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Pink Team: Arizona State University

Autonomous Vehicle Insurance Policy Design

SAFELIFE AUTO INSURANCE

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EXECUTIVE SUMMARY

Autonomous vehicles (AVs) are expected to bring about many changes to how auto insurance is priced. When recommending a design for a new AV insurance policy, many assumptions must be considered. Given assumptions, pure premium estimates can be developed, along with a ten-year forecast of pure premium from the recommended point of launch. To provide this forecast, a baseline estimate of traditionally priced pure premium can be computed, and transformed to account for the change in exposures resulting from the entry of AV policies. Then, a sensitivity analysis can be performed assuming first that AV policies are developed, and then that they are not developed. To ensure consideration of all factors, several concerns will be addressed throughout this report, which leads into explanations of how assumptions were made.

In order to maintain Safelife's dominant market share in the coming years towards 2030, it is recommended that the company launches AV products under both personal and commercial lines as soon as possible to offset the expected migration of traditional auto policyholders towards AV coverage.

1 ASSESSMENT OF NEW RISKS

1.1 ADOPTION OF AUTONOMOUS VEHICLES IN CARBIA

Prior to analysis, arising risks associated with AVs must be discussed. Because Carbia is a primarily urban and suburban country with very few rural areas, assumptions about their adoption of AVs can be derived from an analysis of the impact of AV adoption in urban and suburban cities around the United States. It has been observed that the earliest AVs will be luxury cars and commercial fleets. They will be used in highly "covered metropolitan" areas with extensive highways and well-mapped streets. They will also be used in the rideshare industry. For example, GM has invested in Lyft and Volvo has invested in

Uber in hopes that a certain percentage of Lyft and Uber rides will be self-driving vehicles, Levels 3 and 4 (see Figure 1.3), provided by these manufacturers. Regarding timing, it is anticipated that Level 3 and Level 4 AVs will infiltrate the personal auto and commercial auto markets first. After ten years, it is anticipated that Level 5 will become more prominent in the market (Walker).

1.2 FACTORS AFFECTING POLICY DESIGN

Because fewer people will be owning vehicles as AVs enter the market, there will need to be both personal and commercial coverages. Exclusions will be necessary for coverage in the event the personal owner or company responsible for the vehicle's provision fails to perform proper maintenance on the vehicle. Because it is anticipated that the rideshare industry will be a key player in the AV business, it can be expected that a large portion of the policies will include commercial coverage. Therefore, both personal and commercial policies will need to include cyber liability, products liability, and infrastructure. The extent to which these liabilities should be accounted for will vary by Level of autonomy. For simplification, analysis will proceed under the assumption that Safelife does not include excess and specialty insurance products, and so large trucking commercial use will not be covered.

Traditionally, auto insurance policy designs consider rating factors such as the policyholder's age, gender, vehicle type, vehicle age, and so on. However, as AVs emerge into the market, rating factors will place a heavier weight on the vehicles' characteristics rather than the drivers' characteristics, such as the vehicle manufacturer, reliability of technology, and level of automation. In fact, legislation has already been passed in some American states that waives the requirement of a driver's license to ride in an AV (National Conference of State Legislature). Because the legislation patterns in Carbia mirror those of the United States, one can expect the requirements to be on the road, as well as the rating factors used in actuarial analysis, to shift focus towards the characteristics of the vehicles. Future regulations may place restrictions on the rating variables that insurance underwriters can consider when pricing an insurance

policy; for example, perhaps Carbia will enact legislation forbidding insurance companies from considering any underwriting characteristics regarding the drivers' characteristics and only rate based on the vehicle itself. Currently, however, there are no existing regulations forbidding certain underwriting characters from being used, so both the drivers' and the vehicles' characteristics are utilized in this analysis when using traditional pricing methods.

When projecting the impact that AVs will have on the insurer's book of business, it is best to make conservative assumptions. If the cost of a traditional policy is less expensive than that of an AV policy, it is safer to assume that less of their book of business will consist of AV policies. Similarly, if the cost of a traditional policy is more expensive than that of an AV policy, it is safer to assume that more of their book of business will consist of AVs. This way, at the end of a given year, there is a greater chance of having more premium than planned rather than having less premium than planned.

In summary, the number of traditional insurance policies issued will decrease as the AVs become more popular, more cost efficient to produce, and more available to the general public. Over the 10-year time horizon, the number of traditional policies issued will decline, and a general progression upwards through the Levels of autonomy will be seen.

1.3 ASSIGNMENT OF LIABILITY

Depending on the level of automation, liability is speculated to fall on either the manufacturer of the technology or operator of the vehicle. According to Figure 1.3, the human driver monitors the driving environment for Levels 0-2, and the automated driving system monitors the driving environment for Levels 3-5. Therefore, it can be assumed that patterns in risk and liability exposure for Levels 0-2 will be very similar to those of traditional vehicles. For Levels 3-5, the majority of the risk and liability exposure will fall onto the manufacturer of the AV, and possibly also onto the company contracted to provide the vehicles to customers. In the case of personal ownership of a Level 3-5 AV, a case which is expected to

account for a small minority, the person who owns the vehicle and has taken on the responsibility of its upkeep would face most of the risk and liability exposure. (Munich Reinsurance).

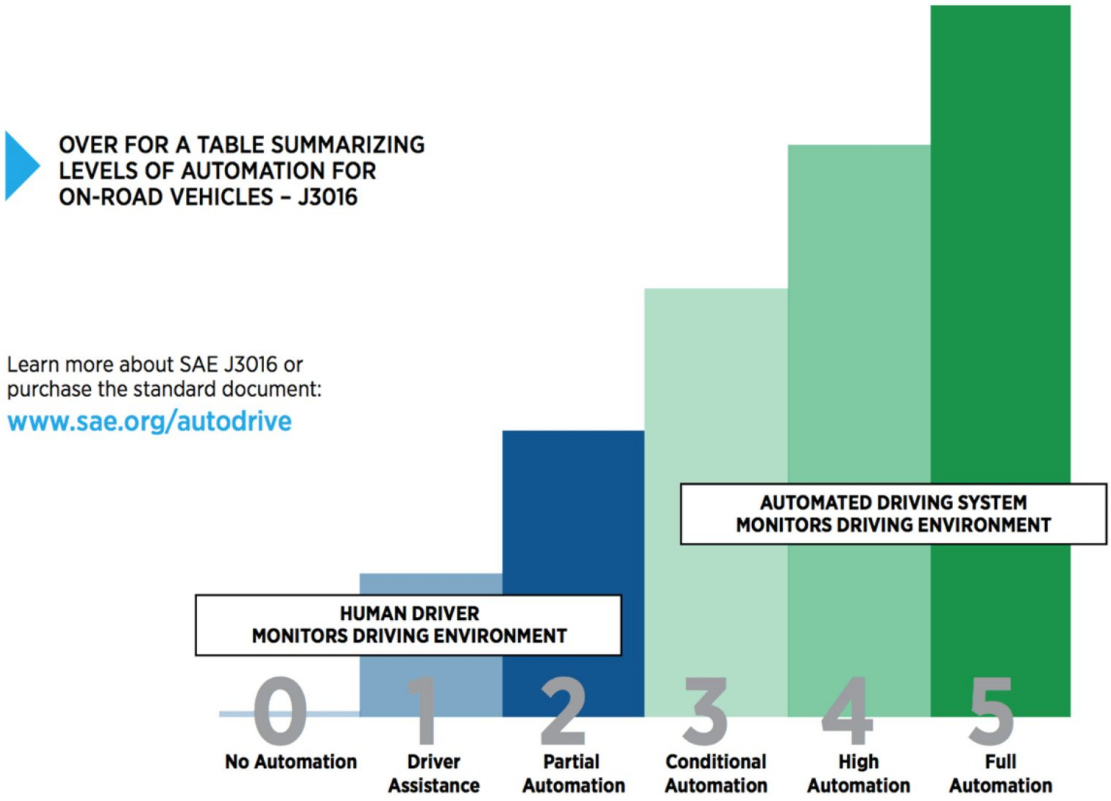

Figure 1.3: The bar graph above compares the different levels of automation for vehicles.

Additionally, AVs with higher Levels are more likely to get hacked, and while those exposures exist today, the auto industry has acknowledged the growing potential for cyber security threats as vehicles become more connected to each other and to the Internet or other networks (Munich Reinsurance). Regarding specifically cyber threat risks, the assignment of liability would be contingent upon the measures taken by the vehicle owner (an individual or a company) to prevent cyber threats, and also upon the results of an investigation into the party responsible for the cyber attack.

2 CONSIDERATIONS FOR POLICY CREATION

2.1 DATA PROVIDED

The data contains ten years (2009-2018) of historical claims from both commercial and personal auto policies. These policies are traditional (not autonomous) and contain vehicle size, driver age, and driver risk. There are three classifications per category, totaling 27 risk classes, and over 2,000 observations. Exposures are given as the number of car years, and claims incurred is categorized by quarter. Claim amounts are net of deductibles and copayments, without reinsurance or coinsurance for the purpose of increased visibility.

2.2 KEY ASSUMPTIONS

2.2.1 OVERALL ASSUMPTIONS

- Policies consider fully autonomous vehicles (Levels 4-5) only.
- Exposure, frequency, and severity were forecast through 2030 using their average annual growth rate from the most recent five years of data.

2.2.2 ADOPTION OF AVs

- Exposure Assumptions:
    - By 2030, 25% of Safelife's book of business will consist of AVs. The 5-year average growth rate of 2.5% was applied to exposures through 2030.
    - Personal and commercial lines will transition to AVs at the same rate.
    - One percent of the book will be autonomous, and this percent will increase exponentially until 25% is reached by 2030.

    - New business growth rates for personal and commercial lines in the first projected year will equal the observed, historical 5-year average growth rate. For each subsequent year, exposures under personal lines will decrease by 1% per year, and exposures under commercial lines will increase by 1% per year.

- Severity Assumptions:
    - Severity is adjusted to account for the increased cost of AV insured vehicles and the eventual ease of production.
    - See Figure 4 in the Appendix for specific severity adjustment factors used for personal and commercial lines.
- Frequency Assumptions:
    - A 90% reduction factor is applied to the number of autonomous claims, while traditional claims occur at the projected rate.

2.2.3 BASELINE ASSUMPTIONS

- Exposure Assumptions:
    - The annual growth for personal lines remains constant at 2.5%, and 2.9% for commercial lines, calculated as the five-year average growth rate from their experience.
    - The same number of insureds would purchase an AV, but would seek coverage elsewhere. i.e., reduced the 2030 projected exposure count for traditional auto policies by 25%.
- Severity Assumptions:
    - Severity would increase similarly to the projection with AV adoption. With 25% of the vehicles in Carbia being autonomous, they are initially more costly than the traditional policies, but level out by 2030.

- Frequency Assumptions:
    - Because the number of exposures are decreasing, claim counts are expected to follow the same growth rate as the five-year average claim rate from the historical experience (2.5% for personal lines, 3% for commercial lines). Other vehicles covered by different insureds being autonomous will not have a significant impact on the frequency of accidents of human drivers that Safelife covers. With the projection of only 25% of the book being AV by 2030, assume this is proportional to the total number of AVs in Carbia.

2.3 MARKET ENTRY

Regarding timing of market entrance, if Safelife launches the product prematurely, the number of AV drivers may be small, resulting in a higher variance of frequency, size, and severity of claims compared to a larger risk pool. With a higher variance of expected claim sizes, the pure premium will have to be more expensive to appropriately spread the risks in the event of an unusually high claim. However, charging a higher premium will risk adverse selection among the exposures, and the early adopters of AVs could likely be unfavorable risks. It is important for Safelife to launch the AV insurance product at an optimal time such that the risk pool is diverse enough for the favorable risks to subsidize the unfavorable ones. Finally, entering the market too early may result in inadequate or dangerous technology underlying the AVs, which could be expected to cause a higher frequency and severity of claims and, once again, would require a higher pure premium. Conversely, if Safelife enters the market too late, competitors could absorb potential business. To launch the product optimally, it must be ensured that the risk pool of insureds is large and diverse enough to subsidize the unfavorable risks, and that the technology is reliable enough that the expected cost of claims is less than that of traditional, non-autonomous vehicles. This will

allow a low variance in the expected cost of AV claims, and thus ensure an appropriately-priced, affordable premium.

2.4 FREQUENCY AND SEVERITY PREDICTIONS

The policy designs for both personal and commercial AV insurance will heavily depend on the covered vehicles' Level (Walker). Because it is assumed that higher levels of automation are safer than lower levels of automation, the frequency of claims decrease as a vehicle approaches full automation. The severity will increase due to the increased cost of AV technologies. When insured AVs fall within Levels 0-2, the vehicle still relies on human interception to prevent collisions. Therefore, an insurance policy covering a Level 1 AV should be priced to expect a higher frequency and lower severity of claims, while a policy covering a Level 5 vehicle will have a lower frequency, but higher severity when a claim is incurred. Thus, the policy design for lower levels of automation will require higher deductibles to cede more of the financial risk onto the policyholder than vehicles with higher levels of automation. As with traditional insurance, the new insurance product will need coverage for comprehensive damages due to weather and non-collision caused damages, as well as new coverage for cyber security as previously mentioned.

The frequency for the new AV policy's pure premiums will be similar to the frequency for the traditional vehicle policy's pure premiums, but with factors adjusting for varying exposures. For example, 90% of traditional automobile claims are caused by human error per the National Highway Traffic Safety Administration (The Rothenburg Law Firm LLP). Introduction of AVs (depending on the level of autonomy) will significantly decrease claims caused by human error. However, new exposures introduced by cyber risk and the possibility of hacking into cars will increase claims. The extent to which cyber risk will affect claims has not been seen yet, and will not be seen until fully autonomous vehicles are streamlined into the market.

The size of claims for the new AV policy's pure premiums will increase due to the higher price of technology installed in AVs and anticipated disregard of seatbelts. Initially, the claim size will spike, as the introduction of fully autonomous technology could add $100,000 to a car's value (Esurance). Even semi-autonomous vehicles can add anywhere from $5,000 to $10,000 to a car. However, once more AVs are on the road, mass adoption will lead to less expensive base models. Self-driving car analyst at ARK Invest, Tash Keeney, estimates that once AVs are widely used, the cost of fully autonomous technology will stay within $10,000 of the car's original price. Then, if the average price of an American vehicle is $31,500, then a $10,000 addition is a 31.74% increase in car value. This percentage increase can then be applied to all claim severity observations to translate them into severity estimates for AVs.

In summary, the severity of claims will spike initially due to cumbersome, high costs of replacing new technology. Over time, severity will plateau, and as the technology is heavily adopted, will only become a percentage of the car's total cost. Frequency, on the other hand, may also spike during the transition to AVs, as the day-to-day interaction of traditional vehicles and AVs has not yet been observed on a large scale. Not knowing how to mitigate cyber risks may also cause a spike in frequency until measures are advanced to adequately protect the AV technology. Eventually, frequency will decline steadily as the mix of vehicles on the road transitions to a higher percentage of AVs, and accidents caused by human error are consequently evaded.

3 PROJECTIONS

3.1 CREATION OF AV POLICY

To project Safelife's expected frequency to the year 2030, the estimated exposures was first projected for both autonomous and traditional vehicle policies under both personal and commercial coverage. Safelife's historical year-to-year exposure growth was analyzed for traditional policies--aggregated by year and

coverage type (personal or commercial)--and the ten, five, and three year averages were computed for each. The ten-year average was disregarded so that a heavier weight was placed on Safelife's most-recent growth experience. Thus, the five-year average exposure growth rate was selected since it takes more years of experience into account than the three-year average, while still considering recent trends. The five-year average growth rates were applied (1.025 for personal coverage and 1.029 for commercial coverage) to the observed exposures in 2018 to calculate the 2019 exposures, and this process was repeated until the personal and commercial policies' exposures were calculated through 2030.

Given total expected exposures for 2019 through 2030, these exposures were allocated to the number of traditional and AVs within these policies based on an exposure-portion assumption (see Figure 1 in the Appendix). In-line with Safelife's expectations, the portion of their AV policies will approach 25% of their total projected exposures in 2030, trending exponentially. This evolved into the exposure count assumption for both the baseline projection and the projection if Safelife adopts AV coverage.

Moreover, exposure growth was adjusted for personal and commercial types separately (see Figure 2 in the Appendix). Because commercial fleets will eagerly adopt AVs and require new policies, a 1% annual growth factor was applied to our commercial exposure counts following 2019. Conversely, individuals will forego their traditional vehicles and rely more on the commercial fleets for travel, so a -.5% reduction factor was used for personal exposure counts after 2020. This allowed for reasonable exposure projections for traditional and AV policies under both personal and commercial lines of coverage (see Figure 3.1a).

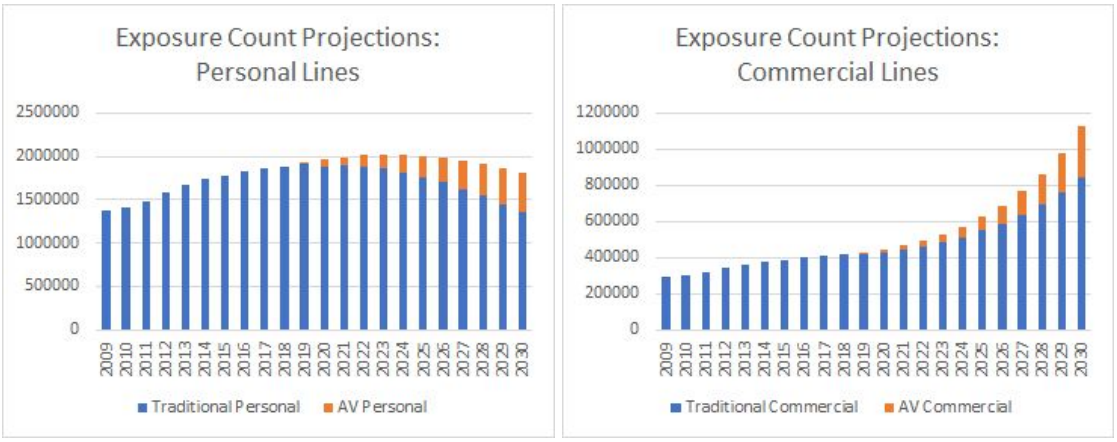

Figure 3.1a: Exposure count projections for personal lines (left) and commercial lines (right). Traditional vehicles shown in blue; AVs, orange.

Next, claim counts were projected using a similar methodology for both baseline and AV adoption projections, with a claim count growth assumption of 1.025 per year for personal and 1.03 per year for commercial (see Figure 3 in the Appendix). However, under the AV adoption projection, 90% of traditional autonomous vehicles claims were reduced since the National Highway Traffic Safety Administration attributes 90% of auto accidents to human error. Thus, the projection model applies a 90% reduction factor to the projected AV claim counts, since the risk of human error has vanished for these drivers (see Figure 3.1b). Finally, the frequency rate was calculated as the ratio of claim counts per exposures for each year.

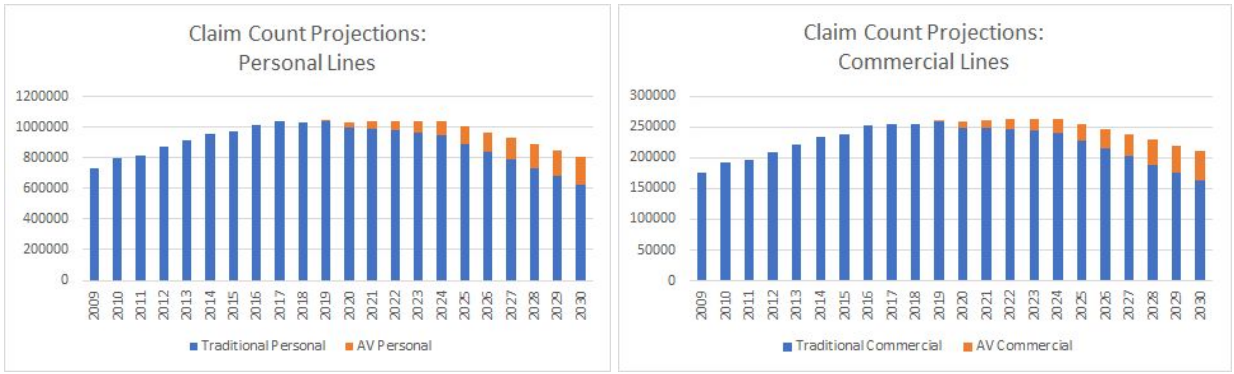

Figure 3.1b: Claim count projections for personal lines (left) and commercial lines (right). Traditional vehicles shown in blue; AVs, orange.

The next component necessary in the pure premium calculation is the annual expected severity. Claim severity will increase initially, since AVs will be more expensive compared to traditional vehicles (i.e., a higher replacement value), but over time, the severity will level-out. Only historical severity growth rates for collision, comprehensive, and property damage were considered. This is because the higher replacement value and severity for an AV will only arise under coverages like collision, comprehensive, and property damage, and not under coverages like bodily injury and personal injury. Therefore, our selected severity growth rates reflect a weighted-average of the collision, comprehensive, and property damage growth rates--weighted by the portion of claims within these coverages--for the first six years of our projection window only (2019 through 2024). For the subsequent six years (2025 through 2030), an inverse relationship was assumed such that the severity adjustment factors reduces to 1.0 in 2030, i.e., levels out to traditional vehicle's projected severity in 2030 (see Figure 4 in the Appendix). With total projected severity for personal and commercial auto policies, the projected severities were allocated to AV policies under each line based on our exposure-base assumption (see Figure 3.1c).

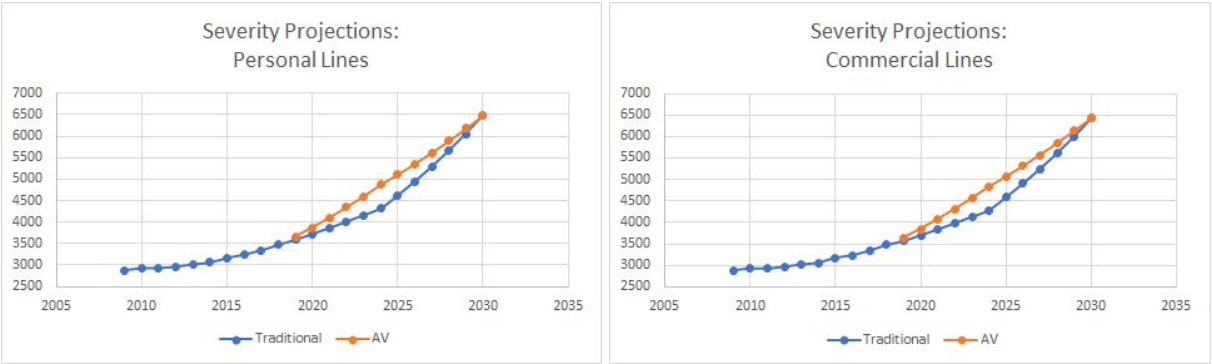

Figure 3.1c: Severity projections for personal lines (left) and commercial lines (right). Traditional vehicles shown in blue; AVs, orange.

Finally, pure premiums were derived by multiplying the expected frequency rate and expected severity for each projected year.

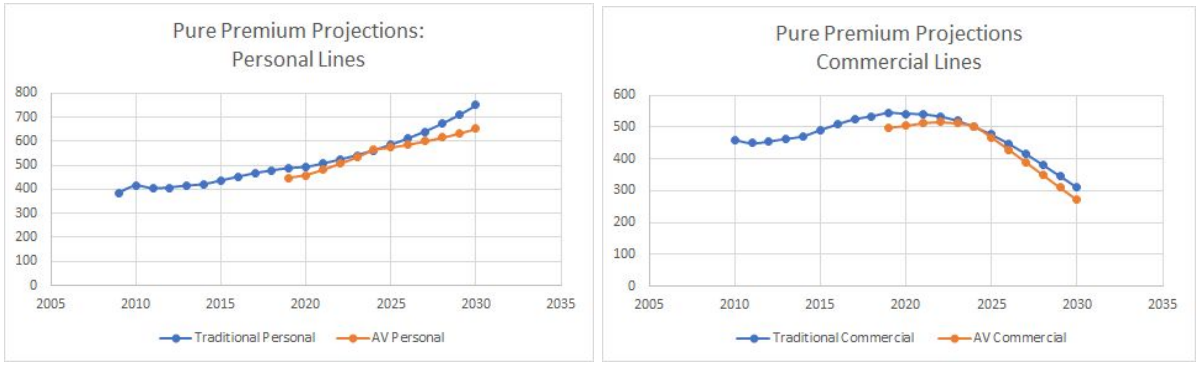

Figure 3.1d: Pure premium projections for personal lines (left) and commercial lines (right). Traditional vehicles shown in blue; AVs, orange.

3.2 WITHOUT AV POLICY

The exposure count assumption remained the same for the baseline projection. Safelife's failure to offer AV policies will not restrict insureds from purchasing these vehicles. Rather, the same projection of AV adoption will apply, but Safelife will lose that business to other insurers. Therefore, the baseline projection assumes 20-25% reduction in business between 2019 and 2030.

As previously stated, claim counts increased by 1.025 per year for personal and 1.03 per year for commercial. For the baseline severity projection, the five-year average severity growth rate of 1.025 was derived from the traditional policies' experience under all five coverage types (bodily injury, collision, comprehensive, etc.).

4 RECOMMENDATIONS

4.1 POLICY DESIGN AND PURE PREMIUM

With the adoption of AV policies, by 2030, Safelife's pure premiums for personal auto policies will cost 653 Carbs for AVs and 750 Carbs for traditional auto policies. For commercial auto policies, pure

premiums will cost 271 Carbs for AVs and 311 Carbs for traditional vehicles. The projections show that the pure premium for AV coverage will never exceed the price for coverage on a traditional vehicle in the same year for both personal and commercial policies. If Safelife does not adopt autonomous vehicle coverage, they should expect personal auto policies to cost 896 Carbs and 998 Carbs for commercial auto policies (see Figure 4.1).

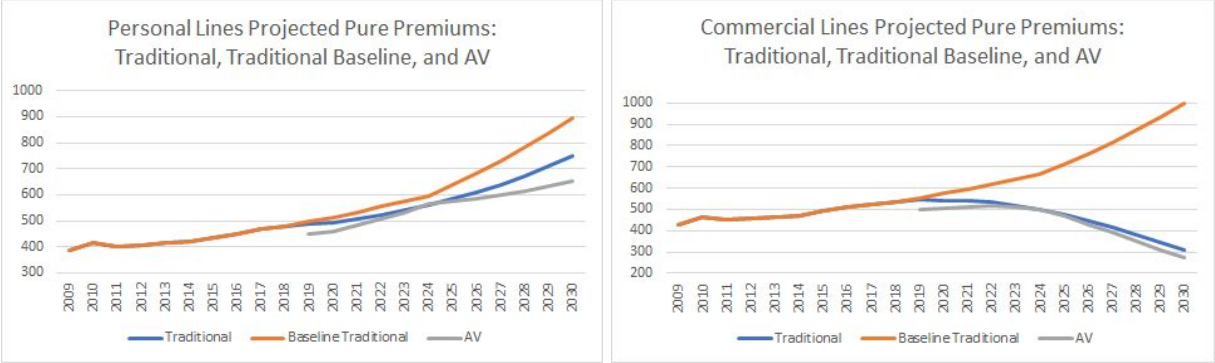

Figure 4.1: Pure premium projections for personal lines (left) and commercial lines (right). Traditional vehicles shown in blue; baseline traditional, orange; AVs, gray.

Regarding exposures, Safelife can anticipate steady growth towards 452,381 AV exposures under personal lines and 281,125 AV exposures under commercial lines in 2030. For the exposures with traditional vehicle policies, we project 1,357,142 exposures under personal lines and 843,375 under commercial lines.

4.2 SENSITIVITY ANALYSIS

Although the selected assumptions were determined from thorough research and actuarial judgement, the future exposures, claim severity, claim frequency, and thus, pure premiums, may differ from our expectations. Therefore, we conducted sensitivity analyses to analyze how the total projected pure premiums will change after adjusting the selected assumptions for both traditional and autonomous vehicles under personal and commercial lines. In each figure below, the "selected assumptions (with AV

adoption)" projection represents our recommended policy design's total pure premiums if Safelife adopts AVs. Each sensitivity test references this model's corresponding assumption in parentheses.

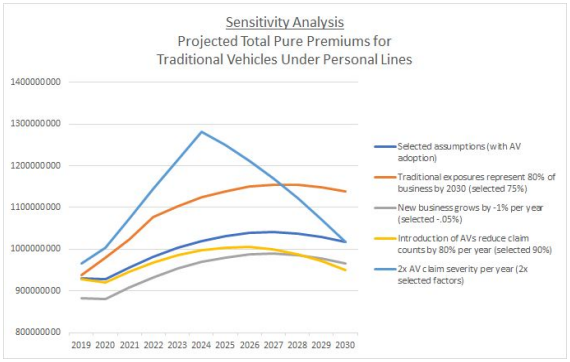

Figure 4.2a: Sensitivity Analysis for Traditional Vehicles Under Personal Lines.

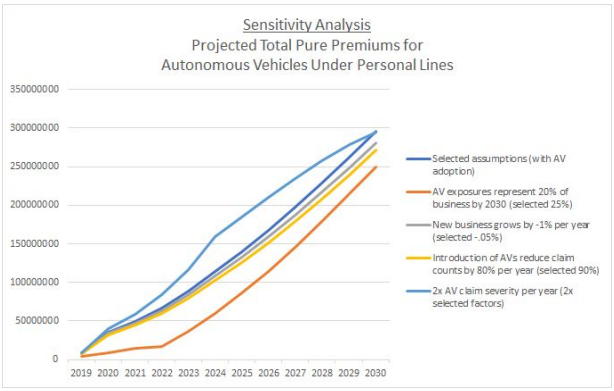

Figure 4.2b: Sensitivity Analysis for Autonomous Vehicles Under Personal Lines.

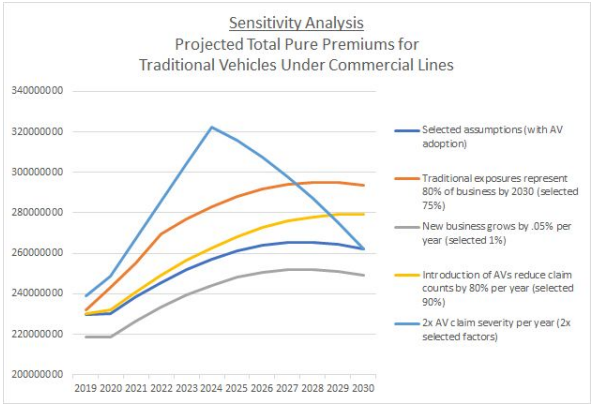

Figure 4.2c: Sensitivity Analysis for Traditional Vehicles Under Commercial Lines.

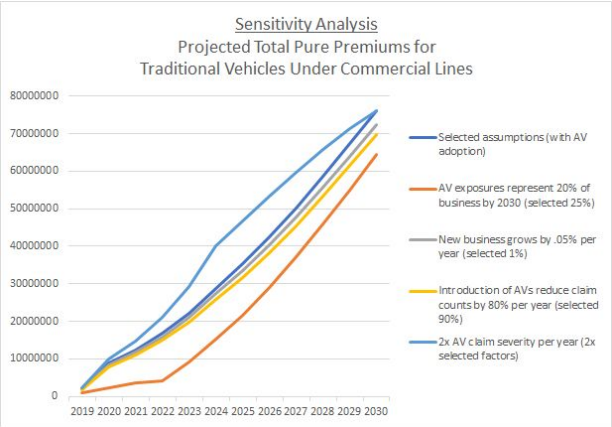

Figure 4.2d: Sensitivity Analysis for Autonomous Vehicles Under Commercial Lines.

From Figures 4.2a and 4.2c, the total projected pure premiums for traditional vehicles under both personal and commercial lines will heavily depend on new business growth. Because the total projected premiums is calculated as the projected pure premiums multiplied by the projected sales, the number of new business exposures that Safelife writes has a direct correlation with the total projected pure premiums. Furthermore, Safelife's personal lines block currently writes over four times as much business relative to its commercial lines block. Thus, if traditional vehicles represent 80 percent of Safelife's personal lines block in 2030 compared to our initially-projected 75 percent, the five point increase in traditional projected exposures will have a larger impact in the total projected pure premiums for personal lines than in the commercial lines block. In order to ensure solvency and profitability for traditional policies under both personal and commercial lines, it is imperative that Safelife heavily invests in marketing these products in the future while maintaining their existing exposures.

According to Figures 4.2b and 4.2d, Safelife should expect steady growth in its total projected pure premiums for its AV policies under personal and commercial lines with each sensitivity test considered. As mentioned previously, the total projected premiums will heavily depend on the exposure growth, but since AVs are expected to represent only 20-25 percent of Safelife's total block of business, the AV total projected premium projections will not vary as much as the traditional policies' projections. From Figures 4.2b and 4.2d, if AV claims turn out to be twice as severe as expected, pure premiums will

warrant an increase for these policies since the replacement costs for these vehicles will be twice as high. However, this will have a heavier impact in the years leading up to 2030, since we expect the severity to level-out overtime.

4.3 RISK ANALYSIS

Decision	Benefits	Risks
Include Autonomous Vehicle Policies	● Maintain market share dominance ● Increase profits ● Business growth	● Larger losses than anticipated ● Loss in profit if after 2030 the majority of Safelife's book is AV
Exclude Autonomous Vehicle Policies	● No new risks with unknown consequences	● Lose business to insurers offering AV coverage ● Cause adverse selection attempting to recoup losses

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6. APPENDIX

	Portion of Exposures within Personal Lines		Portion of Exposures within Commercial Lines	
Year	**Traditional**	**AV**	**Traditional**	**AV**
2019	.99	.01	.99	.01
2020	.96	.04	.96	.04
2021	.95	.05	.95	.05
2022	.93	.07	.93	.07
2023	.92	.08	.92	.08
2024	.90	.10	.90	.10
2025	.88	.12	.88	.12
2026	.86	.14	.86	.14
2027	.83	.17	.83	.17
2028	.81	.19	.81	.19
2029	.78	.22	.78	.22
2030	.75	.25	.75	.25

Figure 1: Projected exposure proportions within personal and commercial lines for traditional and AVs.

Year	**Personal Lines:** Exposure Growth Adjustment Factors Per Year	**Commercial Lines:** Exposure Growth Adjustment Factors Per Year
2019	1.025	1.029
2020	1.020	1.039
2021	1.015	1.050
2022	1.009	1.060
2023	1.004	1.071
2024	.999	1.081
2025	.994	1.092
2026	.989	1.103
2027	.984	1.114
2028	.980	1.125
2029	.975	1.136
2030	.970	1.148

Figure 2: Exposure growth factors for personal and commercial lines per year. Utilized the baseline projected exposure growth assumption for 2019 and applied a -.05% factor to each subsequent year for personal lines; +1% adjustment factor for commercial lines.

Year	**Personal Lines:** Claim Count Adjustment Factors Per Year	**Commercial Lines:** Claim Count Adjustment Factors Per Year
2019	.99	.99
2020	.96	.96
2021	.95	.95
2022	.94	.94
2023	.93	.93
2024	.91	.91
2025	.89	.89
2026	.87	.87
2027	.85	.85
2028	.83	.83
2029	.80	.80
2030	.78	.78

Figure 3: Selected claim count adjustment factors for personal and commercial lines by year.

Year	**Personal Lines:** Severity Adjustment Factors Per Year	**Commercial Lines:** Severity Adjustment Factors Per Year
2019	1.01999	1.01980
2020	1.04046	1.04010
2021	1.06144	1.06089
2022	1.08293	1.08220
2023	1.10495	1.10405
2024	1.12752	1.12645
2025	1.10527	1.10440
2026	1.08342	1.08275
2027	1.06198	1.06149
2028	1.04093	1.04062
2029	1.02027	1.02012
2030	1.00000	1.00000

Figure 4: Selected severity adjustment factors for personal and commercial lines by year.