 7.42e-06 ***
M3       3472.69    1111.68   3.124 0.003638 **
M4       4858.80    1119.80   4.339 0.000121 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2553 on 34 degrees of freedom
Multiple R-squared:  0.7167,    Adjusted R-squared:  0.675
F-statistic:  17.2 on 5 and 34 DF,  p-value: 1.795e-08
```

- setting Y_t as stationary time series and $Y_t \sim N(0, \sigma^2)$

$$\widehat{\sigma^2} = \frac{\sum residual^2}{d.f.} = 2553\text{^}2$$

- $E_p(T+1) = E_p(T) + D_T + Y_t$

- 95% prediction interval for the $E_p(T+1)$

$$E_p(T+1) = E_p(T) + D_T \pm 1.96 * \sigma$$

Commercial Type

- Setting variable D_{T-4} as $D_{T-4} = E_c(T) - E_c(T-4)$, where D_{T-4} represent the difference of exposure between t and t-4.

- $D_{T-4} = \phi_1 D_{T-5} + \phi_2 D_{T-6} + \phi_3 D_{T-7} + \phi_4 D_{T-8} + y_{T-4} + \theta_1 y_{T-5}$

```
Series: D1
ARIMA(4,0,1) with non-zero mean

Coefficients:
         ar1     ar2     ar3      ar4     ma1       mean
      0.4268  0.3257  0.1284  -0.4550  0.9272  3350.0587
s.e.  0.1540  0.1774  0.1697   0.1497  0.1134   409.8995

sigma^2 estimated as 632141:  log likelihood=-290.34
AIC=594.67   AICc=598.67   BIC=605.76

Training set error measures:
                    ME     RMSE      MAE       MPE     MAPE      MASE      ACF1
Training set -28.27468 725.7989 602.2301 -8.061986 24.77393 0.8656641 0.1136851
```

Where $Y_t \sim N(0, \sigma^2)$ and $\sigma^2 = 632141$

- $D_{T+4} = \phi_1 D_{T+3} + \phi_2 D_{T+2} + \phi_3 D_{T+1} + \phi_4 D_T + \theta_1 y_{T+3} + y_{T+4}$

- 95% prediction interval for the $E_c(T+4)$

$$E_c(T+4) = E_c(T) + D_T \pm 1.96 * \sigma$$

A2 the percentage of cars sold that are autonomous

```
MarketShare = seq(2,20,18/43)
MarketShareUp = seq(5,25,20/43)
estimateAVS = (MarketShare+MarketShareUp)/2
```

A3 How to get transition ratio

Generally speaking, self-driving cars could reduce the number of car accidents on average due to repetitive experiments and technological improvements year over year. Considering five different levels of self-driving cars. We give an average of 10% deduction to the frequency when transiting frequency data from regular cars to self-driving cars. However, this decrease in frequency is at the cost of higher severity. Because autonomous cars, especially those that are highly autonomous, are comparatively more expansive than regular cars with similar functionality. Besides, the repair cost for autonomous cars are usually higher than regular cars because the software in autonomous cars are much more vulnerable than regular tools in cars. Car technicians could easily replace gears in regular cars with new ones, but for

autonomous cars, damage to part of the self-driving system or hardware might need a full replacement for the entire system which will greatly increase the repair cost. Furthermore, people are much more concerned with self-driving cars that have accidents history than regular cars. In conclusion, for base transition factor, we choose 0.9 for frequency and 1.2 for severity.

In this project, there are a couple of factors that categorize the risk classes of the exposures: driver age, car size and driver risk. And we subjectively select the weights for each factor for their respective effect on the transition of frequency and severity from regular cars to self-driving cars. (0.55 for car size, 0.15 for driver age, 0.3 for driver risk.)

For each of the three groups under each factor, based on the information we gathered on the internet, we pick a transition ratio for both frequency and severity. Unsurprisingly, these transition ratios work like a smoothing factor, in a way that it decreased the risk of high-risk class like SYH more than the risk of low-risk class like LML.

B. Enclosed file

- transforData.Rmd

- Estimating Parameter.Rmd

- freqSeverityEstimate.xlsx

References

Cox Automotive (2018). Autonomous Vehicle Awareness Rising, Acceptance Declining, According to Cox Automotive Mobility Study. *Vital Findings.* *https://www.coxautoinc.com/news/evolution-of-mobility-study-autonomous-vehicles/*

Cusano, J., & Costonis, M. (2017 December 05). Driverless Cars Will Change Auto Insurance. Here's How Insurers Can Adapt. Retrieved from https://hbr.org/2017/12/driverless-cars-will-change-auto-insurance-heres-how-insurers-can-adapt

Insurance Information Instituion. (2018) Background on: Self-driving cars and insurance. Retrieved March 21,2019, from https://www.iii.org/article/background-on-self-driving-cars-and-insurance

Jurdak, R., & Kanhere, S.S. (2018 March 20). Who's to blame when driverless cars have an accident? Retrieved from https://theconversation.com/whos-to-blame-when-driverless-cars-have-an-accident-93132

Kerr, M. (2016 October 1). Autonomous Risk-When self-driving vehicles meet the sharing economy, numerous industries will need to brace for change; insurance among them. Retrieved from https://riskandinsurance.com/strap-mobility-revolution-2/

Levine S. (2017) What it really costs to turn a car into a self-driving vehicle?

Quartz. .*https://qz.com/924212/what-it-really-costs-to-turn-a-car-into-a-self-driving-vehicle*

Miralles-Guasch,C., & Domene, E. (2010) Sustainable transport challenges in a suburban university: the case of the Autonomous university of Barcelona. *Transport Policy. 17(6),* 454-463. doi: 10.1016/j.tranpol.2010.04.012

Piao, Jinan et al., (2016). Public Views towards Implementation of Automated Vehicles in Urban Areas. Retrieved March 21, 2019, from https://www.sciencedirect.com/science/article/pii/S2352146516302356

Smith, A., & Anderson, M. (2019). Americans and Automation in Everyday Life. Retrieved March 21, 2019, from https://www.pewinternet.org/2017/10/04/automation-in-everyday-life/

Tannert. C (2014) Will you ever be able to afford a self-driving car? *Fast Company.*

https://www.fastcompany.com/90317471/what-you-dont-know-about-your-health-data-privacy-will-make-you-sick