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# Ninth Annual Actuarial Case Competition

Cal Actuarial League

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## Health & Benefits

There are a few specific components to any health insurance plan. These are copayment, coinsurance, out-of-pocket maximum, and deductibles. While copayment, coinsurance, and the out of pocket maximum are inversely related to the price of the premium, the deductible is inversely related. An increase in any one of these components will force the insurer to be responsible for a bigger portion of claims. Consequently, they will have to increase premiums to maintain their loss ratio. On the other hand, the higher the deductible is, the higher the fixed cost amount for the enrollee. Thus, the insurer takes on less risk and can therefore reduce the premium.

Under the Affordable Care Act, premium prices tend to range. The ACA created different metal tiers meant to meet the needs of different sectors of the population. Those with less health issues will generally purchase insurance in the lower tiers, whereas less healthy individuals will purchase insurance in the higher tiers. The four metal tiers are bronze, silver, gold, and platinum. Each subsequent tier has a lower deductible, higher premium, and a higher actuarial value than the tier before it. On average, the actuarial values for each tier are 60%, 70%, 80%, and 90%, respectively. This value refers to the percentage of total claims that the insurer is responsible for.

In designing Bear's health insurance program, we calculated the premium by trending the claims 10% for two years. Then we multiplied by (1 minus the actuarial value) and summed over all rows to obtain the portion of their claims enrollees are responsible for. The premium was obtained by dividing this sum by 0.85, the given loss ratio.

According to the fundamental insurance equation, the sum of the deductibles and coinsurance, taking out of pocket maximum into account will be equal to 40% multiplied by employee claims. Hence, multiple combinations of deductible and out of pocket maximum allowed us to obtain an equivalent value.

In a standalone plan, one single plan is offered to all employees. In a multi-choice plan, multiple options will be offered to employees to choose from. In this scenario, the number of enrollees will be spread across multiple plans. However, in the standalone plan, one entire risk pool that included all of the employees was used to calculate the rates of each tier. However, now that we have enrollees divided between different tiers, our risk pools are different. Therefore, we cannot use the same rates determined for a standalone plan.

Since employees know better than the insurance company how sick they will be in advance, they will sign up for the metal tier that will best benefit them. Healthier employees will sign up for the lower tiers, and less healthy ones will sign up for the higher tiers. In the end, each tier will have different risk levels. In comparison to the standalone platinum plan, since very unhealthy individuals will have a higher propensity to enroll in the platinum tier, there will be a higher concentration of unhealthy individuals. This will produce a greater frequency of claims than anticipated. Therefore, the insurer would need to find a way to increase premiums to maintain the loss ratio. On the other hand, the bronze tier in a multi-choice plan will be healthier than the standalone bronze plan. More healthy people will sign up for the lower metal tiers, thereby decreasing risk and allowing premiums to be lowered.

To account for adverse selection in a multi-choice plan, we simulated enrollment for each metal tier by dividing the employees into four categories: very healthy, healthy, unhealthy, and very unhealthy. These categories were separated based on the size of their historical claims. The larger the claims, the more likely employees will be categorized as unhealthy and vice versa. (Their probabilities can be found on the excel page labeled "Simulation and Rate Load.") In order to simulate enrollment in each plan, we also found the given probabilities. A "very healthy" person should have a higher probability to select a bronze plan, and a "very unhealthy" person should have a higher probability to select a platinum plan. The given probabilities we obtained were chosen to reflect these facts.

To simulate enrollment in each tier, the following formula was used:

$$2000 * [P(\text{Person picks Tier} \mid \text{Very Healthy}) * P(\text{Person is Very Healthy}) + P(\text{Person picks Tier} \mid \text{Healthy}) * P(\text{Person is Healthy}) + P(\text{Person picks Tier} \mid \text{Unhealthy}) * P(\text{Unhealthy}) + P(\text{Person picks Tier} \mid \text{Very Unhealthy})]$$

These are the sum of the expectations for the four different health categories for each tier. The results we obtained from our simulation are in the table below.

Bronze Enrollment	Silver Enrollment	Gold Enrollment	Platinum Enrollment
568.9	372.25	336.65	368.7

Our results tell us that there is a higher likelihood that enrollees will choose lower metal tiers. This follows logically from the fact that most claims are relatively small. One interesting thing to note is that platinum enrollment is greater than gold enrollment. This occurs because the number of claims that exceed a certain threshold is greater than the number of claims that is both bounded below by a minimum threshold and bounded above by a maximum threshold.

The next step is to encapsulate the enrollment values into a ratio that can be multiplied by the tier rates for the standalone plans. This rate load should reflect the results we would expect. That is, bronze premiums should decrease significantly because the healthiest people would sign up for this tier. Silver premiums will similarly decrease, but not to the same extent. On the other hand, gold premiums should decrease since its enrollees contain less healthy people. Lastly, platinum premiums should increase the most, since its enrollees are the most unhealthy. Therefore, the value for our adverse selection rate load should be largest for the bronze tier, and decreasing for each subsequent metal tier.

The rate load was obtained by calculating the expected proportion of enrollees among each plan. The bronze rate load was obtained by dividing the expected number of very healthy individuals by the sum of expected healthy, unhealthy, and very unhealthy members in the bronze plan. The silver rate load was obtained by summing the expected “very healthy” and “healthy people” in the silver tier, and dividing by the expected sum of “unhealthy” and “very unhealthy” members in the same tier. The reason we divide by the unhealthy and healthy members is that we believe that unhealthiness is directly related to the premiums. The greater the amount of unhealthy people, the smaller the rate load. Since we are dividing the rate load by the premiums, a smaller rate load will lead to a greater premium. For the gold and platinum plans, we performed the same operation and obtained a rate load of less than 1. Finally, to obtain the new premium price for our multi-choice plan, we divide the rate load by the standalone premiums. Our results are summed in the following table:

Live Updated Plan Design				
	Plan 1	Plan 2	Plan 3	Plan 4
Plan Name	Bronze	Silver	Gold	Plat
Deductible	6000	4000	2000	500
Out-of-pocket Maximum	6532.642676	4562.490598	2848.281468	1333.080027
Average Coinsurance Paid	312.53	379.1666503	664.2809728	730.3773861
Actuarial Value	0.60	0.70	0.80	0.90
2018 Expected Claims	24289862.54	24289862.54	24289862.54	24289862.54
2016 Expected Claims	\$20,074,266.56	\$20,074,266.56	\$20,074,266.56	\$20,074,266.56
Trend	0.10	0.10	0.10	0.10
2018 Rates	\$8,572.89	\$10,001.71	\$11,430.52	\$12,859.34
Simulated Enrollment	568.9	372.25	336.65	368.7
2018 PEPM Standalone Rates	\$7,286.96	\$8,501.45	\$9,715.95	\$10,930.44
Adverse Selection Rate Load	1.371404752	1.254011505	0.905745825	0.766650695
Proposed Multi-Choice Rates	\$6,251.18	\$7,975.77	\$12,620.01	\$16,773.40

In a health insurance market, the viability of a plan depends on its price. Setting the premiums too high can result in enrollees leaving the plan while setting the premium too low can force the plan to leave the market altogether. Therefore, we recommend pricing the standalone premiums at \$7,286.96, \$8,501.45, \$9,715.95, and \$10,930.44 and the multi-choice rates at \$6,251.18, \$7,975.77, \$12,620.01, and \$16,773.40 respectively.

# Property & Casualty

## Executive Summary

In this report, we propose the new rating algorithm that increases the premium by 10% effective January 1<sup>st</sup>, 2019 and its expected outcomes based on the premiums and losses described to us by AllProvince Fire and Casualty Insurance Company. Without any changes, AllProvince's current loss ratio in a period of two calendar years (2016 & 2017) is approximately 58%. The new base rate and rate relativity requirements to achieve the target loss ratio is described in this report.

We also outline three recommendations that can be taken by AllProvince to resolve some concerns that the management team suggested. Our first recommendation describes a potential rate change in 2018 to smoothen premium increase and avoid a sharp rise in 2019. Our second recommendation describes the relationship between the claims and policyholders' credit score level distribution that may affect AllProvince's future loss. Our third recommendation describes potential non-rate actions such as reinsurance that may be considered to improve the business in general.

Beyond the information provided to us by AllProvince Fire and Casualty Insurance Company, our technical analyses contain several assumptions:

1. All premiums are paid fully.
2. All policyholders insured in 2016 were affected by the rate change in 2017.
3. All case reserves are calculated accurately.
4. The original rating algorithm is assumed to be the following:

$$\text{Total Premium} = \text{Base Rate} * \text{Territory Relativity} * \text{Coverage Relativity} * \text{AOH Relativity} * \text{Credit Relativity}$$

5. Year 2017 and Year 2018 share identical rating algorithm as well as the distributions of risk classification; the only difference is the number of policyholders.
6. Yearly growth rate of policyholder is exponential – the numbers of policyholders in 2018 and 2019 were projected using the exponential relationship between the number of policyholders in 2016 and 2017.
7. Policyholder dislocation rate is 100% when the average premium increases by 100% and they have exponential relationship.

## Approach

The approach for the new algorithm included the following steps:

1. Deriving the base rate and date proration for the policyholders insured in 2016.
2. Calculating the earned premium in 2016 and 2017 using the original rating algorithm.
3. Calculating the total claim amount by each policyholder:

$$\text{Loss}(i) = \text{Paid Loss}(i) + \text{Case Reserve}(i)$$

*\*Note that "i" indicates the ith claim*

4. Combining the total loss incurred in 2016 and 2017:

$$\text{Total Loss} = \sum_1^n \text{Loss}(i) = \$9,557,138 \quad n = \text{Total Number of Claims} = 859$$

5. Measuring current loss ratio and target loss ratio:

$$\text{Current Loss Ratio} = \frac{\text{Total Loss (2016 \& 2017)}}{\text{Earned Premium (2016 \& 2017)}} = \frac{\$9,557,138}{\$16,616,365.91} \approx 58\%$$

$$\text{Target Loss Ratio} = \frac{\text{Total Loss (2016 \& 2017)}}{\text{Earned Premium (2016 \& 2017)} * 1.1} = \frac{\text{Current Loss Ratio}}{1.1} = \frac{\text{Total Loss (2016 - 2019)}}{\text{Earned Premium (2016 - 2019)}} \approx 52\%$$

6. Performing Time Series Analysis and Exponential Regression to project the loss and the number of policyholders for the Year 2018 and 2019.
7. Finding the total premiums collected in 2018 based on the average premium collected in 2017:

$$\text{Total Premium (2018)} = \frac{\text{Total Premium collected in 2017}}{\text{Number of policyholders in 2017}} * \text{projected number of policyholders in 2018} = \frac{\$12,640,809.09}{9011} * 14528 = \$20,380,572.77$$

8. Calculating the total premium and average premium needed in 2019 to achieve the loss ratio:

$$Total\ Premium\ (2019) = \frac{Total\ Loss\ (2016-2019)}{52\%} - \sum_{2016}^{2018} Premium\ Year\ (i) = \$54,392,539.73$$

$$Average\ Premium\ (2019) = \frac{Total\ Premium\ (2019)}{Projected\ Number\ of\ Policyholders\ in\ 2019} = \frac{\$54,392,539.73}{23,424} = \$2,322.11$$

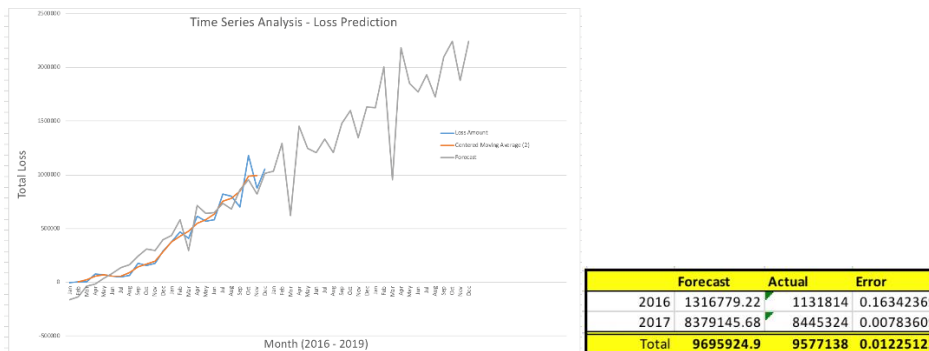
9. Modifying rate relativities to increase the overall premium.
10. Deriving new base rate based on the new rate relativities and base rate in 2019.

## Detailed Observations

Our analyses are based on determining the new rate relativities and new base rate that would lower the loss ratio to 52% by the end of 2019. We noticed that a sharp rise is inevitable without making any changes in 2018 as the loss ratio in 2017 already exceeded 70%. According to our projection, the loss ratio in 2018 would remain at the range between 70% and 80%. Regardless, we chose to consider the total loss and premium from 2016 to 2019, and focused on finding the appropriate amount of change in rate relativities to accomplish the goal. The average premium needed to achieve the goal was \$2322.11 per policyholder effective January 1, 2019 – an increase of 67%. In this section, we explain in detail our technical analyses we performed to get desirable result.

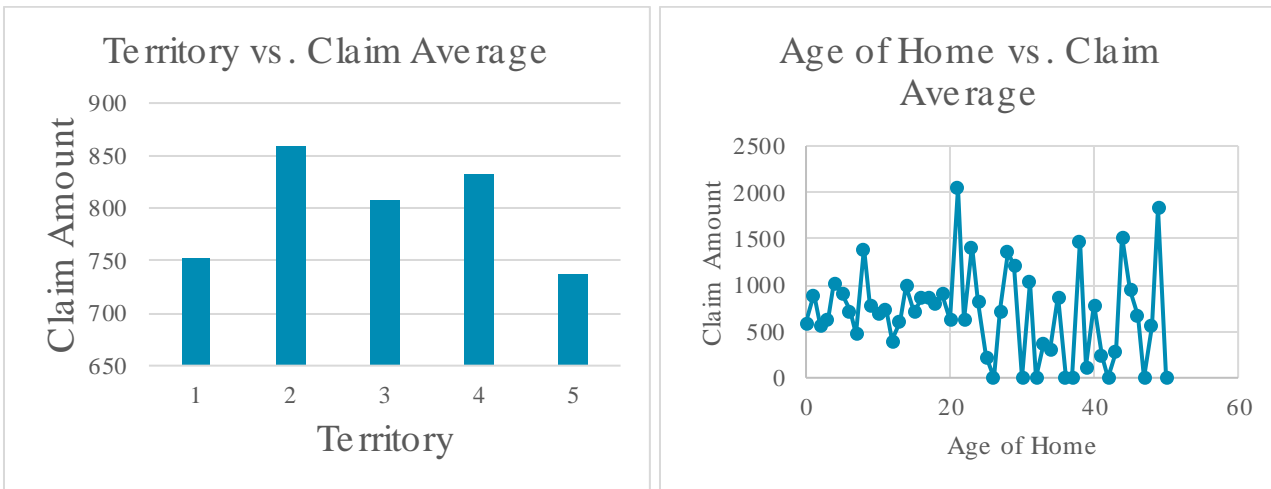
- Time Series Analysis – Loss Prediction for the year 2018 and 2019

In order to determine the necessary premium amount that AllProvince must earn in 2019, we first had to forecast the loss that would incur in 2018 and 2019, because raising 10% premium implies that the expected loss ratio must be 52%. Using time series analysis, we forecasted the loss in 2016, 2017, 2018, and 2019 respectively. The absolute error of our model for 2016 and 2017 was around 1%. Note that month to month projection is not quite exact but this is not an essential problem as we only encounter the yearly loss to calculate the loss ratio. Based on our model, the projected loss in 2019 is: \$ 22,503,878.62.



- New rate relativities – Credit, Theft Detector, and Territory

Before determining any changes for rate relativities, we first must consider the appropriateness of current rating factors. For example, as shown in the graph below, the average claim amount in different territories differ noticeably. The original rate relativity for territory 5 was 1.2 – the highest among all. The idea of rate relativity is that an insurance company must charge for higher risks, so we first matched the original rate relativities in territory. Then, we found the loss ratio in each level of classification then compared them with the current loss ratio. Finally, new rate relativities were determined by multiplying the indicated relativity change factor as shown below. The rate relativities that did not have clear trend or abnormal loss ratio remained unchanged.



Territory	Premium @ Current Rate Level	Loss	Loss Ratio	Indicated Relativity Change Factor		Current Relativity	Indicated Relativity
1	3302735.555	1804997	55%		1.050991828	0.97	1.019462073
2	3384275.28	2035569	60%		1.156689526	1.2	1.388027431
3	3252181.177	1950971	60%		1.153646462	1.05	1.211328785
4	3199960.399	1968506	62%		1.183011034	1.11	1.313142248
5	3477213.5	1817095	52%		1.004946478	0.94	0.94464969
Total	16616365.91	9577138	52%		1		

## Recommendations

1. Rate surge in 2019 by 68% would lead retention rate to decrease significantly – from 67% to 31% according to our dislocation analysis. We first recommend making an increase in 2018 to lower the overall loss ratio while maximizing the retention rate. If no change could be made in 2018, the management team must reconsider raising the rate by 10% in 2019.
2. Current credit level distribution is uniform – each level at 33%. If the distribution changes to 50%-35%-15% for high, medium and low respectively, AllProvince can lower the loss ratio from 58% to 45%. We recommend AllProvince to select the customers more carefully.
3. We strongly recommend Allprovince to consider reinsurance first because of lacking in data and second because of inconsistent claim amount among the policyholders.

## Retirement

Starting a life with the very first job at early 20's is significant one move towards your success. And planning a right retirement plan at earlier stage paves your way to it. This paper provides you an actuarial analysis on adequacy of different retirement plans.

### 1. Final Average Pay

Final Average Pay plan is a defined benefit (DB) plan. It is calculated by taking the average of your highest salaries into the formula below.

$$\text{Pension Benefit} = \text{Average of Final 3 salaries} * \text{Year of Service} * \text{Benefit Multiplier}$$

Starting career at 22, your salary will increase to \$249,516 at age 65 with 3% fixed annual increment [Table 1]. Given the maximum years of service (30) and benefit multiplier (1.5%), the formula yields the annual pension benefit with the amount of \$109,044. And by using the mortality table released by Social Security Administration and annuity PV calculation at the treasury rate of 4%, we can obtain the lump sum value of Final Average Pay at age 65, which is \$1,575,803.

Age	Salary
22	\$70,000
23	\$72,100

⋮ ⋮

63	\$235,193
64	\$242,249
65	\$249,516

[Table 1] Final Average

### 2. Cash Balance

Age	Monthly Salary	Annual Contribution at 7% invest return rate	FV at 65
22	\$5,833	\$2,167	\$39,744
23	\$6,008	\$2,232	\$38,258
⋮	⋮	⋮	⋮
65	\$249,516	\$20,594	\$20,594

[Table 2] Cash Balance

Cash Balance plan is a DB plan but works like in way of a defined contribution (DC) plan. In this plan, you are provided a hypothetical account, where a certain proportion of your salaries will be credited into by the employer

[Table 2]. The employer's monthly contributions with the rate starting at 3% and increasing by 1% every five years up to 25 years will be invested at 7% annual investment return rate. And by using the annuity FV calculation, we

can obtain the lump sum value of Cash Balance plan at age 65 – \$1,531,335. Additionally, annuity PMT calculation based on the mortality table yields your annual pension payment after retirement in the amount of \$123,800.

### 3. 401(k)

401(k) is a DC plan that credits contributions from both the employee and the employer into the hypothetical account. Generally, it is ideal for the employee to set the contribution rate at maximum that the employer is willing to match to. Given that your employer is willing to match 100% of your contribution up to 6%, we would highly recommend you set your contribution rate at 6%. By setting both your employer's and your contribution at 6% of your monthly salary, the annuity FV calculation with 7% investment return rate yields \$3,457,169 for the lump sum value of your 401(k) at age 65. And the annuity PMT calculation based on the mortality table yields \$279,494 for your annual pension payment after retirement.

Age	Monthly Salary	Annual Contribution (employer + employee) 12%	FV at 65
22	\$5,833	\$8,666.20	\$158,975.99
23	\$6,008	\$8,916.20	\$153,032.97
⋮	⋮	⋮	⋮
65	\$20,793	\$30,890.84	\$30,890.84

[Table 3] 401(k)

### 4. Adequacy Determination

Two major standards of measuring adequacy of a retirement plan are as follow:

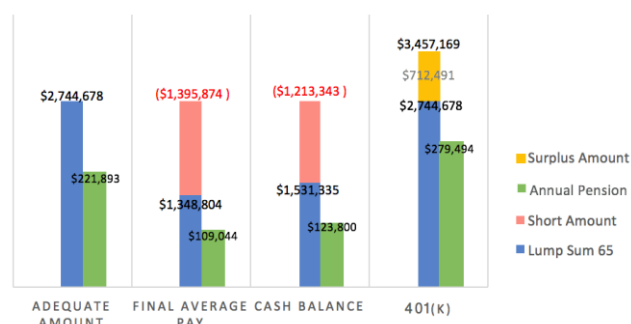
- A retiree can afford minimum needs as defined by low-income group or other thresholds
- A retiree can maintain the pre-retirement standards of life

Despite the annual pension amount under any plan is clearly sufficient for affording minimum needs of living, most retirees may want to maintain their quality of life as before their retirement.

Based upon the study in the above sections, only 401(k) pays you the amount similar with your final salary, while two other plans pay less than a half of it. That is, if you are in either Final Average Pay plan or Cash Balance plan, you will not be able to maintain the similar life standards as before.

According to AON's study on retirement plans conducted and published in 2015, employees need an average of 11 times their final pay for an adequate age 65 retirement. As it appears in the plot above, the lump sum values at 65 in Final Average Pay plan and Cash Balance plan are short by greater than a half of recommended amount, while 401(k)'s lump sum has a surplus.

#### LUMP SUM & ANNUAL PENSION



First, to achieve the recommended amount in Final Average Pay plan, having all other assumptions fixed and private investment and social security benefits disregarded, the average of your final three salaries must be approximately \$493,095. This implies the following:

- If the salary increase is fixed at 3%, your final three salaries must be equal to \$478,593, \$492,951, \$507,740, respectively. And this suggests you target your base salary at \$142,433 or higher.
- If the base salary is fixed at \$70,000, then the increase rate must be 4.72%.

Secondly, to achieve the recommend amount in Cash Balance plan, the contribution rate must start at a higher rate, grows faster, and/or have higher limit. Followings are examples:

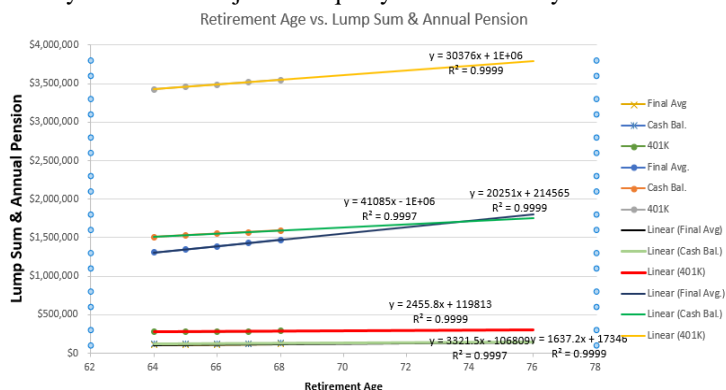


- If the contribution increase rate is fixed at 1%, the base rate is 7.21% and the limit is 12.21%
- If the contribution rate limit is fixed at 11%, for example, the base rate is 8.26% and the increase rate is 0.55%.

Thirdly, to achieve the recommended amount purely from your contribution as an employee, you must credit at least 9.53% of your monthly salary to your retirement account.

## 5. Influences of Change in Factors on Adequacy

From section 4, we observed that your current salary, salary increase rate, contribution rates affect the adequacy of your retirement plan. There are more factors to concern that may have influences on the adequacy. We have, therefore, conducted a sensitivity analysis on this subject. Adequacy increases if any one of the followings holds.



### Base Salary increase Salary Increase Rate increase

As observed earlier, you, as an employee, can target higher base salary or higher salary increase rate to increase the total amount of money that will be credited into the retirement portfolio.

### Current Age decrease Retirement Age increase

If you stay employed for a longer period, you will be able to contribute more of your salaries to the retirement portfolio and collect more interests accrued out of it, resulting in greater lump sum amount at 65. The age you start working, however, is limited to 21. Hence, to increase the employed period, you should consider delaying your retirement.

### Health Care Cost decrease Mortality Rate increase

As human life expectancy increases over time, medical cost is As human life expectancy increases over time, medical cost is

rising faster than your expected salary increase. And since the lump sum amount of your retirement portfolio will be distributed over a longer period after your retirement, the annual pension payment will be lower.

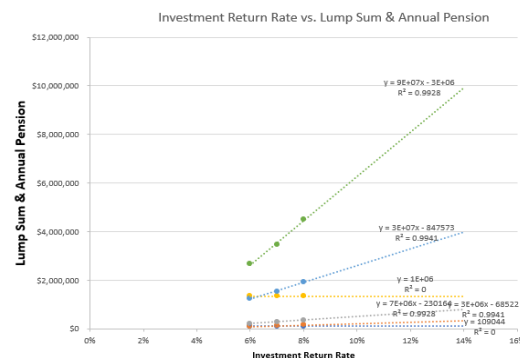
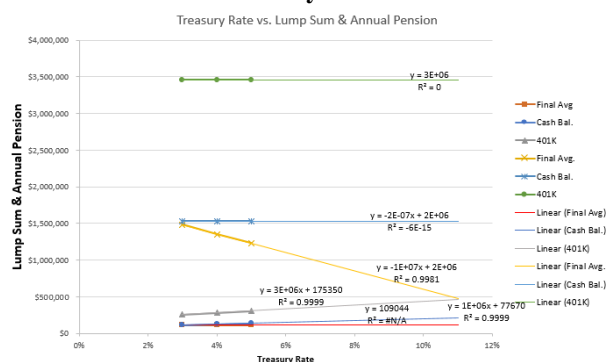
### Social Security Benefit (monthly) increase

Social Security Benefit can be added to your retirement portfolio or personal investment portfolio as if it is an extra monthly income, and it will enhance the adequacy.

### Living Expenses decrease Housing Cost decrease

If housing cost and/or other living expenses increase, it is harder for you to maintain your contribution rate at maximum in say 401(k) plan or your personal investment portfolio. It will also weaken your ability to reallocate your incomes, even if you were in other retirement plans.

### Investment Rate increase Treasury Rate decrease



You can increase the investment rate on your retirement portfolio by choosing more aggressive investment plans. At higher investment rate, you will be earning more interests accrued from your retirement savings. The risk will, however, increase as well. On the other hand, if treasury rate increases, your lump sum amount of retirement portfolio will be distributed in lower annual payment.

### Tax Rate decrease

Decrease in tax rate enables you spend less and invest more money in your portfolio.

### Wage Inflation increase

If there is an inflation in wage, your income will increase as an economic trend, as well, resulting in increase in your retirement savings. However, your living expenses may increase, too.

## 6. Recommendation

For a better adequacy of your retirement portfolio, we would recommend you maintain your contribution rate onto your portfolio at maximum rate, delay your retirement and adjust your post-retirement spending. Then, you may be able to reinvest the surplus money from your pension. You can educate yourself in investment and purchase a deferred annuity to provide longevity protection while maintaining the flexibility of having cash on hand during the first 20 years of retirement. On the other hand, your employer can also significantly improve your retirement plan by maximizing tax-advantaged contributions, increase aggressiveness of the portfolio and automate savings features in defined contribution plans, resulting in enhancement of your participation rate.

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