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Non-Life Insurance

Machine Learning and Traditional Methods Synergy in Non-Life Reserving

2018 REPORT

Machine Learning and Traditional Methods Synergy in Non-Life
Reserving (MLTMS)

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1. Abstract

Actuaries are well acquainted with traditional reserving methods such as chain ladder and Bornhuetter-Ferguson. These traditional actuarial methods have been shown over many decades of actuarial practice, and in certain circumstances, to work well at an aggregate level to calculate appropriate reserve provisions. However, today with improvements in analytical methods and technology, actuaries are better equipped to uncover detailed loss drivers using Machine Learning techniques. Nowadays, insurers are highly interested in the anatomy of their portfolios. From claimants' behaviours, business strategies or portfolio pruning, sources of data volatility are numerous and impact both the reserving and the pricing processes of an insurer. Machine Learning methods can identify obscure trends in the data and incorporate suitable adjustments in its forecasts. When used together, traditional methods and Machine Learning methods can both support reserve estimates as well as provide the business explanations that are demanded by our stakeholders. The aim of our working group is to demonstrate that their joint application can be a powerful decision-making tool.

Our study focused on a real data set provided by Swiss Re. The Line of Business concerned is Professional Liability. After a processing phase, traditional methods such as chain ladder and GLM have been compared to a range of five Machine Learning methods. A synthesis completes the study, highlighting its limits and suggesting avenues of reflection for future research.

2. Introduction

As long as insurance has existed, the need for calculating reserves has existed. Traditionally, Non-Life insurers apply triangulation techniques to aggregated claims data by accident year and development year. The challenge of loss reserving involves making predictions about how claims costs will emerge in the future based on an analysis of past claims data and our expectations about the future. Claims data can be noisy and changeable and a key difficulty can be understanding those changes in the presence of noise.

Traditional methods in loss reserving usually possess two features: *i)* they are based on a statistical model whose algebraic form is very simple, e.g. that the expected amount of paid claims in a cell is equal to the simple product of an accident year factor and a development year factor; and *ii)* they are calibrated by elementary arithmetic procedures, such as averaging over rows and/or columns.

It is common that real-life claim data do not conform neatly with the first characteristic. The true underlying model may be much more complex. Its form may be unknown. Even if it is known, adaptation of the elementary calibration procedures described becomes cumbersome or fails completely.

Machine Learning methods are one option for addressing this situation. They offer a sophisticated and efficient tool for understanding and modelling past claims characteristics. They allow one to discard the simplistic underlying assumptions about data structure implied by traditional reserving models and so provide the ability to build more accurate models.

The application of these two families of methods relies on a specific methodological scheme for each of them. For the traditional methods, the challenge is to integrate in the development factors the particularities of the data (for example, a volatile volumetry of claims by development year). For Machine Learning methods, insofar as a parameters optimization algorithm is introduced to control the risk of over-learning, the challenge behind their use was the upstream choice of the explanatory variables and the understanding of the interest of the parameters of each model.

Machine Learning methods are powerful in the recognition of very fine patterns in data but they cannot, at least not so far, supplant traditional methods. The ambition of this working group is to demonstrate that Machine Learning methods, as well as traditional methods each have their own strengths. We illustrate this by the complementary conclusions that their application to real data leads to.

3. Structure of the study

This medium presents the study on the synergy between traditional methods and Machine Learning techniques for Non-Life reserving. The detailed results are presented in the appendices at the end of the report.

This study has been structured as following:

1. Data processing

In this section, the data set used for the study is presented. The main processing operations applied to prepare the data for the modelling step are developed;

2. Loss reserves modelling

i. *Application of traditional methods :*

In this section, traditional methods such as chain ladder and Generalized Linear Models are applied to the data set.

Their respective application responds to the general academic framework but relies also on expert judgment, especially for tail extrapolation needs.

ii. *Application of Machine Learning methods*

In this section, Machine Learning methods are applied to the data set.

These models do not use a triangular data structure. The modelling dataset use both transactional detail and information about the policies and the claimants.

The modelling separates the projection of Incurred But Not Enough Reported (**IBNER**) from Incurred by not Yet Reported (**IBNYR** or **pure IBNR**):

▪ IBNER projection is based on the two component models:

➤ The first model estimates the incremental paid/incurred amounts conditional upon a claim being open at the beginning of the period. A variety of different Machine Learning models could be employed here such as Gradient Boosting Machine, Neural Networks, Random Forest, etc.

➤ The second model estimates the propensity of a claim to be open at a particular point in time (again we can choose from a variety of Machine Learning methods). From this second model, appropriate conditional probabilities can be calculated to be applied against model 1. Therefore, an estimate of incremental transaction amounts can be made by “blending” these two model results together.

Remark: One should note that there is a claim-specific connection between these two models as both models are modeled at the same level of granularity (e.g. claim or claimant).

▪ IBNYR projection is based on a frequency severity approach. Frequency model predicts the future newly reported claim counts at a given

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development year, then the severity model provides the average severity for these claims reported at that development year.

- For frequency, the number of expected reported claims is estimated at each future time period. The frequency model is based on aggregated data. The target here is the reported ratio. The model will then predict the reported ratio at future development years to derive the future newly reported claims;
- For severity, the results from the IBNER model are utilized as an input into the severity model. This model is at a claim level. The target here is ultimate severity.
Predictors of this model have to be the same variables as the frequency model.

The product of the two models gives a pure IBNR estimate.

One key variable for this approach is the development year when the claim was reported: it is the one used to combine the severity model with frequency model. This approach is in some extent a simplified one since there is no significant history of IBNR claims in the data set of this study.

3. Comparison of models

The results of the various models are compared with different indicators: yearly cash flows, total outstanding and individual cell errors.

4. Findings on the synergy between traditional methods and Machine Learning for Non-Life reserving

The conclusion of the report consists of taking a step back on the contribution of each model to Non-Life reserving in both the case of the data set of this study and on a macro level. Clues for improvement are also identified at the end of the report.

4. Swiss Re Data

4.1. Data presentation

4.1.1.1. Data set

The Line of Business for this portfolio is Professional Liability, covering “Claims made”.

It is, at least in this study, characterized by:

- Long and heavy tail ;
- Claims covers experience from 1994 to 2016 inclusive ;
- Different behavior related to the profession of claimants ;
- Significant deferment between accident year and reporting year (between 3 and 5 years in average). An analysis of claims deferment is presented in [Appendix 9.1.1.1. Claims deferment](#);
- Volatility of the claims development at an individual level ;
- Calendar year effects like inflation, legal changes

4.1.1.2. Variables

The dataset was initially composed of 16 variables, of which we selected those presented in Table 1.

Variable	Type	Description
Paid YY	<i>Numerical</i>	Payment of the year YY (incremental)
O/S YY	<i>Numerical</i>	Case reserve (outstanding) of the year YY (cumulative)
Incurred YY	<i>Numerical</i>	Incurred amount of the year YY (incremental)
UWY	<i>Discrete</i>	Underwriting year
DoL	<i>Discrete</i>	Accident year (Date of Loss)
DoN	<i>Discrete</i>	Reporting year (Date of Notification)
Settlement Year	<i>Discrete</i>	Settlement year for claims that are already closed
Year of Birth	<i>Discrete</i>	Birth date of the claimant
Insured	<i>Categorical</i>	Anonymized code of insured entity
Loss Number	<i>Categorical</i>	Univocal number of claim
Open / Close	<i>Categorical</i>	Status of claim (1 for open and 2 for close)
Age Group	<i>Categorical</i>	Grouping claimants in age classes
Insured Profession	<i>Categorical</i>	Groups of claimants' profession
Incident Grouping	<i>Categorical</i>	Subcategory related to Insured field
Case specialty	<i>Categorical</i>	Description of Claim Event
Event	<i>Categorical</i>	Flag for difficult type of losses (expensive and long-tail claims)

Table 1 Main variables of the study

On the one hand, the data set can be converted into aggregate triangles by accident year and development year, which correspond to the appropriate format to build a classic method to estimate the claims reserve.

On the other hand, the other variables selected are used as explanatory variables in the Machine Learning models.

4.2. Data processing

Data was provided by the reinsurer in the form of a flat text file, detailing insurance losses on a claim level evaluated at various points in time, and some categorical features of the claimant. Broadly, there were three goals in processing the data:

Step	Purpose	Description
1	Initial Processing	Understanding and potentially correcting data issues that may undermine either traditional reserving analyses or Machine Learning methods
2	Data Sets for loss reserving models	<p>The form of these data sets depends on their intended use:</p> <ul style="list-style-type: none"> - For traditional reserving methods, traditional paid and incurred loss triangles are needed. - For Machine Learning methods, target variables and potential features are needed, as well as a further split of between training and test sets.
3	Exploratory Data Analysis	Gaining initial understanding of high level trends and patterns that may inform further analysis

Table 2 Data processing steps

These three steps are described below in more detail.

4.2.1. Initial Processing

This section can be further divided into three parts:

- Exception handling/data issues
- Reformatting
- Derivation of additional fields.

4.2.1.1. *Exception handling and data issues*

In the process of data collection, inconsistencies have been identified on some individual entries. Example of these inconsistencies is that for some claims the date of their reporting was prior to the one of the accident year (reporting year < accident year).

The results of the processing are presented in Table 3.

One should note that the increasing amounts of claims after processing are due to the removal of negative claims.

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Dataset	Transaction type	Claims amounts	Claims amounts	Average
		At the 1st dev year	At the last dev year	Cost
		\$M	\$M	\$M
Original	<i>Incurred</i>	1 771,72	1 689,40	0,04
	<i>Paid</i>	149,75	824,06	0,02
	<i>O/S</i>	1 719,24	1 451,34	0,03
After processing	<i>Incurred</i>	1 769,99	1 690,03	0,04
	<i>Paid</i>	149,82	824,60	0,02
	<i>O/S</i>	1 719,76	1 452,35	0,03

Table 3 Claims data before and after processing

4.2.1.2. *Reformatting*

The data were initially provided in triangular form, but to facilitate further processing they were first converted to long format. Further reformatting mainly consisted of renaming variables to be more consistent and simpler to interpret.

Columns were maintained or derived under the principle that each should represent one potential feature or target variable, and nothing else. Therefore, separate columns were created for incurred loss, paid loss, and case outstanding loss, each on both an incremental and paid basis. Many Machine Learning methods apply to incremental losses, whereas most traditional reserving methods apply to cumulative losses, so both were needed.

4.2.1.3. *Derivation of additional fields*

The data set contained two complementary variables *Open/Close* and *Settlement year*. In order to combine the information of both, a *Claim Status* variable was derived as an indicator variable based on the amount of case outstanding loss **as of end 2016**. Case Outstanding of 0 indicated a closed claim, and case outstanding of 1 indicated an open claim.

Other predictors have also been newly created:

- **Calendar Year** for each transaction. This variable is used for training/validation/test splits ;
- **Report lag**: Lagging years for a claim. It is calculated using Date of Loss (DoL) and Date of Notice (DoN) fields ;
- **Development year at reported basis**. This variable can help to adjust all claims to have the same starting point to remove the late reporting effect ;
- **Initial case reserve**: The case reserve at the end of first development year
- The **ending case reserve, incremental paid, incremental incurred** at the **prior** year.
- The **cumulative paid, case and incurred** as the **current** year.

4.2.2. Data Sets for loss reserving models

4.2.2.1. *Triangles for traditional methods*

In order to apply traditional reserving methods, cumulative claims triangles have been created. The aggregation have been made by accident year and development year.

A separate triangles have been created by:

- Type of claim amount : paid, incurred, outstanding;
- Status of the claim: open, closed, both open and closed.

Thus 9 different triangles of cumulative claims were created.

4.2.2.2. *Train/Test Sets for Machine Learning techniques*

By design, the initial data processing produced a data set already amenable to being split into train and test data sets appropriate for analysis using Machine Learning methods, with potential features including accident period, development period, insured profession, event number, etc., and potential target variables such as incremental paid loss. Therefore, the bulk of the processing in this step relates to splitting the data up into train and test sets.

Two approaches were considered for this split:

- **Scenario A:** Randomly assign a given proportion of claims to either train or test set.

In this common approach, records are randomly assigned to either the train or the test set, where the probability of any given record being in the train set is chosen beforehand - in this case, 80%.

This split was done not on a record level, but rather on a claim level (where a claim may represent many records in the dataset) so that the entire history of any given claim is either in the train set or the test set.

- **Scenario B:** Split claims based on calendar period

In this approach, any records on or after a selected calendar period are put into the test set, and any records prior to the selected period are put into the training set. The selected calendar period used was calendar year 2010. This choice of cut-off produces a training set that is about 80% of the overall data.

In this study, we apply the validation technique of scenario B (Agbeko & al, 2014). For strategy B, the more cut-off times are used, the more relevant the comparison is between the models.

4.2.3. Exploratory Data Analysis

Exploratory analysis consisted of examining distribution of individual variables, correlation with other variables, and extent of missing values.

For each variable, the distribution was examined numerically by looking at the range and graphically by examining a frequency histogram.

Count of claims at each status (Open, Closed) were also examined by Accident Year, Calendar Year, and development age for a preliminary understanding of development patterns and claims handling in the data.

Examples of the graphs produced are presented in [Appendix 9.1. Exploratory Data Analysis](#).

5. Loss reserves Modelling

Data and notation

Two data sets have been analysed, representing claim histories of a Professional Liability portfolio. One of the histories records **cumulative paid claim amounts**, the other **incurred claim amounts**. Each data set consists of the condensation of the unit record claim file into the familiar claim triangle, with rows and columns representing accident and development years respectively. The two triangles appear in [Appendix 9.2. Triangles of claim experience](#).

The structure of the unit record claim files was such that year of origin (the label of rows of the triangles) could have been chosen as either accident or notification year. In fact, the former was chosen, in accordance with conventional practice.

Each claim triangle covers experience from 1994 to 2016 inclusive. The portfolio exhibits rapid growth over the accident years following 1994, but declines rapidly after 2007, dwindling to very little experience in accident year 2010, and with no experience in later accident years.

The quantity tabulated in the data triangle can be either cumulative paid claim amount or cumulative incurred claim amount, but will be generically represented by Y . Separate analyses and forecasts are made on the basis of paid and incurred claim amounts respectively (see Section 1.3.2).

Accident and development period will be respectively denoted by $i (= 1994, \dots, 2010)$, $j (= 0, 1, \dots, 22)$, and the entry in the triangle at the intersection of row i and column j will be denoted Y_{ij} . For given i , the claim triangle contains entries for $j = 0, 1, \dots, \xi_i = 2016 - i$. Similarly, for given j , it contains entries for $i = 1994, \dots, \omega_j = \min(2016 - j, 2010)$.

5.1. Modelling with Traditional Methods

5.1.1. Preamble

Traditional methods (**TM**) of loss reserving are heavily oriented toward the **chain ladder** (Taylor, 2000; Wüthrich & Merz, 2008). There are a number of variants of this approach, notably **Bornhuetter-Ferguson** (Bornhuetter & Ferguson, 1972), **Cape Cod** (Bühlmann, 1983, 2016; Gluck, 1997) and **Benktander-Hovinen** (Benktander, 1976; Hovinen, 1981).

However, all these approaches other than the chain ladder require some the association of some volume metric with each accident year. Often, but not always necessarily, this take the form of earned premium, allowing the any forecast of ultimate claim cost to be converted to a loss ratio. Loss ratios often feature prominently in these approaches.

Unfortunately, the data sets analysed here do not include any form of volume metric. Consequently, TM analysis has been restricted to the chain ladder.

Throughout, the objective has been to forecast future claim experience as an experienced practitioner would on the basis of only the data available here.

In addition to chain ladder, other models are considered as traditional as they generalize the principle of regression by connecting the model to a target variable via a link function: the Generalized Linear Models. Generalized Linear Models assume explicitly a parametric distribution of the claims and thus, by estimating the parameters of the known underlying distributions, claims can be forecasted.

In this section, we present both chain ladder and Generalized Linear Method implementation in the framework of this study.

5.1.2. The chain ladder

5.1.2.1. Classical form

Define the **age-to-age factor**

$$\hat{f}_{ij} = \frac{Y_{i,j+1}}{Y_{ij}}, j = 0, 1, \dots, \xi_i - 1 \quad (1.1)$$

The classical form of chain ladder assumes that, for given j , all \hat{f}_{ij} are equal in expectation, and forms the following estimate of that expectation:

$$\hat{f}_j = \frac{\sum_{i=1994}^{\omega_{j+1}} Y_{ij} \hat{f}_{ij}}{\sum_{i=1994}^{\omega_{j+1}} Y_{ij}} = \frac{\sum_{i=1994}^{\omega_{j+1}} Y_{i,j+1}}{\sum_{i=1994}^{\omega_{j+1}} Y_{ij}}, j = 0, 1, \dots, 21 \quad (1.2)$$

For row i , future observations are $Y_{ij}, j = \xi_i + 1, \dots, 22$, and forecasts \hat{Y}_{ij} of these quantities are constructed by means of the recursion

$$\hat{Y}_{i,j+1} = \hat{Y}_{ij} \hat{f}_j, j = \xi_i, 1, \dots, 21 \quad (1.3)$$

initiated by setting $\hat{Y}_{i,\xi_i} = Y_{i,\xi_i}$.

The recursion terminates with the forecast $\hat{Y}_{i,22}$, which is a forecast of the **ultimate claim cost** of accident year i , assuming no claim development beyond development year 22. The forecast of **loss reserve** for accident year i is then

$$\hat{R}_i = \hat{Y}_{i,22} - Y_{i,\xi_i} \quad (1.4)$$

And the forecast of total loss reserve is

$$\hat{R} = \sum_{i=1994}^{2010} \hat{R}_i \quad (1.5)$$

5.1.2.2. As implemented in this study

The implementation of the chain ladder in this report differs somewhat from the “classical” form set out in Section 1.3.1. There are two main reasons for this:

- The condition of that sub-section that all \hat{f}_{ij} be equal in expectation appears not to hold, as a result of which the estimators \hat{f}_j in (1.2) require re-definition.
- These re-defined estimators are expected to be monotone in j other than for the smallest values of j , but sampling error disrupts this monotonicity.

These two issues are discussed separately below.

i. Non-stationarity of \hat{f}_{ij} over i

The accident year 2010 was the last with any claim experience. It is likely that it relates only to premium written in 2009 and earned in 2010. It exhibits unusual age-to-age factors, quite different from those of earlier accident years. The data relating to this accident year were disregarded in modelling, though the model finally chosen was applied to derive a loss reserve for accident year 2010.

The age-to-age factors \hat{f}_{ij} for accident years 1994 to 2009 are displayed in [Appendix 9.4.1.1.1](#). Triangles of age-to-age factors. In the case of incurred claim data, they appear to display systematic disturbance from approximate constancy within columns, generally attaining a peak in the diagonal that relates calendar years 2008 and 2009, and a trough in the diagonal that relates calendar years 2011 and 2012.

In view of these changes, age-to-age factors from the older diagonals may not be indicative of future experience. Average age-to-age factors were calculated on the basis of only more recent experience, specifically the last 4 diagonals of factors, the last 8, and the last 12. The average of age-to-age factors over the last m diagonals was defined as (c.f. (1.2))

$$\hat{f}_j^{(m)} = \frac{\sum_{i=\max(\omega_{j+1}-m+1, 1994)}^{\omega_{j+1}} Y_{i,j+1}}{\sum_{i=\max(\omega_{j+1}-m+1, 1994)}^{\omega_{j+1}} Y_{ij}} \quad (1.6)$$

for as many values of j as produce non-null sums in both numerator and denominator.

Selection of a model was then a matter of professional judgement. Subject to further comment below, the selection for a **model based on paid claim data** was \tilde{f}_j , defined as:

- $\hat{f}_j^{(8)}, j = 0;$
- $\hat{f}_j^{(12)}, j = 1;$
- $\hat{f}_j^{(8)}, j = 2,3;$
- $\hat{f}_j^{(4)}, j = 4,5,6,7,8,9;$
- Smoothed $\hat{f}_j, j = 10,11, \dots, 21.$

For $j > 10$, see comment below.

The selection for a **model based on incurred claim data** was \tilde{f}_j , defined as:

- $\hat{f}_j^{(8)}, j = 0,1,2,3,4;$
- $\hat{f}_j^{(4)}, j = 5;$
- $\hat{f}_j^{(12)}, j = 6;$
- $\hat{f}_j, j = 7,8;$
- Smoothed $\hat{f}_j, j = 9,10, \dots, 21.$

ii. Monotonicity of \hat{f}_j over j

In the case of incurred claim data, the values of $\hat{f}_j, j > 8$ show a persistent downward trend with increasing j , but without monotonicity. They have been smoothed into a (monotonic) exponential sequence of the form

$$\tilde{f}_j = \hat{f}_8 d^{j-8} = 9, \dots, 21 \quad (1.7)$$

where the decay factor d is manually selected such that the chained development factors $\tilde{f}_j \tilde{f}_{j+1} \dots \tilde{f}_{21}, j = 0, 1, \dots, 21$ never deviate too far from the corresponding factors derived from the classical chain ladder model, i.e. based on factors \hat{f}_j .

The smoothing of factors in the case of paid claim data was slightly different, with (1.7) replaced by the following form:

$$\tilde{f}_j = 1 + (\hat{f}_8 - 1) d^{j-8} = 10, \dots, 21 \quad (1.8)$$

These models enabled the forecast of loss reserves (1.4) and (1.5) on the basis of the full data set, i.e. claim experience to the end of calendar year 2016.

5.1.2.3. Forecasts on the basis of censored data

A part of the current study is to examine the out-of-sample performance of various forecasts. Accordingly, each forecast method is applied to a number of subsets of the data, specifically with the 2016 diagonal of the claim triangle censored, then with the 2015 and 2016 diagonals censored, and so on until the 10 diagonals 2007 to 2016 inclusive have been censored.

Consider the case in which m diagonals are censored. An actuary working with such a triangle would be in a position equivalent to standing at 31 December (2016 – m), where the last m diagonals are unknown.

Chain ladder models were formed for each of the cases $m = 1, 2, \dots, 10$ (the description in Section 1.3.2 relates to $m = 0$). It was required in each case the selection of model be blind to the censored data. Otherwise, models were selected in a manner similar to that described in Section 1.3.2. The forecasts of all models $m = 0, 1, \dots, 10$ are set out in [Appendix 9.4.1.1.3. Forecasts of paid](#) and [Appendix 9.4.1.1.4. Forecasts of incurred](#).

5.1.2.4. Results and discussion

Table 4 displays summary information from the forecasts of future claim experience described in Section 1.4. The table contains forecasts of ultimate claim cost of all accident years 1994 and later, at 11 different valuation standpoints. These are the cases $m = 0, 1, \dots, 10$ from Section

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1.4. Forecasts are obtained separately from paid and incurred chain ladder models. the same information is presented in diagrammatic form in Figure 1.

Not all the forecasts are comparable. Over the period 31 December 2006 to 2010, additional accident years were added, increasing ultimate liability. This explains the general increase in the forecasts over this period. However, no liability attaches to accident years later than 2010, so forecast made at 31 December 2010 to 2016 are comparable.

Valuation standpoint 31 December	Estimated ultimate incurred claim cost for accident years 1994 and later	
	Paid chain ladder	Incurred chain ladder
	\$M	\$M
2006	712,8	637,9
2007	993,1	843,1
2008	1137,5	1886,8
2009	1336,9	2353,7
2010	1693,3	2172,4
2011	1683,6	1730,2
2012	2126,4	839,1
2013	1830,8	1190,1
2014	1811,8	1444,7
2015	1712,8	1602,9
2016	1510,9	1570,0

Table 4 Forecasts of ultimate claim cost by valuation year

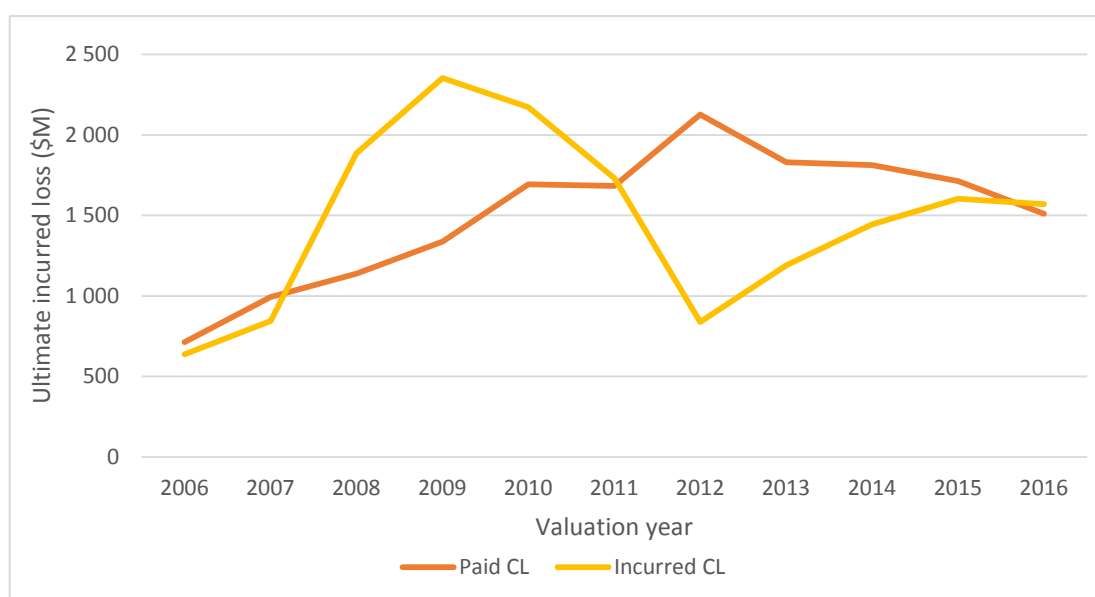


Figure 1 Forecasts of ultimate claim cost by valuation year

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It can be seen that the paid chain ladder forecasts exhibit relative constancy over the period of comparability 2010 to 2016, with the exception of an isolated spike in 2012. This is caused by unusually heavy claim experience (in the form of elevated age-to-age factors) in the calendar year 2013 and just prior, with the result that the model generally peaks in strength in 2012 and 2013 ([Appendix 9.4.1.1.1. Triangles of age-to-age factors\(a. Paid\)](#)).

The incurred chain ladder exhibits wild swings in forecast liability as the point of valuation changes. An extremely high forecast in 2009 (not even all accident years present), it plummets to an extremely low value in 2012, before recovering to approximate consistency with the paid chain ladder in 2015 and 2016.

The reason for this can be seen in the table of cell-specific age-to-age factors in [Appendix 9.4.1.1.1. Triangles of age-to-age factors\(b. Incurred\)](#). These exhibit an upward trend in early diagonals, peaking in the 2008 diagonal (shaded yellow), then declining, bottoming out in the 2011 diagonal (shaded green). Of course, an actuary standing at the end of 2008 would see nothing other than the increasing trend, and would be likely to forecast accordingly.

5.1.3. Generalized Linear Models

5.1.3.1. Classical form

Generalized Linear Models (GLM) were introduced by J. Nelder and R. Wedderburn (Nelder & Wedderburn, 1972).

Generalized Linear Models are an extension of the linear regression and consist of three components: the random component, the systematic component and the link function

- The random component :
The random variables $x_{i,j}$ are independent and of a distribution that belongs to the exponential family. That means their density function can be written as:

$$f(x_{i,j}; \theta_{i,j}, \phi) = \exp\left(\frac{x_{i,j}\theta_{i,j} - b(\theta_{i,j})}{\phi/\omega_{i,j}} + c(\theta_{i,j}, \phi)\right)$$

where:

- Both $\theta_{i,j}$ and ϕ are the parameters of the exponential family
- The parameter ϕ is the dispersion parameter and is strictly positive. This noise/variance parameter is independent from i .
- Functions b and c are known. Function b (resp. c) is 2 times differentiable in \mathbb{R} (resp. in \mathbb{R}^2)
- $\omega_{i,j}$ is a known weight for each observation $x_{i,j}$
- The systematic component
This component matches each observation $x_{i,j}$ with a linear predictor:

$$\eta_i = \beta_0 + \sum_{j=1}^{p-1} x_{i,j}\beta_j$$

Regarding the case of reserving, this component can be written as following:

$$\eta_i = \mu + \alpha_i + \beta_j, \quad 0 \leq i \leq I \text{ and } 0 \leq j \leq J$$

- The link function
The role of the link function is to linearize the expectation. It links the random and the systematic components.

$$\begin{cases} \eta_i = g(\mu_{i,j}) \\ \mathbb{E}(X_{i,j}) = \mu_{i,j} \\ \mathbb{V}(X_{i,j}) = \phi v(\mu_{i,j}) \end{cases}$$

where v is the specific variance function of each distribution.

In particular, the log link function enables to have the formula:

$$\ln(\mu_{i,j}) = \eta_i = \mu + \alpha_i + \beta_j \Leftrightarrow \mu_{i,j} = \exp(\mu + \alpha_i + \beta_j)$$

Then, the expectation and the variance are derived from the score function ($U_{i,j} = \frac{\partial \log f(x_{i,j}; \theta_{i,j}, \phi)}{\partial \theta_{i,j}}$):

$$\begin{cases} \mathbb{E}(X_{i,j}) = \mu_{i,j} = b'(\theta_{i,j}) \\ \mathbb{V}(X_{i,j}) = \phi v(\mu_{i,j}) = \phi b''(\mu_{i,j}) \end{cases}$$

The forecast of claims reserves with a GLM model consists in explaining the incremental claims by explanatory drivers that are the accident year and the development year. This operation is based on a triangle presentation of the claims (see Figure 2).

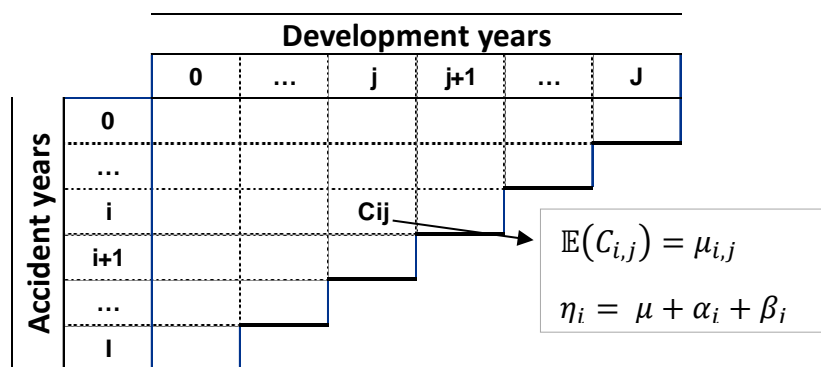


Figure 2 Scheme of loss reserving with Generalized Linear Models

In Figure 2, $C_{i,j}$ depicts to the incremental claims transactions observed at the i^{th} accident year and the j^{th} development year. The other notations in this figure are those presented above.

5.1.3.2. As implemented in the study

A given distribution and link function are associated to the claims in the triangle. In our case, we use:

- the log link function and the Gamma distribution for paid
- the identity link function and the Normal distribution for incurred.

We use the ChainLadder package from R for General Linear Models modelling.

- For paid claims, the Gamma distribution is the one that fits the best the data:

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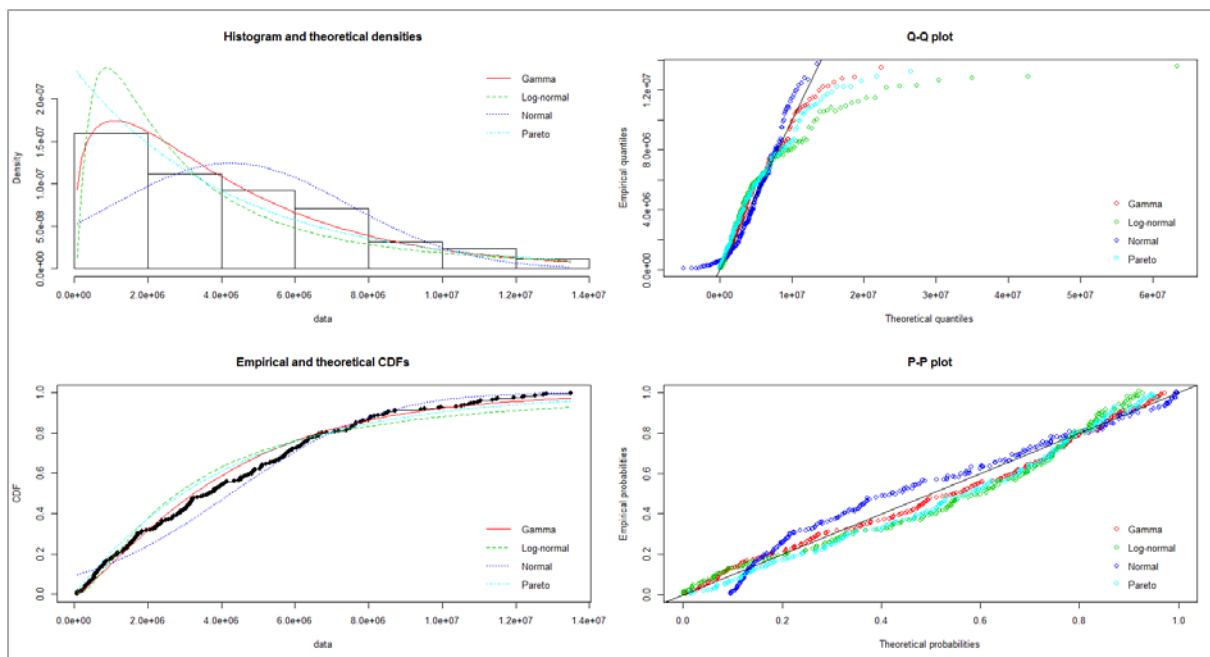


Figure 3 - Fitting paid claims distribution with known distributions

It is the one which minimizes the most the statistics (distance between original data and adjusted distribution) and errors criteria, as showed in Figure 4

Goodness-of-fit statistics				
	1-mle-gamma	2-mle-lnorm	3-mle-norm	4-mle-pareto
Kolmogorov-Smirnov statistic	0.07317775	0.1078843	0.1023953	0.09028679
Cramer-von Mises statistic	0.29106376	0.9353808	0.6532280	0.66226184
Anderson-Darling statistic	1.65786455	5.4701857	4.6128554	3.64436177
Goodness-of-fit criteria				
	1-mle-gamma	2-mle-lnorm	3-mle-norm	4-mle-pareto
Akaike's Information Criterion	8285.541	8338.447	8368.346	8297.824
Bayesian Information Criterion	8292.623	8345.529	8375.428	8304.906

Figure 4 - Goodness-of-fit statistics – Application to paid claims

We remind that for the Gamma distribution:

$$X \sim \Gamma(\alpha, \beta) \Rightarrow \begin{cases} \mathbb{E}(X) = \alpha \times \beta \\ \mathbb{V}(X) = \alpha \times \beta^2 \end{cases}$$

- For the incurred, the incremental amounts showed a proportion of negative values due to the consideration of Subrogations & Salvages in the triangles. However, a Poisson family can still often be invoked so long as the sample mean is positive which is the case : the mean of incurred is 10.7M\$

```
> mean(Data_Dens$Inc_m0)
[1] 10686033
```

Figure 5 Average amount of incremental Incurred

Thus, the incurred are modelled with a normal distribution that accepts the existence of negative values.

5.1.3.3. Forecast on the basis of censored data

The Generalized Linear Models (GLM) provide a forecast until the last development of the cut-off dates. It means that for the 2006 cut-off date for instance, the last development year is the 12th one. In order to obtain forecasts until the 22nd development year, which corresponds to the last development year of 2016 cut-off date, the following strategies have been applied:

Let J be the final development year of the entire triangle ($J = J_{2016} = J_{2010} = 22$)

The GLM provide forecasts until $J_K = K - 1994$ for the K^{th} cut-off date

i. Paid

To extend the forecast beyond J_K , the development factors were derived from the historical claims development and from the projections provided by the GLM:

$$f_{i,j} = \frac{Y_{i,j+1}}{Y_{ij}}, \quad j \in [7 - |K - 2010| - 1 - \mathbb{I}_{\{K=2006\}}; J_K] \text{ and } i \in [1; I_K]$$

where:

- K is the cut-off date
- Y_{ij} the cumulated payment for the i^{th} accident year and the j^{th} development year.
- I_K is the number of rows for each cut-off date : $I_K = \min(K, 2010) - 1994 + 1$

1. Development factor at J_K

The development factor for the development year is assumed to be

$$\hat{f}_{J_K} = \frac{1}{I_K} \sum_{i=1}^{I_K} f_{i,J_K}$$

2. Decreasing factor

For each accident year, the evolution of the development factors is assessed as the ratio of the development factor between 2 successive development years

$$\ddot{t} = \frac{1}{I_K} \sum_{j=7-|K-2010|-1-\mathbb{I}_{\{K=2006\}}}^{J_K} \frac{f_{i,j+1}}{f_{i,j}}$$

3. Development factor beyond J_K

Finally the development factor for $j \in [J_K; J]$ is defined as following

$$\tilde{f}_j = 1 + (\hat{f}_{j-1} - 1) \ddot{t}^{j-8}, j \in [J_K + 1; J]$$

Therefore the forecasted paid forecasts \hat{Y}_{ij} beyond J_K are given by:

$$\hat{Y}_{i,j+1} = \hat{Y}_{ij} \hat{f}_j, j \in [J_K + 1; J]$$

ii. Incurred

The incurred claims show more volatility than paid amounts. Thus, the forecast of the triangles beyond the cut-off times is based on an adjusted methodology that aims to reflect the historical volatility on the forecasts.

The historical volatility is catch on the triangle of 2010 cut-off date.

1. Development factors on historical incurred:

We are interested in the forecast of the triangles of cut-off dates 2006, 2011 and 2014. In particular, we are analysing how to build development factors from the 13th development year since it is the development year from which data are blinded (it corresponds to the triangle of cut-off date 2006).

$$f_{j,k} = \frac{\sum_{i=1}^{10-k+1} Y_{i,j+1}}{\sum_{i=1}^{10-k+1} Y_{i,j}} \mathbb{I}_{\{j < 14\}}, \text{ for } j \in [2, 22] \text{ and } k \in [1, 9]$$

2. Adjustment of development factors:

The development factors shows the evolution, by development period presented in Figure 6.

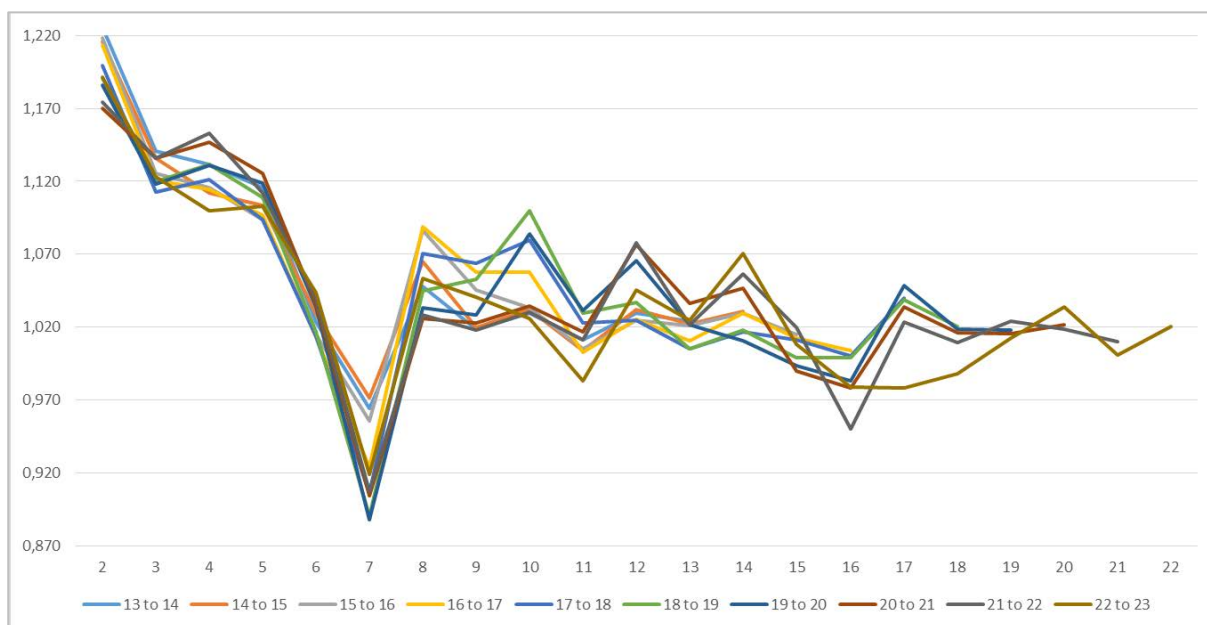


Figure 6 Evolution of development factors by accident year

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A logarithmic regression is then built on specific intervals of accident years as presented in Table 5.

Interval of accident years	Logarithmic regression parameters to smooth development factors			
	Development factor = A ln(X) + B			
	A	B	Adjusted development factor	Initial development factor
1994 to 1995	-0,09	1,21	0,984	1,024
1994 to 1996	-0,08	1,19	0,990	1,031
1994 to 1997	-0,07	1,18	0,992	1,015
1994 to 1998	-0,07	1,18	0,995	1,004
1994 to 1999	-0,06	1,16	0,995	1,040
1994 to 2000	-0,06	1,16	0,995	1,021
1994 to 2001	-0,06	1,16	0,990	1,018
1994 to 2002	-0,06	1,16	0,993	1,022
1994 to 2003	-0,06	1,16	0,992	1,010
1994 to 2004	-0,05	1,15	0,986	1,021

Table 5 Logarithmic regression to smooth development factors

The adjusted development factors \hat{f} are then used to forecast the incurred \hat{Y}_{ij} :

$$\hat{Y}_{i,j+1} = \hat{Y}_{ij} \hat{f}_j, j \in [J_K + 1; J]$$

5.1.3.4. Results and discussion

We present hereafter the results of the Generalized Linear Model described above.

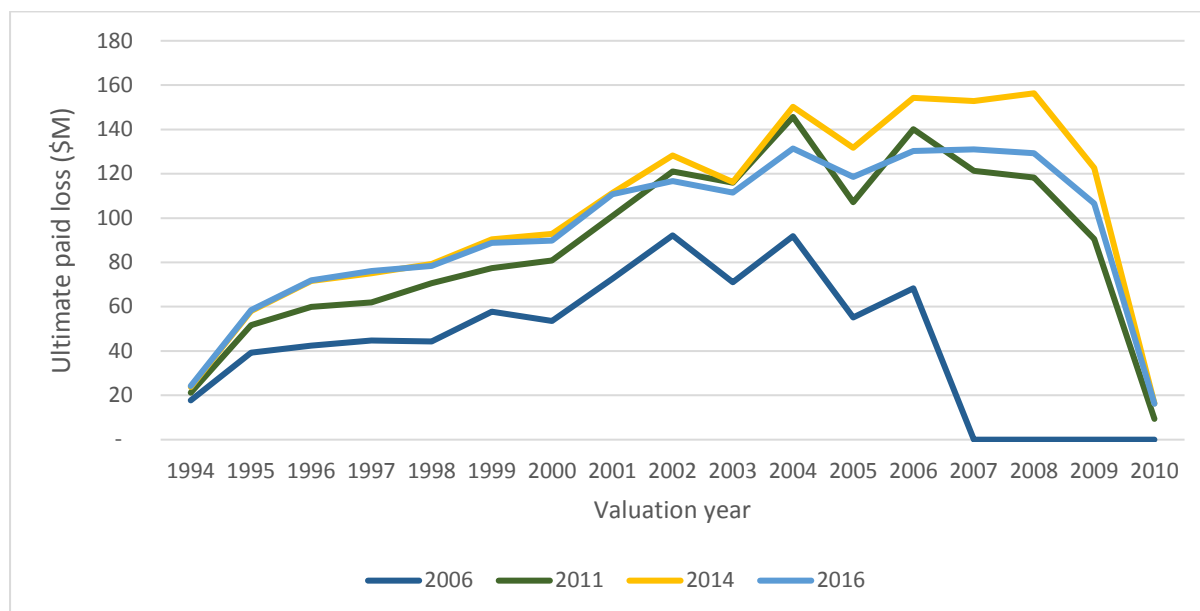


Figure 7 Estimated Ultimate Paid Results - Generalized Linear Models

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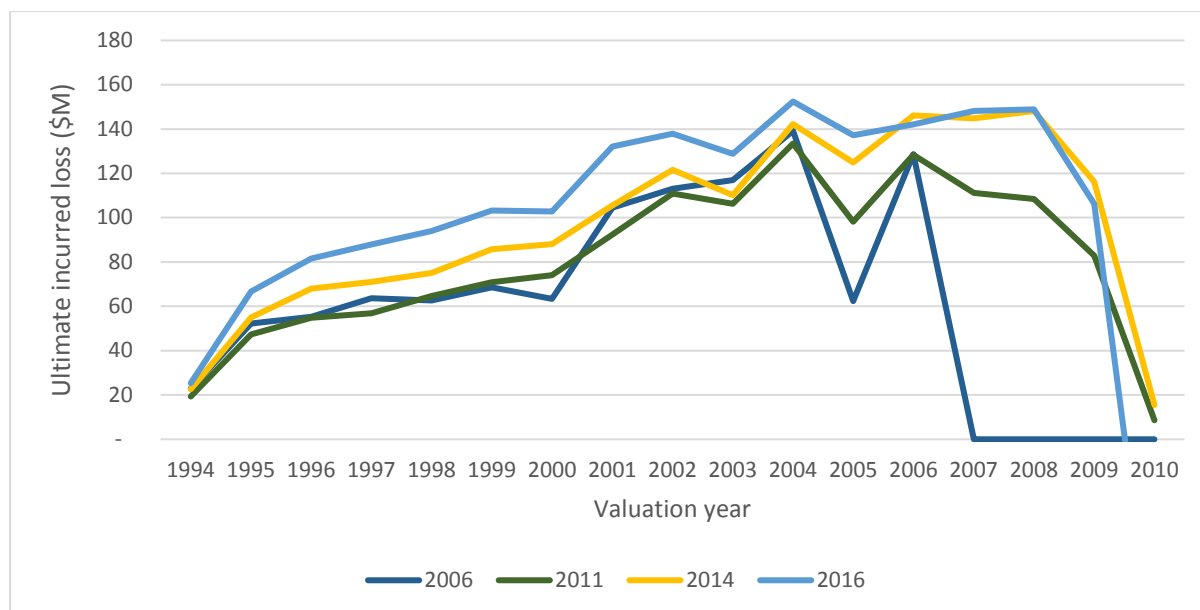


Figure 8 Estimated Ultimate Incurred Results - Generalized Linear Models

For the different cut-off dates, the forecasted claims for paid present a homogeneous increasing trend for the first 9 accident years, and although less pronounced, the same homogenous increasing trend is observed on ultimate incurred.

However, the ultimate paid for 2006 cut-off date shows a lag which can be explained by the volumetry of the claims that is less important for this cut-off time (claims triangles are smaller).

After the 9th accident year (2002), the ultimate paid of data related to cut-off dates 2011, 2014 and 2016 shows a fast and stressed increase while those of 2006 cut-off year starts decreasing slowly. This is due to calendar years with a specific development of (long-tail) claims that are not included in the 2006 cut-off date triangles.

For incurred, the ultimates of the 3 last cut-off dates (2011, 2014 and 2016) decrease softly from the 15th accident year (2008) and all collapse at 2010 because of the porosity of the claims for the last accident year (2010).

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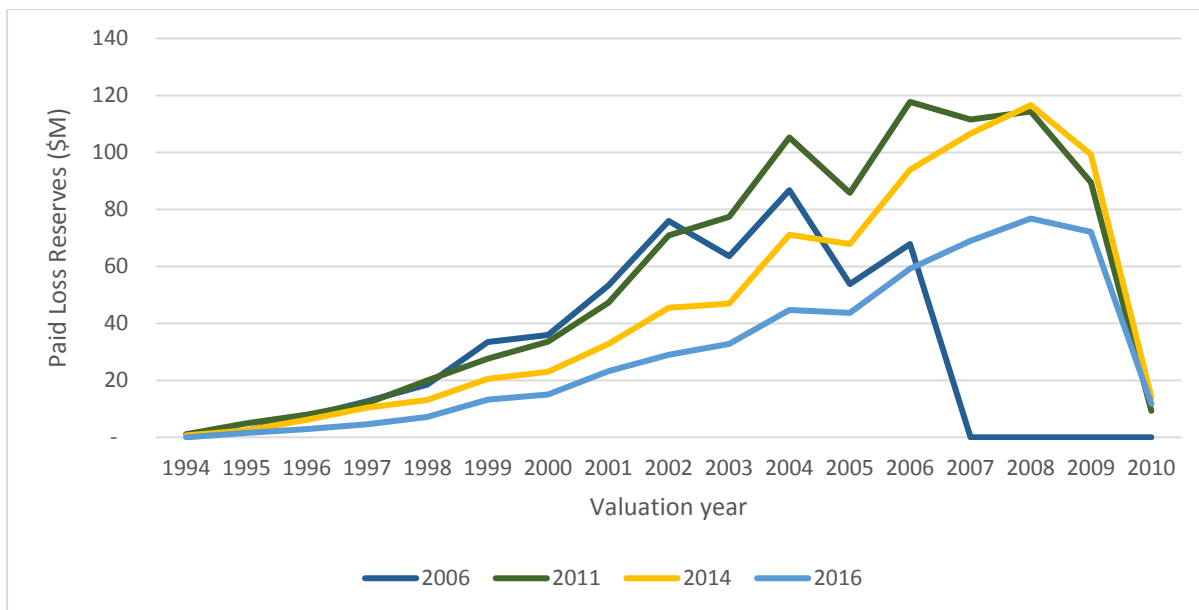


Figure 9 Estimated Paid Loss Reserves Results – Generalized Linear Models

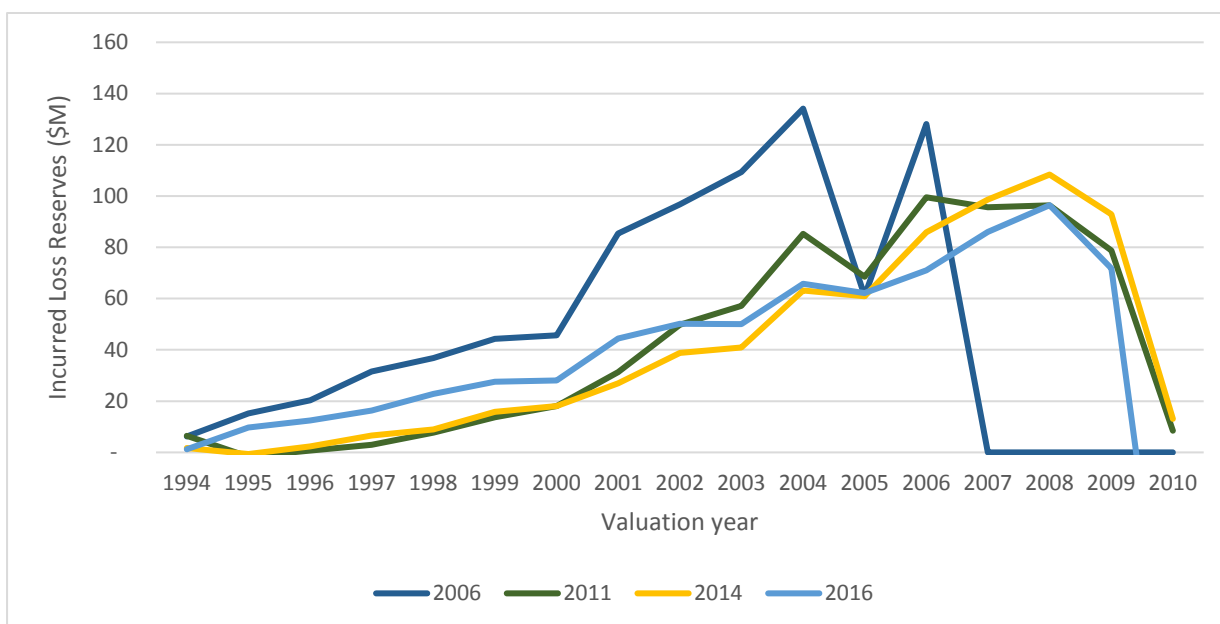


Figure 10 Estimated Incurred Loss Reserves Results – Generalized Linear Models

Unlike the ultimate claims, loss reserves for both incurred and paid raise significantly, especially for paid claims. For paid, the evolution of loss reserves present an exponential growth until the 8th accident year (2007) for the last 3 cut-off dates and the 7th accident year (2006) for 2006 cut-off-date.

Regarding loss reserves on incurred, their evolution lean on incurred ultimates and the paid of the last calendar year of the triangles. It means that incurred loss give an information on both ultimate outstanding and paid loss reserves.

5.2. Modelling with Machine Learning

In this section we describe an approach on how Machine Learning methods can be used to assess an ultimate claims from a claim level.

5.2.1. Preamble

5.2.1.1. General approach

Actuarial practice in Non-Life reserving is traditionally based on claims data aggregated and structured in triangles. Modern approaches introduce Machine Learning to estimate future payments varying by accident year and reporting delay at an individual claim level (Aleandri, 2017).

Reporting year	Closing delay					Tail
	0	1	...	n-1	n	
$T-n$	$P_{T-n,0}$	$P_{T-n,1}$	...	$P_{T-n,n-1}$	$P_{T-n,0}$	$\tilde{P}_{T-n,c}$
$T-(n-1)$	$P_{T-(n-1),0}$	$P_{T-n,0}$	...	$P_{T-n,0}$	$\tilde{P}_{T-(n-1),n}$	$\tilde{P}_{T-(n-1),c}$
.
.
.
$T-1$	$P_{T-n,0}$	$P_{T-n,0}$	...	$\tilde{P}_{T-1,n-1}$	$\tilde{P}_{T-1,n}$	$\tilde{P}_{T-1,c}$
T	$P_{T-n,0}$	$\tilde{P}_{T,1}$	...	$\tilde{P}_{T,n-1}$	$\tilde{P}_{T,n}$	$\tilde{P}_{T,c}$

Table 6 Traditional scheme of Non-Life reserving

Standard actuarial methods for reserving generally apply development factors to losses paid-to-date and reported-to-date to calculate an estimate of ultimate losses.

Modern approaches (Schlemmer & Tarkowski, 2013) calculate total IBNR as a sum of:

- “Pure IBNR” (or “IBNYR”) as the estimate of ultimate losses for **claims not yet reported**
- and “IBNER” as the estimate of ultimate losses for **known claims**

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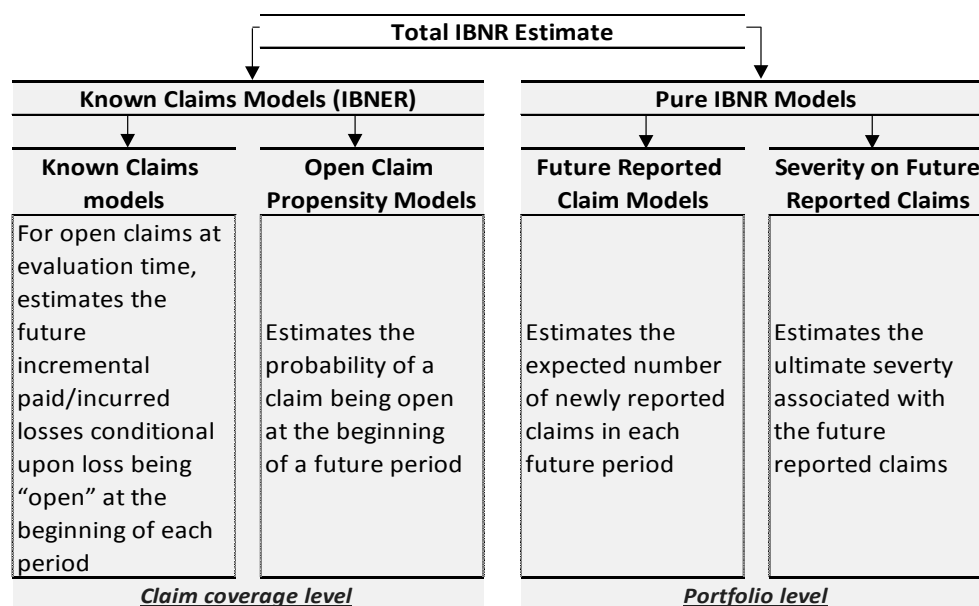


Figure 11 Scheme of evaluating total IBNR according to modern approaches

5.2.1.2. Technical specifications

In this section we describe the technical specifications of a Machine Learning method which separates the projection of **Incurred But Not Enough Reported (IBNER)** from **Incurred by not Yet Reported (IBNYR or pure IBNR)** (Golfin, Laurie, Li, Martin, & Nyce, 2017). First we outline the technical specifications for the IBNER component. Then we discuss the IBNYR of pure IBNR component.

The **IBNER** component is based on two component models.

- The first model is referred to as the **Known Claims Model (KCM)** which estimates as of a given evaluation time the **future incremental paid/incurred losses** conditional upon the loss being open at the beginning of each period.
- The second model is referred to as an **Open Propensity Model (OPM)** which estimates the **probability of the claim being open at the beginning of the period**. The target variable of this model (the **claim status at the beginning of the development year**) is defined based on ending case reserve at the prior year: if the case reserve is zero at the end of prior year, then the claim status is defined as 'Closed' for current year. Otherwise the claim status is defined as 'Open'.

The results of these two models can be blended together to generate a granular estimate of the expected ultimate settlement of a claim. An appealing characteristic of this approach is that claim characteristics can be used as predictors in the KCM and OPM models.

In the next section we will describe the technical specifications utilizing notation consistent with emerging literature in this area of research (Wüthrich, 2016).

- Let i denote the accident year
- Let j denote the reporting delay
- Let N_{ij} denote the number of claims occurring in accident year i reported in calendar period $i + j$
- Let \mathcal{F}_t denote the information available at time t
- Each claim v generates cash flows $X_{i,j|0}^{(v)}, X_{i,j|1}^{(v)}, \dots$, where the variable $X_{i,j|k}^{(v)}$ denotes payments in calendar year $i + j + k$

We can utilize this notation to express the ultimate for known claims as:

$$\sum_{j=0}^{t-i} \sum_{v=1}^{N_{ij}} \left(\sum_{k=0}^{t-(i+j)} X_{i,j|k}^{(v)} + \sum_{k>t-(i+j)} E \left[X_{i,j|k}^{(v)} \mid \mathcal{F}_t \right] \right)$$

In addition,

- Let $x_{i,j|k}^{(v)}$ represent the feature-space which in our case is represented by the features in the Swiss Re dataset.
- The term on the left-hand side represents known claim transactions (paid or incurred loss amounts) and the right-hand side represents future development on these “known claims” given information known at time t .
- Let $OPM_{j+k}(x_{i,j|k}^{(v)})$ denote the **probability** of a claim being **open** at the beginning of the calendar period $i + j + k$
- Let $KCM_{j+k}(x_{i,j|k}^{(v)})$ denote the **expected payment** amount during the calendar period $i + j + k$ conditional upon the claim being open at the beginning of each future period.

Therefore, incorporating this notation the ultimate loss estimate for known claims becomes:

$$\sum_{j=0}^{t-i} \sum_{v=1}^{N_{ij}} \left(\sum_{k=0}^{t-(i+j)} X_{i,j|k}^{(v)} + \sum_{k>t-(i+j)} KCM_{j+k}(x_{i,j|k}^{(v)}) * \frac{OPM_{j+k}(x_{i,j|k}^{(v)})}{OPM_{j+k}(x_{i,j|k=j}^{(v)})} \right)$$

5.2.1.3. Steps of the analysis

When dealing with the process of estimating a Machine Learning model there is one important aspect that anyone must take care of carefully: choosing the best set of hyper parameters and parameters, according to a preselected metric.

Each family of Machine Learning model is characterized by a set of hyper parameters and parameters. Rigorously, the hyper parameters are defined as those model settings that cannot be learned within the estimation process directly. While parameters are defined as those that can be learned during the process of estimation, i.e. the process of fitting the model. For example, in case of a General Linear Model, the weights are parameters, while the link function and the error distribution are considered hyper parameters. Instead if we consider a Multilayer Perceptron then the parameters are the weights inside each neuron, while (to name a few) the number of layers, number of neurons and type of activation functions inside each layer are all hyper parameters.

For each family of Machine Learning model under study, we aim to find a set of hyper parameters that overall perform well during all years covered by the dataset. We choose the following approach:

- We divide the dataset into 5 folds (or disjoint subsets) with respect to cut in times;
 - For each fold we consider the year ahead as the validation set.
- So for each set of hyper parameter we estimate/fit 5 models on the five different folds, and each model is tested on the corresponding validation diagonal (see [Figure 12](#)). *This approach is analogue to a k-fold cross validation validation in a context outside time series analysis.*

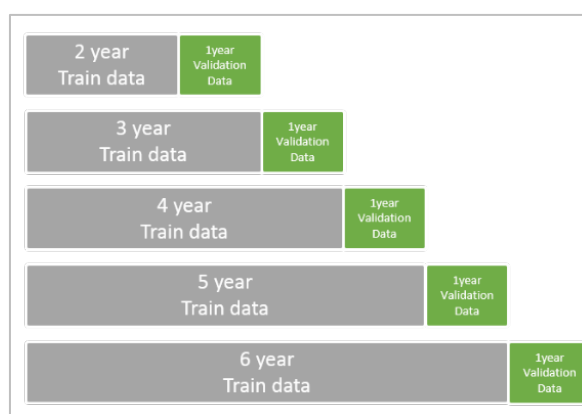


Figure 12 - Example of a 5-folds cross validation

- At this point we compute the Mean Square Error (MSE) by comparing the observed and predicted on each validation diagonal and we compute the average of the 5 Mean Square Errors just computed. This average represents how well the set of hyper parameters perform on different time windows.

In Table 7 we report the exact cut in years:

	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Training	[2002 , 2006]	[2003 , 2007]	[2004 , 2008]	[2005 , 2009]	[2006 , 2010]	[2007 , 2011]	[2012 , 2016]
Validation	2007	2008	2009	2010	2011	[2012 , 2014]	[2012 , 2016]
Ultimate losses	2006					[2011 , 2014]	2016

Table 7 Modelling steps with Machine Learning methods

- Steps 1 to 5 represent our 5 folds that allows us to determine the optimal set of hyper parameters for each family of models.
Note that the KCM and the OPM will have different set of hyper parameters.
- With the chosen set hyper parameters we fit 3 different models in step 1, 6 and 7 in order to estimate the ultimate losses and compare the results with the TM findings.

The choice of these particular cut-off times is dictated by the amount of data available. From a practical point of view, if one knows that starting from a particular year the process of handling the claims has been modified then the cut in times should be selected in accordance to the modification of the process.

This entire procedure aims to find a good trade-off between train-test (or Cross Validation) error (see Figure 13): the ML models must have learned those relationship that hold both on the train and the test set, avoiding to fit noise in the train set. If the analyst does not take into account this trade-off then he/she will risk to produce predictions that are highly affected by noise, hence unreliable.

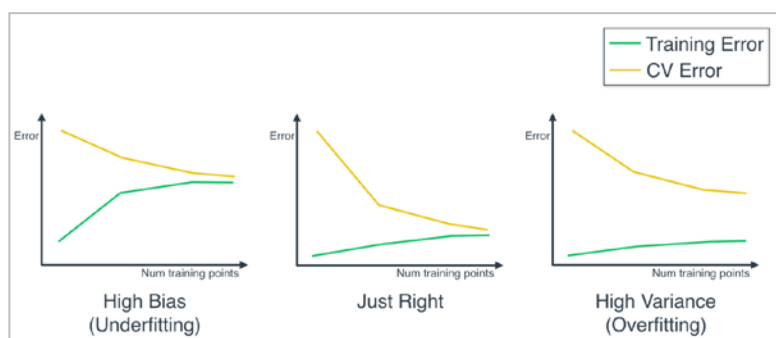


Figure 13- Illustration of the procedure to evaluate goodness of models

5.2.1.4. Cross-Validation error

We discuss here the metrics used to evaluate goodness of models (James, Witten, Hastie & Tibshirani, 2017).

■ Know Claims Model

- The variable of interest is numerical: it is a regression problem. To evaluate the goodness of fit of the Know Claims Model, the Root Mean Squared Error (RMSE) is used.
- This metric represents the square root of the average of squared differences between predictions and observations. In other words, it represents the sample standard deviation of the differences between predicted and observed values.

$$RMSE = \sqrt{\frac{1}{n} \sum_{j=1}^n (y_j - \hat{y}_j)^2}$$

■ Open Claim Propensity Model

- The evaluation of Open Claim Propensity Model is a classification problem. Gini coefficient is used to assess the goodness of this model. This index represents a measure of total variance across the K classes.

$$G = \sum_{k=1}^K \hat{p}_{mk}(1 - \hat{p}_{mk})$$

Where \hat{p}_{mk} represents the proportion of the training observations in the m^{th} region of the k^{th} class.

- Gini index is referred to as a measure of node purity: a small value indicates that a node contains predominantly observations from a single class.
- Gini calculation is closely related to the calculation of Area Under Curve (AUC) and can be computed as: $G = 2 \times AUC - 1$

5.2.2. Random forests

Random Forests algorithm have been devised by Breiman in the early 2000's (Breiman, 2001). A random forest is a bootstrapping algorithm with Decision Trees capable of performing both regression and classification tasks. It is generally recognized for its accuracy and its ability to deal with small sample sizes and high-dimensional feature spaces.

5.2.2.1. Classification and Regression Trees

The Classification and Regression Trees model (**CART** or Decision Trees), being at the core of the Random Forest model and the Gradient Boosting Machine (GBM) model, is briefly presented below.

Decision Trees (Friedman, 2001) partition the feature space into a set of rectangles, and then fit a simple model (like a constant) in each one. In particular the model, at each step, splits the population (or sample) into two homogeneous sets (or subpopulations) based on the most significant splitter on input variables in order to give the best homogeneous sets of sub-population.

A tree can be presented as a function $f: \mathbb{R}^n \rightarrow \mathbb{R}$ defined as:

$$f(x) = \sum_{j=1}^K c_j I(x \in A_j)$$

where:

- $x \in \mathbb{R}^N$ represents the vector containing the features;
- $\{A_j\}_1^K$ is a partition of \mathbb{R}^N ;
- $I(x \in A_j)$ is the indicator function over the set A_j ;
- c_j is a constant and represents the prediction for all $x \in \mathbb{R}^N$;
- the predicted value $f(x)$ belongs to \mathbb{R} .

Decision Trees use multiple algorithms to decide when and where to split a node in two or more sub-nodes. The idea is that the creation of sub-nodes increases the homogeneity of the resultant sub-nodes.

5.2.2.2. Principle of random forests

More formally, Random Forests are a combination of tree predictors such that each tree depends on the values of a random vector sampled independently and with the same distribution for all trees in the forest.

Among the forests' essential ingredients, both **bagging** and the Classification and Regression Trees (CART) split criterion play critical roles. **Bagging** (a contraction of bootstrap-aggregation) is a general aggregation scheme, which generates bootstrap samples from the original data set, constructs a predictor from each sample and decides by averaging.

i. Random forests algorithm

Let M be the dimension of the dataset. Our data consists of a sample $\{x_i, y_i\}_{i=1}^M$ where $x_i \in \mathbb{R}^N$ and $y_i \in \mathbb{R}$.

The algorithm for fitting a random forest for regression works as follows:

1. For $b = 1$ to B number of bootstraps:
 - a. Draw a bootstrap sample K of size p from the training data. As suggested by Breiman (Breiman, 2001) the subset should be about 66% of the total set of size M ;
 - b. Grow a random forest tree T_b to the bootstrapped data by recursively repeating the following steps for each terminal node of the tree until some constraints on the tree size are reached:
 - i. Select l variables at random from the N variables;
 - ii. Pick the best variable & split-point¹ among the l variables;
 - iii. Split the node into two daughter nodes.
2. Output the ensemble of trees $\{T_b\}_1^B$.
3. To make prediction at a new point x , compute:

$$\hat{f}^B(x) = \frac{1}{B} \sum_{b=1}^B T_b(x)$$

Breiman (Breiman, 2001) shows that the error of the forest, independently of the type of forest, is small as soon as the predictive power of each tree is good and the correlation between the tree errors is low.

A second result is obtained by observing that if we would sample the bootstrap B from *iid* random variable's y with $\mathbb{E}[y] = m$ and $Var(y) = \sigma^2$ then the bootstrap will have a variance of $\frac{1}{B} \sigma^2$.

However, since we are sampling from the same dataset, we have a positive pairwise correlation $\rho = \rho(x)$ and the variance of the average is:

$$\rho(x) \sigma^2(x) + \frac{1 - \rho(x)}{B} \sigma^2(x)$$

As B increases, the second term of the equation disappears, but the first remains limiting the benefits of averaging.

The idea in random forests is to improve the variance reduction of bagging by reducing the correlation between the trees, without increasing the variance too much. This is achieved in the tree-growing process through random selection of the input variables.

¹ It is the pair of variable & split point that minimize the error metric of the two daughter nodes (e.g. RMSE).

ii. Random forests hyper parameters

The performance of the model is highly affected by the chosen hyper parameters. Hence the fine tuning of the model is an important part of the process.

The most sensitive hyper parameters are:

▪ Number of trees B

A high number of trees produces a more stable prediction, but the computation time increases as well. The approach adopted consists of choosing a high number for B (e.g. 1000) and stop to add trees when the *out-of-bag error*² does not decrease of more than (for example) 0.001;

▪ Size of the sample

Even if it is suggested so use 66%, it is often appropriate to test different values;

▪ Number of variables l among which to search for the best split

If $l = N$ then the algorithm tends to overfit and choose always the same variables, while if $l = 1$ the algorithm is purely random;

▪ The maximum depth of the trees

If we allow to have a really high depth (e.g. 100), then the trees perfectly replicate the training data. On the other hand a depth of 1 means that each tree divides the dataset into two subset and then return the average observed value for each subset. Hence a good trade-off must be determined in order to have a model that does not overfit on the training data but it has learnt the important relationship within the data.

iii. Optimization of hyper parameters

In order to identify the best set of hyper parameters, one can test all possible combination of hyper parameters and choose the one that produces the lowest Cross Validation Error (see Section 5.2.1.4). However, this is often an infeasible task due to the computational time needed.

The approach adopted is the so-called *Randomized Hyper Parameter Grid Search*: a random sample of a set of hyper parameter from all possible combination is performed. It is tested and the process is repeated until the Cross Validation Error does not decrease for K (set at 10) consecutive combination of hyper parameters.

This hyper parameter search has been performed for both the KCM and OPM model, so we obtained two sets of optimal hyper parameters.

The package used to fit the Random Forest is the *H2O* package, interface in *R*.

² For each observation, construct its random forest predictor by averaging only those trees corresponding to bootstrap samples in which the observation did not appear. Then compute the error.

5.2.2.3. Results and discussion

We present hereafter the results of the random forest model described above.

We can see that the estimated paid and incurred loss reserves tend to be a bit noisy and unstable. However, the main trend is overall the same.

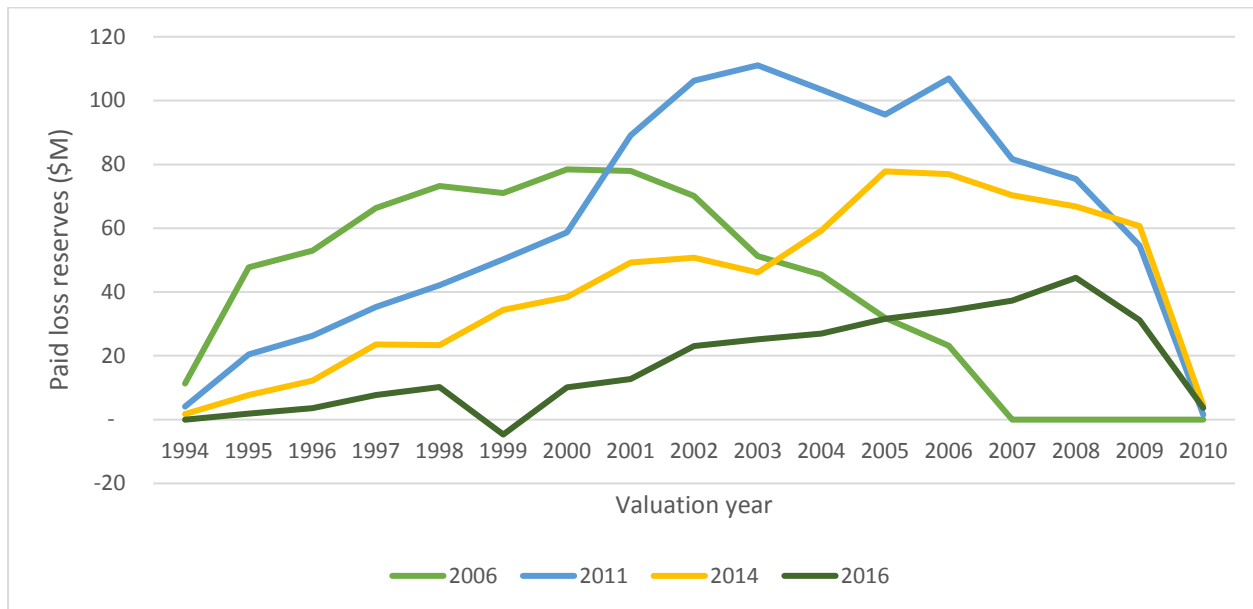


Figure 14 Estimated Paid Loss Reserves Results – Random Forests

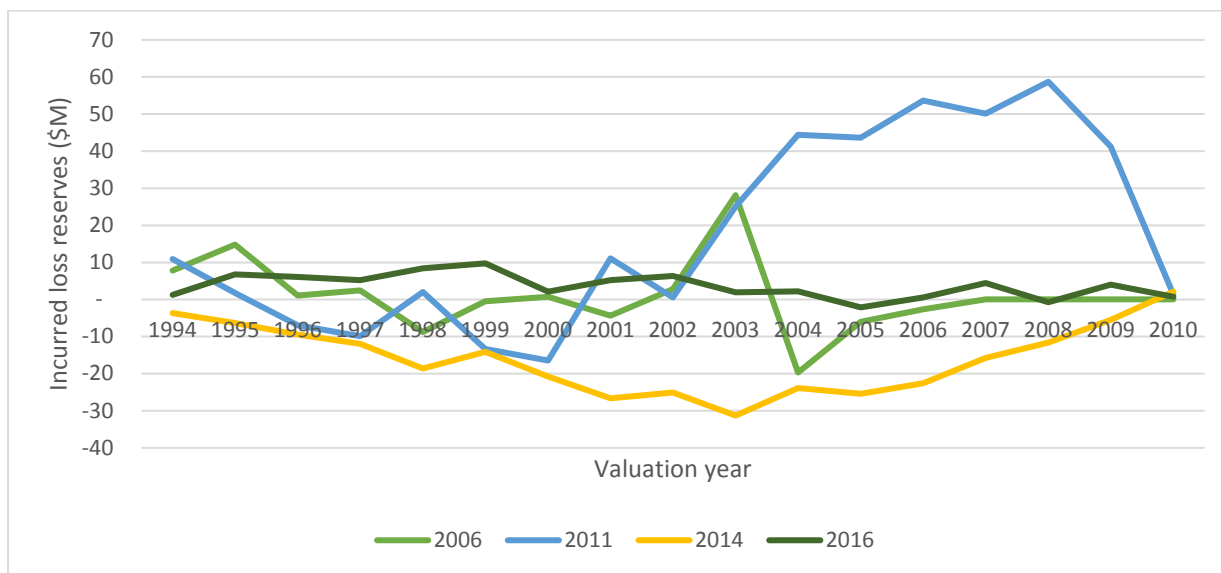


Figure 15 - Estimated Incurred Loss Reserves Results – Random Forests

Regarding the ultimate estimations, predictions are more stable with respect to the different evaluation years. Observe that prediction at year 2006 behaves quite different from the others.

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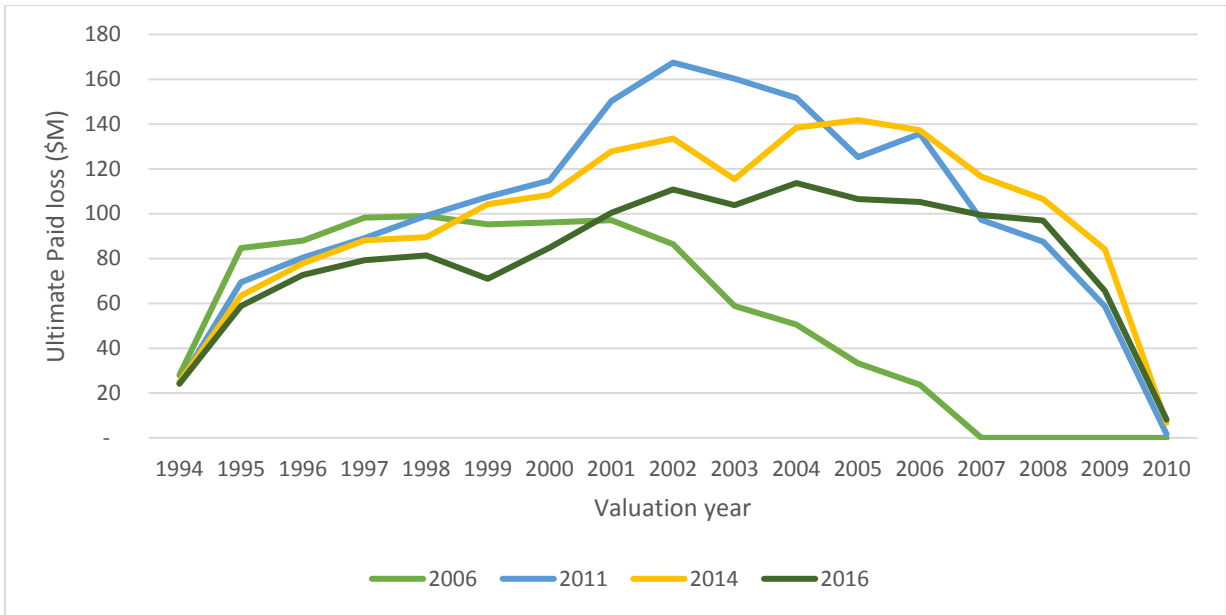


Figure 16 Estimated Ultimate Paid Results – Random Forests

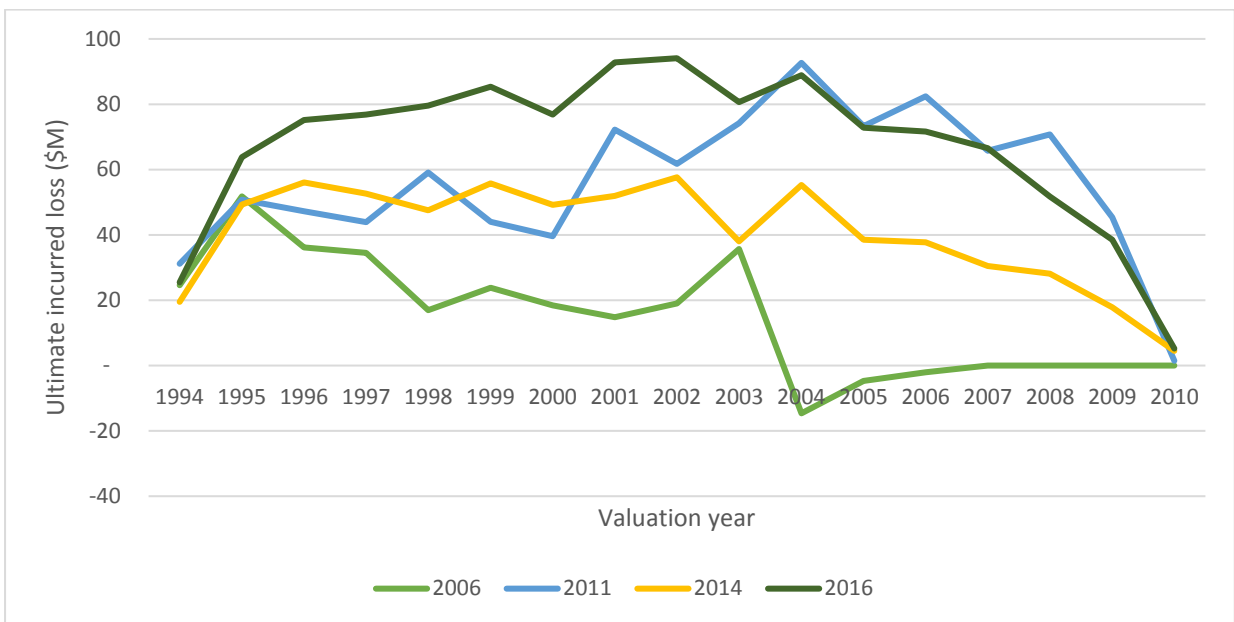


Figure 17 Estimated Ultimate Incurred Results – Random Forests

5.2.3. Neural Networks

Neural networks are powerful tools for solving any kind of regression or classification problems, in particular, on high-dimensional covariate spaces. Neural networks should be understood as semi-parametric models. The universality theorems imply that general neural networks can approximate arbitrarily well every compactly supported function on the covariate space. Therefore, they typically lead to better in-sample performance than generalized linear models, and they capture interactions in covariates more easily than generalized additive models. However, their use also needs some care, covariates also need to be pre-processed, for instance, co-linearity and non-uniformity of covariates in insurance portfolios may pose major difficulties in neural network calibrations. Dealing successfully with these issues typically leads to regression models which have better out-sample performance than other regression models.

State-of-the-art research in neural networks aims at solving questions about the stability of neural networks over time, i.e. for sequential observations over different accounting years. Interpretability, illustration and communication of neural network results need to be improved, and important from a pricing and risk management point of view, uncertainty measures need to be derived if using these models in a predictive modelling fashion.

5.2.3.1. *Principle of neural networks*

The technique adopted in order to find a model that fits the data followed the following steps:

1. **Initial design of a Neural Network**

The neural network designed at this step overfits deliberately the training set. This involves, in the case of this study: *i)* creating many layers with many neurons, *ii)* finding an appropriate activation function and *iii)* determining where to insert the batch normalization layers.

2. **Dimension reduction and use of dropout layers**

The purpose of this step is to decrease the overfit on the training data and to start reducing the Cross Validation Error. This is achieved by decreasing manually the number of neurons and removing one layer at the time. Dropout allows us to reduce the overfitting of the Neural Network.

During these steps the learning rate has always been kept constant and equal to 1%. This rate represents the speed with which the model crosses the whole dataset.

A found working architecture is composed as follow:

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- 2 hidden layers of respectively 500 and 250 hidden neurons
- Specific activation function by model and by layer :

	Hidden layer	Output layer
KCM	Rectified Linear Unit : $g(x) = \max(x, 0)$	Linear : $g(x) = x$
OPM	Hyperbolic tangent : $g(x) = \frac{\sinh(x)}{\cosh(x)} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$	Sigmoid : $g(x) = \frac{1}{1 + e^{-x}}$

Table 8 - Activation functions of selected neural networks

- Dropout layer of 0.1
Dropout is a technique used to improve over-fit on neural networks. A dropout layer of 0.1 means that during training 10% of the neurons will be deactivated. This improve generalization because force the layer to learn with different neurons the same "concept". While the Batch Normalization layer transforms the normalized input sample using a linear transformation, whose parameters are learnt during training. This, sometimes, helps a lot because the output of a hidden layer should not have obviously mean zero and unit variance.
- Batch Normalization layer
- The **optimizer** used is the *Rmsprop* with approximate 20 epochs and batch size of 128. One epoch consists of one full training cycle on the training set. Once every sample in the set is seen, you start again, marking the beginning of the 2nd epoch. While Batch size defines number of samples that going to be propagated through the network in order to update the weights of the activated neurons.

All categorical variables have been encoded using the **One Hot Encoding Scheme**: it transforms the categorical variable into n number of new variables (or columns in the dataset), where n is the number of possible values that the categorical variable can assume. So each column contains either 1 or 0 if the value corresponding to the label associated to the new column is assumed by the sample considered or not. In this way, we treat the categorical variables as numerical ones.

In general, the process of finding a good architecture requires a lot of time and experience with the database under analysis. It is almost impossible to find the optimal one, usually a good one is enough. One possible further study could be to use *Genetic Algorithm* to find a sound working architecture.

The package use to train the Neural Network is the *Keras* package, interface in *R*.

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5.2.3.2. Results and discussion

We present hereafter the results of the neural network model described above.

Overall we have a stable trend of predictions, except of the 2006 case. This highlights the fact that the model is not able to well extrapolate beyond the data on which has been trained. One other reason of this weird behaviour might be due to the fact that the model evaluated at year 2006 has been trained on a small subset of the entire dataset, so making the predictions unreliable.

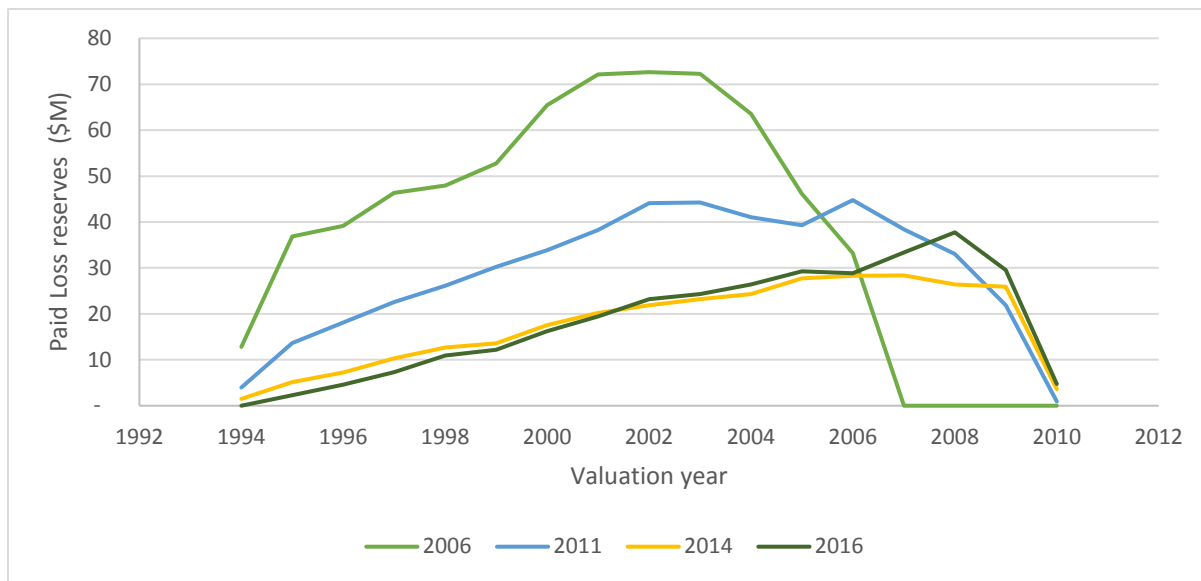


Figure 18 - Estimated Paid Loss Reserves Results- Neural Networks

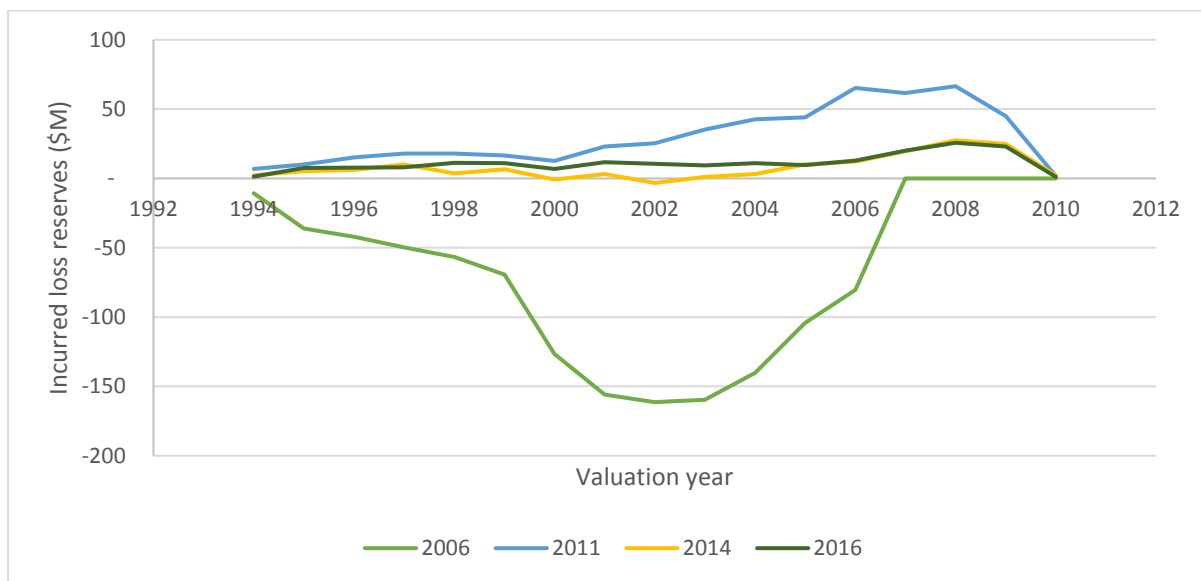


Figure 19 - Estimated Incurred Loss Reserves Results- Neural Networks

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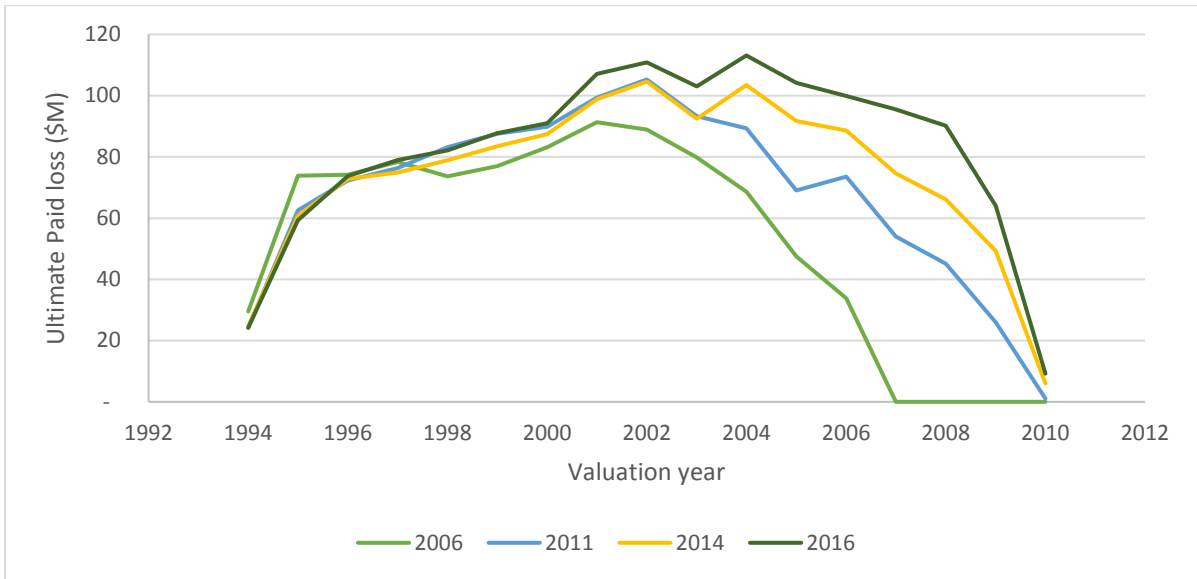


Figure 20 - Estimated Ultimate Paid Results- Neural Networks

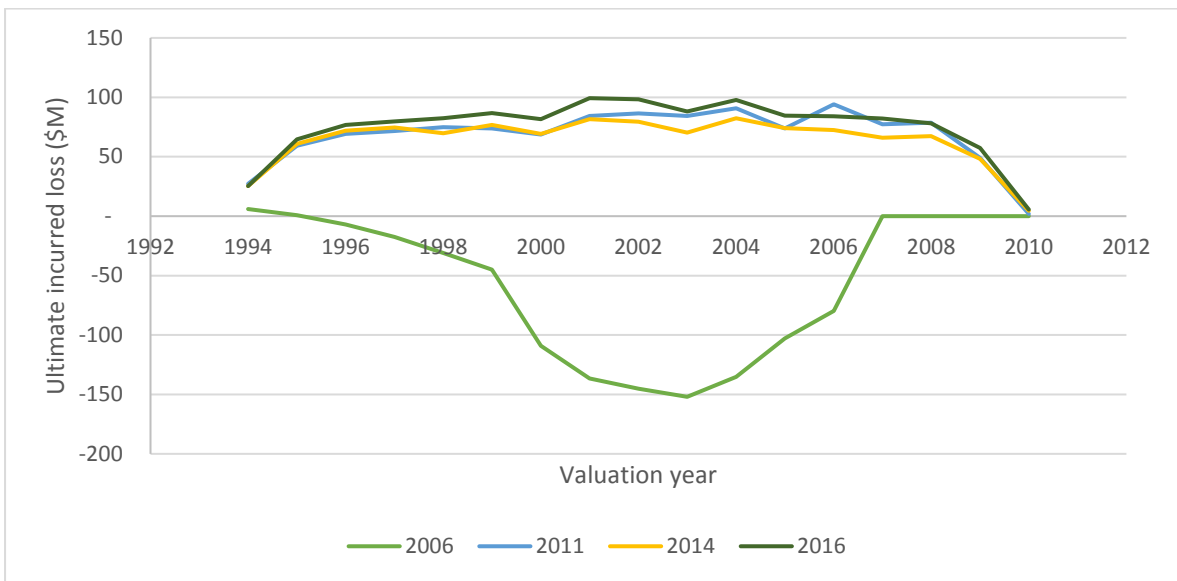


Figure 21 - Estimated Ultimate Incurred Results- Neural Networks

5.2.4. Gradient Boosting Machine (GBM)

Jerome Friedman applied the gradient boosting concept to decision trees in 2001 to create Gradient Boosting Machine (GBM) (Friedman J.H., 2001 ; James, Witten, Hastie & Tibshirani, 2017). It belongs to the ensemble methods with the principle that a group of “weak learners” can come together to form a “strong learner”. Each classifier/regressor individually, is a “weak learner,” while all the classifiers/regressors taken together are a “strong learner”.

5.2.4.1. Principle of Gradient Boosting Machine

i. From Boosting to Gradient Boosting Machine

Boosting uses bagging methodology (Bootstrap aggregation) as Random Forest applying decorrelated trees, except that the collection of trees is grown sequentially: each tree is grown using information from previously grown trees.

In practice this is carried out by building a single model from the training data, then adding new models on the errors made by existing models, in order to correct the predictions of the previous model. Models are sequentially added until no further improvements is observed (additive training).

In essence, at each step a weak learner is introduced to compensate the shortcomings of the existing weak learners. In general one observe that when the class of trees is used as base learner/model, the boosting approach learns slowly by fitting many small trees to the residuals. This is helpful since a smaller tree prevents on fit on pure noise, hence overfit.

The approach is called **gradient boosting** because it uses a gradient descent algorithm to minimize the loss function in the process adding new models fit of the residuals of the previous models.

ii. GBM algorithm

Formally, for a given training dataset, the algorithm works as follow:

1. Set an initial model $\hat{f}(x)$ with an offset value or $\hat{f}(x) = 0$ and compute residual r_i and the initial weights;
2. For $b = 1, 2, \dots, B$ iterations until the model converge (i.e. error under a predefined threshold) the gradient descent optimization is used to minimize the cost function. It consists of:
 - a. Calculate negative gradients;
 - b. Fit a regression tree \hat{f}^b to the negative gradients;

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- c. Get an estimate of the shrinkage parameter λ to reduce the cost function;
 - d. Update the model $\hat{f}(x)$ applying a shrinkage version of the new tree;
 - e. Update the residuals, weights applying a shrinkage version of the new tree;
3. Output the boosted model as a linear combination of the different trees:

$$\hat{f}(x) = \sum_{b=1}^B \lambda \hat{f}^b(x)$$

The R package used to fit the GBM is the *gbm* one.

iii. GBM parameters

Relevant parameters to tune:

- **Distribution**
Specify the name of the loss function to use.
 - For KCM model, we use a **Gaussian** distribution
 - For OPM model, we use a **Bernoulli** distribution
- **n.trees**
The total number of trees to fit. It's equivalent to the number of iterations. It is taken equal to 100;
- **interaction.depth**
The maximum nodes per tree (number of leaves). It's the depth of each tree. Equivalent at complexity of the tree. It is utilized to control over-fitting. It is taken equal to 1;
- **n.minobsinnode**
Minimum number of observations in tree terminal nodes. A really high value might lead to underfitting and a really low value might lead to overfitting. It is linked with interaction depth. It is taken equal to 10;
- **shrinkage**
It is the learning rate. A gradient descent step size. How quickly the algorithm adapts. It reduces the size of incremental steps and thus penalizes the importance of each consecutive iteration. It is taken equal to 0.1%.
- **bag.fraction**
It is the subsampling rate. The fraction of the training set observations randomly selected to propose the next tree in the expansion. It introduces the randomness into the model to fit. It is taken equal to 50%

A Cartesian Grid Search technique has been used to search the optimal parameters of the model. It defined a grid of parameters that will be tested using cross-validation. Each axis of the grid is an algorithm parameter, and points in the grid are specific combinations of parameters. It test all the possible combinations of the provided hyper-parameter values to find the model that best fit the data. This search has been performed both for the KCM and the OPM model.

5.2.4.2. Results and discussion

We present hereafter the results of the Gradient Boosting Machine model described above.

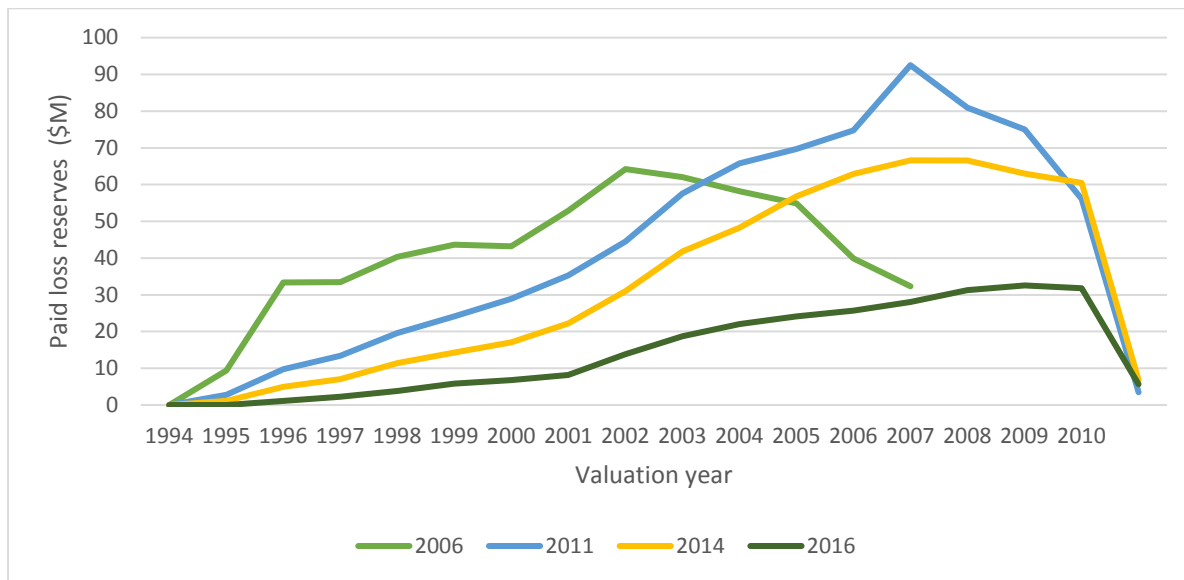


Figure 22 Estimated Paid Loss Reserves Results – Gradient Boosting Machine (GBM)

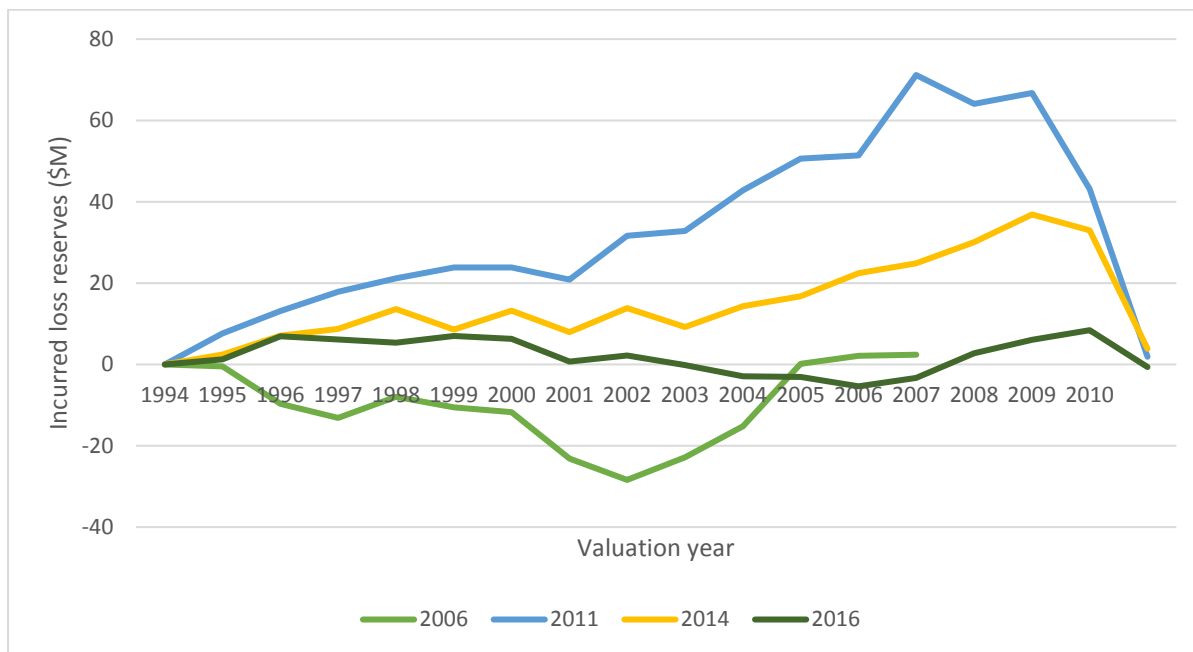


Figure 23 Estimated Incurred Loss Reserves Results – Gradient Boosting Machine (GBM)

Gradient Boosting Machine model shows a stable trend on paid values. Regarding incurred losses, the model shows a volatility trend at 2006 and 2016 evaluation years. An explanation

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may be, at these evaluation years, incremental incurred are less consistent in amount (cumulative amounts of incurred for 2006 and 2016 evaluation years are lower than those for 2011 and 2014 evaluation years).

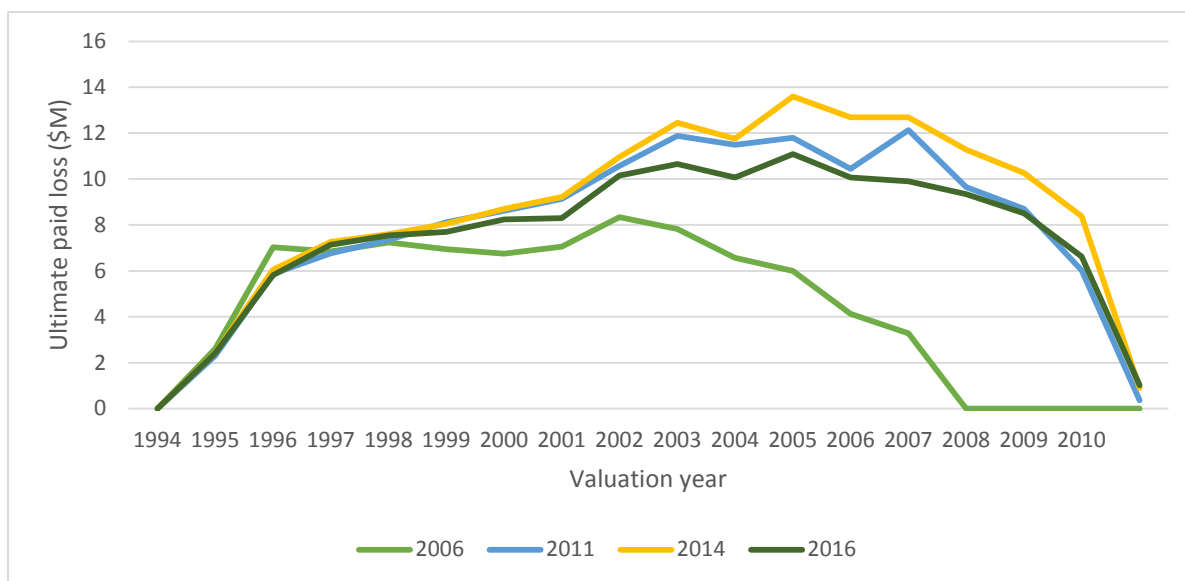


Figure 24 - Estimated Ultimate Paid Results – Gradient Boosting Machine (GBM)

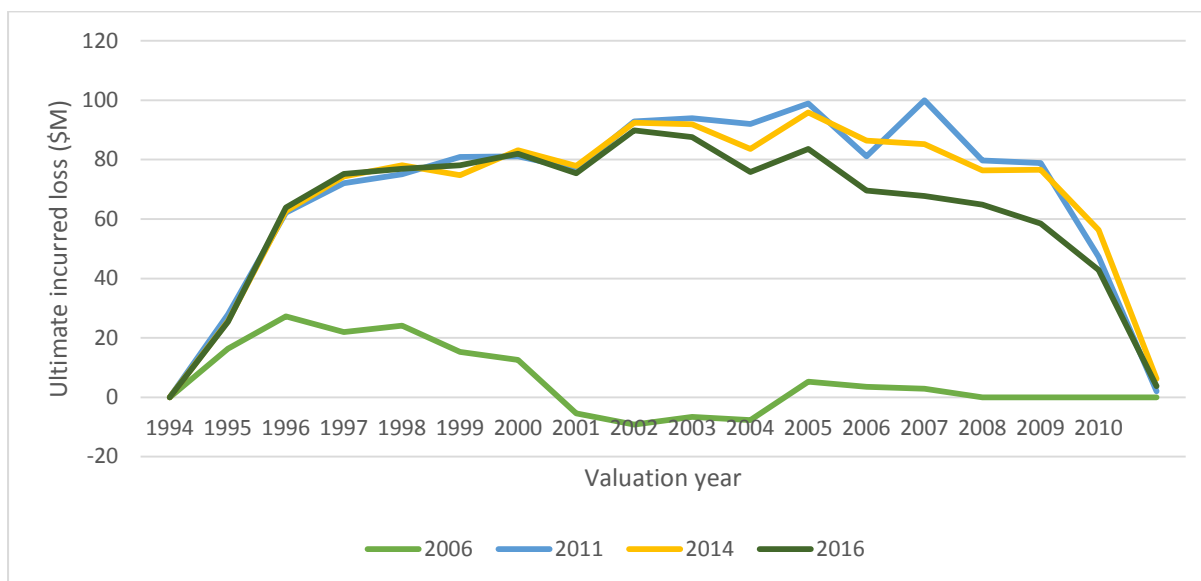


Figure 25 - Estimated Ultimate Incurred Results – Gradient Boosting Machine (GBM)

Ultimate claim costs shows a trend without volatility, both on paid and incurred, with the exception of 2006 evaluation year for incurred.

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5.2.5. Gradient Boosting Machine (GBM) Combined

An alternate approach for estimating IBNER is to directly model $E \left[X_{i,j|k}^{(\psi)} \mid Ft \right]$ without separating KCM and OPM components (See Section 5.2.1 for annotation details), referred as “combined model”.

In such a case, all claim transactions (open and closed) were included in the modelling dataset. Gradient Boosting Machine (GBM) was used as the modelling approach. The detailed technical specification was described in Section 5.2.4.

Similar to KCM/OPM modelling approach, the combined model was also organized in 7 steps (See Section 5.2.1 for details). Ultimate losses and predicted paid/incurred losses were also calculated at these calendar dates: 2006, 2011, 2014 and 2016 to have a comparison with traditional method.

“Combined model” is a simplified approach with no need to build two separate models and also to have a composite scoring. At the same time, one of the major drawbacks with this method was that, given the nature of insurance data, majority of the data points were closed transaction with no payment. Such a skewed distribution made the model assumption most likely invalid. This contributed to a more volatile reserve estimates as compared to other Machine Learning methods. (Appendix 9.4.2.5. Gradient Boosting Machine (GBM) combined and the graph below)

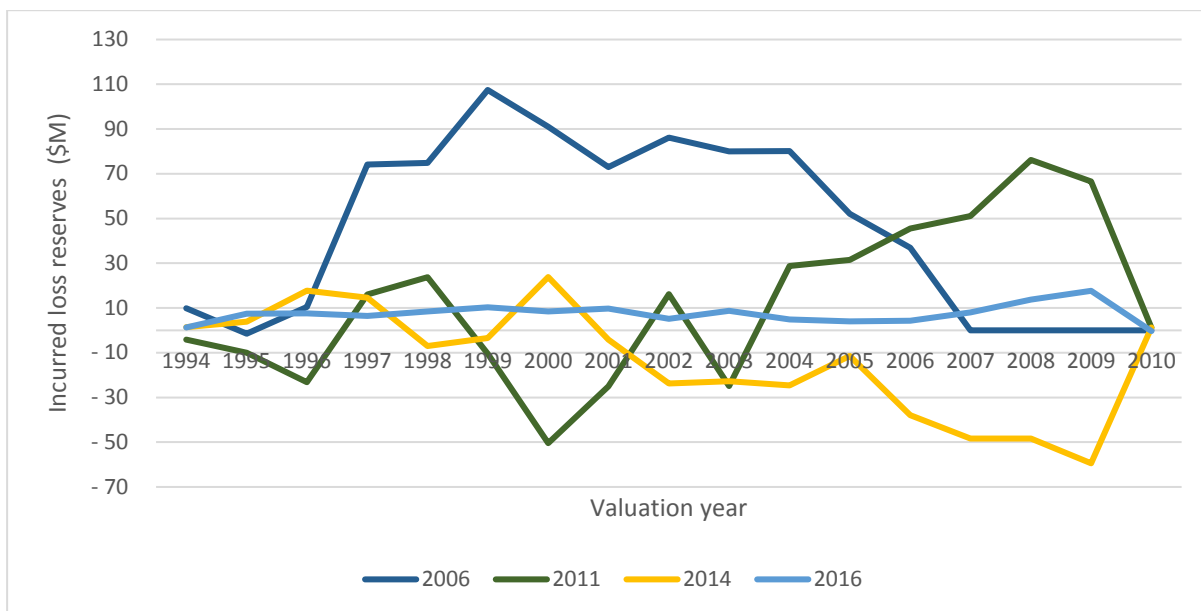


Figure 26 - Estimated Incurred Loss Reserves Results

5.2.6. Boosted Tweedie Compound Poisson Model (TDboost)

The idea of the TDBoost algorithm (Yang, Qian & Zou, 2016) is to integrate the Tweedie model into the tree-based Gradient Boosting Machine (GBM) algorithm in order to predict claim size. In other words: it allows the target variable to be fitted with a Gamma distribution which is a widely used distribution in the insurance market given that data tend to be highly skewed.

Moreover, TDboost looks to overcome limitation of a linear form in the Tweedie GLM used to predict insurance premiums.

5.2.6.1. Principle of TDBoost

The Tweedie distribution assumes the following relation between mean and variance of a variable of interest:

$$\text{Var}(Y_i^*) = \phi[E(Y_i^*)]^p, \quad Y_i \sim Tw(\mu_i, \phi/w_i, p)$$

where ϕ is a constant and Y_i is the pure premium and p is the exponent.

This distribution is a generalization of all the most known and used distributions, indeed for different values of p we obtain:

- Normal distribution if $p = 0$;
- Poisson distribution if $p = 1$;
- Gamma distribution if $p = 2$;
- Compound Poisson-Gamma distribution if $1 < p < 2$.

All the parameters to tune are the same as of those of the Gradient Boosting Machine Model (see Section 5.2.4.1), with the exception of the distribution:

- For KCM model, we use a **Gamma** distribution (instead of Gaussian in GBM)
- For OPM model, we use a **Poisson** distribution (instead of a Bernoulli in GBM).

As for the Gradient Boosting Machine model, the TDboost model uses the Cartesian Grid Search technique to search the optimal set of parameters, both for KCM model and OPM model.

5.2.6.2. Results and discussion

We present hereafter the results of the TDBoost model described above.

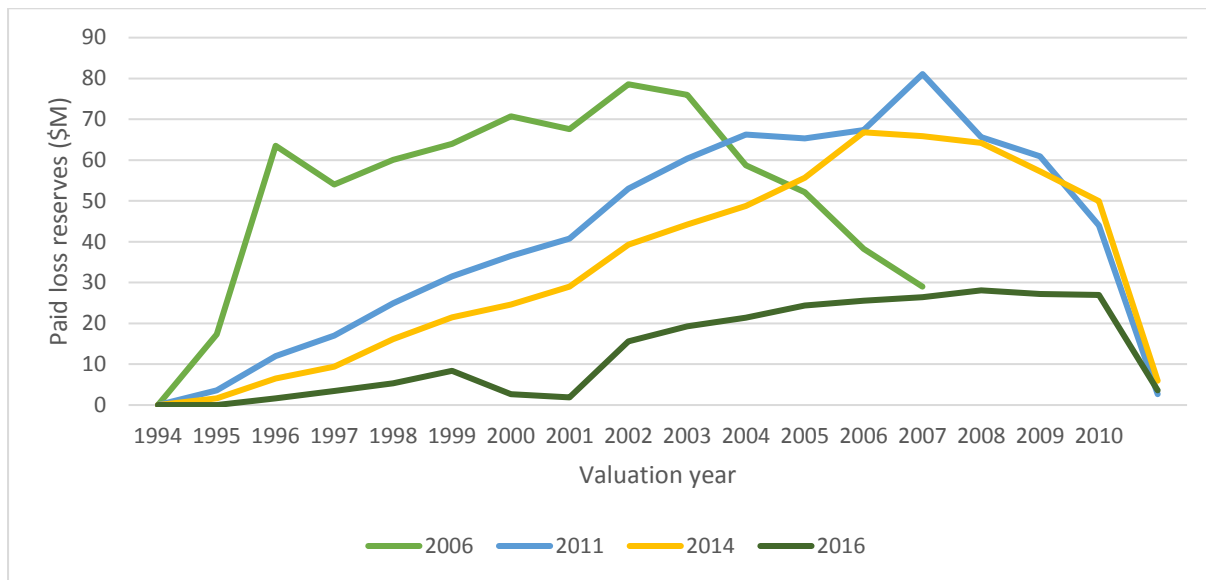


Figure 27 - Estimated Paid Loss Reserves Results- TDBoost

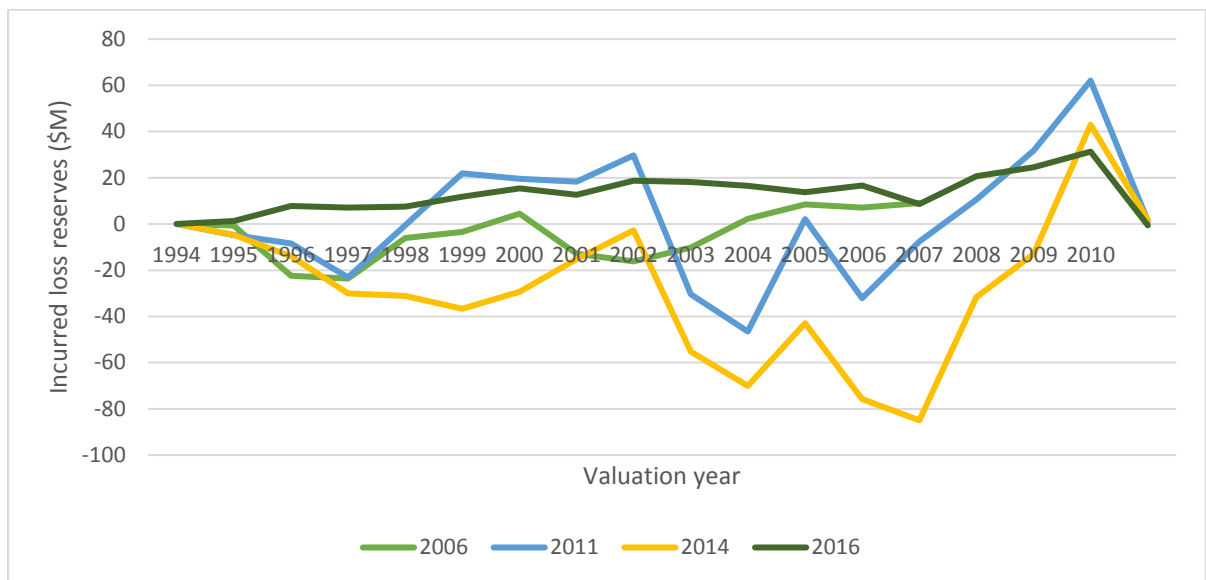


Figure 28 - Estimated Incurred Loss Reserves Results- TDBoost

The predicted values on paid shows coherent positive trends. Regarding the results on incurred, the model assumes a quite volatile trend at each evaluation year, with the exception of 2016. This can be explained by the fact that incurred are generally better adjusted with a lognormal distribution than with a Gamma distribution.

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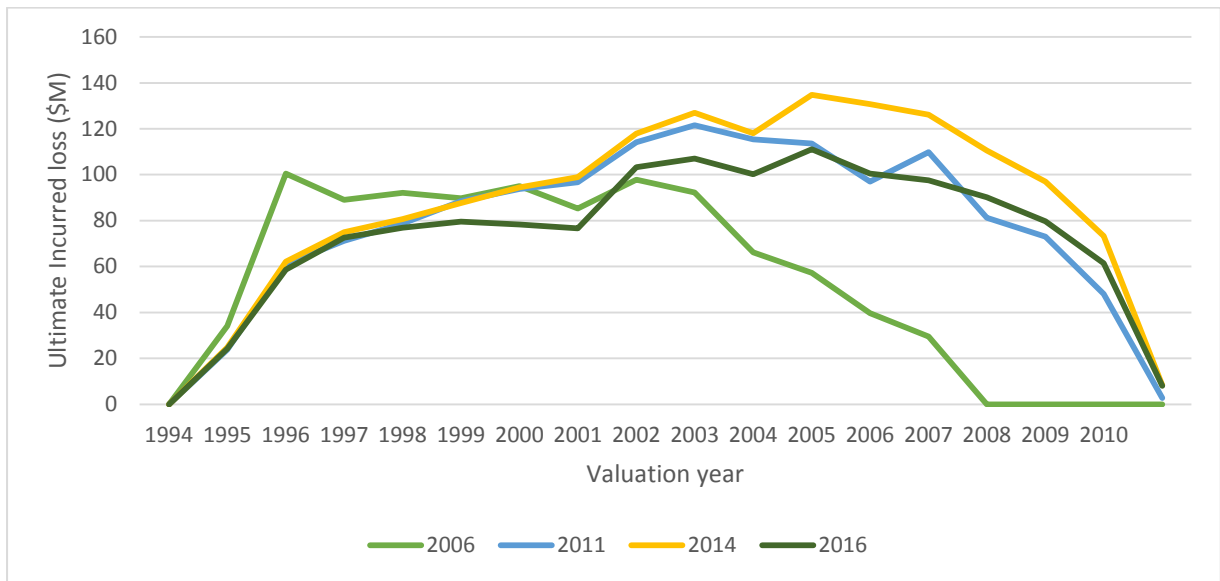


Figure 29 Estimated Ultimate Incurred Results - TDBoost

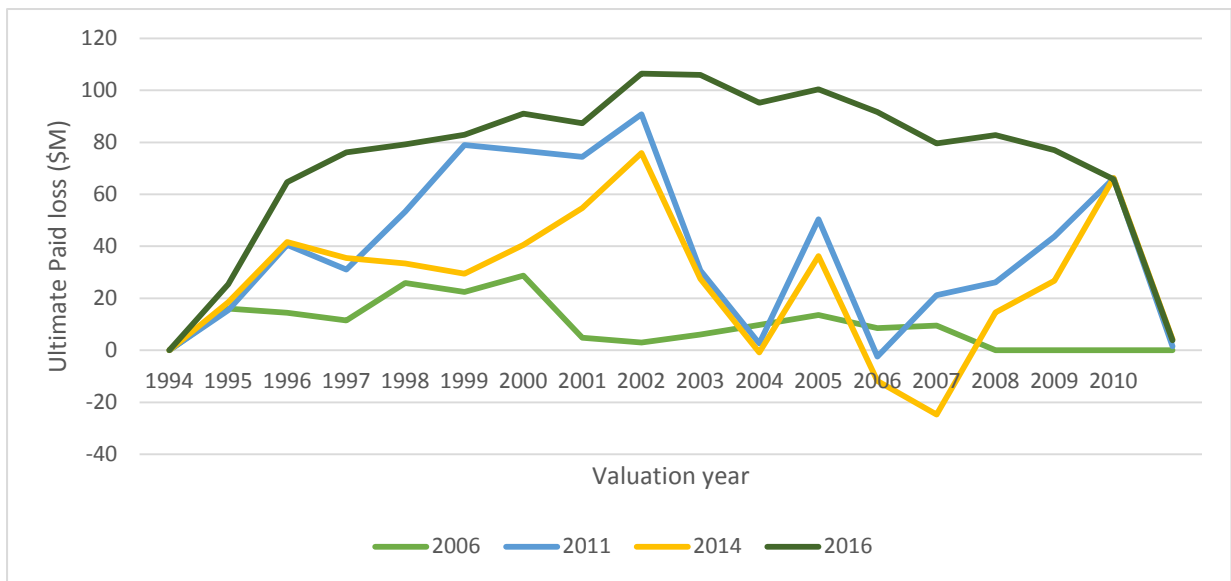


Figure 29 Estimated Ultimate Paid Results - TDBoost

Regarding the assessment of ultimate paid, the model shows a stable trend while a significant volatility is observed on ultimate incurred, with the exception of 2016 evaluation year. It might be due to loss of importance over time.

5.2.7. Pure IBNR Estimation

Pure IBNR was estimated adapting a frequency and severity approach at an aggregated level.

5.2.7.1. Pure IBNR Frequency Estimation

For Pure IBNR Frequency, newly reported claims ($C_{i,j}$: incremental reported claims during the period, i : accident year, j : development period) were estimated at each of the future development period j ($j > J_i$). (J_i : the development period for accident year i at current evaluation.)

Incremental reported ratios Irr_j for a specific development period j for all accident years were derived by comparing the incremental report claims in development period j to the cumulated reported claims prior to j : $Irr_j = C_j / \sum_{j=1}^{j-1} C_j$. This ratio was then applied to the cumulated reported claims at current evaluation to derive incremental newly reported claims for future periods:

For accident year i :

$$\hat{C}_{i,j} = \begin{cases} Irr_j \times \sum_{j=1}^{J_i} C_j, & j = J_i + 1 \\ Irr_j \times \left(\sum_{j=1}^{J_i} C_j + \hat{C}_{i,J_i+1} \right), & j = J_i + 2 \\ \dots \\ Irr_j \times \left(\sum_{j=1}^{J_i} C_j + \sum_{j=J_i+1}^{J_i+n} \hat{C}_{i,j} \right), & j = J_i + n \end{cases}$$

5.2.7.2. Pure IBNR Severity Estimation

For Pure IBNR severity, the ultimate severity for newly reported claims was estimated based on the period when the claims were first reported. All closed claims in the dataset were grouped by their report period k and the average severity for report period k (\hat{S}_k) was derived by averaging the ultimate loss amounts (cumulated incurred loss).

5.2.7.3. Pure IBNR Estimation

Pure IBNR $R_{i,j}$ for claims newly reported in accident year i and development period j was estimated by combining the frequency and severity estimation:

$$R_{i,j} = \hat{C}_{i,j} * \hat{S}_j$$

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5.2.7.4. Pure IBNR allocation

To allocate Pure IBNR into incremental development periods, paid pattern was derived from closed claims and applied for allocation. p_1, p_2, \dots, p_j represent the percentage of paid amount in each of the development period.

Pure IBNR $R_{i,j}$ was then allocated in each of the future development periods.

For accident year i :

- allocated Pure IBNR for development period j : $R_{i,j} * p_1$
- allocated Pure IBNR for development period $j + 1$: $R_{i,j} * p_2$
- ...
- allocated Pure IBNR for development period $j + n$: $R_{i,j} * p_{n+1}$

5.2.7.5. Results and discussion

We present hereafter the results of the Pure IBNR model described above.

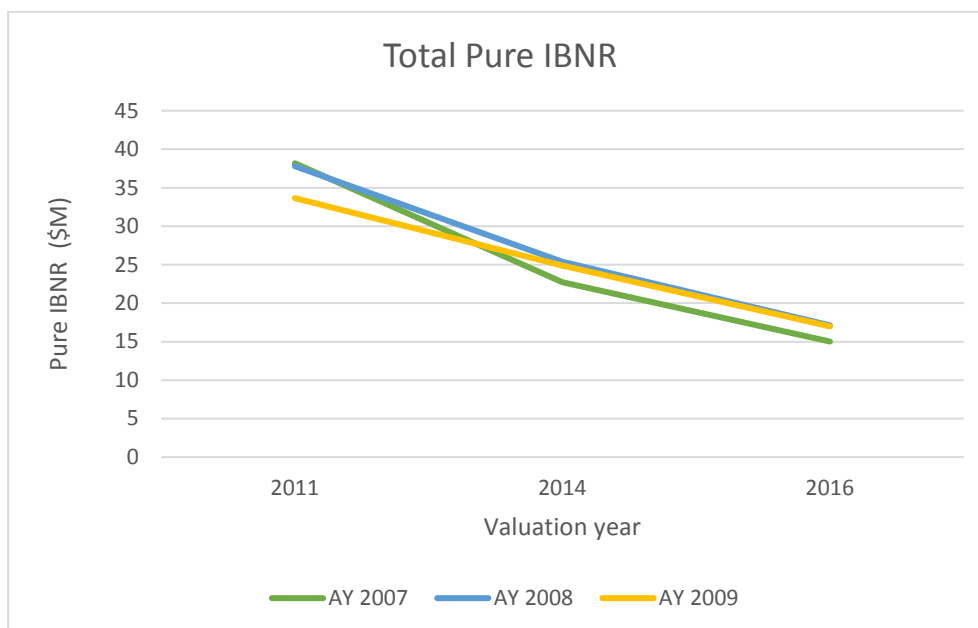


Figure 30 Total Pure IBNR on Paid

As shown in the above graph, total Pure IBNR for each accident year had a decreasing pattern along different evaluation period. It is the highest at 2011 evaluation, and the lowest at 2016 evaluation. This matches our expectation, as there should be less Pure IBNR claims at later evaluation time for a given accident year.

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To measure the stability of Pure IBNR estimation, the average Pure IBNR amounts by development years were plotted for different evaluation periods. The same accident years across evaluation periods were included in the calculation. As an example, for development year 9, the average Pure IBNR was calculated for accident years 2009 & 2010, as these were the accident years where Pure IBNR estimation were available for all three evaluation periods. (See [Appendix 9.4.2.7. Pure IBNR](#) for triangle details)

The Pure IBNR estimation was relatively stable at three evaluation periods for different development years, except development year 15. Both 2011 and 2014 evaluations had a higher Pure IBNR estimation as compared to 2016 evaluation.

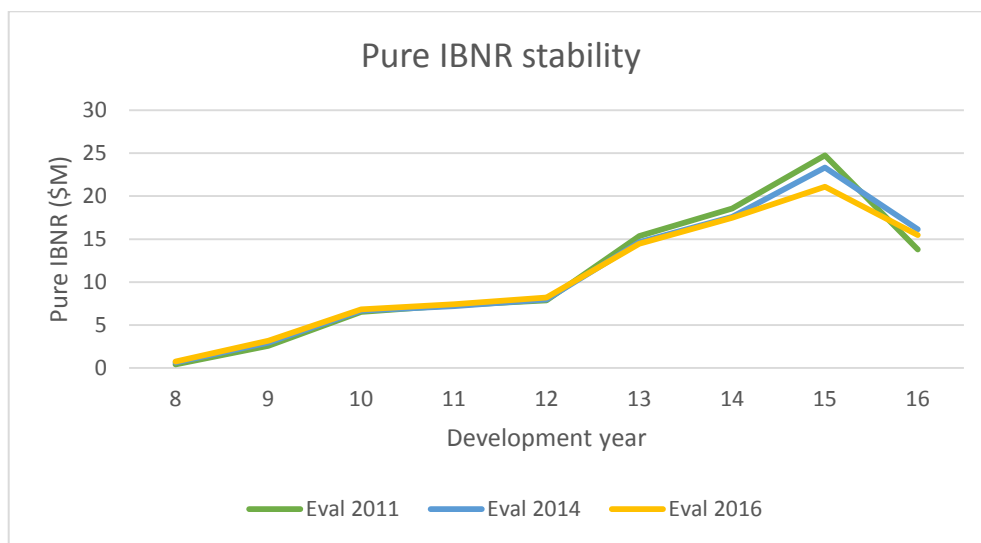


Figure 31 Pure IBNR stability on Paid

Currently, the Pure IBNR was estimated at an aggregated level, only considering the report period as the determination factor for claim frequency and severity. One of the potential further improvements is to include additional claim/policy level characteristics as modelling features to improve the accuracy and stability of the estimation.

6. Comparison and evaluation of models

The main challenge in the evaluation of different methods is that reserving is a **forecasting problem**. In contrast, most of classical statistical literature is concerned with in-sample estimation problems. In particular methods like regression or Machine Learning are often evaluated via in-sample techniques (e.g. R^2 , cross-validation/ randomized test and training set). Those evaluation techniques are not suitable for forecasting evaluations.

In forecasting one distinguishes between distributional forecasts, i.e., the output of a method is the distribution of the future target, or point forecasts, i.e., a specific value is the forecasted. In a full stochastic model the latter is usually derived as functional of the former, for instance the mean or median functional. Machine Learning algorithms are not based on an underlying stochastic model, hence those point forecasts are not functionals of a distribution forecast. Some papers dig deeper into the area of evaluation of point forecasts. For instance, Gneiting (Gneiting, 2011) discusses a few examples that can (and went) wrong in practice. The main point is that one can use different functionals (e.g. mean or median) which are optimal for different performance evaluations (scoring rules). In other words the forecaster should know in advance how he will be evaluated so he can fine-tune his forecast accordingly. Further, a scoring rule only makes sense (is *proper*) if we can expect that forecasting according to the true (in practice unknown) distribution will give a higher score/better forecast evaluation.

6.1. General strategy

The general strategy for evaluation will be a back testing approach. This means that all methods will be trained on a data set which has been historically available for a given cut-off time. Forecasts can then be compared with actual realizations.

For the evaluation of the models, we used a back-testing strategy with data split according to Strategy B described in Section 4.2.2.2. As cut-off dates, we chose the years 2006, 2011, 2014, 2016.

We further chose three different metrics for the evaluation: individual cell errors, yearly cash flow and total outstanding. More details in the sections below.

A few words about why we chose cut-off dates as validation method. Generally, if errors (residuals) are *iid*, then any sensible validation method will work well. The problem arises when this is not the case. The hope for Machine Learning methods is that they can capture features in the data which traditional methods cannot account for. If these features are really present, then the errors traditional methods produces will not be *iid* and one needs to be careful when comparing the performance via reshuffling techniques. Cut-off dates/ back-testing is a good choice because it resembles the way the data is actually used to predict future claims.

6.2. Yearly Cash Flows

Assume that the cut-off date is 2006. In this case we evaluated the forecasts for payments in the years 2007-2020 for claims with accident date 2006 and prior.

This is done by summing up the future diagonals in the corresponding run-off triangle. In the figure below, a first comparison is done in a descriptive manner where the results can be compared to actual observed payments in the period 2007-2016.

An analogue summary is given for the cut-off dates 2011, 2014, 2016 where forecast are available 15 years ahead compared to actual observations until 2016 in each case.

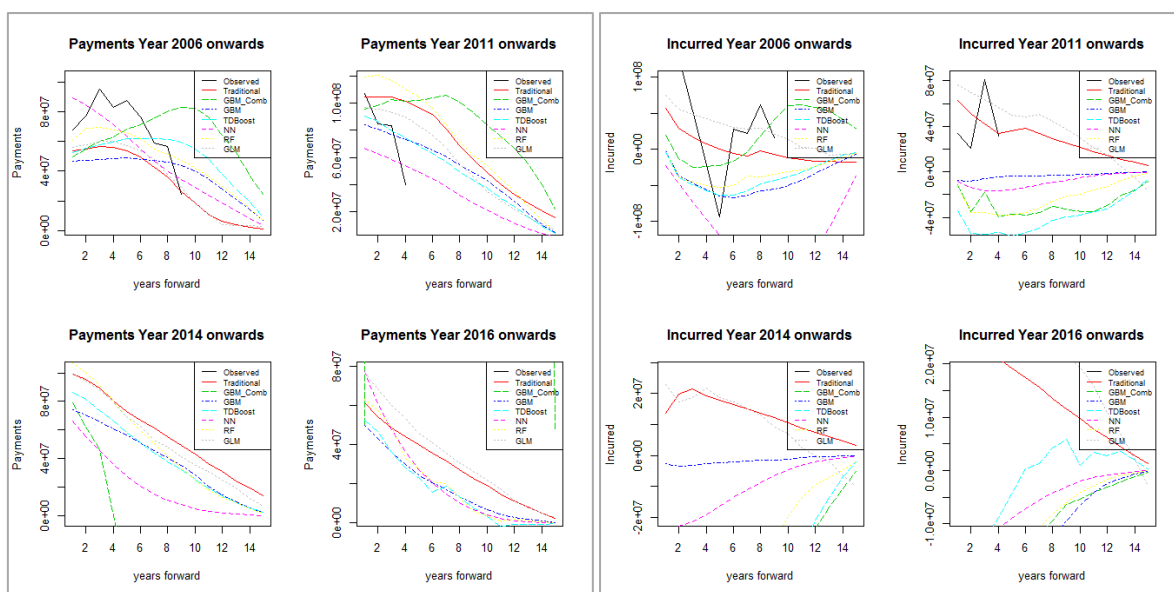


Figure 32 - Yearly cash flow evaluation by development year on

Afterwards, we summarized the results with a root mean squared error criterion:

$$RMSE_m = \sqrt{\sum_{j=m+1}^{2016} (\hat{R}_j^{m*} - R_j^m)^2}$$

where $m \in \{2006, 2011, 2014\}$ and R_j^{m*} are the aggregated payments for calendar year j for claims with accident date m and earlier. This gave the results in Figure 33.

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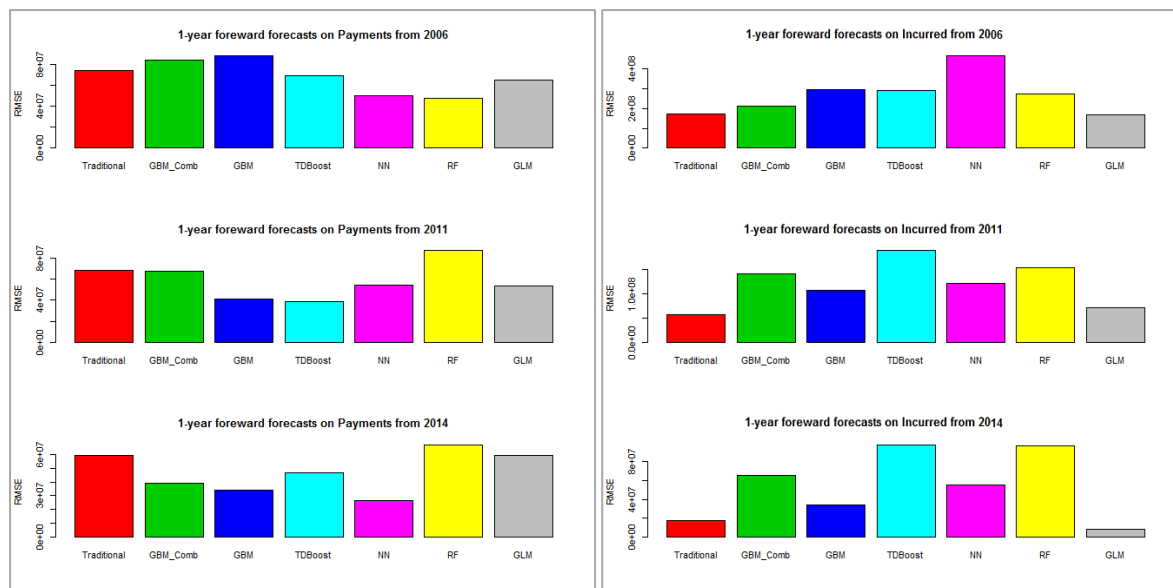


Figure 33 - RMSE on one-year forward forecast for each cut-off date full triangle

The most important RMSE for paid is given by Gradient Boosting Machine and Random forests. For incurred, the highest error is given by neural networks and TDBost model.

One should emphasize that while neural networks outperform for incurred, they provide one of the lowest errors for paid.

Moreover, traditional methods are not always the methods of the lowest errors: they provide one of the most important RMSE on paid but perform well on incurred.

6.3. Total Outstanding

In this approach we compared the total outstanding forecast for the different methods. This is done by summing up all future payments with accident date before cut-off date and calendar date equal or earlier than 2016. The latter constraint is dropped for 'Total outstanding from 2016'.

Generally, a method which performed well in Section 6.2, e.g. TDBost, will not necessarily also do as good for total outstanding. The reason is that when the total outstanding is evaluated, the forecasts are summarized into a single number. Hence, less biased estimates with the cost of extra variance for the individual claim forecasts will be rewarded. Indeed the most volatile, the Gradient Boosting Machine combined model, performed very competitive for the total outstanding.

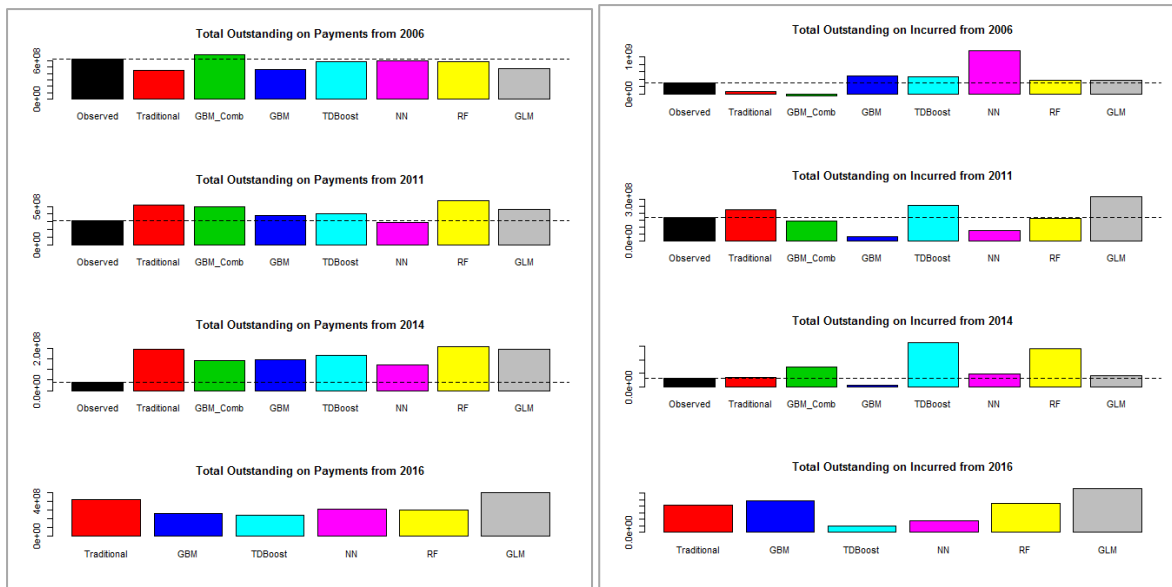


Figure 34 - Total outstanding by model for each cut-off date full triangle on Paid & Incurred

6.4. Individual Cell Errors

In this approach we compared how good the different methods were able to predict the individual cells in the run-off triangle. Generally, individual cells are not very informative. However this metric can be used to get a better understanding of bias and variance produced by the different methods. Below, we find the cell errors produced via:

$$cell\ error = estimated - observed.$$

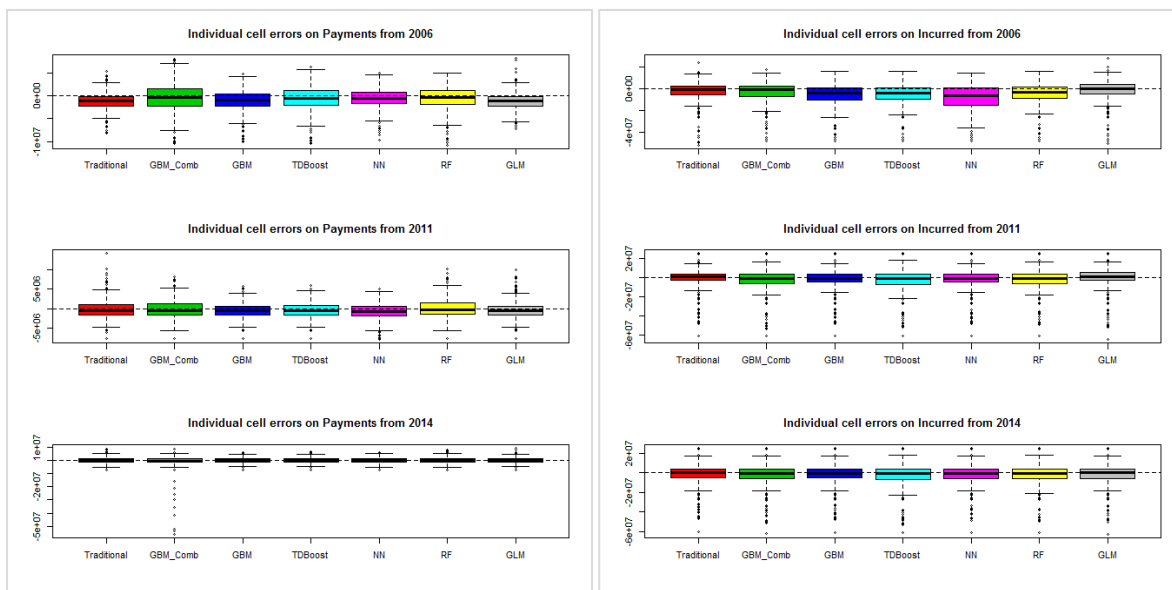


Figure 35 - Individual Cell errors by model for each cut-off date full triangle on Paid & Incurred

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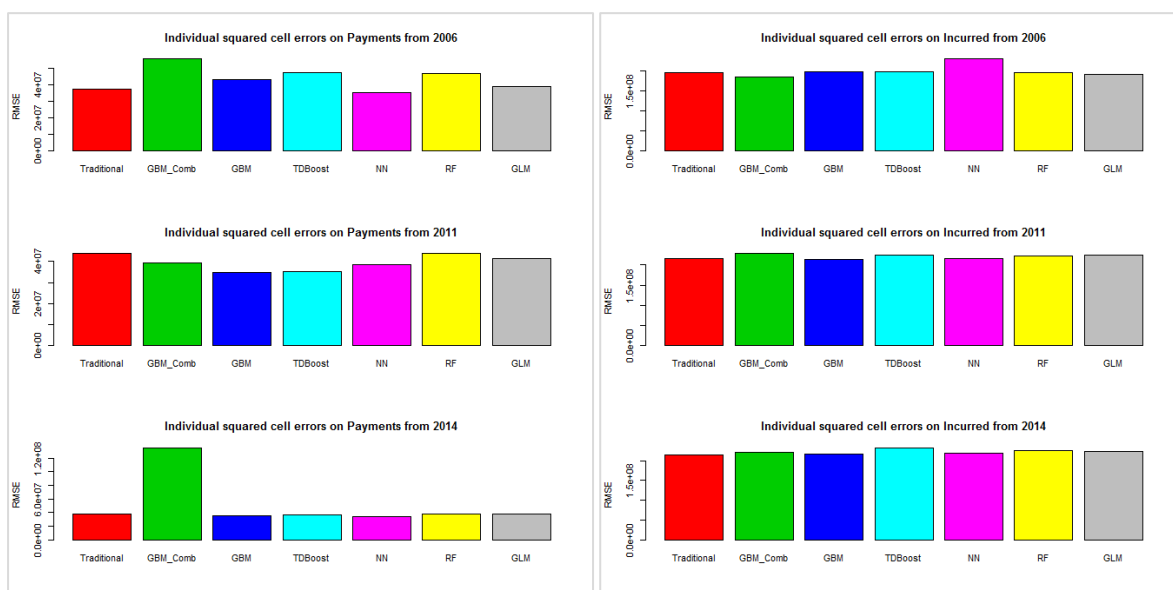


Figure 36 - Individual squared cell-error by cutt-off date full triangle on Paid & Incurred

Regarding paid loss reserves, while all methods are comparable, in 2006, Gradient Boosting Machine combined model, has been fitted with a higher variance than the other methods. This lead Gradient Boosting Machine combined model having the best performance in 2006 for total outstanding, see Section 6.3, but had a poorer performance in 2006 for the cash flows, see Section 6.2. This result indicates that different hyper parameter tunings for different purposes (cash flow prediction or prediction of total outstanding) can be beneficial.

7. Conclusion

7.1. Step back on the study

Along this study, we applied different approaches to estimate claims reserves.

The traditional methods, when applied, involved both judgement expert when choosing development factors and extrapolation rules to estimate the ultimate.

In the same time, Machine Learning required a deep understanding of the underlying techniques, which meant in particular understanding how to link the hyper parameters and parameters to the analysis of the projection of claims.

When comparing the different models, it was difficult to delicate to select an obvious winner. In Section 6, we proposed various ways to compare the models according to the RMSE or to the accuracy in assessing total outstandings. However, on [Table 9](#), GBM combined, TDBoost and Random forests have led to the least satisfactory results while Neural Networks performed well in various cases, especially on paid datasets. On incurred datasets, GBM was the model with the best performance.

		Individual squared errors			1 year forward			Total outstandings		
		2006	2011	2014	2006	2011	2014	2006	2011	2014
Paid	Best model	NN	GBM	NN	RF	TD Boost	NN	NN	NN	NN
	Worst model	GBM Combined	chain ladder	GBM Combined	GBM	RF	RF	GBM Combined	RF	RF
Incurred	Best model	GLM	GBM	NN	GLM	chain ladder	GLM	GBM Combined	GBM	GBM
	Worst model	NN	GBM Combined	TDBoost	NN	TDBoost	TDBoost	NN	GLM	TDBoost

Table 9 - Synthesis of best and worst models in terms of accuracy of predictions

With regard to traditional methods, one should emphasize that even if they do not appear to be the most accurate, these methods are rarely part of the “worst” models. Indeed, they lead to stable results. Thus, the results they provide are less likely to be extremely accurate at the time of evaluation before becoming obsolete a few years after, at isoperimeter. On the other hand, chain ladder and GLM led to particularly close results even if they were based on different techniques and extrapolation rules. This can be explained by their focus on the “big picture”: these methods were applied to aggregate data without considering variables other than transaction information. Therefore, they have not been influenced by specific claims (the specificity here being related to the features of the claims other than transaction information) for the forecasting step.

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Finally, regarding the study, different graphs are produced to compare the ultimate (paid and incurred) along development years and by cut-off date. Hereafter, we present examples of ultimate paid/incurred and related loss reserves estimated on 2014. Other graphs are presented on [Appendix 9.3.2. Ultimates](#) and [Appendix 9.3.1. Loss Reserves](#).

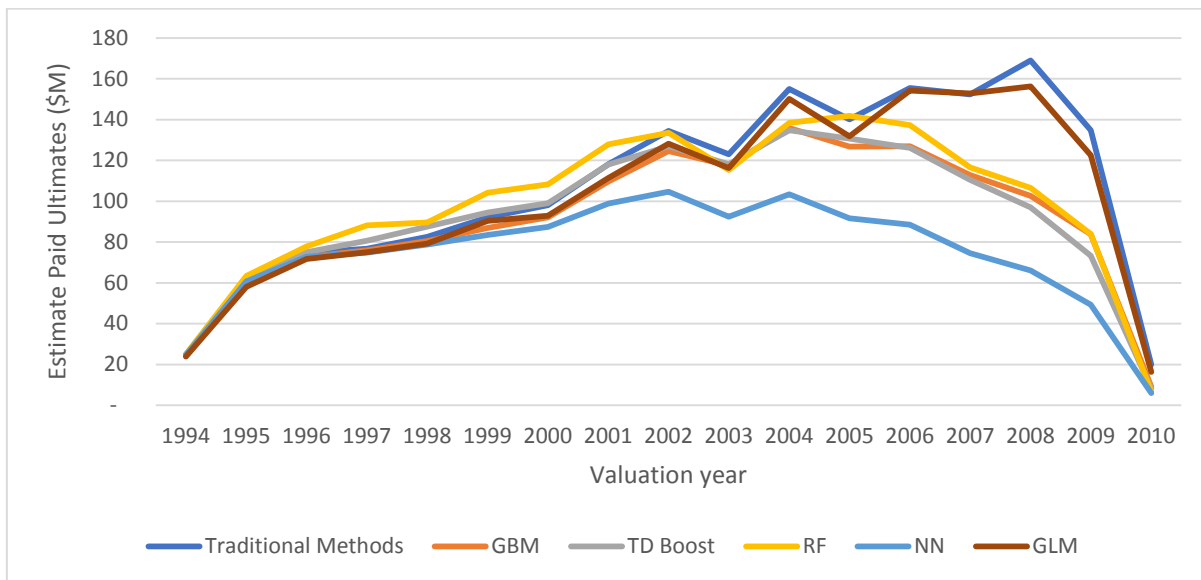


Figure 37 - 2014 Ultimate Paid - Comparison of models

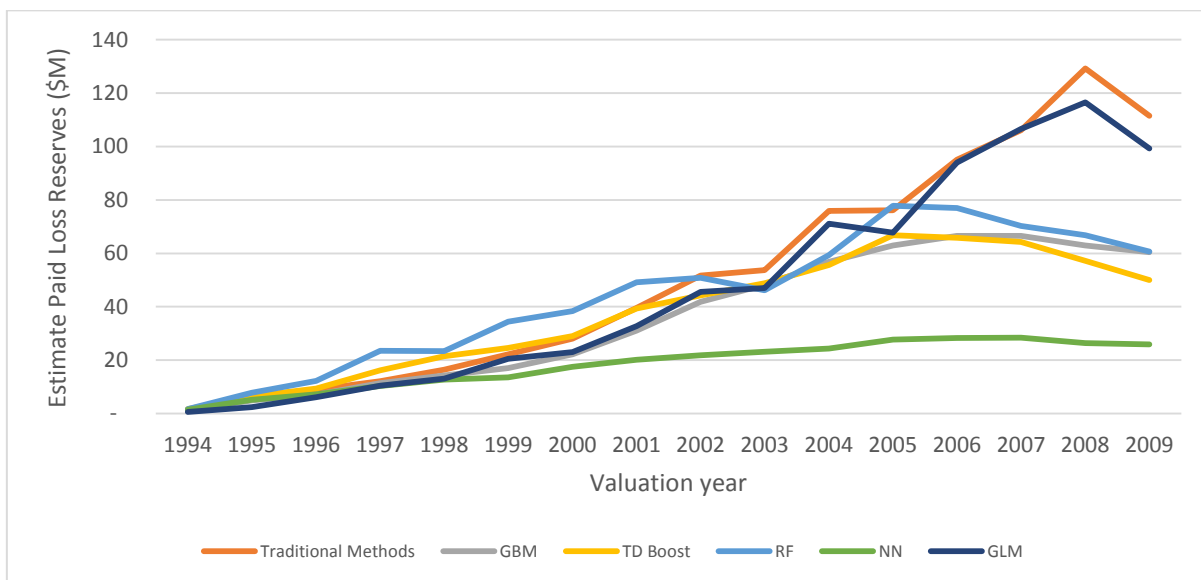


Figure 38 - 2014 Loss Reserves Paid - Comparison of models

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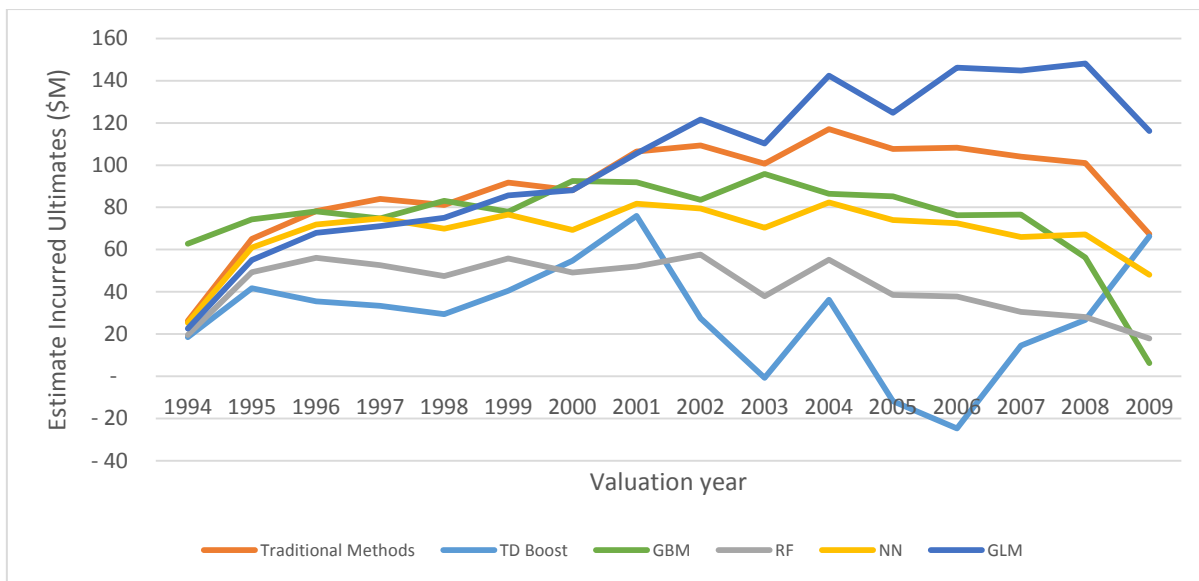


Figure 39 - 2014 Ultimate Incurred - Comparison of models

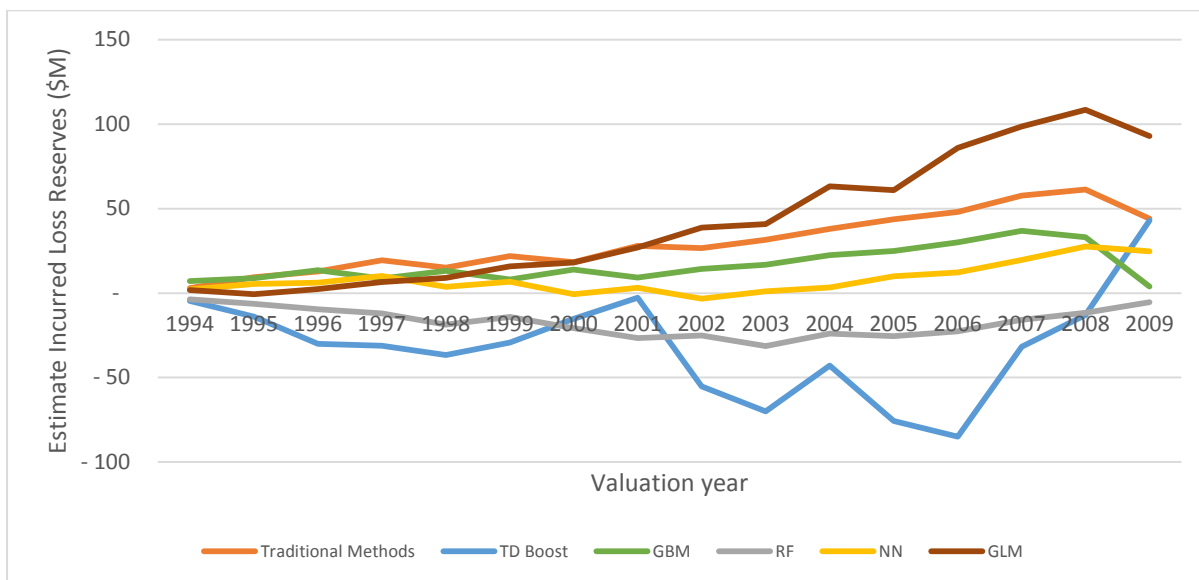


Figure 40 - 2014 Loss Reserves Incurred - Comparison of models

As underlined in the report (see Section 5.2.5), GBM combined models proved to be inappropriate to fit the data (skewed distribution of claims closed with no payment). However and despite the lack of accuracy, only predictions provided by this model on paid on 2014 (see [Figure 56](#) in [Appendix 9.3.2.1 Paid.](#)) showed a particular pattern in comparison of the one of the other methods.

Also, even if they showed a good fit to the data, neural networks present a weird development pattern on [2006 Ultimate Incurred](#) (See [Figure 46](#) in [Appendix 9.3.2.2. Incurred](#)) which can be due to volatile data on Incurred at this valuation time.

7.2. Synergy between Machine Learning and traditional methods

Our research has shown that the Machine Learning approach presented here is not superior to traditional methods in forecasting ultimate loss amounts. However, research is still in the early stages in this area and further research will continue to improve upon the quality of Machine Learning models in loss reserving.

Traditional methods have been around for decades (a century or more in the case of chain-ladder) and they're not going away any time soon. Unfortunately, chain-ladder does a poor job of explaining loss movements. However, if we have a Machine Learning model this can be very helpful in explaining drivers of reserve movements. They can also be helpful for other tasks such as allocation of IBNR.

Thus, it is not a question of replacing the aggregated methods, which have the consequent advantages of being very robust and simple to implement, but rather of providing additional information thanks to the individual models.

This information could be used in many ways by the insurer, whether for to detect possible problems in the management of claims or to refine the forecast of its technical provisions on certain perimeters.

About Machine Learning's ability to reveal more about claim mechanisms than LDF-based aggregate methods, and the capacity of the former to supplement traditional methods:

- One should emphasize the desirability of avoiding arrogance by claiming that Machine Learning should necessarily supersede traditional methods. So care is required in expression of conclusions when comparing traditional methods and Machine Learning techniques.
- On the other hand, we should give the chain ladder a free pass. Sometimes it works well, and on other occasions very badly. It assumes implicitly a specific multiplicative parametric structure for cell means, well documented in the literature, and failures occur when data are inconsistent with this assumed structure.

As an example, this occurs when rates of claim settlement are changing. These are precisely the circumstances Machine Learning is likely to incorporate allowance for the trending data and out-perform traditional methods and in particular chain ladder.

Suggesting that Machine Learning should merely supplement, rather than supplant traditional methods in some cases, is not a recent discussion. Similar ones took place 30-40 years ago, along perfectly parallel lines. At that time the contest was between insurer's physical estimates (or case estimates, or manual estimates) and actuarial estimates (now 'traditional methods'). Some actuaries rather timidly suggested that the actuarial estimates provided no more than some kind of check on the physical estimates. It is delicate to argue that case now.

The interest aroused by these methods is not that of a fashion effect. They respond to concrete insurance issues, particularly in non-proportional reinsurance and in financial communication. For example, traditional reserving methods require to apply excess loss treaties (XS) to aggregate data. Priority overruns would be best captured by individual approaches –allowed by Machine Learning techniques. That would determine the appropriateness aspect of an XS treaty given the risk profiles of a portfolio. As for the financial and accounting communication requirements, a more granular vision would make it possible to identify the profitable/expensive contracts and to better adjust the underwriting strategies accordingly.

Moreover, the implementation and operational handling of these models still raises questions. Upstream of their use, they require data extractions on deep histories. In addition to the issue of data storage, setting these models requires an investment of time and resources over periods when research and development will not yield immediate, lucrative results. Moreover, in view of the high decision-making potential of these models, their interpretation must be made more accessible to the operational and executive bodies of companies. Once mastered, these models present a considerable possibility of automation and strategic introspection: on the aggregation parameters of the Asset and Liability Models (ALM) models, the risk profiles of the policyholders/claimants, ... Since they exploit data from different stakeholders (commercial, inventory, legal, technical, ...), they invite to lead prospective reflections on transversal strategies. Thus, a communicating vase would naturally be constituted between pricing, reserving and risk management by the use of common data made reliable upstream.

Despite their disadvantages, individual methods generally produce better results than aggregate methods. Some studies (Huang, 2015) demonstrated that individual reserving methods have better accuracy, in the sense that they reduce more the mean squared error and provide lower bias and variance than traditional methods.

To date, 2 major issues impede insurers in their use: the poverty of graphical outputs and the slowness of the simulations. Collaboration with data scientists and involvement in these models development could on the one hand remedy progressively the first two aspects and, on the other hand, prepare to face future stakes linked to the exponential growth of data sources. Moreover, error metrics and data visualization techniques offer an increasingly rich range of solutions for interpreting and understanding the theories underlying these models, making the hermetic reputation of these models more and more obsolete.

We must pursue this type of study with precaution, and by taking a step back to understand their limits regarding reality and incorporate all elements (regulations and new society needs among others).

7.3. Advantages and drawbacks of traditional methods and Machine Learning techniques

In this section, we list the advantages and drawbacks for traditional methods and Machine Learning techniques:

	Advantages	Drawbacks
Machine Learning	<ul style="list-style-type: none"> - Some Machine Learning algorithms such as trees models (decision trees, random forests, etc.), are easy to explain to unfamiliar users of those techniques. Decision trees, in particular, offer graphical outputs that help to see how individuals are associated to the nodes of the tree and thus facilitate the interpretation of their results. - Are able to capture high non-linearity and complex relationships between variables - Do not requires to separate large and attritional claims - Do not need to have assumption for extrapolation/tail factor - Have an intrinsic ability to minimize the variance of the model - Neural networks are able to approach, under some conditions, any continuous bounded function (Funahashi, 1989; Hornik & al., 1989). They are specified also by their parcimonial abilities. It means that once the model parameters properly initialized, the network adjusts itself its weights (according to the selected learning algorithm) to reach its purpose (explaining a target variable or describing the space of data). - Trees models are† able to adapt to missing data - Many Machine Learning techniques are able to adapt to heterogeneous (numerical and categorical) data: support vector machine, neural networks, trees models, etc. 	<ul style="list-style-type: none"> - Risk of overfitting data (linked to the sampling method, and to specific features of the models such as the size of a tree in terms of number of nodes, etc.) - Risk of local minima (can be controlled with the learning rate and the momentum) - Time-consuming either in designing or in implementation - If implemented in R, R packages do not propose the same hyper parameters: for neural networks for instance, the packages that provide the most interesting hyper parameters are RSNNS and H2O but some hyper parameters of a one are missing in the other. The choice of hyper parameters (before optimization step) is in itself an issue: the hyper parameters are related to a certain specificity of the underlying model (for instance the learning rate is linked to the speed of crossing the data) but hyper parameters interact between each other and to date, research did not, to our knowledge, do a significant progress in documenting the interconnections between the hyper parameters of Machine Learning techniques - Automation is possible but once the hyper parameters and the first explicative variables are chosen - Neural networks are sensitive to colinearity and heterogeneity of the covariables - Decision trees are instable with respect to the data: often a small change in the data can result in a very different series of splits, making interpretation somewhat precarious. This means that a single tree has a high variance. This problem can be addressed by aggregating the models (bagging, boosting)
Traditional methods	<ul style="list-style-type: none"> - Ability of some methods to consider variables other than transactional information (GLM, survival analysis) - Robustness and reliability over time - Significant and rich academic literature - Understandable by non-actuaries (accountant, auditor) - Easy to implement and do not necessitate a huge IT volume - Need a high level of data granularity 	<ul style="list-style-type: none"> - Subjective choice of development factor and sometimes of the tail factor/extrapolation method - Misalignment with pricing approach for the same underlying contracts (pricing focus on homogenous group of policies) - Difficulty to link potential changes in reserves to specific contracts - Non proportional reinsurance cannot be included in loss reserves estimation as it is related to specific claims - Large and attritional claims have to be separated

Table 10 Advantages and drawbacks of loss reserving models

7.4. Clues for future works

In this section, we identify lines of thought for futures studies:

- **Mix models**

The different **Machine Learning** models tested in this study could be aggregated all together with the Cobra method (Biau & al., 2014). This non-linear method to aggregate **regression** models makes it possible to gather the strengths of the different models by enhancing at the same time the quality of the prediction.

This is also dictated by the *No Free Lunch Theorem*: there is no model that is always better than all other models, one should try them all and then understand which one perform better on the underlying dataset.

- **Ensemble of Models**

An Ensemble Model is to be understood as a model that combine both traditional methods and Machine Learning. Indeed, in the case of this study for instance, we have observed that there is no clear winner between the models: each one performs better than the others but on a specific subset of the dataset.

The Ensemble of Models approach can be achieved by, for instance, weighting appropriately the predictions obtained by each model so that the error of prediction of this hybrid model can be less important than those of each model taken separately.

- **Time dependency**

In this study, explanatory variables have been considered as static. Some variables are not frozen: the age of the claimant, the status of the claim, etc. these variables could be considered as time-dependant variables in further studies. This could create a synergy opportunity between time series and survival models on the one hand and Machine Learning models on the other hand.

- **Combined/Simultaneous models for incurred and paid**

To predict the incurred, it would be interesting to:

- include as an explanatory variable, at each $(j + 1)^{th}$ development period, the predicted paid obtained at the j^{th} development period. And inversely. This would rise the interaction between different types of transaction.
- produce a single model that incorporate both paid and incurred claim data (Harej & al, 2017).

- **Pure IBNR**

In this study, we decided to take a simple approach for Pure IBNR estimation and focus mainly on IBNER side. This is partly due to data constraint, as we don't have policy level information. One alternate way is to add some of the claim level variables, such as event, Age group, for the estimation. The current framework still applies.

- **Generalized Linear Models**

The application of GLM to individual claims data, by using multiple explanatory variables would be a kind of bridge between traditional methods and Machine Learning. For this purpose, a knowledge of the life of claims should be introduced. In this study, we began an annex analysis of modelling the duration of claims with Kaplan Meier estimator combined to a GLM approach. This approach implies, when using GLM, to optimize the parameters of the fitted distribution with a numerical optimization method such as Newton-Raphson. Such a work should be interesting to deepen.

8. References

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9. Appendices

9.1. Exploratory Data Analysis

The following graphs shows the distribution of claims in terms of number of claims and of amounts of claims by different variables:

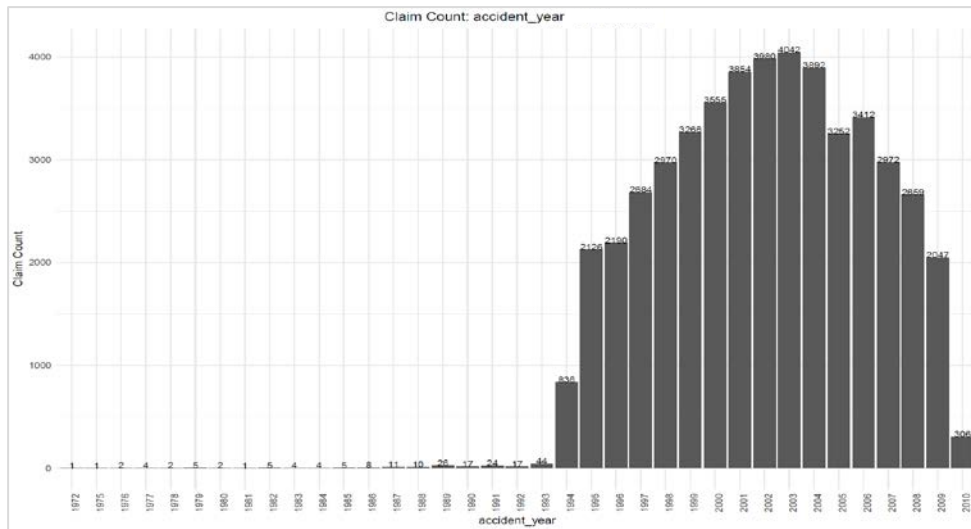


Figure 41 Claims number by accident year

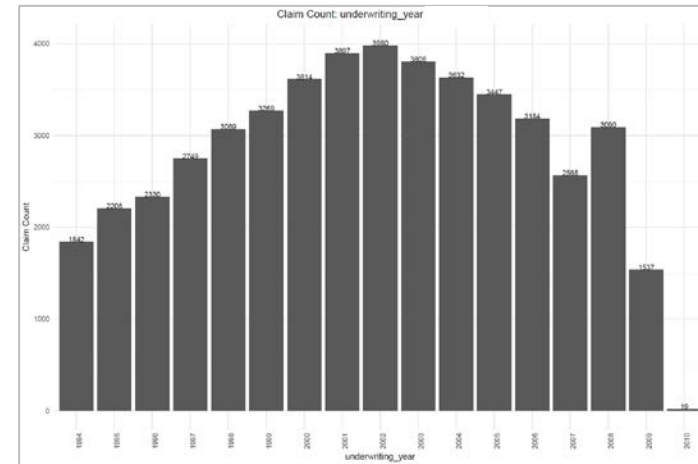


Figure 42 - Claims number by underwriting year

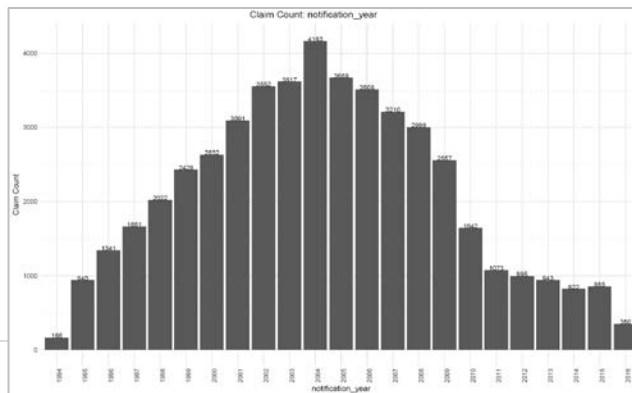


Figure 43 - Claims number by notification year

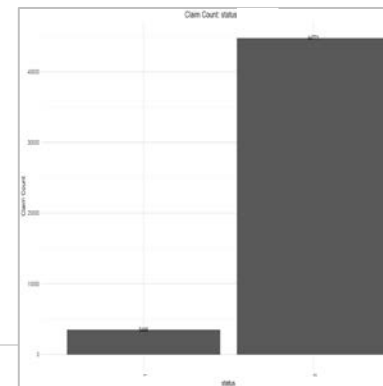


Figure 44 - Claims number by status (1 for open and 2 for close)

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9.1.1. Further analysis

9.1.1.1. Claims deferment

The next table shows the average deferment of the claims (express in years):

Date of Loss	Count	Average deferment
1994	789	3,72
1995	2 084	3,5
1996	2 182	3,27
1997	2 648	2,94
1998	2 944	2,7
1999	3 307	2,32
2000	3 532	2,37
2001	3 845	2,13
2002	3 954	2,00
2003	4 007	1,81
2004	3 974	1,72
2005	3 257	1,85
2006	3 362	1,63
2007	2 979	1,78
2008	2 668	1,81
2009	2 175	1,83
2010	336	2,26

Table 11- Claims Deferment on original data

The IBNR component is particularly high which is specific to the Professional Liability line of business.

9.1.1.2. Claims evolution

The graph on Figure 8 compares the amount of incurred at the opening of a claim (Start Amount) and the last amount observed for the claim, either it is closed or not (Last Amount).

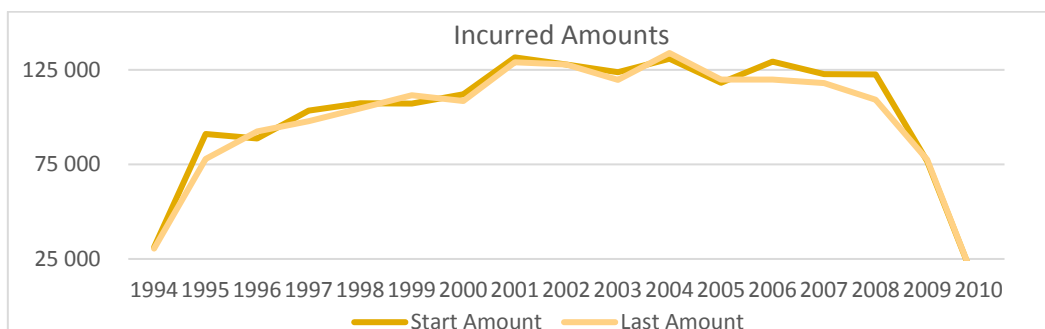


Figure 45 - Evolution of incurred claims by development year: comparison between 2 claims life time

The *Start Amount* and the *Last Amount* variables are close to each other and reflects the same trends. It means that the insurer estimated accurately the cost of the claims. Thereafter, this behaviour will impact positively the IBNER estimation. .

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9.2. Triangles of claim experience

a. Paid

Accident year	Total claims paid (\$) to the end of development year																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 604 122	24 185 065
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	56 471 294	57 004 109	
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	66 459 669	69 101 217		
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 619 839			
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	71 161 106				
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758					
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660						
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298							
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933								
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	78 697 051									
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	86 695 449										
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	74 957 466											
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 570	48 094 227	60 286 032	68 279 969	71 055 378												
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	62 098 797													
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	32 541 630	39 719 013	47 251 511	52 468 999														
2009	372 907	985 838	4 120 617	9 610 390	16 686 438	23 337 975	29 405 359	34 460 997															
2010	66 268	136 381	420 236	973 357	2 375 480	3 809 040	4 463 242																

b. Incurred

Accident year	Total claims incurred (\$) to the end of development year																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 406 914	25 439 358
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	64 619 050	64 916 166	
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	77 469 194		
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013			
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463				
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012					
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396						
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066							
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493								
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615									
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692										
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492											
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601												
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	92 618 291														
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 094 805	83 207 042	79 449 123	84 834 047	89 292 714														
2009	17 193 212	38 002 433	50 937 746	48 829 445	58 044 114	58 744 756	62 895 252	69 006 711															
2010	1 136 121	2 133 857	1 612 655	4 909 603	6 539 149	6 426 980	7 370 584																

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9.3. Summary of results

9.3.1. Ultimates

9.3.1.1. Paid

Accident year	Estimated ultimate paid for accident years 2006						
	chain ladder	GBM	TD Boost	RF	NN	GBM combined	GLM
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	17,9	26,1	34,1	28,0	29,5	34,7	17,7
1995	41,5	70,3	100,5	84,7	73,9	119,2	39,3
1996	43,1	68,5	89,1	88,0	74,2	112,2	42,4
1997	46,3	72,4	92,1	98,3	78,4	128,4	44,7
1998	45,4	69,4	89,8	99,0	73,7	119,5	44,3
1999	56,2	67,5	95,0	95,3	77,0	114,1	57,7
2000	52,6	70,6	85,3	96,1	83,2	118,9	53,6
2001	75,7	83,4	97,8	97,1	91,3	114,6	72,6
2002	89,7	78,2	92,2	86,4	88,9	109,2	92,2
2003	60,8	65,7	66,2	58,8	79,8	83,5	71,1
2004	80,9	59,9	57,2	50,5	68,6	61,3	91,8
2005	45,4	41,3	39,6	33,2	47,5	43,1	55,1
2006	57,2	32,8	29,6	23,7	33,8	31,3	68,3
2007	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-

Accident year	Estimated ultimate paid for accident years 2014						
	chain ladder	GBM	TD Boost	RF	NN	GBM combined	GLM
	\$M		\$M				
1994	24,5	24,3	24,8	24,9	24,7	24,9	23,8
1995	60,9	60,6	62,1	63,4	60,8	69,9	58,0
1996	74,7	72,6	75,0	77,8	72,8	86,3	71,7
1997	76,7	76,0	80,7	88,1	74,9	99,7	75,0
1998	82,5	80,5	87,6	89,6	78,8	93,0	79,3
1999	92,1	87,0	94,5	104,3	83,5	-20,7	90,4
2000	98,0	92,2	99,0	108,3	87,5	-158,1	92,9
2001	118,2	109,6	117,9	127,8	98,8	-125,7	111,4
2002	134,4	124,6	126,9	133,5	104,6	-29,8	128,2
2003	123,0	117,5	118,1	115,4	92,5	-84,8	116,3
2004	155,0	136,0	134,8	138,4	103,4	-135,4	150,2
2005	140,0	126,9	130,8	141,8	91,7	-175,6	131,8
2006	155,4	126,9	126,2	137,3	88,6	-115,7	154,2
2007	152,4	112,8	110,5	116,5	74,6	-49,4	152,9
2008	169,0	102,7	96,9	106,5	66,1	-79,6	156,3
2009	134,8	83,8	73,3	84,0	49,2	-38,7	122,6
2010	20,0	9,1	8,3	6,7	6,0	3,1	16,3

Accident year	Estimated ultimate paid for accident years 2011						
	chain ladder	GBM	TD Boost	RF	NN	GBM combined	GLM
	\$M		\$M				
1994	22,0	23,0	23,8	24,4	24,2	23,7	21,1
1995	54,8	58,8	61,0	69,4	62,6	60,7	51,6
1996	63,0	67,6	71,1	80,4	72,3	71,3	59,9
1997	65,8	73,5	78,7	89,2	76,4	85,4	62,0
1998	74,1	81,1	88,5	99,1	83,2	101,6	70,6
1999	80,4	86,2	93,8	107,5	87,5	109,8	77,4
2000	86,7	91,3	96,8	114,8	89,9	106,9	80,8
2001	106,8	105,7	114,2	150,3	99,4	143,3	100,9
2002	124,3	118,8	121,6	167,4	105,3	153,0	121,0
2003	125,9	114,8	115,3	160,2	93,4	138,8	115,9
2004	163,5	117,9	113,5	151,7	89,3	174,4	145,6
2005	122,9	104,4	97,1	125,2	69,0	163,5	107,2
2006	165,5	121,3	109,9	135,7	73,6	177,1	140,0
2007	127,8	96,5	81,3	97,2	54,0	167,5	121,4
2008	163,7	87,1	73,0	87,5	45,1	132,7	118,3
2009	127,1	60,2	48,1	58,6	26,0	102,9	90,5
2010	9,5	3,6	2,8	1,7	1,0	0,2	9,4

Accident year	Estimated ultimate paid for accident years 2016						
	chain ladder	GBM	TD Boost	RF	NN	GBM combined	GLM
	\$M		\$M				
1994	24,2	24,2	24,2	24,2	24,2	24,2	24,2
1995	58,3	58,2	58,6	58,9	59,3	58,2	58,5
1996	72,6	71,3	72,6	72,7	73,7	70,8	72,0
1997	77,4	75,5	76,9	79,3	78,9	76,0	76,2
1998	79,4	77,0	79,5	81,4	82,1	79,7	78,3
1999	87,4	82,4	78,3	70,9	87,8	77 698,8	88,9
2000	89,8	82,9	76,6	84,9	91,0	247,5	89,8
2001	110,0	101,5	103,3	100,3	107,1	2 897,5	110,8
2002	115,5	106,5	107,0	110,8	110,9	204,7	116,7
2003	109,2	100,7	100,1	103,9	103,0	179,0	111,5
2004	127,6	110,8	111,1	113,7	113,1	218,7	131,4
2005	117,8	100,6	100,5	106,5	104,2	250,8	118,6
2006	120,0	99,1	97,5	105,2	99,9	236,4	130,2
2007	113,6	93,4	90,2	99,4	95,5	225,0	131,0
2008	108,7	85,0	79,7	96,9	90,2	802,0	129,3
2009	86,0	66,3	61,4	65,6	64,0	1 562,1	106,6
2010	13,6	10,1	8,1	8,1	9,2	16,1	16,2

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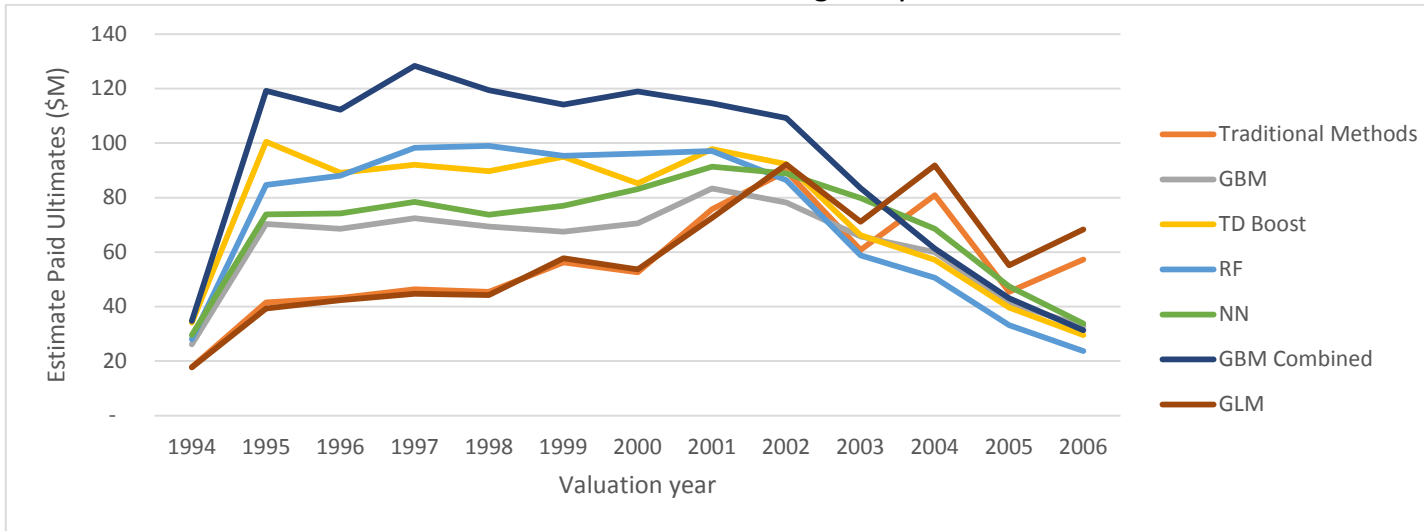


Figure 46 - 2006 Ultimate Paid - Comparison of models

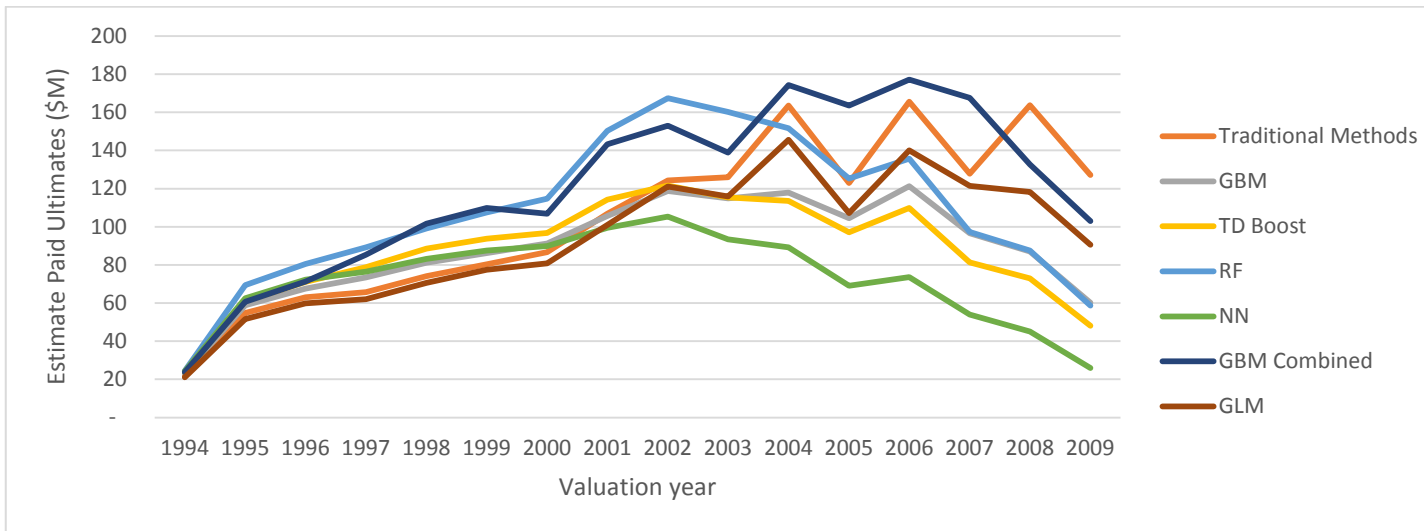


Figure 47- 2011 Ultimate Paid - Comparison of models

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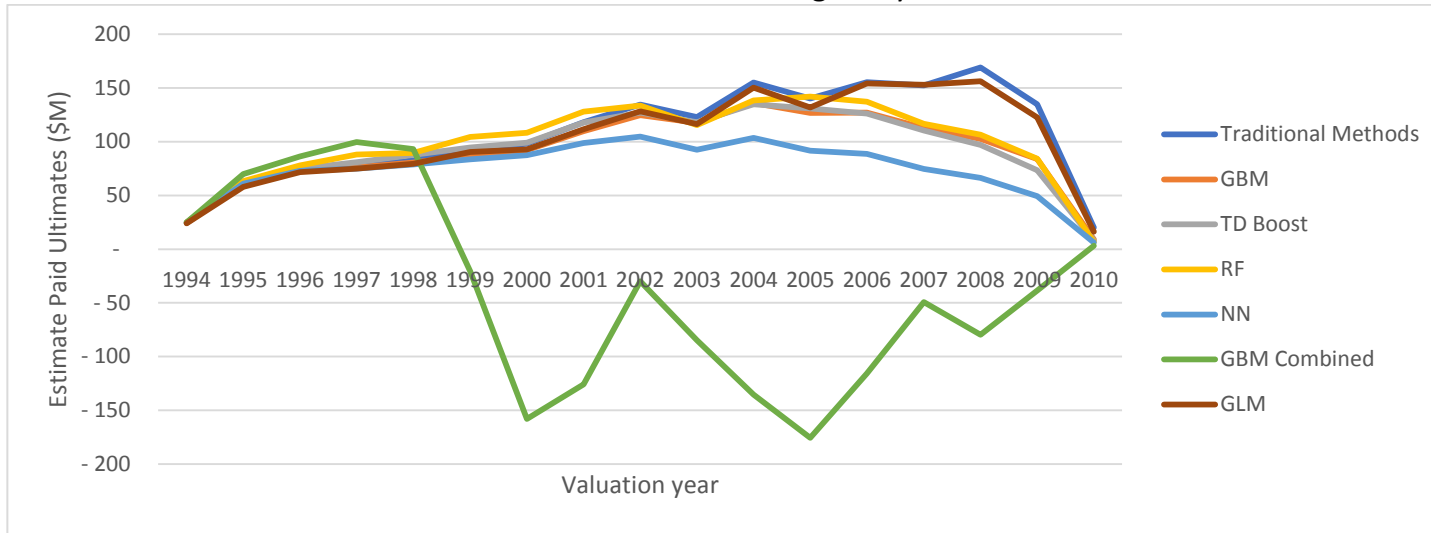


Figure 48- 2014 Ultimate Paid - Comparison of models

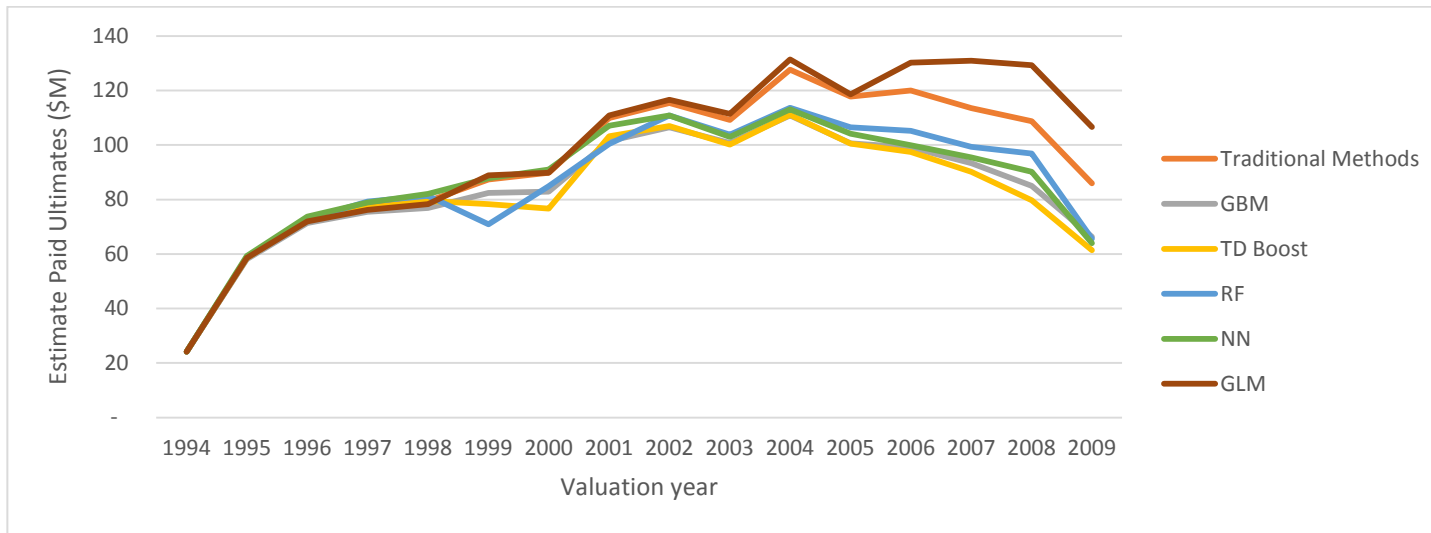


Figure 49- 2016 Ultimate Paid - Comparison of models

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9.3.1.2. Incurred

Accident year	Estimated ultimate incurred for accident years 2006						
	chain	GBM	TD	RF	NN	GBM	GLM
	ladder	Boost	combined				
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	18,9	16,3	16,1	24,6	6,0	26,7	22,9
1995	40,9	27,3	14,5	51,8	0,9	35,5	52,2
1996	43,2	21,9	11,4	36,2	-7,0	45,5	55,3
1997	47,5	24,1	26,0	34,5	-17,6	106,2	63,6
1998	46,1	15,2	22,4	17,0	-30,9	100,6	62,6
1999	48,9	12,6	28,7	23,8	-45,1	131,7	68,6
2000	44,9	-5,5	4,8	18,4	-109,0	108,7	63,4
2001	58,5	-9,2	2,9	14,8	-136,7	92,2	104,6
2002	59,7	-6,6	6,0	19,0	-145,1	102,4	113,1
2003	59,4	-7,7	9,8	35,7	-152,0	87,6	116,9
2004	63,0	5,2	13,5	-14,6	-135,2	85,2	139,2
2005	45,1	3,5	8,5	-4,7	-102,9	53,5	62,4
2006	61,8	2,9	9,6	-2,1	-79,9	37,4	128,6
2007	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-

Accident year	Estimated ultimate incurred for accident years 2011						
	chain	GBM	TD	RF	NN	GBM	GLM
	ladder	Boost	combined				
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	28,7	27,9	15,4	31,2	27,1	16,2	26,7
1995	65,3	62,1	40,6	50,7	59,1	38,9	47,3
1996	77,6	72,0	31,1	47,2	69,3	31,0	54,9
1997	84,2	75,0	53,4	43,9	71,8	69,8	56,8
1998	91,9	80,9	78,9	59,1	74,9	80,9	64,7
1999	95,9	81,1	76,8	44,0	73,8	46,8	70,9
2000	95,7	76,9	74,4	39,6	68,7	5,6	74,1
2001	119,4	92,8	90,8	72,2	84,3	36,1	92,5
2002	129,3	94,0	30,7	61,7	86,5	77,4	110,9
2003	131,3	92,0	2,6	74,2	84,4	24,2	106,2
2004	146,4	98,8	50,4	92,7	90,9	77,0	133,5
2005	118,4	81,1	-2,4	73,3	73,8	61,1	98,2
2006	145,9	100,0	21,2	82,4	94,1	74,2	128,3
2007	131,8	79,7	26,2	65,7	77,2	66,7	111,2
2008	151,6	78,8	43,8	70,8	78,6	88,2	108,4
2009	110,8	47,2	66,2	45,4	49,1	70,6	82,9
2010	6,0	2,0	1,5	1,5	1,9	1,3	8,6

Accident year	Estimated ultimate incurred for accident years 2014						
	chain	GBM	TD	RF	NN	GBM	GLM
	ladder	Boost	combined				
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	26,2	25,6	18,5	19,5	25,4	24,7	24,9
1995	65,1	62,7	41,7	49,3	61,0	59,5	55,0
1996	78,3	74,3	35,5	56,1	71,8	83,4	67,9
1997	83,9	78,1	33,4	52,6	74,7	79,2	71,1
1998	81,2	74,7	29,4	47,5	69,9	59,1	75,1
1999	91,7	83,1	40,6	55,8	76,7	66,4	85,7
2000	88,2	77,9	54,7	49,2	69,2	93,8	88,0
2001	106,5	92,5	75,9	52,0	81,7	74,4	105,6
2002	109,4	91,9	27,5	57,6	79,5	59,0	121,5
2003	100,8	83,6	-0,8	38,0	70,3	46,5	110,2
2004	117,1	95,9	36,2	55,2	82,4	54,5	142,3
2005	107,6	86,4	-11,8	38,5	74,0	52,5	124,9
2006	108,3	85,2	-24,7	37,7	72,5	22,4	146,1
2007	104,0	76,3	14,5	30,4	65,9	-2,1	144,9
2008	100,9	76,6	26,8	28,1	67,2	-8,7	148,1
2009	67,4	56,3	66,3	17,9	48,1	-36,1	116,2
2010	8,2	6,2	4,3	4,5	4,6	3,7	15,5

Accident year	Estimated ultimate incurred for accident years 2016						
	chain	GBM	TD	RF	NN	GBM	GLM
	ladder	Boost	combined				
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	25,4	25,4	25,4	25,4	25,4	25,4	25,4
1995	65,7	63,9	64,7	63,8	64,6	64,5	66,7
1996	79,5	75,2	76,2	75,2	76,8	76,7	81,5
1997	84,3	76,9	79,2	76,9	79,7	78,1	87,9
1998	89,0	78,1	83,0	79,6	82,3	79,6	94,0
1999	95,8	81,9	91,0	85,4	86,7	86,0	103,2
2000	93,1	75,4	87,4	76,8	81,6	83,2	102,8
2001	116,3	89,9	106,4	92,9	99,3	97,4	132,1
2002	119,6	87,6	106,0	94,1	98,4	92,8	137,9
2003	110,7	75,8	95,2	80,7	88,1	87,4	128,8
2004	125,2	83,6	100,4	88,9	97,7	91,6	152,4
2005	112,9	69,6	91,6	72,8	84,7	79,0	137,1
2006	115,5	67,7	79,6	71,6	84,0	75,4	142,1
2007	117,0	64,8	82,8	66,5	82,1	70,1	148,2
2008	115,6	58,5	77,0	51,7	78,2	66,3	148,9
2009	94,2	42,9	65,8	38,5	57,5	52,1	106,3
2010	10,1	3,8	3,9	5,2	5,6	4,1	-102,3

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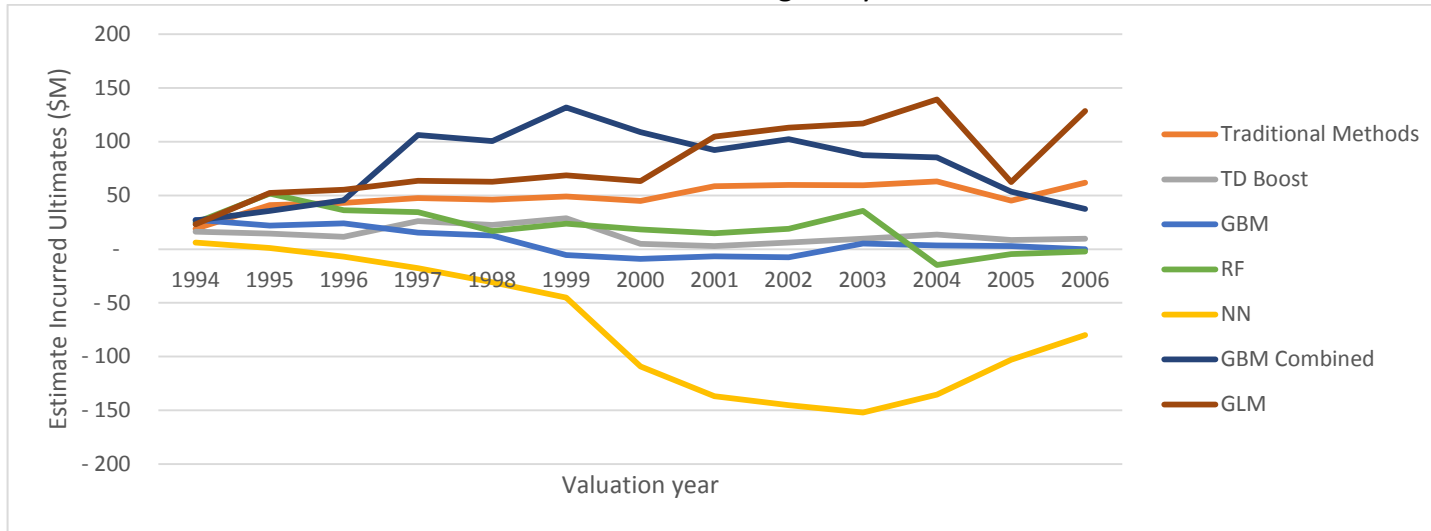


Figure 50- 2006 Ultimate Incurred - Comparison of models

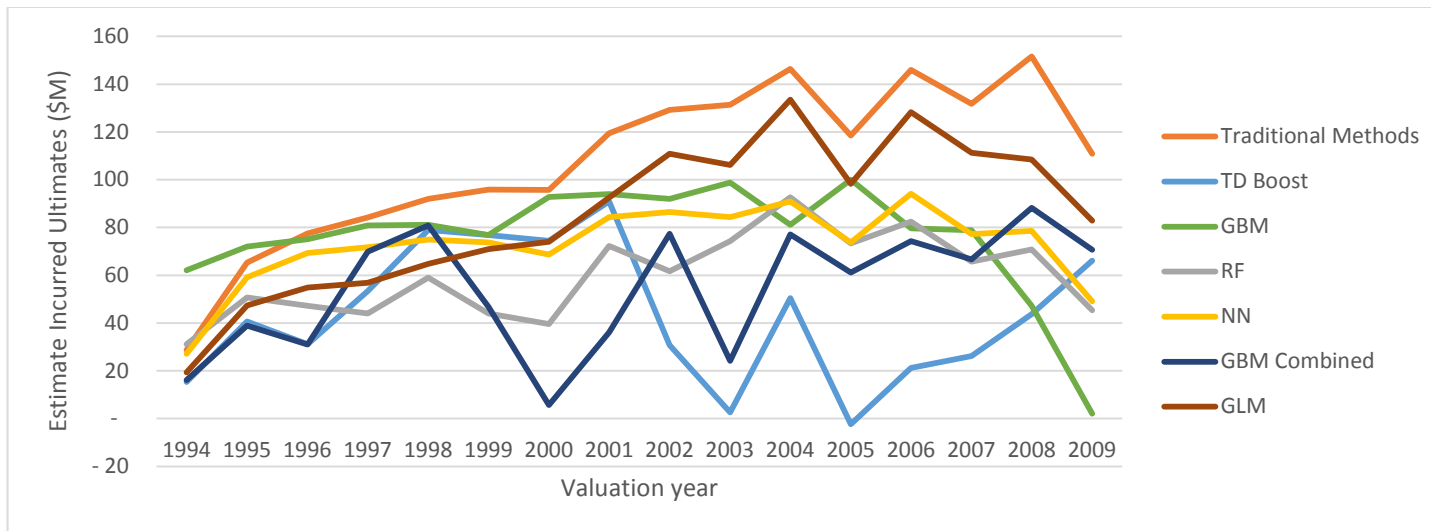


Figure 51- 2011 Ultimate Incurred - Comparison of models

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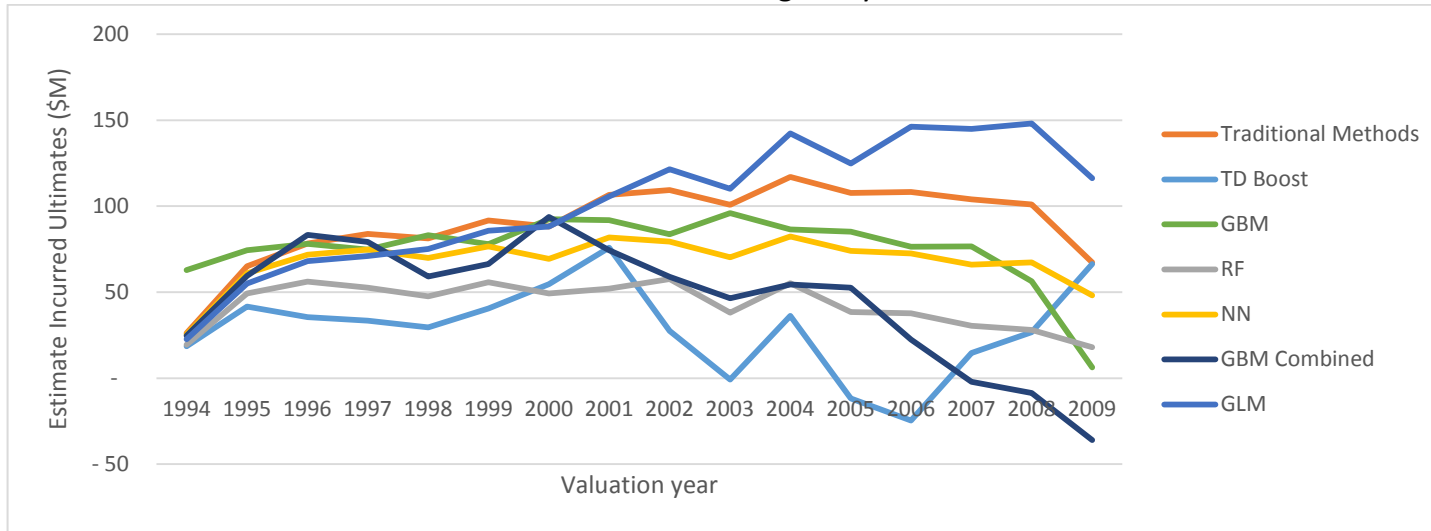


Figure 52- 2014 Ultimate Incurred - Comparison of models

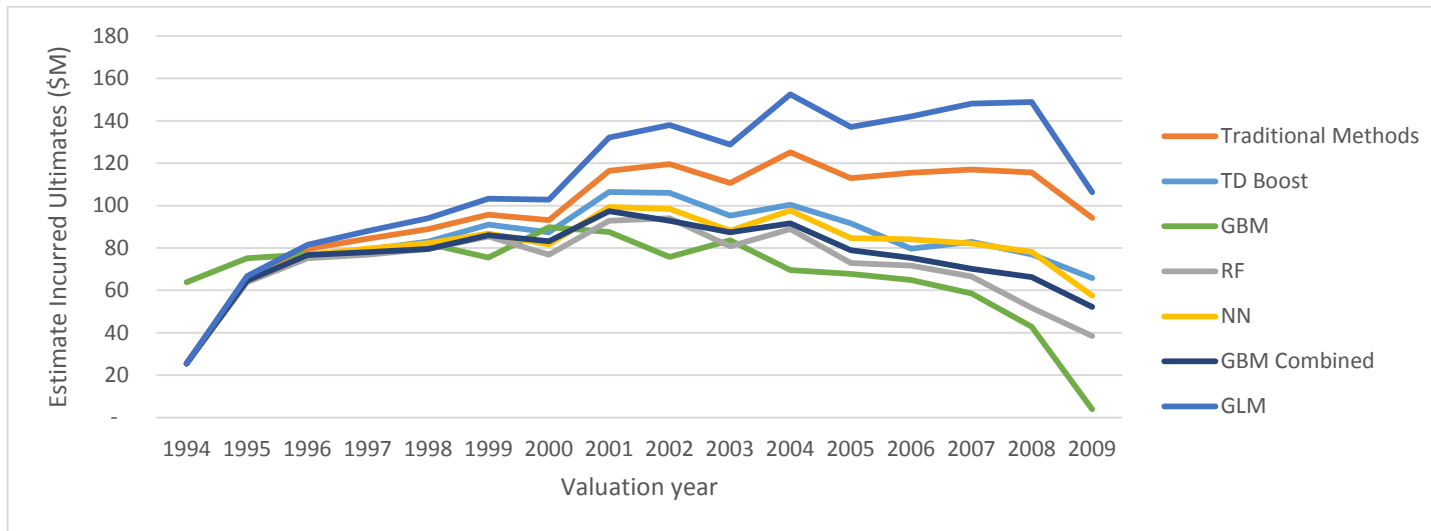


Figure 53 - 2016 Ultimate Incurred - Comparison of models

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9.3.2. Loss Reserves

9.3.2.1. Paid

Accident year	Estimated Loss Reserves for paid claims for accident years 2006						
	chain	GBM	TD	RF	NN	GBM	GLM
	ladder	Boost		combined			
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	1,1	9,4	17,4	11,3	12,8	17,9	0,9
1995	4,5	33,4	63,5	47,7	36,9	82,2	2,3
1996	8,1	33,5	54,0	52,9	39,2	77,2	7,3
1997	14,3	40,3	60,0	66,3	46,3	96,3	12,7
1998	19,7	43,6	64,0	73,2	47,9	93,7	18,5
1999	32,0	43,2	70,7	71,0	52,8	89,9	33,5
2000	34,9	52,9	67,6	78,4	65,5	101,2	35,9
2001	56,5	64,2	78,6	78,0	72,1	95,4	53,4
2002	73,5	62,0	76,0	70,1	72,6	93,0	76,0
2003	53,3	58,2	58,7	51,2	72,3	75,9	63,6
2004	75,8	54,9	52,2	45,5	63,5	56,3	86,7
2005	44,0	39,9	38,3	31,9	46,1	41,7	53,8
2006	56,7	32,3	29,0	23,1	33,3	30,8	67,8
2007	-	0,0	0,0	0,0	0,0	0,0	0,0
2008	-	0,0	0,0	0,0	0,0	0,0	0,0
2009	-	0,0	0,0	0,0	0,0	0,0	0,0
2010	-	0,0	0,0	0,0	0,0	0,0	0,0

Accident year	Estimated Loss Reserves for paid claims for accident years 2011						
	chain	GBM	TD	RF	NN	GBM	GLM
	ladder	Boost		combined			
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	1,7	2,7	3,6	4,1	4,0	3,5	1,1
1995	5,8	9,8	12,0	20,5	13,6	11,7	4,9
1996	8,8	13,4	17,0	26,2	18,1	17,1	8,0
1997	11,9	19,6	24,9	35,3	22,6	31,5	12,0
1998	17,1	24,1	31,5	42,1	26,1	44,6	19,9
1999	23,1	28,9	36,5	50,3	30,2	52,6	27,6
2000	30,6	35,3	40,7	58,7	33,9	50,8	33,5
2001	45,7	44,5	53,0	89,1	38,2	82,2	47,3
2002	63,1	57,6	60,4	106,3	44,1	91,8	70,8
2003	76,8	65,7	66,2	111,1	44,2	89,7	77,4
2004	115,3	69,7	65,3	103,5	41,1	126,1	105,3
2005	93,2	74,8	67,4	95,6	39,3	133,9	85,8
2006	136,7	92,5	81,1	106,9	44,8	148,4	117,7
2007	112,2	80,9	65,6	81,6	38,4	151,9	111,6
2008	151,6	75,0	60,9	75,4	33,0	120,7	114,3
2009	122,9	56,1	44,0	54,5	21,9	98,8	89,5
2010	9,4	3,5	2,7	1,5	0,9	0,0	9,3

Accident year	Estimated Loss Reserves for paid claims for accident years 2014						
	chain	GBM	TD	RF	NN	GBM	GLM
	ladder	Boost		combined			
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	1,4	1,2	1,6	1,7	1,5	1,7	0,7
1995	5,3	4,9	6,5	7,7	5,2	14,2	2,4
1996	9,1	7,0	9,4	12,2	7,2	20,7	6,1
1997	12,2	11,4	16,2	23,6	10,3	35,1	10,5
1998	16,4	14,3	21,4	23,4	12,7	26,9	13,1
1999	22,2	17,1	24,6	34,4	13,6	-90,6	20,5
2000	28,1	22,2	29,0	38,4	17,6	-228,0	23,0
2001	39,5	31,0	39,3	49,2	20,2	-204,3	32,8
2002	51,7	41,8	44,2	50,8	21,9	-112,5	45,5
2003	53,7	48,2	48,8	46,1	23,2	-154,1	47,0
2004	75,9	56,8	55,6	59,3	24,3	-214,5	71,1
2005	76,1	62,9	66,8	77,8	27,7	-239,6	67,8
2006	95,1	66,6	65,9	77,0	28,3	-175,9	93,9
2007	106,1	66,6	64,2	70,3	28,4	-95,6	106,6
2008	129,3	63,0	57,2	66,8	26,4	-119,3	116,6
2009	111,5	60,5	50,0	60,7	25,9	-62,0	99,3
2010	17,6	6,8	5,9	4,3	3,6	0,7	14,0

Accident year	Estimated Loss Reserves for paid claims for accident years 2016						
	chain	GBM	TD	RF	NN	GBM	GLM
	ladder	Boost		combined			
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	0,00	0,00	0,00	0,00	0,00	0,00	0,00
1995	1,34	1,16	1,60	1,85	2,29	1,19	1,52
1996	3,47	2,24	3,48	3,58	4,62	1,66	2,86
1997	5,78	3,86	5,33	7,68	7,33	4,37	4,53
1998	8,22	5,79	8,35	10,19	10,92	8,56	7,18
1999	11,75	6,76	2,64	-4,68	12,17	77 623,19	13,23
2000	15,05	8,20	1,89	10,12	16,23	172,77	15,07
2001	22,30	13,85	15,61	12,68	19,45	2 809,88	23,18
2002	27,73	18,74	19,25	23,11	23,18	116,93	28,93
2003	30,52	22,04	21,44	25,16	24,31	100,31	32,75
2004	40,92	24,12	24,41	26,98	26,43	132,04	44,69
2005	42,81	25,67	25,57	31,58	29,24	175,88	43,66
2006	48,93	28,01	26,43	34,13	28,85	165,33	59,17
2007	51,49	31,29	28,09	37,30	33,36	162,92	68,90
2008	56,22	32,55	27,21	44,46	37,75	749,53	76,78
2009	51,50	31,83	26,98	31,14	29,57	1 527,68	72,13
2010	9,15	5,69	3,60	3,65	4,74	11,66	11,74

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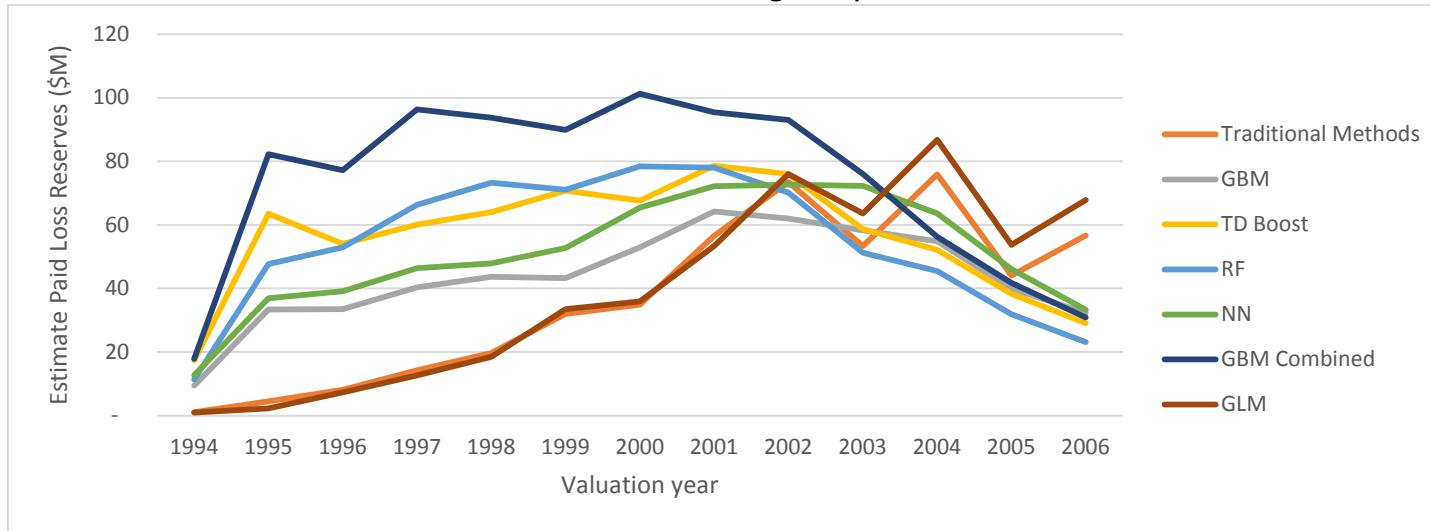


Figure 54 - 2006 Paid Loss Reserves - Comparison of models

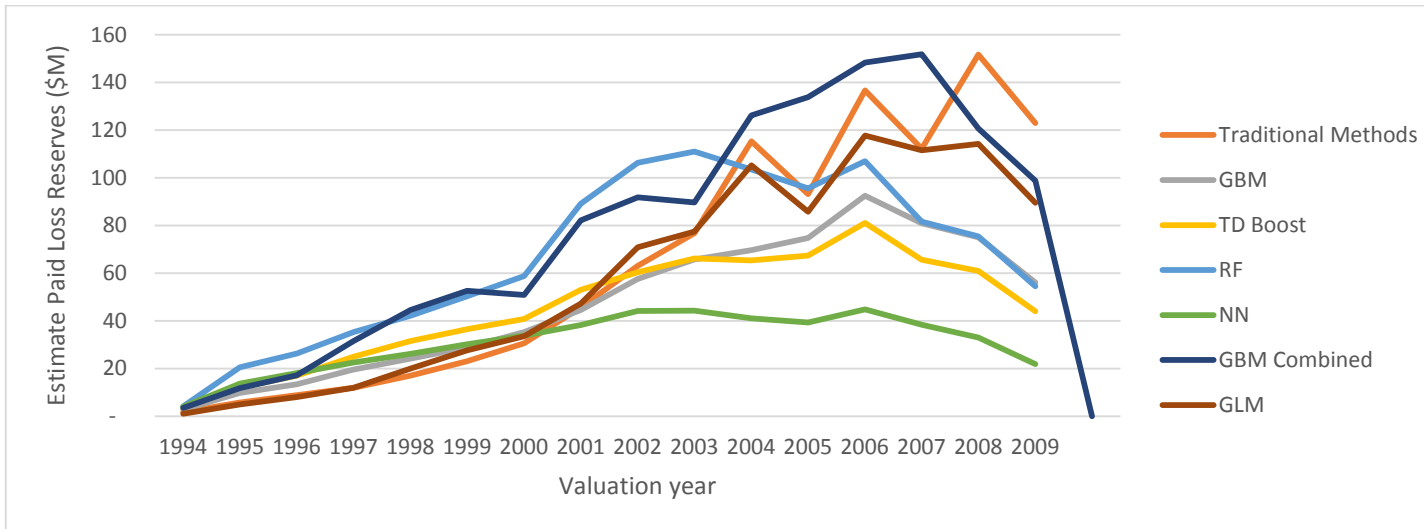


Figure 55 - 2011 Paid Loss Reserves - Comparison of models

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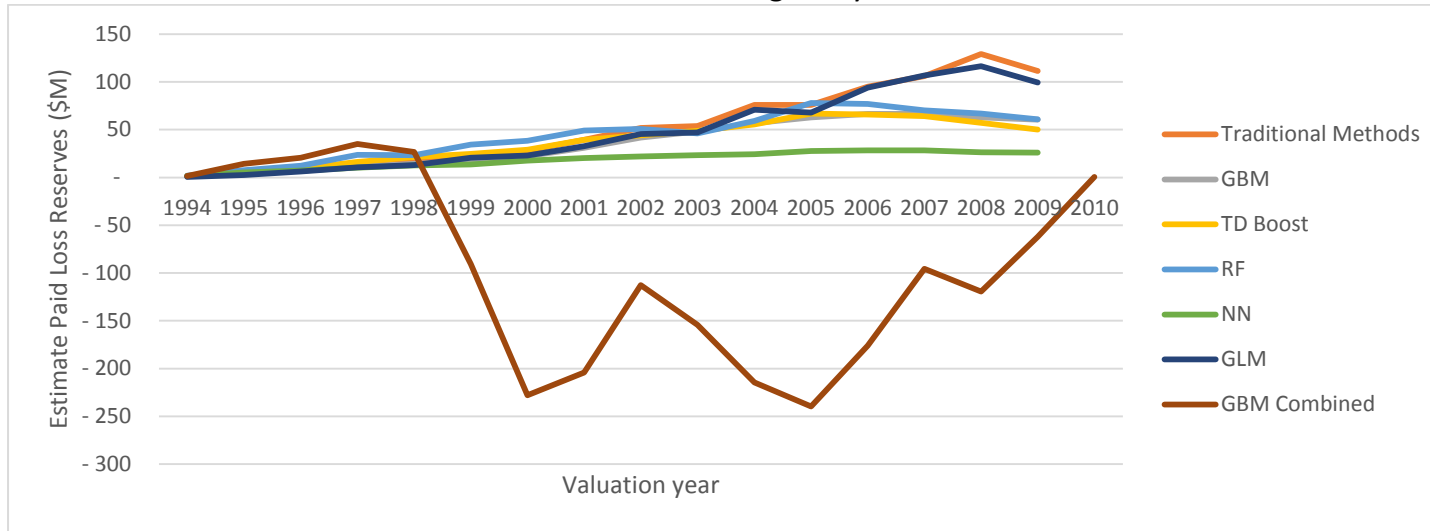


Figure 56 - 2014 Paid Loss Reserves - Comparison of models

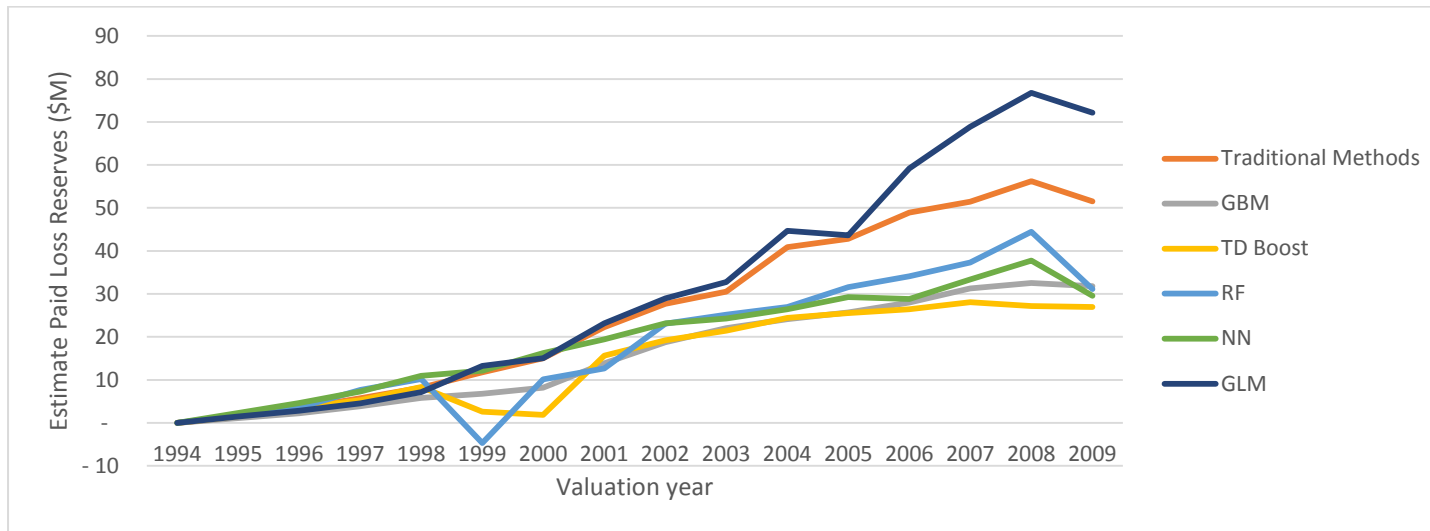


Figure 57 - 2016 Paid Loss Reserves - Comparison of models

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9.3.2.2. Incurred

Accident year	Estimated Loss Reserves for incurred claims for accident years 2006						
	chain ladder	GBM	TD Boost	RF	NN	GBM combined	GLM
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	2,1	-0,4	-0,6	7,8	-10,8	9,9	6,2
1995	4,0	-9,7	-22,5	14,8	-36,0	-1,5	15,2
1996	8,1	-13,1	-23,6	1,1	-42,1	10,5	20,3
1997	15,5	-7,9	-6,1	2,4	-49,7	74,2	31,6
1998	20,3	-10,5	-3,4	-8,8	-56,6	74,8	36,8
1999	24,6	-11,7	4,4	-0,4	-69,4	107,5	44,4
2000	27,2	-23,2	-12,9	0,7	-126,7	91,0	45,7
2001	39,4	-28,4	-16,2	-4,4	-155,9	73,0	85,4
2002	43,5	-22,8	-10,2	2,8	-161,3	86,2	96,8
2003	51,8	-15,2	2,3	28,1	-159,5	80,0	109,4
2004	58,0	0,2	8,5	-19,7	-140,3	80,1	134,1
2005	43,7	2,1	7,2	-6,0	-104,2	52,2	61,0
2006	61,3	2,4	9,0	-2,6	-80,4	36,9	128,1
2007	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-

Accident year	Estimated Loss Reserves for incurred claims for accident years 2011						
	chain ladder	GBM	TD Boost	RF	NN	GBM combined	GLM
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	8,5	7,6	-4,9	10,9	6,9	-4,1	6,5
1995	16,3	13,1	-8,4	1,8	10,2	-10,1	-1,7
1996	23,4	17,9	-23,1	-7,0	15,1	-23,2	0,7
1997	30,3	21,2	-0,5	-9,9	17,9	16,0	3,0
1998	34,9	23,8	21,9	2,0	17,9	23,8	7,7
1999	38,6	23,9	19,5	-13,3	16,5	-10,5	13,7
2000	39,7	20,9	18,4	-16,5	12,6	-50,4	18,0
2001	58,2	31,7	29,7	11,1	23,1	-25,0	31,3
2002	68,1	32,8	-30,5	0,6	25,3	16,2	49,7
2003	82,2	42,8	-46,5	25,1	35,3	-25,0	57,1
2004	98,2	50,6	2,1	44,4	42,6	28,8	85,2
2005	88,8	51,4	-32,1	43,6	44,1	31,4	68,5
2006	117,1	71,2	-7,6	53,6	65,4	45,5	99,5
2007	116,2	64,1	10,5	50,1	61,6	51,0	95,6
2008	139,5	66,8	31,7	58,7	66,5	76,2	96,4
2009	106,7	43,1	62,0	41,2	44,9	66,5	78,8
2010	5,9	1,9	1,3	1,3	1,8	1,1	8,5

Accident year	Estimated Loss Reserves for incurred claims for accident years 2014						
	chain ladder	GBM	TD Boost	RF	NN	GBM combined	GLM
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	3,0	2,4	-4,7	-3,7	2,2	1,5	1,7
1995	9,4	7,1	-14,0	-6,3	5,3	3,8	-0,6
1996	12,7	8,7	-30,1	-9,5	6,2	17,8	2,3
1997	19,4	13,6	-31,2	-12,0	10,1	14,7	6,5
1998	15,0	8,6	-36,7	-18,6	3,7	-7,0	9,0
1999	21,8	13,2	-29,3	-14,1	6,7	-3,5	15,8
2000	18,2	8,0	-15,2	-20,7	-0,7	23,8	18,1
2001	27,9	13,8	-2,7	-26,7	3,1	-4,2	27,0
2002	26,7	9,2	-55,2	-25,1	-3,2	-23,8	38,8
2003	31,5	14,3	-70,1	-31,3	1,0	-22,8	40,9
2004	38,0	16,8	-42,9	-23,9	3,3	-24,6	63,2
2005	43,7	22,5	-75,8	-25,4	10,0	-11,5	60,9
2006	48,0	24,9	-85,0	-22,6	12,2	-37,9	85,9
2007	57,8	30,1	-31,7	-15,8	19,7	-48,3	98,6
2008	61,2	36,9	-13,0	-11,6	27,5	-48,4	108,4
2009	44,0	33,0	43,0	-5,5	24,8	-59,4	92,9
2010	5,8	3,9	1,9	2,1	2,2	1,3	13,1

Accident year	Estimated Loss Reserves for incurred claims for accident years 2016						
	chain ladder	GBM	TD Boost	RF	NN	GBM combined	GLM
	\$M	\$M	\$M	\$M	\$M	\$M	\$M
1994	1,3	1,3	1,3	1,3	1,3	1,3	1,3
1995	8,7	6,9	7,7	6,8	7,6	7,5	9,7
1996	10,4	6,1	7,1	6,1	7,7	7,6	12,4
1997	12,7	5,3	7,6	5,3	8,0	6,5	16,3
1998	17,8	7,0	11,8	8,4	11,2	8,4	22,9
1999	20,1	6,3	15,4	9,7	11,1	10,4	27,6
2000	18,3	0,7	12,7	2,1	6,9	8,4	28,1
2001	28,7	2,2	18,7	5,2	11,6	9,7	44,5
2002	31,9	-0,2	18,2	6,4	10,6	5,1	50,2
2003	32,0	-2,9	16,5	2,0	9,4	8,7	50,1
2004	38,5	-3,1	13,7	2,2	11,0	4,9	65,7
2005	38,0	-5,4	16,6	-2,1	9,7	4,0	62,2
2006	44,4	-3,3	8,6	0,6	13,0	4,3	71,1
2007	54,9	2,7	20,7	4,4	20,0	8,0	86,1
2008	63,1	6,1	24,5	-0,8	25,7	13,8	96,4
2009	59,7	8,4	31,3	4,0	23,0	17,7	71,8
2010	5,7	-0,7	-0,6	0,7	1,1	-0,3	-106,8

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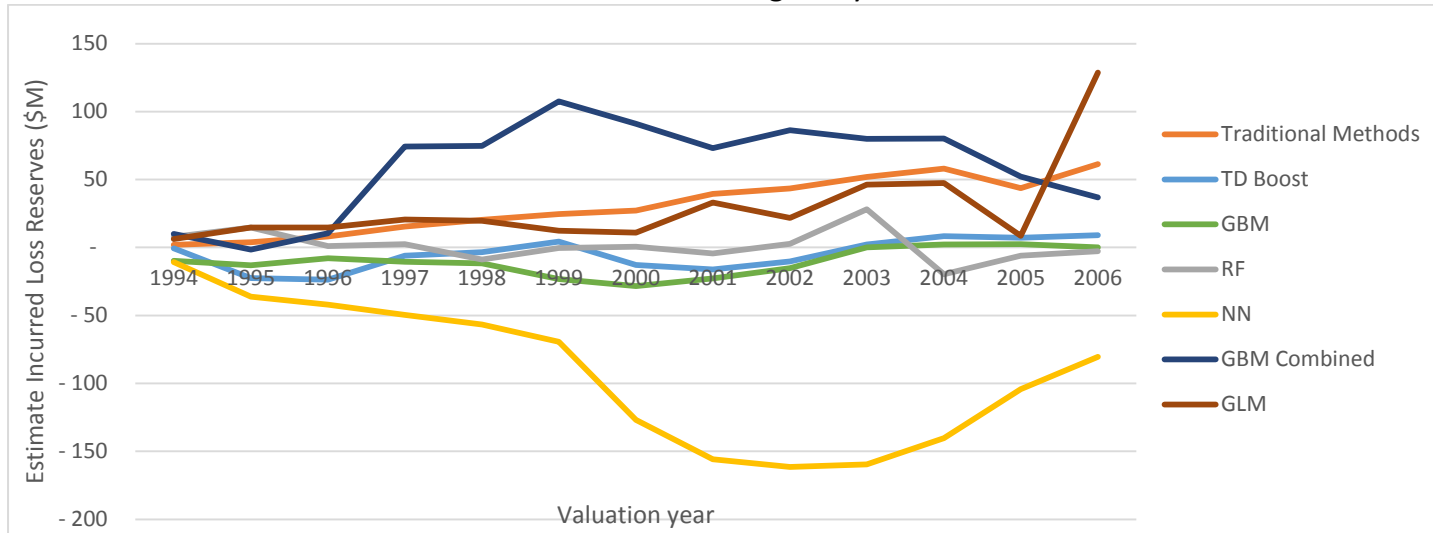


Figure 58 - 2006 Incurred Loss Reserves - Comparison of models

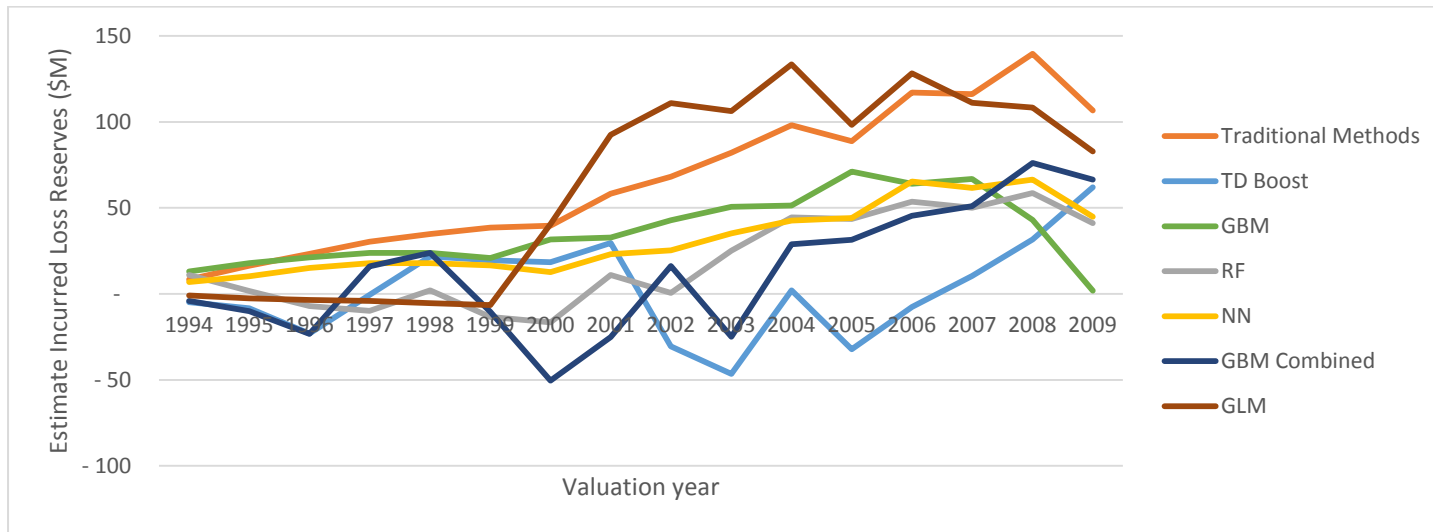


Figure 59 - 2011 Incurred Loss Reserves - Comparison of models

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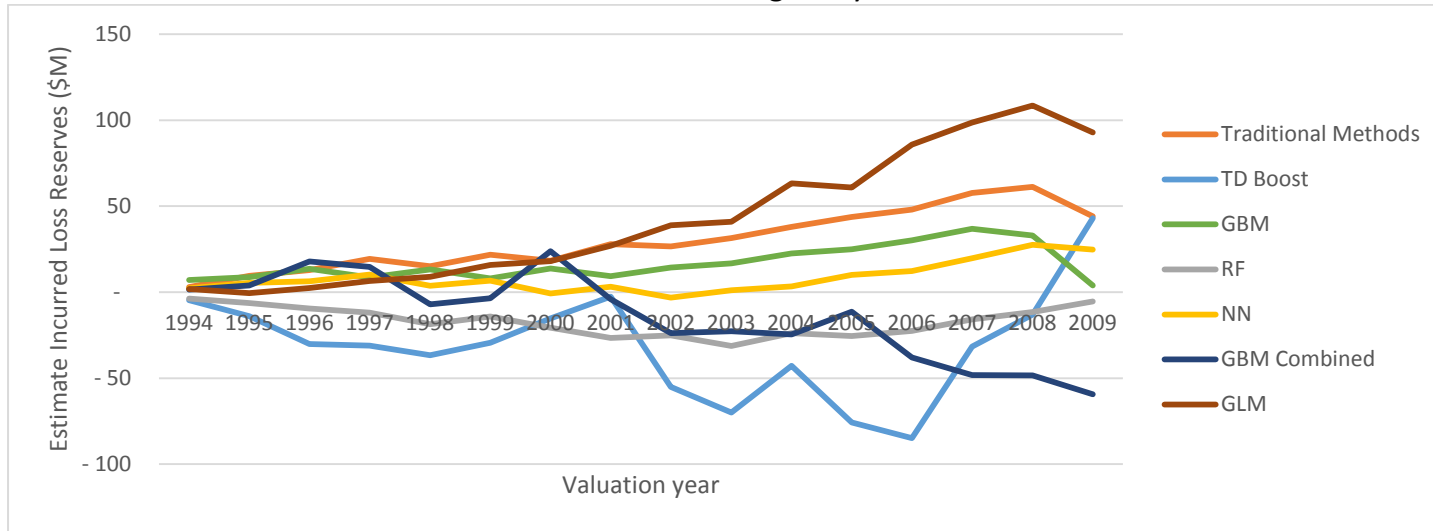


Figure 60 - 2014 Incurred Loss Reserves - Comparison of models

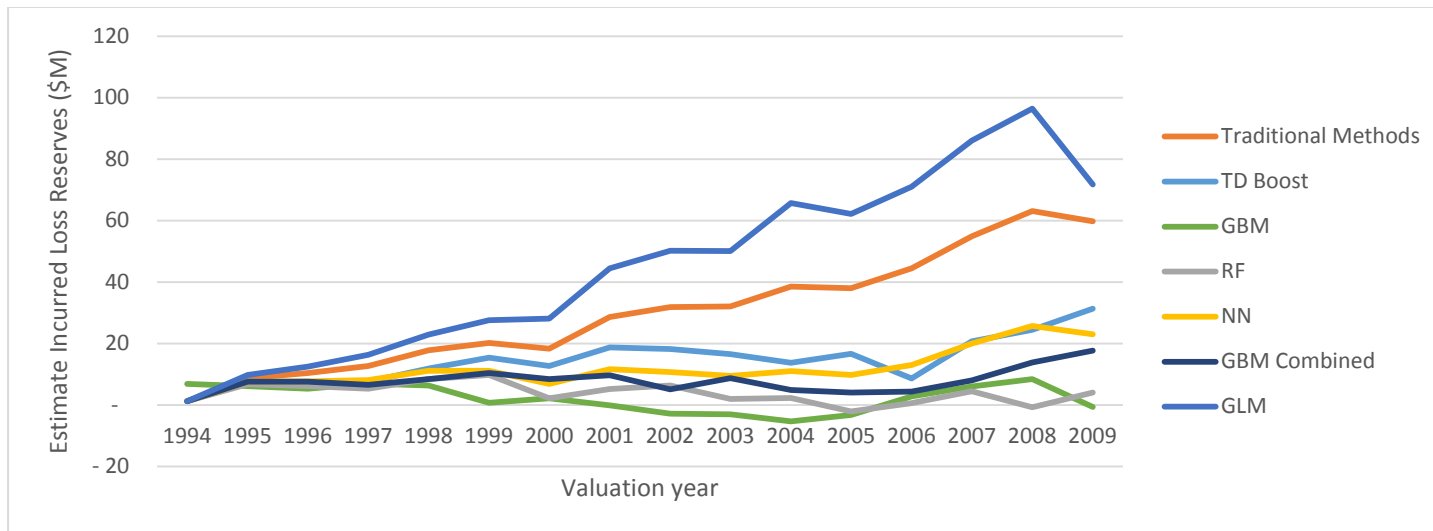


Figure 61 - 2016 Incurred Loss Reserves - Comparison of models

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9.4. Results by Method

9.4.1. Forecasts based on Traditional Methods

9.4.1.1. Chain ladder

9.4.1.1.1. Triangles of age-to-age factors

a. Paid

Accident year	Age j to age j+1 factor where j=																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1994	5,166	2,789	2,153	2,078	1,133	1,338	1,415	1,318	1,196	1,083	1,075	1,006	1,053	1,037	1,043	1,052	1,009	1,118	1,011	1,013	1,018	1,025
1995	4,633	1,946	2,873	1,299	1,778	1,221	1,195	1,190	1,161	1,152	1,222	1,082	1,049	1,071	1,038	1,049	1,033	1,011	1,088	1,015	1,009	
1996	3,507	2,105	2,391	1,455	1,237	1,239	1,420	1,363	1,246	1,243	1,154	1,102	1,050	1,109	1,044	1,089	1,047	1,062	1,013	1,040		
1997	2,787	2,989	2,091	1,400	1,412	1,477	1,308	1,301	1,247	1,204	1,098	1,105	1,068	1,076	1,058	1,104	1,027	1,089	1,019			
1998	3,692	1,770	1,619	1,679	1,715	1,281	1,374	1,285	1,182	1,208	1,219	1,130	1,125	1,061	1,054	1,037	1,048	1,026				
1999	3,703	1,642	1,645	1,563	1,456	1,400	1,200	1,310	1,153	1,212	1,120	1,151	1,093	1,099	1,017	1,057	1,023					
2000	4,304	1,905	1,943	1,599	1,334	1,287	1,352	1,327	1,297	1,149	1,185	1,086	1,105	1,040	1,045	1,023						
2001	3,830	2,180	2,412	1,430	1,413	1,300	1,227	1,361	1,287	1,141	1,137	1,070	1,056	1,097	1,017							
2002	3,167	2,745	2,013	1,323	1,470	1,356	1,158	1,340	1,218	1,162	1,123	1,037	1,056	1,005								
2003	2,873	1,705	1,994	1,984	1,497	1,298	1,328	1,275	1,163	1,103	1,099	1,092	1,041									
2004	2,766	2,253	2,239	1,719	1,414	1,466	1,195	1,280	1,175	1,091	1,057	1,037										
2005	2,653	2,172	2,742	1,600	1,663	1,385	1,383	1,305	1,194	1,120	1,047											
2006	3,495	2,739	2,153	2,055	1,290	1,377	1,213	1,253	1,133	1,041												
2007	3,744	1,872	2,082	1,597	1,490	1,525	1,302	1,249	1,075													
2008	3,333	2,756	3,001	1,826	1,477	1,221	1,190	1,110														
2009	2,644	4,180	2,332	1,736	1,399	1,260	1,172															
2010		Excluded from modelling																				

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b. Incurred

Accident year	Age j to age j+1 factor where j=																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1994	3,773	1,229	1,085	1,156	1,213	1,102	0,856	1,094	1,022	0,999	0,988	1,018	0,973	1,032	1,017	1,040	1,050	0,897	0,975	1,048	0,993	1,001
1995	2,148	1,177	1,138	1,078	1,058	1,017	0,951	1,035	1,050	1,038	0,981	1,058	1,047	1,086	1,005	0,955	0,948	1,031	1,028	1,029	1,005	
1996	1,919	1,150	1,154	1,227	1,123	1,034	0,894	0,997	0,987	1,037	1,051	1,121	1,017	1,039	1,034	0,915	1,084	1,035	1,038	1,001		
1997	2,005	1,162	1,136	1,134	1,155	1,027	0,897	1,021	1,034	1,043	1,028	1,074	1,068	1,027	0,928	1,042	1,057	1,029	0,998			
1998	1,746	1,231	1,069	1,086	1,098	1,028	0,838	1,057	1,045	1,243	1,070	1,038	0,982	0,912	1,007	0,998	1,092	1,025				
1999	2,022	1,210	1,126	1,134	1,074	0,953	0,899	1,092	1,145	1,153	1,025	0,944	0,945	1,046	1,019	1,059	1,006					
2000	2,102	1,240	1,082	1,072	1,019	0,998	0,993	1,194	1,112	0,998	0,993	0,967	1,007	1,013	1,071	1,005						
2001	2,403	1,285	1,159	1,082	1,110	1,010	1,011	1,168	1,035	0,967	0,912	1,030	1,039	1,093	1,018							
2002	2,258	1,250	1,155	1,122	1,077	1,025	1,136	1,075	0,985	0,911	1,018	1,022	1,080	1,029								
2003	1,982	1,198	1,213	1,086	1,174	1,120	1,065	0,954	0,869	1,019	0,995	1,085	1,029									
2004	2,246	1,304	1,177	1,269	1,190	0,993	0,921	0,941	1,008	1,012	1,068	1,015										
2005	2,702	1,370	1,291	1,273	1,133	0,933	0,904	1,100	1,037	1,037	1,023											
2006	2,161	1,305	1,329	1,153	1,083	0,840	0,986	1,009	1,052	1,023												
2007	2,408	1,418	1,140	1,104	1,021	0,928	0,998	1,121	1,038													
2008	2,604	1,197	1,147	0,991	1,001	0,955	1,068	1,053														
2009	2,210	1,340	0,959	1,189	1,012	1,071	1,097															
2010	Excluded from modelling																					

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9.4.1.1.2. Model age-to-age factors

a. Paid

Model based on data to 31 Dec	Model age j to age j+1 factor where j=																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
2006	3,237	2,100	1,977	1,462	1,402	1,326	1,284	1,314	1,219	1,175	1,096	1,053	1,029	1,016	1,009	1,005	1,003	1,001	1,001	1,000	1,000	1,000	
2007	3,198	2,092	2,014	1,539	1,416	1,326	1,300	1,299	1,224	1,201	1,129	1,082	1,053	1,034	1,022	1,014	1,009	1,006	1,004	1,002	1,001	1,001	
2008	3,180	2,163	2,121	1,588	1,462	1,320	1,254	1,309	1,191	1,218	1,135	1,084	1,052	1,032	1,020	1,012	1,008	1,005	1,003	1,002	1,001	1,001	
2009	3,126	2,130	2,187	1,583	1,456	1,320	1,227	1,335	1,213	1,208	1,146	1,102	1,071	1,050	1,035	1,025	1,017	1,012	1,008	1,006	1,004	1,003	
2010	3,075	2,140	2,197	1,663	1,508	1,379	1,235	1,344	1,249	1,187	1,144	1,111	1,085	1,066	1,051	1,039	1,030	1,023	1,018	1,014	1,011	1,008	
2011		2,261	2,273	1,660	1,422	1,389	1,221	1,323	1,262	1,163	1,129	1,102	1,081	1,064	1,050	1,040	1,031	1,025	1,020	1,015	1,012	1,010	
2012			2,334	1,718	1,446	1,411	1,290	1,297	1,220	1,151	1,132	1,115	1,100	1,087	1,075	1,066	1,057	1,050	1,043	1,038	1,033	1,028	
2013				1,790	1,411	1,426	1,252	1,286	1,185	1,136	1,116	1,099	1,085	1,073	1,062	1,053	1,045	1,039	1,033	1,028	1,024	1,021	
2014					1,457	1,358	1,291	1,278	1,178	1,117	1,104	1,092	1,081	1,072	1,064	1,056	1,050	1,044	1,039	1,035	1,031	1,027	
2015						1,322	1,232	1,268	1,166	1,104	1,093	1,083	1,075	1,067	1,060	1,053	1,048	1,043	1,038	1,034	1,031	1,027	
2016								1,223	1,204	1,132	1,083	1,075	1,067	1,061	1,055	1,049	1,044	1,040	1,036	1,032	1,029	1,026	1,023

b. Incurred

Model based on data to 31 Dec	Model age j to age j+1 factor where j=																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2006	2,214	1,246	1,136	1,118	1,091	0,992	0,890	1,033	1,023	1,017	1,011	1,005	0,999	0,993	0,987	0,981	0,975	0,969	0,963	0,958	0,952	0,946
2007	2,234	1,263	1,143	1,101	1,092	0,988	0,906	1,045	1,028	1,023	1,018	1,013	1,008	1,003	0,998	0,993	0,988	0,983	0,978	0,973	0,968	0,963
2008	2,278	1,277	1,171	1,126	1,102	1,012	0,924	1,070	1,053	1,050	1,048	1,046	1,044	1,042	1,040	1,038	1,036	1,034	1,032	1,030	1,028	1,026
2009	2,315	1,303	1,202	1,151	1,112	1,053	0,956	1,089	1,064	1,060	1,056	1,053	1,049	1,045	1,042	1,038	1,034	1,031	1,027	1,024	1,020	1,016
2010	2,310	1,286	1,207	1,154	1,117	1,041	0,972	1,086	1,058	1,054	1,051	1,047	1,043	1,040	1,036	1,032	1,029	1,025	1,022	1,018	1,014	1,011
2011		1,297	1,203	1,155	1,116	1,011	0,964	1,065	1,045	1,042	1,038	1,034	1,031	1,027	1,023	1,020	1,016	1,013	1,009	1,006	1,002	0,999
2012			1,180	1,138	1,112	0,923	0,961	1,048	1,020	1,013	1,006	0,999	0,992	0,985	0,978	0,971	0,964	0,958	0,951	0,944	0,938	0,931
2013				1,145	1,097	0,897	0,965	1,053	1,019	1,016	1,013	1,010	1,007	1,004	1,002	0,999	0,996	0,993	0,990	0,988	0,985	0,982
2014					1,091	0,903	0,973	1,049	1,020	1,020	1,019	1,018	1,018	1,017	1,016	1,015	1,015	1,014	1,013	1,013	1,012	1,011
2015						0,975	0,986	1,055	1,023	1,023	1,023	1,022	1,022	1,021	1,021	1,021	1,020	1,020	1,019	1,019	1,018	1,018
2016								1,005	1,054	1,025	1,024	1,023	1,022	1,021	1,020	1,019	1,018	1,017	1,016	1,015	1,014	1,013

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.1.1.3. Forecasts of paid

2016

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 604 122	24 185 065	-
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	56 471 294	57 004 109	58 342 889	1 338 779
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	66 459 669	69 101 217	70 904 425	72 569 663	3 468 446
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 619 839	73 696 431	75 619 553	77 395 529	5 775 689
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	71 161 106	73 453 651	75 583 414	77 555 777	79 377 226	8 216 121
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758	78 328 704	80 852 163	83 196 443	85 367 469	87 372 381	11 750 623
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660	77 703 975	80 485 456	83 078 398	85 487 226	87 718 031	89 778 148	15 046 688
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298	91 535 263	95 175 911	98 582 815	101 758 786	104 709 246	107 441 653	109 964 992	22 303 694
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933	92 041 905	96 109 460	99 932 038	103 509 192	106 843 872	109 941 773	112 810 724	115 460 158	27 726 226
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	78 697 051	82 990 647	87 065 711	90 913 356	94 529 269	97 913 026	101 067 419	103 997 833	106 711 676	109 217 870	30 520 820
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	86 695 449	91 950 979	96 967 691	101 729 066	106 224 719	110 449 614	114 403 253	118 088 900	121 512 846	124 683 746	127 612 027	40 916 578
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	74 957 466	80 006 318	84 856 349	89 485 988	93 879 961	98 028 775	101 927 692	105 576 281	108 977 556	112 137 321	115 063 565	117 765 910	42 808 444
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	68 279 969	71 055 378	76 373 180	81 517 389	86 459 023	91 176 101	95 653 093	99 880 235	103 852 790	107 570 290	111 035 804	114 255 248	117 236 760	119 990 143	48 934 765
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	62 098 797	67 262 675	72 296 630	77 166 259	81 844 124	86 309 421	90 547 445	94 548 956	98 309 469	101 828 541	105 109 077	108 156 678	110 979 046	113 585 663	51 486 666
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	32 541 630	39 719 013	47 251 511	52 468 999	59 419 676	64 360 769	69 177 546	73 837 084	78 313 133	82 585 784	86 640 968	90 469 842	94 068 115	97 435 365	100 574 369	103 490 488	106 191 091	108 685 059	56 216 060
2009	372 907	985 838	4 120 617	9 610 390	16 686 438	23 337 975	29 405 359	34 460 997	41 498 818	46 996 252	50 904 265	54 713 953	58 399 279	61 939 479	65 318 806	68 526 136	71 554 471	74 400 420	77 063 647	79 546 351	81 852 770	83 988 733	85 961 264	51 500 267
2010	66 268	136 381	420 236	973 357	2 375 480	3 809 040	4 463 242	5 457 388	6 571 927	7 442 524	8 061 413	8 664 731	9 248 355	9 808 996	10 344 160	10 852 086	11 331 666	11 782 363	12 204 122	12 597 294	12 962 548	13 300 808	13 613 186	9 149 944
Total																							427 159 611	

2015

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 604 122	24 253 159	649 037	
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	56 471 294	57 004 109	58 206 241	59 806 725	3 335 431
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	66 459 669	68 741 028	70 852 934	72 801 161	74 801 161	6 341 492
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 619 839	73 696 431	75 495 401	77 814 820	79 954 475	9 660 656
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	72 323 875	75 097 797	77 675 677	80 062 079	82 263 527	12 911 644	
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	77 438 880	80 757 431	83 854 814	86 733 296	89 397 972	91 856 127	17 955 700	
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	76 981 558	80 667 539	84 124 451	87 350 974	90 349 468	93 125 243	95 685 885	22 613 601	
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	91 386 903	96 275 985	100 885 809	105 209 151	109 244 360	112 994 388	116 465 874	119 668 309	33 435 954	
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	93 154 085	98 722 380	104 003 901	108 983 748	113 654 117	118 013 226	122 064 263	125 814 399	129 273 888	41 951 852	
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	81 269 347	86 697 150	91 879 481	96 974 916	101 429 588	105 776 232	109 833 191	113 603 432	117 093 629	120 313 325	44 687 430	
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	90 596 903	97 357 540	103 859 838	110 068 071	115 956 572	121 508 730	126 715 842	131 575 922	136 092 525	140 273 647	144 130 718	60 506 252	
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	78 283 047	84 810 127	91 138 936	97 225 908	103 037 597	108 549 976	113 747 496	118 622 010	123 171 657	127 399 768	131 313 825	134 924 530	63 312 812	
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	68 279 969	75 387 168	82 410 216	89 281 412	95 943 883	102 351 766	108 469 854	114 272 852	119 744 391	124 875 894	129 665 404	134 116 425	138 236 836	142 037 902	73 757 933	
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	67 340 706	74 350 138	81 276 577	88 053 252	94 624 073	100 943 809	106 977 736	112 700 908	118 097 180	123 158 094	127 881 720	132 271 512	136 335 242	140 084 021	82 333 711	
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	32 541 63																			

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2014

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 899 522	24 547 327	1 358 036
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	57 573 398	59 336 729	60 945 073	5 297 491
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	68 161 708	70 520 606	72 680 478	74 650 509	9 053 915
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	67 420 008	70 056 426	72 480 895	74 700 806	76 725 599	12 158 534
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 460 928	72 530 111	75 366 356	77 974 588	80 362 757	82 541 019	16 383 179
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 850 925	77 538 109	80 964 188	84 130 242	87 041 769	89 707 644	92 139 202	22 232 096
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	74 390 194	78 586 927	82 510 567	86 156 358	89 525 449	92 623 690	95 460 525	98 048 017	28 115 721
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	84 282 970	89 655 665	94 713 601	99 442 404	103 836 341	107 896 796	111 630 822	115 049 798	118 168 265	39 548 239
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	89 447 355	95 890 183	102 002 790	107 757 291	113 137 332	118 136 389	122 756 039	127 004 304	130 894 132	134 442 065	51 726 823
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 657 655	81 815 357	87 708 458	93 299 514	98 563 018	103 484 013	108 056 531	112 282 015	116 167 801	119 725 734	122 970 943	53 685 155
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	87 328 393	95 359 548	103 120 767	110 548 482	117 595 496	124 229 661	130 432 125	136 195 365	141 521 200	146 418 878	150 903 327	154 993 616	75 885 738
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 478 112	78 905 778	86 162 347	93 175 016	99 886 345	106 253 691	112 248 007	117 852 257	123 059 647	127 871 818	132 297 127	136 349 061	140 044 852	76 077 662
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	70 989 587	79 325 067	87 568 151	95 621 355	103 403 883	110 851 991	117 918 352	124 570 731	130 790 223	136 569 286	141 909 744	146 820 868	151 317 629	155 419 148	95 133 116
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	59 105 061	69 598 940	77 771 133	85 852 739	93 748 186	101 378 258	108 680 961	115 608 396	122 130 459	128 228 115	133 893 969	139 129 810	143 944 728	148 353 400	152 374 572	106 311 120
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	32 541 630	39 719 013	51 286 912	65 551 250	77 189 625	86 253 103	95 216 116	103 972 665	112 434 898	120 533 503	128 217 021	135 450 401	142 213 086	148 496 877	154 303 756	159 643 804	164 533 300	168 993 035	129 274 022
2009	372 907	985 838	4 120 617	9 610 390	16 686 438	23 337 975	31 686 773	40 915 335	52 295 045	61 579 831	68 810 433	75 960 886	82 946 628	89 697 573	96 158 424	102 288 131	108 058 730	113 453 820	118 466 861	123 099 435	127 359 583	131 260 293	134 818 151	111 480 176
2010	66 268	136 381	420 236	973 357	2 375 480	3 460 796	4 698 841	6 067 348	7 754 848	9 131 692	10 203 921	11 264 263	12 300 181	13 301 281	14 259 363	15 168 339	16 024 063	16 824 102	17 567 488	18 254 454	18 886 192	19 464 630	19 992 226	17 616 746
Total																							851 157 769	

2013

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 529 913	24 100 534	24 600 247	1 719 320
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	52 826 494	54 324 844	55 642 270	56 795 985	5 665 679
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	64 180 223	66 309 326	68 190 098	69 843 769	71 291 945	9 508 892
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	65 752 289	68 303 464	70 569 351	72 570 953	74 330 863	75 872 078	12 974 091
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	67 171 653	70 219 893	72 944 410	75 364 255	77 501 858	79 381 347	81 027 280	17 241 133
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	73 022 114	76 897 826	80 387 440	83 506 455	86 276 683	88 723 802	90 875 433	92 759 691	24 005 626
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	72 126 829	76 604 249	80 670 086	84 330 884	87 602 905	90 509 028	93 076 191	95 333 372	97 310 663	30 065 506
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	80 790 009	86 655 746	92 035 078	96 919 920	101 318 133	105 249 255	108 740 775	111 825 057	114 536 914	116 911 781	42 445 302
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	87 698 538	95 145 706	102 053 734	108 388 928	114 141 765	119 321 504	123 951 153	128 063 086	131 695 418	134 889 149	137 686 010	57 910 683
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	70 358 149	77 346 056	83 914 113	90 006 675	95 594 023	100 667 759	105 236 049	109 319 185	112 945 720	116 149 269	118 965 992	121 432 694	58 396 945
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	82 352 036	91 918 268	101 047 505	109 628 238	117 587 766	124 887 267	131 515 768	137 483 936	142 818 284	147 556 111	151 741 336	155 421 199	158 643 782	86 142 033
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 479 353	72 103 833	80 479 606	88 472 766	95 985 680	102 954 694	109 345 817	115 149 441	120 374 908	125 045 429	129 193 663	132 858 062	136 079 989	138 901 541	85 325 743
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	61 872 928	73 310 219	83 270 347	92 943 253	102 174 290	110 850 707	118 898 993	126 279 891	132 982 306	139 017 026	144 410 857	149 201 516	153 433 411	157 154 308	160 412 826	112 318 599
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	44 481 964	57 225 775	67 804 033	77 016 076	85 962 468	94 500 181	102 524 929	109 968 724	116 795 257	122 994 267	128 575 731	133 564 442	137 995 285	141 909 330	145 350 758	148 364 535	112 842 059
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	32 541 630	46 420																	

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2012

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	23 604 954	24 492 257	25 293 227	26 012 861	3 385 554
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	53 110 873	55 405 609	57 488 288	59 368 329	61 057 454	10 459 416
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	62 353 848	65 450 506	68 278 396	70 844 959	73 161 803	75 243 375	16 256 696
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	60 712 376	64 178 053	67 365 307	70 275 928	72 917 578	75 302 203	77 444 673	20 470 555
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 981	65 111 803	69 384 001	73 344 685	76 987 179	80 313 527	83 332 487	86 057 711	88 506 193	27 960 590
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	67 994 289	73 122 251	77 920 040	82 367 991	86 458 606	90 194 182	93 584 553	96 645 050	99 394 760	36 824 489
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	66 923 736	72 725 143	78 209 894	83 341 510	88 098 928	92 474 156	96 469 644	100 095 907	103 369 345	106 310 372	45 450 695
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	77 539 714	85 265 773	92 657 193	99 645 170	106 183 215	112 244 528	117 818 892	122 909 437	127 529 564	131 700 166	135 447 250	65 875 503
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	80 421 730	89 632 332	98 563 300	107 107 440	115 185 220	122 742 897	129 749 496	136 193 203	142 077 639	147 418 292	152 239 315	156 570 772	85 504 383
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	65 779 590	74 438 964	82 964 367	91 230 939	99 139 460	106 616 314	113 611 758	120 097 119	126 061 464	131 508 142	136 451 491	140 913 867	144 923 096	87 788 683
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	75 277 554	86 668 022	98 077 197	109 309 858	120 201 496	130 621 383	140 472 526	149 689 387	158 234 186	166 092 519	173 268 800	179 781 919	185 661 331	190 943 698	129 216 148
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 230 799	64 915 655	74 738 234	84 576 945	94 263 439	103 655 851	112 641 448	121 136 589	129 084 755	136 453 369	143 230 009	149 418 480	155 035 073	160 105 189	164 660 442	123 605 133
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	51 156 278	66 327 342	80 887 060	93 126 320	105 385 680	117 455 372	129 158 629	140 354 981	150 940 209	160 843 888	170 025 426	178 469 344	186 180 385	193 178 846	199 496 378	205 172 374	165 523 625
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	32 864 903	42 403 509	54 978 825	67 047 395	77 192 534	87 354 334	97 358 919	107 059 765	116 340 436	125 114 546	133 323 719	140 934 308	147 933 483	154 325 176	160 126 210	165 362 820	170 067 662	146 773 474
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	31 849 869	44 935 794	57 977 817	75 171 898	91 673 111	105 544 441	119 438 550	133 117 701	146 381 553	159 070 905	171 067 641	182 291 947	192 697 816	202 267 706	211 006 991	218 938 676	226 098 632	232 531 507	210 506 241
2009	372 907	985 838	4 120 617	9 610 390	16 508 800	23 872 726	33 681 140	43 456 647	56 344 286	68 712 592	79 109 697	89 523 877	99 776 937	109 718 714	119 229 882	128 221 906	136 634 963	144 434 570	151 607 578	158 158 015	164 103 124	169 469 792	174 291 484	164 681 093
2010	66 268	136 381	420 236	980 983	1 685 141	2 436 815	3 438 012	4 435 850	5 751 359	7 013 858	8 075 145	9 138 176	10 184 760	11 199 570	12 170 425	13 088 288	13 947 054	14 743 201	15 475 388	16 144 025	16 750 874	17 298 678	17 790 854	17 370 618
Total																								1 357 652 898

2011

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	28 297 223	28 557 114	28 718 524	28 779 764	28 740 190	8 495 318
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	63 490 108	64 298 266	64 888 803	65 255 566	65 394 718	65 304 796	16 331 108
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	74 187 009	75 395 210	76 354 907	77 056 176	77 491 712	77 656 956	77 550 173	23 384 079
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	78 969 054	80 537 014	81 848 631	82 890 473	83 651 766	84 124 582	84 303 970	84 188 047	30 347 115
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	84 231 914	86 206 092	87 917 747	89 349 565	90 486 886	91 317 948	91 834 094	92 029 921	91 903 375	34 857 394
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	85 547 435	87 859 955	89 919 165	91 704 544	93 198 034	94 384 341	95 251 198	95 789 576	95 993 838	95 861 841	38 603 409
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	82 898 706	85 438 661	87 748 241	89 804 832	91 587 941	93 079 532	94 264 331	95 130 086	95 667 779	95 871 782	95 739 952	39 709 703
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	99 961 140	103 385 726	106 553 388	109 433 741	111 998 585	114 222 359	116 082 572	117 560 173	118 639 885	119 310 460	119 564 879	119 400 470	58 228 078
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	104 257 817	108 208 332	111 915 459	115 344 466	118 462 460	121 238 913	123 646 158	125 659 845	127 259 355	128 428 147	129 154 048	129 429 457	129 251 484	68 081 744
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	101 684 886	105 908 589	109 921 654	113 687 479	117 170 779	120 338 142	123 158 557	125 603 916	127 649 488	129 274 323	130 461 622	131 199 016	131 478 785	131 297 994	82 188 810
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	108 474 995	113 377 561	118 086 944	122 561 659	126 760 323	130 644 166	134 175 742	137 320 474	140 047 024	142 327 813	144 139 488	145 463 313	146 285 499	146 597 439	146 395 859	98 165 248
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	82 392 249	87 757 369	91 723 595	95 533 533	99 153 469	102 550 385	105 692 453	108 549 533	111 093 653	113 299 460	115 144 642	116 610 305	117 681 293	118 346 450	118 598 813	118 435 732	88 752 217
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	105 275 941	101 512 338	108 122 498	113 009 133	117 703 212	122 163 197	126 348 407	130 219 628	133 739 728	136 874 241	139 591 931	141 865 309	143 671 097	144 990 620	145 810 134	146 121 061	145 920 136	117 136 877
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	94 008 567	95 080 133	91 681 029	97 651 005	102 064 377	106 303 842	110 331 885	114 111 763	117 608 063	120 787 247	123 618 187	126 072 673	128 125 878	129 756 778	130 948 508	131 688 65			

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2010

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 667 763	21 145 666	21 522 160	21 817 222	22 047 534	22 226 747	-
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 507 051	49 963 717	51 119 033	52 029 196	52 742 499	53 299 273	53 732 515	433 242
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 534 374	56 661 214	58 362 749	59 712 277	60 775 440	61 608 652	62 259 021	62 765 092	1 156 439
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 319 528	56 020 126	58 204 910	59 952 803	61 339 097	62 431 226	63 287 138	63 955 226	64 475 084	2 043 858
1998	373 884	1 380 324	2 443 138	3 954 886	6 388 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	55 030 064	58 649 851	61 620 426	64 023 622	65 946 250	67 471 132	68 672 440	69 613 917	70 348 794	70 920 622	3 449 490
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	55 274 396	59 996 291	63 942 748	67 181 405	69 801 479	71 897 617	73 500 112	74 869 833	75 896 275	76 697 470	77 320 904	5 423 287
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	54 117 463	60 121 439	65 257 399	69 549 923	73 072 580	75 922 409	78 202 359	80 010 639	81 435 211	82 551 661	83 423 114	84 101 216	8 178 807
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	63 645 310	72 815 477	80 893 874	87 804 349	93 579 975	98 319 738	102 154 206	105 221 895	107 654 951	109 571 724	111 073 917	112 246 464	113 158 856	14 839 118
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	62 721 215	74 457 606	85 185 633	94 636 419	102 720 870	109 477 680	115 022 651	119 508 532	123 097 372	125 943 764	128 186 165	129 943 556	131 315 300	132 382 692	22 905 012
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	51 745 107	64 650 279	76 747 636	87 805 616	97 547 071	105 880 169	112 844 792	118 560 305	123 184 155	126 883 374	129 817 310	132 128 678	133 940 120	135 354 053	136 454 274	30 574 105
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	49 872 912	67 007 913	83 719 611	99 385 220	113 704 877	126 319 684	137 110 724	146 129 641	153 531 010	159 518 717	164 309 062	168 108 395	171 101 528	173 447 276	175 278 264	176 703 008	50 383 324
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 557 027	36 508 335	49 051 623	61 285 043	72 752 697	83 235 077	92 469 461	100 368 797	106 970 891	112 388 895	116 772 061	120 278 724	123 059 940	125 250 995	126 968 146	128 308 480	129 351 431	46 116 354
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	33 654 960	46 421 815	57 339 432	77 039 730	96 253 352	114 264 274	130 727 740	145 231 122	157 637 698	168 006 846	176 516 280	183 400 413	188 907 925	193 276 060	196 717 298	199 414 229	201 519 336	203 157 380	88 893 106
2007	670 926	2 512 008	4 701 870	9 787 798	16 275 893	24 544 687	33 855 601	41 817 860	56 185 360	70 197 926	83 333 358	95 340 225	105 917 595	114 965 757	122 528 015	128 733 977	133 754 600	137 771 249	140 956 947	143 466 654	145 433 536	146 968 798	148 163 430	77 965 504
2008	437 577	1 458 651	4 020 558	8 834 186	14 690 154	22 153 330	30 557 094	37 743 600	50 711 293	63 358 633	75 214 297	86 051 350	95 598 181	103 764 792	110 590 269	116 191 593	120 723 063	124 348 375	127 223 694	129 488 884	131 264 135	132 649 819	133 728 059	83 016 766
2009	372 907	985 838	2 109 219	4 634 488	7 706 578	11 621 823	16 030 508	19 800 610	26 603 570	33 238 471	39 458 051	45 143 261	50 151 608	54 435 881	58 016 584	60 955 085	63 332 332	65 234 201	66 742 618	67 930 955	68 862 267	69 589 208	70 154 862	50 354 252
2010	66 268	203 789	436 009	958 023	1 593 073	2 402 417	3 313 762	4 093 103	5 499 383	6 870 924	8 156 610	9 331 834	10 367 140	11 252 767	11 992 956	12 600 391	13 091 806	13 484 953	13 796 767	14 042 415	14 234 932	14 385 202	14 502 132	11 188 370
Total																							496 921 034	

2009

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	19 549 493	19 885 056	20 123 983	20 293 241	20 412 718	20 496 844	20 555 975	1 474 386
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 539 700	47 680 908	48 499 343	49 082 081	49 494 899	49 786 301	49 991 484	50 135 704	5 171 125
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	49 155 033	50 876 947	52 124 509	53 019 217	53 656 263	54 107 553	54 426 113	54 650 418	54 808 079	7 995 688
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 192 768	52 704 575	54 550 830	55 888 481	56 847 797	57 530 844	58 014 723	58 356 286	58 596 789	58 765 834	11 921 950
1998	373 884	1 380 324	2 443 138	3 954 886	6 388 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	49 459 611	52 995 494	55 647 559	57 596 908	59 009 252	60 022 135	60 743 324	61 254 221	61 614 858	61 868 790	62 047 274	17 170 849
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	50 908 842	56 108 112	60 119 298	63 127 862	65 339 247	66 941 442	68 090 480	68 908 613	69 488 187	69 897 301	70 185 367	70 387 844	25 960 840
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	49 740 636	56 997 725	62 818 846	67 309 786	70 678 184	73 154 059	74 947 882	76 234 350	77 150 334	77 799 227	78 257 273	78 579 793	78 806 487	37 644 999
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	50 519 564	61 049 183	69 956 174	77 100 729	82 612 685	86 746 889	89 785 655	91 987 305	93 566 251	94 690 485	95 486 904	96 049 087	96 444 931	96 723 164	55 061 326
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 000 866	60 631 553	73 268 779	83 958 592	92 533 201	99 148 428	104 110 135	107 757 139	110 399 471	112 294 459	113 643 719	114 599 549	115 274 258	115 749 335	116 083 259	78 623 239
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	35 561 947	47 467 356	57 559 393	69 556 300	79 704 467	87 844 606	94 124 645	98 834 945	102 297 158	104 805 605	106 604 575	107 885 469	108 792 868	109 433 390	109 884 395	110 201 400	81 211 113
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	36 355 406	44 596 627	59 526 662	72 182 628	87 227 406	99 953 762	110 161 942	118 037 454	123 944 428	128 286 233	131 431 963	133 687 969	135 294 281	136 432 209	137 235 458	137 801 043	138 198 584	110 649 775
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	18 761 542	24 759 090	30 371 602	40 539 391	49 158 473	59 404 405	68 071 424	75 023 492	80 386 945	84 409 767	87 366 662	89 508 996	91 045 402	92 139 347	92 914 309	93 461 345	93 846 525	94 117 262	81 235 525
2006	526 864	1 841 235	5 043 862	10 860 470	17 195 746	25 044 658	33 050 745	40 542 850	54 115 764	65 621 319	79 298 546	90 868 092	100 148 362	107 307 999	112 678 037	116 625 178	119 484 964	121 535 903	122 996 202	124 030 694	124 760 930	125 275 104	125 636 509	114 776 039
2007	670 926	2 512 008	4 701 870	10 284 225	16 283 358	23 715 815	31 297 108	38 391 690	51 244 439	62 139 522	75 091 150	86 046 729	94 834 597	101 614 352	106 699 462	110 437 171	113 145 220	115 087 338	116 470 156	117 449 759	118 141 249	118 628 141	118 970 370	114 268 501
2008	437 577	1 458 651	3 106 804	6 795 397	10 759 380	15 670 446	20 679 856	25 367 667	33 860 241	41 0														

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2008

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	18 652 186	18 882 864	19 027 654	19 118 112	19 174 462	19 209 503	19 231 267	19 244 777	957 376
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	43 327 502	44 191 772	44 738 308	45 081 352	45 295 669	45 429 178	45 512 197	45 563 763	45 595 770	3 618 801
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 877 025	48 385 208	49 350 366	49 960 700	50 343 788	50 583 123	50 732 216	50 824 927	50 882 512	50 918 256	6 353 781
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	45 929 500	48 312 885	49 867 265	50 861 986	51 491 015	51 885 836	52 132 503	52 286 163	52 381 713	52 441 062	52 477 900	10 095 672
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	41 784 470	45 281 712	47 631 481	49 163 938	50 144 630	50 764 787	51 154 040	51 397 227	51 548 720	51 642 922	51 701 435	51 737 753	14 923 094
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 629 855	50 654 681	54 894 334	57 742 924	59 600 698	60 789 576	61 541 383	62 013 269	62 308 081	62 491 733	62 605 934	62 676 867	62 720 896	26 070 991
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	37 817 188	46 051 297	52 268 011	56 642 696	59 582 012	61 498 955	62 725 698	63 501 450	63 988 365	64 292 567	64 482 069	64 599 906	64 673 099	64 718 530	32 972 486
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	40 068 439	47 731 166	58 123 890	65 970 349	71 491 880	75 201 754	77 621 235	79 169 575	80 148 694	80 763 256	81 147 206	81 386 387	81 535 116	81 627 497	81 684 837	51 066 763
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	40 571 641	53 094 205	63 247 993	77 019 267	87 416 516	94 733 030	99 648 939	102 854 963	104 906 650	106 204 070	107 018 418	107 527 186	107 844 121	108 041 200	108 163 613	108 239 594	75 880 688
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	29 487 243	36 971 146	48 382 406	57 635 104	70 184 258	79 658 812	86 326 028	90 805 679	93 727 187	95 596 799	96 779 080	97 521 160	97 984 778	98 273 587	98 453 177	98 564 726	98 633 964	76 299 372
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	28 488 984	37 612 579	47 158 703	61 714 384	73 516 703	89 523 829	101 609 137	110 113 533	115 827 571	119 554 113	121 938 904	123 446 968	124 393 532	124 984 901	125 353 293	125 582 369	125 724 656	125 812 973	106 325 568
2005	509 627	1 351 807	2 936 518	8 051 538	12 782 431	18 686 863	24 671 329	30 932 946	40 480 497	48 222 027	58 721 628	66 648 779	72 227 093	75 975 119	78 419 481	79 983 744	80 972 932	81 593 814	81 981 713	82 223 353	82 373 612	82 466 943	82 524 873	74 473 335
2006	526 864	1 841 235	5 043 862	10 697 650	16 983 336	24 828 240	32 779 482	41 098 959	53 784 281	64 070 040	78 020 302	88 552 685	95 964 294	100 944 096	104 191 790	106 270 143	107 584 425	108 409 358	108 924 738	109 245 793	109 445 434	109 569 437	109 646 406	104 602 544
2007	670 926	2 512 008	5 432 521	11 521 967	18 292 002	26 741 403	35 305 335	44 265 877	57 928 679	69 007 016	84 032 228	95 376 194	103 358 911	108 722 437	112 220 384	114 458 887	115 874 442	116 762 941	117 318 034	117 663 828	118 012 411	118 095 311	115 583 303	
2008	437 577	1 391 575	3 009 449	6 382 813	10 133 203	14 813 909	19 558 062	24 521 925	32 090 694	38 227 750	46 551 252	52 835 458	57 257 636	60 228 863	62 166 618	63 406 679	64 190 853	64 683 054	64 990 558	65 182 117	65 301 234	65 375 221	65 421 146	64 983 568
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																							764 207 344	

2007

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 229 605	18 623 599	18 881 205	19 048 353	19 156 275	19 225 736	19 270 353	19 298 974	19 317 318	1 683 219
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	42 139 837	43 562 904	44 504 424	45 120 019	45 519 450	45 777 349	45 943 340	46 049 959	46 118 353	46 162 191	6 134 450
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	43 786 080	46 096 487	47 653 171	48 683 093	49 356 489	49 793 424	50 075 537	50 257 113	50 373 743	50 448 559	50 496 513	10 045 482
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	43 555 775	47 146 798	49 634 537	51 310 701	52 419 673	53 144 754	53 615 225	53 918 992	54 114 504	54 240 086	54 320 645	54 372 279	15 787 147
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 603 912	41 319 329	44 725 965	47 085 967	48 676 065	49 728 095	50 415 946	50 862 259	51 150 429	51 335 902	51 455 036	51 531 458	51 580 441	21 109 824
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	38 913 859	46 746 657	52 768 690	57 119 288	60 133 233	62 163 939	63 507 480	64 385 931	64 955 916	65 323 935	65 560 802	65 712 947	65 810 546	65 873 101	34 090 716
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 083 171	38 057 753	45 718 229	51 607 777	55 862 661	58 810 299	60 796 330	62 110 313	62 969 438	63 526 883	63 886 806	64 118 462	64 267 260	64 362 711	64 423 891	40 501 797
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	32 426 956	42 133 963	51 588 170	61 972 124	69 955 544	75 723 138	79 718 730	82 410 841	84 191 976	85 356 539	86 112 169	86 600 054	86 914 069	87 115 767	87 245 154	87 328 084	62 381 438
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	31 658 215	41 151 003	53 469 554	65 467 292	78 644 913	88 776 167	96 095 457	101 166 011	104 582 399	106 842 725	108 320 599	109 279 521	109 898 665	110 297 161	110 553 124	110 717 320	110 822 562	86 956 388
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	21 125 691	28 022 995	36 425 754	47 329 801	57 949 875	69 614 347	78 582 260	85 061 097	89 549 414	92 573 508	94 574 287	95 882 461	96 731 273	97 279 322	97 632 061	97 858 632	98 003 974	98 097 131	83 178 582
2004	812 119	2 246 467	5 061 713	11 334 302	17 448 635	24 708 465	32 775 505	42 603 316	55 356 616	67 777 782	81 420 471	91 909 281	99 486 885	104 736 390	108 273 350	110 613 448	112 143 480	113 136 245	113 777 239	114 189 800	114 454 796	114 624 787	114 733 743	103 399 441
2005	509 627	1 351 807	2 936 518	5 913 718	9 103 897	12 891 743	17 100 754	22 228 455	28 882 542	35 363 336	42 481 465	47 954 045	51 907 691	54 646 642	56 492 065	57 713 021	58 511 321	59 029 300	59 363 742	59 578 997	59 717 260	59 805 953	59 862 801	56 926 284
2006	526 864	1 841 235	3 852 260	7 757 891	11 942 915	16 911 988	22 433 565	29 160 321	37 889 461	46 391 268	55 729 160	62 908 344	68 094 921	71 688 004	74 108 916	75 710 623	76 757 870	77 437 380	77 876 115	78 158 497	78 339 877	78 456 229	78 530 805	76 689 571
2007	670 926	2 145 907	4 489 702	9 041 604	13 919 133	19 710 448	26 145 691	33 985 536	44 159 105	54 067 723	64 950 775	73 317 912	79 362 722	83 550 360	86 371 865	88 238 609	89 459 147	90 251 096	90 762 430	91 091 538	91 302 931	91 438 536	91 525 453	90 854 526
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																							689 738 866	

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2006

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 241 489	17 517 887	17 672 343	17 758 043	17 805 406	17 831 525	17 845 912	17 853 831	17 858 189	17 860 586	1 107 406
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	38 940 688	40 075 702	40 718 155	41 077 169	41 276 368	41 386 458	41 447 169	41 480 610	41 499 016	41 509 145	41 514 717	4 533 831
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	38 429 442	40 466 011	41 645 484	42 313 102	42 686 179	42 893 180	43 007 583	43 070 672	43 105 422	43 124 550	43 135 075	43 140 865	8 088 845
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	37 651 717	41 279 631	43 467 246	44 734 196	45 451 330	45 852 076	46 074 430	46 197 318	46 265 086	46 302 414	46 322 960	46 334 266	46 340 486	14 301 655
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	31 420 155	36 924 655	40 482 514	42 627 885	43 870 371	44 573 656	44 966 664	45 184 724	45 305 239	45 371 699	45 408 306	45 428 455	45 439 543	45 445 642	19 677 426
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 876 077	38 867 699	45 676 936	50 078 117	52 732 007	54 269 001	55 138 986	55 625 149	55 894 896	56 043 977	56 126 190	56 171 473	56 196 399	56 210 115	56 217 660	31 950 602
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	22 713 748	29 835 721	36 379 816	42 753 200	46 872 666	49 356 684	50 795 295	51 609 594	52 064 638	52 317 119	52 456 657	52 533 608	52 575 993	52 599 323	52 612 161	52 619 223	34 925 736
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	25 452 404	32 674 141	42 919 230	52 333 031	61 501 260	67 427 187	71 000 492	73 069 961	74 241 345	74 895 934	75 259 133	75 459 860	75 570 555	75 631 527	75 665 088	75 683 555	75 693 714	56 502 618
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	22 750 367	30 172 926	38 734 040	50 879 231	62 038 959	72 907 571	79 932 548	84 168 574	86 621 857	88 010 491	88 786 484	89 217 043	89 454 998	89 586 223	89 658 503	89 698 288	89 720 180	89 732 224	73 501 475
2003	769 845	2 212 022	3 772 127	7 521 103	10 996 759	15 413 971	20 442 950	26 243 329	34 472 015	42 033 024	49 396 794	54 156 400	57 026 419	58 688 583	59 629 419	60 155 174	60 446 889	60 608 110	60 697 018	60 745 990	60 772 946	60 787 778	60 795 938	53 274 835
2004	812 119	2 246 467	5 061 713	10 008 078	14 633 016	20 510 851	27 202 744	34 921 113	45 870 748	55 931 928	65 730 649	72 064 096	75 883 134	78 094 919	79 346 858	80 046 463	80 434 638	80 649 170	80 767 477	80 832 641	80 868 510	80 888 247	80 899 105	75 837 392
2005	509 627	1 351 807	2 838 342	5 612 002	8 205 424	11 501 404	15 253 864	19 581 919	25 721 896	31 363 675	36 858 281	40 409 744	42 551 259	43 791 511	44 493 533	44 885 834	45 103 502	45 223 801	45 290 141	45 326 682	45 346 795	45 357 863	45 363 951	44 012 145
2006	526 864	1 705 249	3 580 452	7 079 312	10 350 807	14 508 551	19 242 126	24 701 790	32 447 121	39 563 995	46 495 215	50 975 241	53 676 675	55 241 203	56 126 774	56 621 646	56 896 226	57 047 977	57 131 662	57 177 757	57 203 130	57 217 091	57 224 771	56 697 907
2007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																							474 411 874	

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.1.1.4. Forecasts of incurred

2016

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 406 914	25 439 358	1 254 293
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	64 619 050	64 916 166	65 738 830	8 734 270
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	77 469 194	78 521 609	79 516 691	10 415 474
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	82 166 234	83 282 458	84 337 873	12 718 033
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463	85 421 992	86 660 440	87 837 717	88 950 859	17 789 754
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	90 565 887	91 961 676	93 294 936	94 562 342	95 760 704	20 138 946
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	86 602 290	88 016 207	89 372 700	90 668 425	91 900 150	93 064 775	18 333 115
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	106 413 912	108 248 708	110 016 037	111 711 589	113 331 182	114 870 780	116 326 505	28 665 207
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	107 450 813	109 401 950	111 288 266	113 105 220	114 848 382	116 513 453	118 096 281	119 592 882	31 858 949
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	97 624 212	99 486 451	101 292 967	103 039 468	104 721 748	106 335 705	107 877 359	109 342 867	110 728 538	32 031 487
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	108 231 713	110 395 652	112 501 514	114 544 363	116 519 345	118 421 705	120 246 804	121 990 141	123 647 370	125 214 318	38 518 869
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	95 607 196	97 606 572	99 558 076	101 457 205	103 299 570	105 080 604	106 796 209	108 442 137	110 014 330	111 508 868	112 921 989	37 964 523
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	95 701 614	97 790 976	99 836 020	101 832 099	103 774 606	105 658 988	107 480 768	109 235 559	110 919 082	112 527 186	114 055 861	115 501 259	44 445 881
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 618 291	94 810 921	96 968 109	99 085 121	101 157 229	103 179 724	105 147 937	107 057 257	108 903 146	110 681 159	112 386 962	114 016 347	115 565 253	117 029 778	54 930 981
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 094 805	83 207 042	79 449 123	84 834 047	89 292 714	91 488 954	93 654 848	95 785 733	97 876 932	99 923 773	101 921 607	103 865 821	105 751 860	107 575 241	109 331 574	111 016 577	112 626 094	114 156 113	115 602 781	63 133 782
2009	17 193 212	38 002 433	50 937 746	48 829 445	58 044 114	58 744 756	62 895 252	69 006 711	72 763 728	74 553 422	76 314 388	78 054 824	79 758 920	81 426 871	83 054 885	84 639 205	86 176 119	87 661 974	89 093 192	90 466 284	91 777 863	93 024 660	94 203 536	59 742 539
2010	1 136 121	2 133 857	1 612 655	4 909 603	6 539 149	6 426 980	7 408 558	7 811 912	8 004 053	8 193 540	8 379 964	8 562 915	8 741 986	8 916 770	9 086 863	9 251 866	9 411 387	9 565 042	9 712 458	9 853 269	9 987 125	10 113 689	5 650 447	
Total																							486 327 000	

2015

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 406 914	25 865 888	2 261 766
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	64 619 050	65 812 715	67 001 619	10 530 325
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	78 876 306	80 333 336	81 784 553	15 324 885
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	82 699 611	84 260 970	85 817 468	87 367 756	17 073 937
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	83 659 722	85 273 318	86 883 269	88 488 206	90 086 741	20 734 859
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	90 321 494	92 100 420	93 876 817	95 649 201	97 416 066	99 175 882	25 275 455
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	86 456 259	88 194 335	89 931 365	91 665 926	93 396 568	95 121 822	96 840 193
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 823 601	106 973 714	109 124 263	111 273 519	113 419 719	115 561 071	117 695 754	119 821 922	33 589 567
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	104 643 900	106 833 060	109 024 391	111 216 166	113 406 623	115 593 965	117 776 367	119 951 972	122 118 898	34 796 862
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 069 705	97 097 411	99 128 699	101 162 000	103 195 713	105 228 203	107 257 803	109 282 819	111 301 528	113 312 185	37 686 289
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	108 231 713	111 361 245	113 690 934	116 022 932	118 355 402	120 686 469	123 014 222	125 336 717	127 651 980	129 958 007	46 333 541
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	95 607 196	97 606 572	99 558 076	101 457 205	103 299 570	105 080 604	106 796 209	108 442 137	110 014 330	111 508 868	112 921 989	44 814 549
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 564 150	95 674 508	97 793 334	99 919 099	102 050 237	104 185 138	106 322 156	108 459 606	110 595 770	112 728 898	114 857 208	116 978 889	119 092 107	50 812 138
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	91 350 725	93 448 539	95 556 290	97 672 498	99 795 636	101 924 141	104 056 40								

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2014

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 899 576	26 189 760	3 000 468
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	63 605 794	64 363 500	65 084 641	9 437 060
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	75 590 832	76 544 892	77 456 735	78 324 576	12 727 982
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	79 939 621	81 005 272	82 027 669	83 004 827	83 934 829	19 367 764
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	76 232 344	77 302 686	78 333 185	79 321 857	80 266 781	81 166 106	15 008 266
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	84 899 694	86 152 037	87 361 657	88 526 249	89 643 571	90 711 453	91 727 802	21 820 696
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	80 347 730	81 590 041	82 793 564	83 956 029	85 075 221	86 148 987	87 175 239	88 151 968	18 219 672
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	95 536 934	97 082 052	98 583 103	100 037 288	101 441 864	102 794 155	104 091 558	105 331 552	106 511 707	27 891 681
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	96 944 648	98 123 942	99 710 900	101 252 598	102 746 160	104 188 770	105 577 679	106 910 214	108 183 785	109 395 897	26 680 655
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	87 334 762	88 871 603	90 372 184	91 833 773	93 253 677	94 629 248	95 957 893	97 237 078	98 464 343	99 637 303	100 753 658	31 467 870
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	99 648 051	101 472 602	103 258 229	105 001 725	106 699 917	108 349 677	109 947 927	111 491 654	112 977 915	114 403 851	115 766 691	117 063 763	37 955 885
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 579	89 917 112	91 627 629	93 305 326	94 947 232	96 550 399	98 111 908	99 628 883	101 098 494	102 517 970	103 884 606	105 195 772	106 448 920	107 641 594	43 674 404
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	88 693 851	90 444 409	92 164 958	93 852 493	95 504 028	97 116 596	98 687 263	100 213 133	101 691 362	103 119 162	104 493 813	105 812 668	107 073 164	108 272 833	47 986 801
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	83 490 427	85 197 923	86 879 482	88 532 213	90 153 234	91 739 672	93 288 680	94 797 437	96 263 164	97 683 128	99 054 651	100 375 118	101 641 989	102 852 803	104 005 186	57 761 733
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 094 805	83 207 042	79 449 123	77 268 973	81 034 726	82 692 000	84 324 099	85 928 218	87 501 560	89 041 337	90 544 783	92 009 164	93 431 779	94 809 978	96 141 160	97 422 789	98 652 397	99 827 597	100 946 085	61 227 072
2009	17 193 212	38 002 433	50 937 746	48 829 445	58 044 114	58 744 756	53 021 497	51 566 543	54 079 672	55 185 677	56 274 881	57 345 413	58 395 405	59 422 997	60 426 343	61 403 618	62 353 021	63 272 781	64 161 165	65 016 478	65 837 075	66 621 561	67 367 799	44 029 825
2010	1 136 121	2 133 857	1 612 655	4 909 603	6 539 149	7 133 541	6 438 550	6 261 871	6 567 047	6 701 352	6 833 618	6 963 615	7 091 119	7 215 902	7 337 741	7 456 415	7 571 703	7 683 392	7 791 271	7 895 134	7 994 782	8 090 020	8 180 662	5 805 182
Total																							484 063 015	

2013

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	24 131 431	23 767 408	23 343 332	462 405
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	60 502 766	59 757 403	58 855 963	57 805 810	6 675 504
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	71 605 248	70 921 688	70 047 669	68 991 296	67 760 301	5 977 248
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	74 308 101	73 805 395	73 100 832	72 200 267	71 111 127	69 842 308	6 944 321
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 160 609	74 870 666	74 364 154	73 654 258	72 746 875	71 649 489	70 371 064	6 584 917
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	82 177 798	82 800 862	81 754 484	81 201 402	80 426 235	79 435 425	78 237 142	76 841 176	8 087 111
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	78 397 854	78 525 247	78 432 619	78 120 747	77 592 248	76 851 535	75 904 764	74 759 741	73 425 821	6 181 265
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	91 063 669	91 467 753	91 616 384	91 508 313	91 144 449	90 527 842	89 663 644	88 559 034	87 223 121	85 666 820	11 200 341
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	93 762 752	94 443 253	94 862 334	95 016 480	94 904 399	94 527 031	93 887 541	92 991 270	91 845 665	90 460 174	88 846 115	9 070 788
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	87 352 210	88 233 239	88 873 609	89 267 975	89 413 031	89 307 560	88 952 446	88 350 669	87 507 254	86 429 209	85 125 425	83 606 553	20 570 804
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	98 145 051	99 413 293	100 415 969	101 144 758	101 593 576	101 758 660	101 638 626	101 234 481	100 549 613	99 589 745	98 362 850	96 879 047	95 150 458	22 648 710
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	86 598 701	87 964 039	89 100 721	89 999 385	90 652 574	91 054 833	91 202 793	91 095 210	90 732 989	90 119 166	89 258 869	88 159 245	86 829 363	85 280 088	31 704 290
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	90 736 125	92 425 487	93 882 691	95 095 855	96 054 986	96 752 124	97 181 450	97 339 365	97 224 544	96 837 950	96 182 826	95 264 644	94 091 032	92 671 669	91 018 151	42 923 925
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	76 965 262	81 041 506	82 550 369	83 851 880	84 935 424	85 792 078	86 414 731	86 798 186	86 939 229	86 836 675	86 491 387	85 906 259	85 086 179	84 037 961	82 770 249	81 293 399	45 770 92

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2012

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	23 834 718	22 504 916	21 100 562	19 645 356	2 981 950	
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	56 717 765	53 930 847	50 921 903	47 744 270	44 451 573	6 146 466	
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	64 160 152	61 437 604	58 418 769	55 159 432	51 717 368	48 150 665	10 836 014	
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	69 531 418	67 050 299	64 205 112	61 050 291	57 644 134	54 047 020	50 319 652	6 654 466	
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	73 109 929	70 998 104	68 464 649	65 559 446	62 338 078	58 860 072	55 187 080	51 381 088	9 164 515	
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	77 265 200	75 562 283	73 379 620	70 761 185	67 758 531	64 429 107	60 834 438	57 038 241	53 104 583	9 465 687	
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	76 864 328	75 700 147	74 031 724	71 893 272	69 327 875	66 386 041	63 124 057	59 602 200	55 882 898	52 028 918	8 830 758	
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	87 704 995	86 985 521	85 668 046	83 779 931	81 359 896	78 456 697	75 127 495	71 435 985	67 450 383	63 241 338	58 879 882	10 691 865	
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	91 740 161	91 628 989	90 877 325	89 500 905	87 528 315	85 000 005	81 966 915	78 488 761	74 632 091	70 468 169	66 070 808	61 514 217	9 552 172	
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	85 683 547	86 182 995	86 078 556	85 372 425	84 079 381	82 226 281	79 851 124	77 001 763	73 734 299	70 111 246	66 199 555	62 068 564	57 787 989	653 576	
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	97 740 099	99 002 844	99 579 930	99 459 257	98 643 359	97 149 315	95 008 155	92 263 786	88 971 499	85 196 115	81 009 868	76 490 114	71 716 971	66 770 990	5 043 440	
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	80 975 748	82 600 148	83 667 254	84 154 949	84 052 968	83 363 453	80 291 343	77 972 079	75 189 769	71 999 194	68 461 399	64 641 756	60 607 976	56 428 130	15 372 821		
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	84 036 441	88 071 938	89 638 607	90 999 310	91 529 743	91 418 825	90 668 886	89 295 623	87 327 557	84 805 047	81 778 913	78 308 737	74 460 912	70 306 541	65 919 266	61 373 126	21 724 376	
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 345 789	76 287 517	79 950 905	81 554 707	82 608 346	83 089 869	82 989 179	82 308 391	81 061 755	79 275 162	76 985 251	74 238 154	71 087 959	67 594 939	63 823 639	59 840 911	55 713 966	32 419 777	
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 094 805	92 432 325	85 307 160	82 019 116	85 957 739	87 682 038	88 814 839	89 332 539	89 224 284	88 492 347	87 152 049	85 231 227	82 769 271	79 815 781	76 428 907	72 673 451	68 618 807	64 336 850	59 899 842	37 874 576	
2009	17 193 212	38 002 433	50 937 746	48 829 445	55 581 162	61 826 922	57 060 980	54 861 645	57 496 146	58 649 509	59 407 226	59 753 510	59 681 100	59 191 515	58 295 006	57 010 190	55 363 416	53 387 860	51 122 419	48 610 438	45 898 333	43 034 181	40 066 317	30 455 927	
2010	1 136 121	2 133 857	1 612 655	1 903 187	2 166 343	2 409 779	2 224 021	2 138 299	2 240 982	2 285 936	2 315 469	2 328 965	2 326 143	2 307 061	2 272 118	2 222 041	2 157 856	2 080 856	1 992 558	1 894 651	1 788 943	1 677 309	1 561 633	1 141 398	
Total																									70 361 997

2011

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	20 746 782	21 153 121	21 480 416	21 742 980	21 952 941	1 708 069
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 510 591	51 762 848	52 776 657	53 593 253	54 248 345	54 772 193	5 798 506
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	56 317 806	58 085 184	59 525 230	60 691 071	61 630 123	62 383 453	62 985 858	8 819 765
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 548 268	58 794 611	60 639 717	62 143 095	63 360 208	64 340 559	65 127 020	65 755 918	11 914 986
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 676 992	63 728 073	66 259 629	68 339 004	70 033 262	71 404 909	72 509 733	73 396 049	74 104 797	17 058 816
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	61 871 767	65 809 943	69 119 128	71 864 840	74 120 119	75 957 703	77 445 384	78 643 670	79 604 964	80 373 668	23 115 235
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	61 744 653	66 719 443	70 966 177	74 534 638	77 495 478	79 927 459	81 909 018	83 513 259	84 805 432	85 842 043	86 670 976	30 640 727
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 069 658	76 113 922	82 246 451	87 481 487	91 880 405	95 530 293	98 528 247	100 970 956	102 948 538	104 541 426	105 819 278	106 841 121	45 668 729
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 165 845	80 353 251	88 548 305	95 682 676	101 772 937	106 890 485	111 136 640	114 624 355	117 466 118	119 766 769	121 619 880	123 106 489	124 295 265	63 125 525
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	61 955 880	72 080 453	81 385 933	89 686 308	96 912 369	103 080 900	108 264 218	112 564 943	116 097 482	118 975 767	121 305 985	123 182 912	124 688 626	125 892 681	76 783 496
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	63 787 336	80 473 757	93 624 444	105 711 222	116 492 481	125 878 325	133 890 557	140 623 107	146 209 268	150 797 641	154 536 211	157 562 903	160 000 821	161 956 576	163 520 508	115 289 946
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	36 242 410	47 932 405	60 471 262	70 353 224	79 435 722	87 537 199	94 590 105	100 610 823	105 669 936	109 867 605	113 315 495	116 124 809	118 399 189	120 231 140	121 700 773	122 875 976	93 192 461
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 979 460	48 813 356	64 558 111	81 446 162	94 755 756	106 988 584	117 900 119	127 399 377	135 508 425	142 322 328	147 975 989	152 619 806	156 403 550	159 466 815	161 934 192	163 913 579	165 496 409	136 713 150
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	22 229 095	30 875 837	37 698 189	49 857 745	62 900 260	73 179 160	82 266 482	91 053 378	98 389 584	104 652 141	109 914 467	114 280 747	117 867 132	120 789 289	123 155 026	125 060 563	126 589 229	127 811 636	112 178 684
2008																								

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2010

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 385 981	28 074 353	28 679 298	29 194 738	29 615 423	29 937 023	7 710 276
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	67 546 144	69 487 185	71 233 810	72 768 753	74 076 593	75 144 010	75 960 014	22 660 740
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 865 235	75 222 406	77 384 036	79 329 156	81 038 537	82 495 006	83 683 729	84 592 467	22 983 815
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	78 141 714	80 952 913	83 571 719	85 973 279	88 134 297	90 033 411	91 651 541	92 972 206	93 981 810	31 550 584
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	87 130 965	90 582 597	93 841 365	96 877 109	99 661 019	102 166 092	104 367 563	106 243 313	107 774 241	108 944 583	41 473 451
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	92 017 887	95 999 108	99 802 046	103 392 490	106 737 209	109 804 465	112 564 502	114 990 038	117 056 701	118 743 445	120 032 905	48 135 288
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	84 845 339	88 827 129	92 670 300	96 341 369	99 807 313	103 036 053	105 996 950	108 661 282	111 002 711	112 997 712	114 625 968	115 870 715	39 948 305
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	105 009 510	110 323 738	115 501 229	120 498 474	125 271 937	129 778 677	133 976 983	137 827 014	141 291 425	144 335 967	146 930 051	149 047 260	150 665 794	52 346 057
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	107 562 505	113 402 842	119 141 833	124 733 157	130 129 829	135 284 831	140 151 791	144 685 664	148 843 426	152 584 744	155 872 634	158 674 061	160 960 497	162 708 400	53 230 720
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	110 754 900	117 178 701	123 541 171	129 793 232	135 884 427	141 763 566	147 379 431	152 681 502	157 620 708	162 150 178	166 225 974	169 807 804	172 859 682	175 350 527	177 254 694	71 374 525
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	107 437 463	116 699 459	123 468 046	130 172 009	136 759 638	143 177 766	149 372 457	155 289 742	160 876 392	166 080 701	170 853 281	175 147 838	178 921 916	182 137 598	184 762 135	186 768 504	60 448 820
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	95 406 368	92 690 736	100 681 442	106 520 981	112 304 767	117 988 187	123 525 371	128 869 787	133 974 873	138 794 707	143 284 679	147 402 181	151 107 272	154 363 326	157 137 627	159 401 923	161 132 901	77 897 823
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	107 414 105	111 847 428	108 663 820	118 031 539	124 877 386	131 657 872	138 320 697	144 812 085	151 077 486	157 062 315	162 712 734	167 976 448	172 803 506	177 147 083	180 964 241	184 216 628	186 871 123	188 900 395	74 636 121
2007	19 586 963	47 169 049	66 896 340	76 261 682	87 989 863	98 300 785	102 357 972	99 444 471	108 017 405	114 282 431	120 487 641	126 585 173	132 525 813	138 259 639	143 736 698	148 907 720	153 724 845	158 142 361	162 117 417	165 610 717	168 587 162	171 016 442	172 873 544	102 675 618
2008	23 441 702	61 042 168	73 074 376	88 185 498	101 747 427	113 670 503	118 362 048	114 993 008	124 906 355	132 150 943	139 326 362	146 377 267	153 246 750	159 877 083	166 210 592	172 190 033	177 760 335	182 868 547	187 465 119	191 504 610	194 946 434	197 755 542	199 903 010	149 191 716
2009	17 193 212	38 002 433	48 853 597	58 956 080	68 022 856	75 993 983	79 130 498	76 878 139	83 505 670	88 349 011	93 146 111	97 859 967	102 452 533	106 885 217	111 119 401	115 116 993	118 840 998	122 256 074	125 329 094	128 029 680	130 330 699	132 208 717	133 644 399	113 843 789
2010	1 136 121	2 624 417	3 373 790	4 071 459	4 697 603	5 248 083	5 464 688	5 309 142	5 766 834	6 101 311	6 432 595	6 758 130	7 075 289	7 381 406	7 673 815	7 949 886	8 207 063	8 442 905	8 655 125	8 841 625	9 000 532	9 130 226	9 229 373	5 915 611
Total																							976 023 262	

2009

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 574 557	27 487 157	28 331 588	29 099 754	29 784 136	30 377 919	30 875 096	11 793 507
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	67 845 995	70 422 381	72 840 764	75 078 499	77 114 133	78 927 742	80 501 260	81 818 777	36 854 198
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 751 830	73 696 499	76 495 052	79 121 978	81 552 678	83 763 849	85 733 849	87 443 055	88 874 184	42 061 794
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	73 802 957	77 144 620	80 355 356	83 406 772	86 271 054	88 921 381	91 332 342	93 480 342	95 343 983	96 904 422	50 060 539
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	84 732 712	88 880 335	92 904 674	96 771 338	100 446 135	103 895 568	107 087 336	109 990 838	112 577 658	114 822 027	116 701 252	71 824 826
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	90 618 184	95 387 755	100 056 937	104 587 332	108 940 225	113 077 124	116 960 319	120 553 448	123 822 062	126 734 172	129 260 768	131 376 303	86 949 299
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	85 755 817	90 586 516	95 354 421	100 021 971	104 550 783	108 902 155	113 037 608	116 919 446	120 511 319	123 778 791	126 689 883	129 215 597	131 330 392	90 168 905
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	102 374 673	108 521 352	114 634 454	120 668 091	126 574 733	132 305 805	137 812 333	143 045 622	147 957 968	152 503 374	156 638 259	160 322 156	163 518 369	166 194 578	124 532 740
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	102 955 348	109 520 212	116 095 916	122 635 700	129 090 472	135 409 385	141 540 474	147 431 346	153 029 908	158 285 126	163 147 791	167 571 282	171 512 308	174 931 610	177 794 613	140 334 592
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	110 754 900	117 178 701	123 541 171	129 793 232	135 884 427	141 763 566	147 379 431	152 681 502	157 620 708	162 150 178	166 225 974	169 807 804	172 859 682	175 350 527	177 254 694	102 675 618
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	107 437 463	116 699 459	123 468 046	130 172 009	136 759 638	143 177 766	149 372 457	155 289 742	160 876 392	166 080 701	170 853 281	175 147 838	178 921 916	182 137 598	184 762 135	186 768 504	60 448 820
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	89 973 282	94 729 897	90 523 310	98 544 724	104 828 348	111 122 348	117 381 967	123 560 215	129 608 425	135 476 857	141 115 363	146 474 081	151 504 165	156 158 513	160 392 501	164 164 693	167 437 511	170 177 863	157 296 125
2006	22 256 213	48 097 250	62 743 804	83 357 713	95 970 074	106 759 624	112 403 681	107 412 271	116 930 242	124 386 204	131 854 477	139 281 954	146 612 881	153 789 507	160 752 814	167 443 297	173 801 794	179 770 342	185 293 053	190 316 977	194 792 948	198 676 377	201 927 996	191 067 527
2007	19 586 963	47 169 049	66 896 340	80 387 287	92 550 210	102 955 278	108 398 211	103 5																

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2008

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	26 172 034	27 163 968	28 137 110	29 086 824	30 008 457	30 897 374	31 748 997	32 558 845	14 271 445	
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	62 496 820	64 995 474	67 458 837	69 875 532	72 234 047	74 522 824	76 730 355	78 845 271	80 856 443	38 879 474	
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	69 480 745	72 403 426	75 298 151	78 151 991	80 951 765	83 684 137	86 335 717	88 893 172	91 343 331	93 673 302	49 108 827	
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	68 543 867	71 570 279	74 580 856	77 562 636	80 502 301	83 386 275	86 200 819	88 932 142	91 566 508	94 090 352	96 490 393	54 108 165	
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	78 884 316	82 532 354	86 176 399	89 801 377	93 391 681	96 931 276	100 403 813	103 792 751	107 081 484	110 253 474	113 292 386	116 182 230	79 367 570	
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	78 140 778	81 918 268	85 706 613	89 490 811	93 255 208	96 983 598	100 659 328	104 265 422	107 784 701	111 199 922	114 493 909	117 649 700	120 650 689	84 000 785	
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	76 581 623	80 444 629	84 333 492	88 233 529	92 129 298	96 004 683	99 842 997	103 627 100	107 339 514	110 962 553	114 478 466	117 869 571	121 118 405	124 207 874	92 461 830	
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	88 152 610	92 784 861	97 465 207	102 176 880	106 902 093	111 622 134	116 317 477	120 967 907	125 552 656	130 050 546	134 440 153	138 699 967	142 808 566	146 744 793	150 487 935	119 869 861	
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	76 914 876	82 323 307	86 649 239	91 020 086	95 420 189	99 832 936	104 240 852	108 625 705	112 968 614	117 250 185	121 450 642	125 549 975	129 528 099	133 365 007	137 040 941	140 536 559	108 177 653	
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	86 480 377	79 920 045	85 539 790	90 034 742	94 576 364	99 148 385	103 733 544	108 313 684	112 869 858	117 382 451	121 831 308	126 195 883	130 455 383	134 588 937	138 575 758	142 395 317	146 027 513	123 692 921	
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	103 086 789	104 316 732	96 403 348	103 182 152	108 604 176	114 082 496	119 597 484	125 128 320	130 653 102	136 148 976	141 592 279	146 958 702	152 223 459	157 361 470	162 347 559	167 156 652	171 763 984	176 145 312	156 657 906	
2005	13 296 154	35 928 219	49 225 566	63 527 170	71 524 788	78 787 946	79 727 976	73 679 876	78 860 831	83 004 817	87 191 828	91 406 864	95 634 013	99 856 535	104 056 963	108 217 212	112 318 702	116 342 490	120 269 408	124 080 213	127 755 743	131 277 070	134 625 664	126 574 126	
2006	22 256 213	48 097 250	62 743 804	73 484 028	82 735 144	91 136 685	92 224 049	85 228 007	91 220 993	96 014 481	100 857 739	105 733 415	110 623 101	115 507 435	120 366 212	125 178 513	129 922 845	134 577 296	139 119 695	143 527 783	147 779 393	151 852 631	155 726 063	150 682 201	
2007	19 586 963	47 169 049	60 215 857	70 523 357	79 401 746	87 464 789	88 508 343	81 794 172	87 545 700	92 146 059	96 794 182	101 473 417	106 166 098	110 853 642	115 516 659	120 135 072	124 688 256	129 155 179	133 514 565	137 745 051	141 825 363	145 734 490	149 451 862	146 939 854	
2008	23 441 702	53 391 363	68 159 244	79 826 460	89 876 043	99 002 724	100 183 939	92 584 066	99 094 309	104 301 525	109 562 806	114 859 303	120 171 020	125 476 922	130 755 062	135 982 714	141 136 532	146 192 710	151 127 165	155 915 717	160 534 284	164 959 085	169 166 834	168 729 257	
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																							1 513 521 876		

2007

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	24 454 621	24 398 884	24 221 557	23 925 292	23 514 487	22 995 182	22 374 909	21 662 510	20 867 930	3 233 831	
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	57 708 783	57 866 585	57 734 695	57 315 090	56 614 041	55 641 960	54 413 137	52 945 394	51 259 656	49 379 453	9 351 712	
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	60 114 472	60 581 761	60 747 420	60 608 963	60 168 468	59 432 519	58 412 043	57 122 044	55 581 232	53 811 571	51 837 763	11 386 732	
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	64 860 941	65 693 594	66 204 251	66 385 284	66 233 978	65 752 601	64 948 350	63 833 166	62 423 444	60 739 631	58 805 731	56 648 738	18 063 606	
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	61 955 139	63 065 818	63 875 426	64 371 950	64 547 973	64 400 854	63 932 800	63 150 807	62 066 488	60 695 782	59 058 571	57 178 195	55 080 900	24 610 283	
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	78 140 778	81 918 268	85 706 613	89 490 811	93 255 208	96 983 598	100 659 328	104 265 422	107 784 701	111 199 922	114 493 909	117 649 700	120 650 689	28 959 144	
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	76 581 623	80 444 629	84 333 492	88 233 529	92 129 298	96 004 683	99 842 997	103 627 100	107 339 514	110 962 553	114 478 466	117 869 571	121 118 405	124 207 874	35 603 515	
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	73 789 432	77 109 624	79 282 826	81 109 689	82 563 755	83 623 668	84 273 702	84 504 145	84 311 542	83 698 781	82 675 021	81 255 464	79 460 980	77 317 596	74 855 867	72 110 155	47 163 509	
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	80 223 865	72 700 259	75 971 443	78 112 567	79 912 465	81 345 068	82 389 336	83 029 775	83 256 817	83 067 057	82 463 340	81 454 692	80 056 088	78 288 092	76 176 345	73 750 953	71 045 769	47 179 596	
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	79 534 414	78 561 351	71 193 660	74 397 054	76 493 807	78 256 405	79 659 319	80 681 946	81 309 113	81 531 450	81 345 622	80 754 417	79 766 671	78 397 051	76 665 694	74 597 710	72 222 580	69 573 457	54 654 908	
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	103 086 789	104 316 732	96 403 348	103 182 152	108 604 176	114 082 496	119 597 484	125 128 320	130 653 102	136 148 976	141 592 279	146 958 702	152 223 459	157 361 470	162 347 559	167 156 652	171 763 984	176 145 312	66 266 940	
2005	13 296 154	35 928 219	49 225 566	56 255 019	61 963 671	67 677 550	66 849 549	60 580 222	63 306 059	65 090 231	66 590 064	67 783 834	68 654 009	69 187 679	69 376 870	69 218 745	68 715 676	67 875 182	66 709 743	65 236 494	63 476 801	61 455 752	59 201 556	56 265 038	
2006	22 256 213	48 097 250	60 215 857	70 523 357	79 401 746	87 464 789	88 508 343	81 794 172	87 545 700	92 146 059	96 794 182	101 473 417	106 166 098	110 853 642	115 516 659	120 135 072	124 688 256	129 155 179	133 514 565	137 745 051	141 825 363	145 734 490	149 451 862	71 218 322	
2007	19 586 963	47 169 049	60 215 857	70 523 357	79 401 746	87 464 789	88 508 343	81 794 172	87 545 700	92 146 059	96 794 182	101 473 417	106 166 098	110 853 642	115 516 659	120 135 072	124 688 256	129 155 179	133 514 565	137 745 051	141 825 363	145 734 490	149 451 862	65 800 427	
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-																						

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2006

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	25 020 831	24 838 874	24 510 290	24 040 936	23 439 087	22 715 191	21 881 570	20 952 070	19 941 682	18 866 139	2 112 959
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	54 357 230	54 287 657	53 892 863	53 179 935	52 161 580	50 855 748	49 285 112	47 476 406	45 459 672	43 267 435	40 933 831	3 952 945
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	57 065 678	57 336 658	57 263 271	56 846 839	56 094 833	55 020 660	53 643 253	51 986 527	50 078 682	47 951 408	45 639 010	43 177 496	8 125 476
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	62 102 916	62 774 462	63 072 551	62 991 822	62 533 730	61 706 495	60 524 862	59 009 662	57 187 199	55 088 495	52 748 410	50 204 683	47 496 922	15 458 092
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	59 291 668	60 294 582	60 946 574	61 235 983	61 157 605	60 712 852	59 909 705	58 762 479	57 291 398	55 522 003	53 484 410	51 212 464	48 742 806	46 113 891	20 345 675
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	61 430 733	62 846 911	63 909 962	64 601 049	64 907 811	64 824 733	64 353 312	63 502 006	62 285 991	60 726 702	58 851 209	56 691 438	54 283 263	51 665 519	48 878 969	24 611 911
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	54 605 603	56 418 719	57 719 354	58 695 672	59 330 375	59 612 109	59 535 809	59 102 850	58 321 001	57 204 198	55 772 128	54 049 654	52 066 094	49 854 397	47 450 230	44 891 029	27 197 542
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	79 986 081	71 213 640	73 578 207	75 274 423	76 547 685	77 375 429	77 742 851	77 643 346	77 078 704	76 059 059	74 602 586	72 734 958	70 488 601	67 901 752	65 017 377	61 881 994	58 544 424	39 353 327
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	82 247 545	81 580 869	72 633 521	75 045 233	76 775 270	78 073 918	78 918 166	79 292 913	79 191 424	78 615 524	77 575 549	76 090 036	74 185 172	71 894 026	69 255 599	66 313 715	63 115 817	59 711 701	43 480 952
2003	23 272 575	46 129 306	55 251 952	67 031 626	74 940 673	81 758 481	81 095 770	72 201 624	74 598 996	76 318 745	77 609 671	78 448 899	78 821 418	78 720 533	78 148 057	77 114 266	75 637 586	73 744 049	71 466 527	68 843 788	65 919 397	62 740 515	59 356 641	51 835 538
2004	21 393 949	48 047 041	62 660 447	71 196 364	79 596 808	86 838 213	86 134 327	76 687 580	79 233 902	81 060 501	82 431 634	83 323 003	83 718 668	83 611 514	83 003 470	81 905 449	80 337 021	78 325 836	75 906 810	73 121 118	70 015 032	66 638 643	63 044 525	57 982 812
2005	13 296 154	35 928 219	44 782 366	50 882 843	56 886 499	62 061 809	61 558 753	54 807 322	56 627 136	57 932 575	58 912 501	59 549 548	59 832 323	59 755 741	59 321 183	58 536 445	57 415 517	55 978 157	54 249 319	52 258 432	50 038 565	47 625 516	45 056 861	43 705 055
2006	22 256 213	49 278 585	61 422 795	69 790 113	78 024 634	85 123 009	84 433 025	75 172 868	77 668 896	79 459 416	80 803 467	81 677 230	82 065 080	81 960 042	81 364 008	80 287 675	78 750 227	76 778 766	74 407 519	71 676 850	68 632 114	65 322 415	61 799 287	61 272 423
2007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Total 399 434 707

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.1.2. Generalized Linear Models

9.4.1.2.1. Forecasts of paid

2016

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 604 122	24 185 065	-
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	56 471 294	57 004 109	58 524 746	1 520 637
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 390	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	66 459 669	69 101 217	70 094 350	71 960 311	2 859 094
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 619 839	73 211 221	74 232 450	76 151 200	4 531 361
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	71 161 106	73 497 345	75 196 782	76 287 353	78 336 388	7 175 282
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758	80 540 988	83 247 231	85 215 819	86 479 111	88 852 664	13 230 906
2000	404 734	1 742 023	3 317 960	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660	77 033 886	81 781 594	84 393 477	86 293 425	87 512 669	89 803 462	11 071 802
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298	92 588 095	95 375 926	101 125 060	104 287 864	106 588 565	108 064 982	110 838 968	23 177 670
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 020	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933	91 266 776	96 666 067	99 721 260	106 021 754	109 487 880	112 009 225	113 627 235	116 667 255	28 933 322
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	78 697 051	83 898 724	87 262 903	92 404 424	95 313 757	101 313 455	104 614 102	107 015 074	108 555 837	111 450 721	32 753 670
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	86 695 449	92 788 445	98 918 810	102 883 620	108 943 093	112 371 850	119 442 717	123 332 653	126 162 288	127 978 135	131 389 864	44 694 415
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	74 957 466	80 428 543	85 634 885	90 873 159	94 261 010	99 438 708	102 368 512	108 410 425	111 734 297	114 152 163	115 703 767	118 619 020	43 661 554
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	68 279 969	71 055 378	79 953 636	86 252 418	92 246 415	98 277 174	102 177 564	108 138 583	111 511 629	118 467 608	122 294 340	125 077 999	126 864 342	130 220 637	59 165 259
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	62 098 797	71 049 136	80 065 770	86 448 347	92 522 083	98 633 071	102 585 349	108 625 669	112 043 588	119 092 105	122 969 745	125 790 435	127 600 542	131 001 486	68 902 689
2008	437 577	1 458 650	4 020 558	12 065 305	22 025 266	32 541 630	39 719 013	47 251 511	52 468 999	62 421 754	71 103 088	79 848 725	86 039 472	91 930 660	97 857 980	101 691 471	107 550 247	110 865 439	117 702 110	121 463 206	124 199 120	125 954 824	129 253 552	76 784 553
2009	372 907	985 838	4 120 617	9 610 390	16 686 438	23 337 975	29 405 359	34 460 997	43 767 502	51 910 185	59 012 676	66 167 774	71 232 631	76 052 410	80 901 749	84 038 057	88 831 318	91 543 588	100 213 977	102 452 320	103 888 720	106 587 520	112 726 523	72 126 523
2010	66 268	136 381	420 236	973 357	2 375 480	3 809 040	4 463 242	5 508 974	6 888 968	8 096 387	9 149 564	10 210 542	10 961 573	11 676 263	12 395 336	12 860 396	13 571 154	13 973 337	14 802 728	15 259 006	15 590 914	15 803 977	16 204 092	11 740 850
Total																							506 329 587	

2014

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 515 591	23 843 998	654 706
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	56 454 566	57 248 945	58 048 455	2 400 874
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 390	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	68 741 592	69 721 338	70 702 394	71 689 789	6 093 195
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 955 257	72 966 957	73 993 683	75 027 042	10 459 977
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	68 082 059	72 519 238	75 999 400	77 083 558	78 168 209	79 259 868	13 102 028
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	74 845 820	77 154 046	82 476 732	86 651 414	87 951 933	89 189 514	90 435 091	20 527 985
2000	404 734	1 742 023	3 317 960	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	72 871 578	77 659 018	79 896 542	85 056 193	89 103 003	90 363 687	91 635 204	92 914 936	22 982 640
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	83 971 253	87 478 397	93 190 759	95 860 568	102 017 051	106 845 695	108 349 940	109 874 544	111 408 998	32 788 972
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 020	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	89 126 156	95 532 626	99 731 366	106 570 185	109 766 470	117 136 989	122 917 824	124 718 700	126 473 631	128 239 899	45 524 657
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 167 806	80 952 870	86 733 924	90 522 772	96 693 968	99 578 224	106 229 214	111 445 709	113 070 779	114 661 810	116 263 121	46 977 333
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	80 299 607	97 787 254	105 151 481	112 510 603	117 333 703	125 189 466	128 861 044	137 327 571	143 968 026	146 036 696	148 091 595	150 159 769	71 051 891
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	72 734 008	81 998 743	88 197 165	94 293 418	100 385 445	104 378 102	110 881 258	113 920 663	120 929 422	126 426 522	128 139 008	129 942 066	131 756 773	67 789 583
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	72 346 939	82 953 841	94 163 168	101 662 589	109 038 395	116 409 089	121 239 773	129 107 888	132 785 240	141 265 081	147 915 978	149 987 901	152 098 397	154 222 528	93 936 497
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	59 514 835	71 502 165	82 044 359	93 185 304	100 638 975	107 969 785	115 295 514	120 096 728	127 916 844	131 571 762	139 999 871	146 610 194	148 669 477	150 761 422	152 866 882	106 623 429
2008	437 577	1 458 650	4 020 558	12 06																				

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2011

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	20 425 437	20 606 139	20 786 966	20 967 905	21 148 943	1 083 738
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	49 418 081	49 858 843	50 299 940	50 741 342	51 183 017	51 624 934	4 938 648
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 390	51 905 400	54 166 094	56 829 670	57 331 194	57 842 533	58 354 262	58 866 343	59 378 742	59 891 422	7 986 021
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 063 688	58 829 984	59 350 849	59 880 202	60 409 958	60 940 079	61 470 528	62 001 268	11 972 547
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	61 240 461	63 812 882	67 014 348	67 617 151	68 220 231	68 823 771	69 427 727	70 032 056	70 636 717	19 937 690
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	61 591 847	66 548 784	69 588 809	73 372 226	74 084 604	74 745 368	75 406 635	76 068 358	76 730 490	77 392 986	27 638 520
2000	404 734	1 742 023	3 317 960	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	61 120 243	65 305 284	70 092 499	73 028 437	76 682 313	77 370 300	78 060 369	78 750 964	79 442 035	80 133 533	80 825 411	33 523 342
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	70 103 062	76 419 864	81 613 598	87 554 644	91 198 211	95 732 756	96 586 564	97 448 024	98 310 140	99 172 850	100 036 094	100 899 812	47 286 602
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 020	50 201 114	61 169 740	71 907 597	82 993 494	90 834 722	97 281 853	104 656 644	109 179 509	114 808 370	115 868 227	116 901 661	117 935 882	118 970 816	120 006 390	121 042 532	70 841 418
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	59 810 387	69 852 545	80 220 195	87 553 395	93 582 821	100 479 804	104 709 635	109 973 806	110 964 995	111 954 696	112 945 152	113 936 290	114 928 041	115 920 337	77 407 285
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	62 384 559	75 709 886	88 214 560	101 124 542	110 255 973	117 763 922	126 352 168	131 619 229	138 174 268	139 408 514	140 651 904	141 896 242	143 141 437	144 387 403	145 634 053	105 257 108
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	37 080 533	47 251 062	56 826 140	65 811 528	75 088 155	81 649 657	87 044 586	93 215 776	97 000 488	101 710 692	102 597 575	103 512 647	104 428 416	105 344 817	106 261 785	107 179 255	85 750 955
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	37 551 790	47 340 479	60 799 435	73 470 414	85 361 038	97 637 067	106 320 093	113 459 359	121 625 874	126 634 293	132 867 443	134 041 081	135 236 600	136 433 028	137 630 282	138 828 277	140 026 928	117 709 898
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	22 648 354	30 440 185	39 138 542	51 098 347	62 357 945	72 924 109	83 832 749	91 548 600	97 892 645	105 149 517	109 600 064	115 138 923	116 181 833	117 218 064	118 255 083	119 292 818	120 331 196	121 370 142	111 582 344
2008	437 577	1 458 650	4 020 558	12 065 305	17 942 546	24 593 741	31 981 057	40 227 837	51 566 746	62 241 799	72 259 419	82 601 735	89 917 116	95 931 709	102 811 839	107 031 334	112 282 642	113 271 409	114 281 682	115 292 724	116 304 463	117 316 828	118 329 749	114 309 190
2009	372 907	985 838	4 120 617	8 258 603	12 808 386	17 957 314	23 676 100	30 060 227	38 838 082	47 102 023	54 857 021	62 863 378	68 526 399	73 182 588	78 508 743	81 775 205	85 840 430	86 605 870	87 378 312	88 151 342	88 924 904	89 698 946	90 473 412	89 487 574
2010	66 268	136 381	339 003	772 190	1 248 486	1 787 504	2 386 178	3 054 503	3 973 416	4 838 530	5 650 365	6 488 514	7 081 350	7 568 785	8 126 356	8 468 307	8 893 877	9 274 007	9 054 047	9 134 147	9 214 303	9 294 508	9 374 758	9 308 490
Total																							936 021 371	

2006

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	16 856 436	16 957 465	17 056 299	17 152 969	17 247 507	17 339 947	17 430 321	17 518 663	17 605 005	17 689 382	936 202
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	37 215 917	37 445 292	37 669 721	37 889 273	38 104 018	38 314 028	38 519 377	38 720 136	38 916 380	39 108 183	39 295 618	2 314 733
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	39 908 745	40 151 988	40 399 460	40 641 594	40 878 467	41 110 154	41 336 733	41 558 282	41 774 880	41 986 606	42 193 540	42 395 764	7 343 744
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	36 918 072	42 072 423	42 330 572	42 591 471	42 846 744	43 096 469	43 340 727	43 579 600	43 813 170	44 041 520	44 264 734	44 482 896	44 696 092	12 657 261
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	31 412 768	36 393 735	41 655 546	41 919 077	42 177 440	42 430 231	42 677 528	42 919 412	43 155 963	43 387 262	43 613 392	43 834 436	44 050 478	44 261 601	18 493 385
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	32 454 797	40 222 530	47 077 072	54 318 097	54 680 754	55 017 772	55 347 522	55 670 105	55 985 627	56 294 192	56 595 907	56 890 880	57 179 218	57 461 030	57 736 427	33 469 369
2000	404 734	1 742 023	3 317 960	6 445 612	10 304 137	13 749 429	17 693 487	23 585 819	30 899 570	37 838 148	43 961 012	50 429 105	50 753 051	51 065 861	51 371 925	51 671 337	51 964 195	52 250 596	52 530 639	52 804 424	53 072 051	53 333 621	53 589 236	35 895 749
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	25 076 800	32 855 232	42 510 071	51 669 646	59 752 402	68 290 893	68 718 532	69 142 070	69 556 474	69 961 872	70 358 396	70 746 177	71 125 349	71 496 047	71 858 408	72 212 568	72 558 665	53 367 569
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 337 090	30 939 068	40 985 694	53 455 889	65 286 401	75 726 093	86 754 412	87 306 751	87 844 855	88 371 354	88 886 412	89 390 194	89 882 869	90 364 606	90 835 578	91 295 956	91 745 916	92 185 632	75 954 883
2003	769 845	2 212 022	3 772 127	7 521 103	12 054 615	17 582 478	23 495 885	31 310 929	41 011 213	50 213 902	58 334 703	66 913 384	67 343 036	67 758 096	68 164 205	68 561 489	68 950 075	69 330 094	69 701 677	70 064 955	70 420 063	70 767 134	71 106 303	63 585 200
2004	812 119	2 246 467	5 061 713	10 771 665	16 543 858	23 582 086	31 111 200	41 061 530	53 412 200	65 129 318	75 468 947	86 391 561	86 938 606	87 474 441	87 998 720	88 511 606	89 013 264	89 503 861	89 983 567	90 452 553	90 910 990	91 359 053	91 796 914	86 735 201
2005	509 627	1 351 807	2 992 558	6 424 674	9 894 202	14 124 713	18 650 284	24 631 190	32 054 883	39 097 763	45 312 667	51 877 990	52 206 805	52 528 575	52 843 405	53 151 394	53 452 641	53 747 245	54 035 310	54 316 936	54 592 229	54 861 291	55 124 228	53 772 422
2006	526 864	1 821 918	3 850 557	8 094 055	12 383 810	17 614 451	23 209 906	30 604 751	39 783 470	48 491 349	56 175 511	64 292 934	64 699 484	65 098 251	65 488 419	65 870 107	66 243 439	66 608 540	66 965 536	67 314 554	67 655 722	67 989 169	68 315 024	67 788 160
2007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																							512 313 878	

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.1.2.2. Forecasts of incurred

2016

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 406 914	25 439 358	1 254 293	
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	64 619 050	64 916 166	66 744 486	9 740 376	
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	77 469 194	79 064 933	81 536 378	12 435 162	
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	83 304 866	85 178 494	87 927 828	16 307 989	
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 657 578	75 258 337	75 124 198	82 043 829	84 125 463	86 312 628	88 891 512	91 031 170	94 046 535	22 885 429	
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	91 677 809	94 262 466	97 238 842	99 775 992	103 188 849	27 567 091	
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	88 839 694	91 391 418	93 961 002	96 922 304	99 444 381	102 842 165	28 110 506	
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	106 782 600	111 761 322	115 586 469	119 429 477	123 664 203	127 459 704	132 130 912	44 469 614	
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	108 557 304	111 076 415	116 307 714	120 385 439	124 481 024	128 968 328	133 016 406	137 940 191	50 206 259	
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	99 474 254	102 194 382	104 315 811	109 149 427	112 829 469	116 527 371	120 616 992	124 267 388	128 793 490	50 096 439	
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 688	97 787 807	104 403 799	106 014 692	110 098 885	114 890 257	118 638 119	121 787 281	127 648 631	132 356 407	137 082 043	142 199 398	146 877 527	152 431 363	65 735 914	
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	97 363 407	100 782 117	104 908 006	107 990 384	110 474 063	115 669 929	119 712 221	123 772 373	128 224 244	132 236 890	137 125 242	62 167 776	
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	96 176 550	100 193 136	103 829 517	108 173 077	111 473 127	114 174 477	119 588 015	123 847 979	128 125 803	132 795 346	137 025 663	142 131 687	71 076 310	
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	82 468 285	92 468 291	96 456 894	99 323 051	103 601 846	107 500 436	112 106 205	115 668 463	118 632 022	124 307 768	128 829 940	133 369 973	138 301 724	142 794 520	148 162 483	86 063 686	
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 094 805	83 207 042	79 449 123	84 834 047	89 292 714	92 794 519	96 815 745	99 714 525	104 025 942	107 957 154	112 595 546	116 190 427	119 186 609	124 894 978	129 449 773	134 022 428	138 986 802	143 511 950	148 912 805	96 443 806	
2009	17 193 212	38 002 433	50 937 746	48 829 445	58 044 114	58 744 756	62 895 252	69 006 711	72 607 898	74 255 834	76 423 192	77 468 104	79 925 653	82 002 997	84 787 520	86 528 533	87 670 846	91 525 347	94 226 274	96 945 061	100 055 566	102 726 846	106 273 833	71 812 836	
2010	1 136 121	2 133 857	1 612 655	4 909 603	6 539 149	6 426 980	7 370 584	-3 555 224	-9 024 278	-16 446 584	-23 349 468	-31 374 798	-37 987 491	-44 980 389	-51 266 108	-58 595 337	-66 523 266	-71 739 007	-78 108 322	-84 459 777	-90 419 513	-96 818 475	-102 341 730	-106 804 972	
Total																									609 568 511

2014

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 334 925	24 939 287	1 749 996
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	64 619 050	64 916 166	66 744 486	9 740 376
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	77 469 194	79 064 933	81 536 378	12 435 162
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	83 304 866	85 178 494	87 927 828	16 307 989
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 657 578	75 258 337	75 124 198	82 043 829	84 125 463	86 312 628	88 891 512	91 031 170	94 046 535	22 885 429
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	91 677 809	94 262 466	97 238 842	99 775 992	103 188 849	27 567 091
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	88 839 694	91 391 418	93 961 002	96 922 304	99 444 381	102 842 165	28 110 506
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	106 782 600	111 761 322	115 586 469	119 429 477	123 664 203	127 459 704	132 130 912	44 469 614
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	108 557 304	111 076 415	116 307 714	120 385 439	124 481 024	128 968 328	133 016 406	137 940 191	50 206 259
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	99 474 254	102 194 382	104 315 811	109 149 427	112 829 469	116 527 371	120 616 992	124 267 388	128 793 490	50 096 439
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 688	97 787 807	104 403 799	106 014 692	110 098 885	114 890 257	118 638 119	121 787 281	127 648 631	132 356 407	137 082 043	142 199 398	146 877 527	152 431 363	65 735 914
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	97 363 407	100 782 117	104 908 006	107 990 384	110 474 063	115 669 929	119 712 221	123 772 373	128 224 244	132 236 890	137 125 242	62 167 776
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	96 176 550	100 193 136	103 829 517	108 173 077	111 473 127	114 174 477	119 588 015	123 847 979	128 125 803	132 795 346	137 025 663	142 131 687	71 076 310
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545																	

Machine Learning & Traditional Methods Synergy in Non-Life reserving

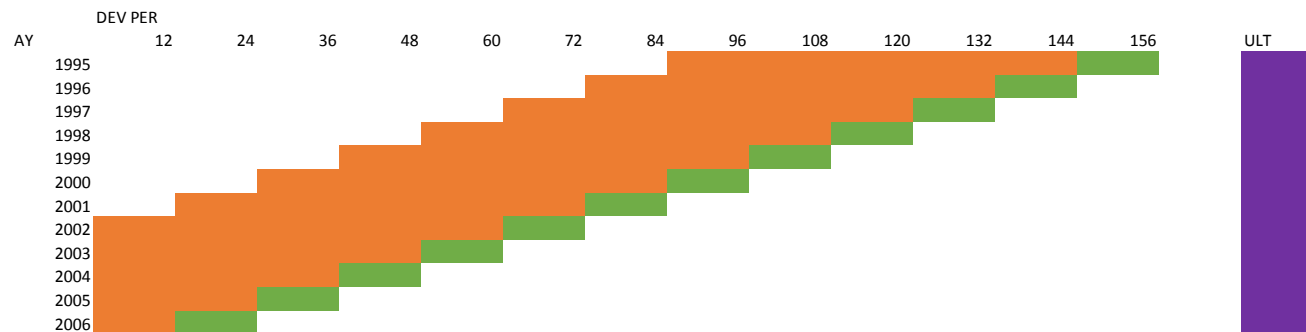
ASTIN 2018 Working Party

9.4.2. Forecasts based on Machine Learning Methods

9.4.2.1. General approach for training

Step 1

INITIAL TRAINING - USE LAST 5 CAL YEARS (2002-2006) (ORANGE); COMPARE NEXT CALENDAR PERIOD (GREEN) AND ULTIMATE (PURPLE) FROM TRADITIONAL METHODS

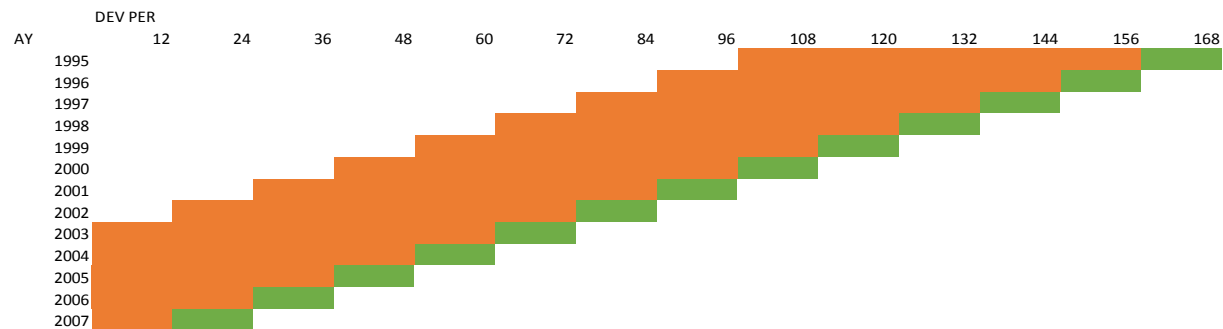


Step 2

NEXT PERIOD - MOVE FORWARD BY 1 CALENDAR PERIOD (CY 2003-2007)

USE LAST 5 CAL YEARS (ORANGE); COMPARE NEXT CALENDAR PERIOD (GREEN)

FIT SEVERAL MODELS (PERMUTATIONS OF HYPERPARAMETER SELECTIONS)



Machine Learning & Traditional Methods Synergy in Non-Life reserving

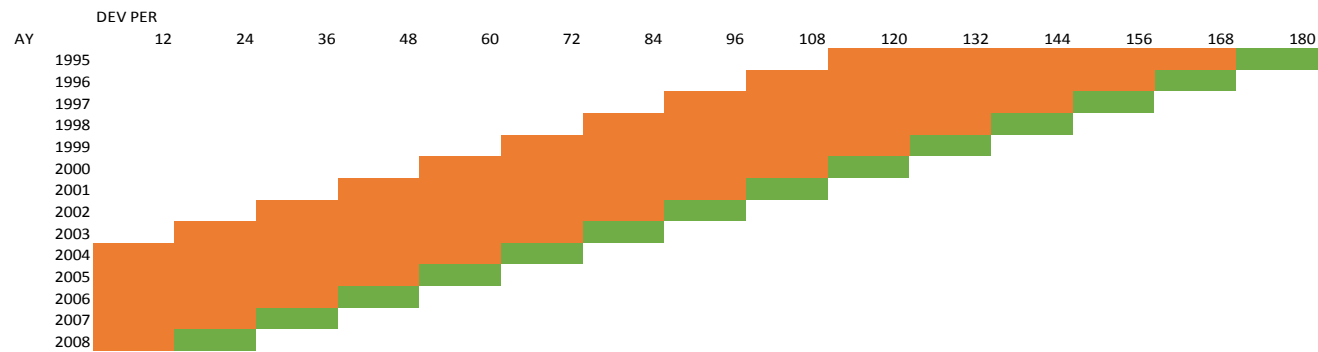
ASTIN 2018 Working Party

Step 3

NEXT PERIOD - MOVE FORWARD BY 1 CALENDAR PERIOD (CY 2004-2008)

USE LAST 5 CAL YEARS (ORANGE); COMPARE NEXT CALENDAR PERIOD (GREEN)

FIT SEVERAL MODELS (PERMUTATIONS OF HYPERPARAMETER SELECTIONS)

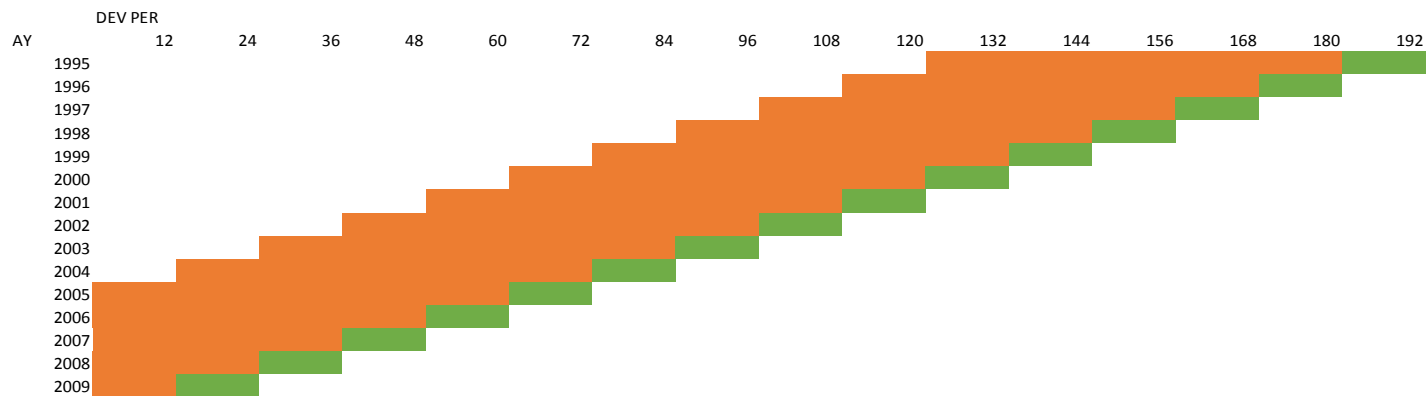


Step 4

NEXT PERIOD - MOVE FORWARD BY 1 CALENDAR PERIOD (CY 2005-2009)

USE LAST 5 CAL YEARS (ORANGE); COMPARE NEXT CALENDAR PERIOD (GREEN)

FIT SEVERAL MODELS (PERMUTATIONS OF HYPERPARAMETER SELECTIONS)



Machine Learning & Traditional Methods Synergy in Non-Life reserving

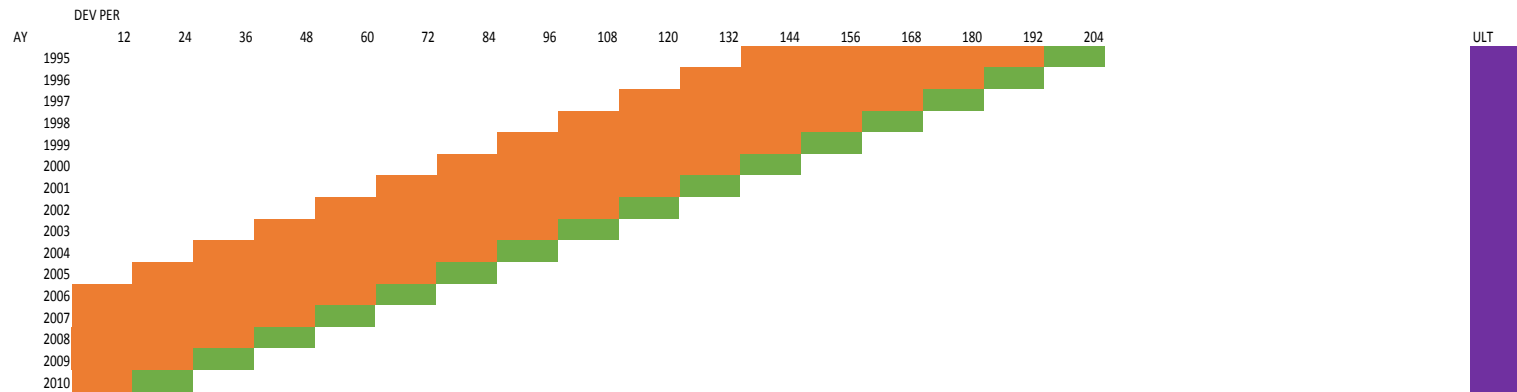
ASTIN 2018 Working Party

Step 5

NEXT PERIOD - MOVE FORWARD BY 1 CALENDAR PERIOD (CY 2006-2010)

USE LAST 5 CAL YEARS (ORANGE); COMPARE NEXT CALENDAR PERIOD (GREEN) AND TRADITIONAL METHODS (PURPLE)

FIT SEVERAL MODELS (PERMUTATIONS OF HYPERPARAMETER SELECTIONS)

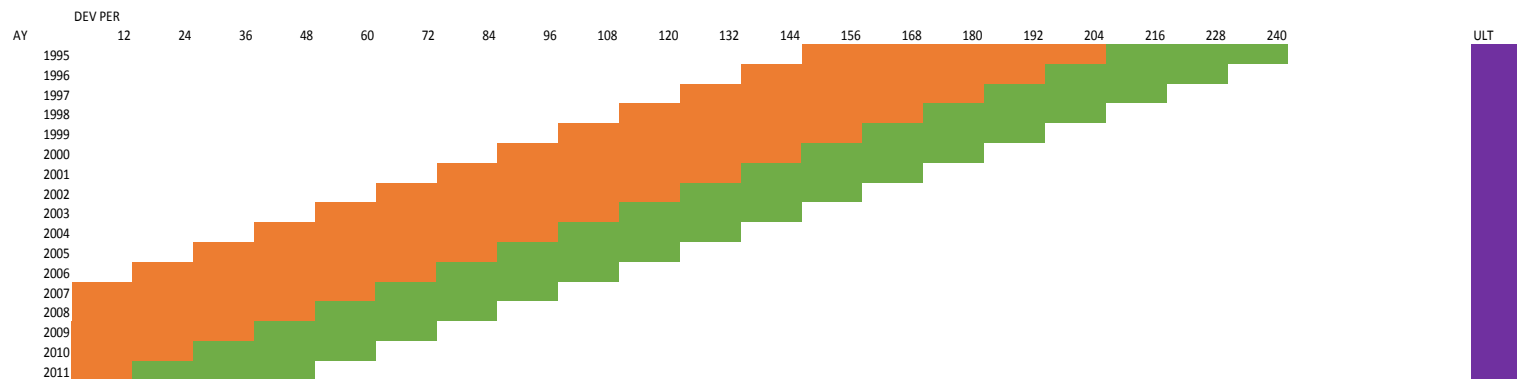


Step 6

NEXT PERIOD - MOVE FORWARD BY 1 CALENDAR PERIOD (CY 2007-2011)

USE LAST 5 CAL YEARS (ORANGE); COMPARE NEXT 3 CALENDAR PERIODS (GREEN) AND TRADITIONAL METHODS (PURPLE)

USE SELECTED HYPERPARAMETERS BASED ON AVERAGE OF PERFORMANCE OF HYPERPARMS OVER EARLIER PERIODS



Machine Learning & Traditional Methods Synergy in Non-Life reserving

-

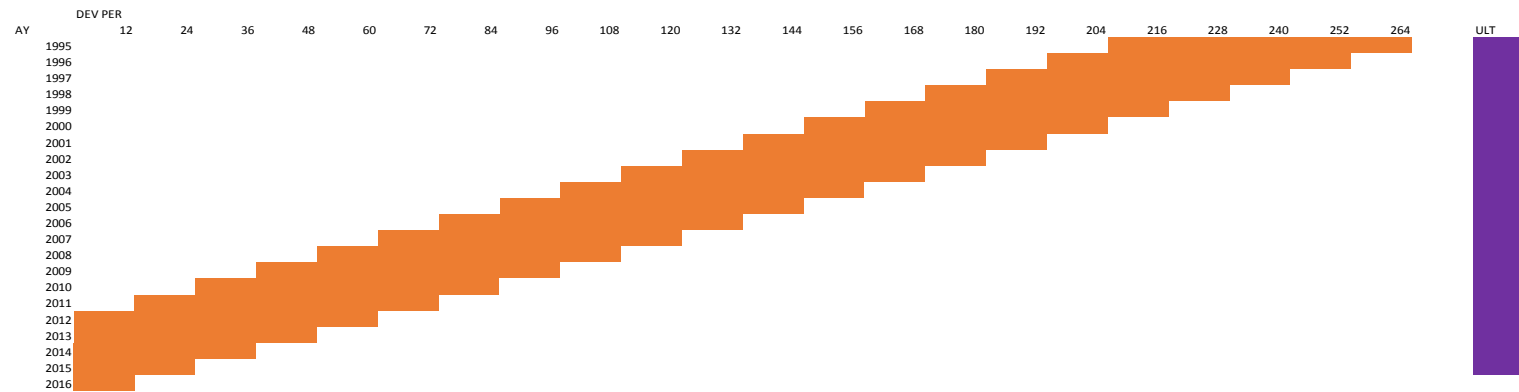
ASTIN 2018 Working Party

Step 7

NEXT PERIOD - MOVE FORWARD BY 4 CALENDAR PERIODS (CY 2012-2016) THIS IS OUR "FINAL" MODEL

USE LAST 5 CAL YEARS (**ORANGE**); COMPARE NEXT 3 CALENDAR PERIODS (**GREEN**) AND TRADITIONAL METHODS (**PURPLE**)

USE SELECTED HYPERPARAMETERS BASED ON AVERAGE OF PERFORMANCE OF HYPERPARMS OVER EARLIER PERIODS



Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.2.2. Random Forests

9.4.2.2.1. Forecasts of paid

2016

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 604 122	24 185 065	-
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	56 471 294	57 004 109	58 855 107	1 850 998
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	66 459 669	69 101 217	70 778 009	72 682 637	3 581 420
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 619 839	74 323 531	77 049 262	79 297 507	7 677 668
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	71 161 106	73 877 441	77 045 483	79 398 162	81 350 067	10 188 962
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758	73 985 621	71 139 445	71 391 725	70 379 120	70 945 841	4 675 916
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660	77 727 234	79 769 272	81 846 821	82 899 297	83 820 711	84 854 169	10 122 509
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298	90 526 417	93 630 686	95 958 083	96 680 750	97 767 493	98 400 304	100 340 938	12 679 640
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933	92 768 060	97 096 875	100 890 058	103 708 609	106 037 078	107 559 192	109 380 846	110 841 184	23 107 251
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	78 697 051	83 748 345	88 527 431	92 857 836	96 087 196	98 771 111	99 877 682	101 623 726	102 760 108	103 857 336	25 160 285
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	86 695 449	92 584 983	98 228 145	102 852 387	105 495 532	108 063 915	109 558 887	111 452 759	112 433 545	113 006 580	113 680 107	26 984 658
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	74 957 466	81 767 883	88 625 359	93 869 753	97 963 256	101 350 982	103 761 977	105 637 302	106 779 925	106 810 842	106 861 717	106 536 545	31 579 079
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	68 279 969	71 055 378	77 308 775	82 760 962	91 860 760	94 865 774	98 045 745	100 831 922	102 908 798	103 832 044	104 334 846	104 783 293	105 190 301	34 134 923	
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	62 098 797	69 442 162	76 169 987	81 513 249	85 799 861	89 574 742	92 817 954	95 256 349	97 615 608	98 082 178	98 667 806	98 649 828	99 058 627	99 398 858	37 300 061
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	32 541 630	39 719 013	47 251 511	52 468 999	60 077 276	67 941 882	74 638 894	79 858 897	84 298 725	88 074 245	91 506 650	92 948 642	94 602 972	95 341 759	95 747 728	96 223 903	96 627 073	96 930 756	44 461 757
2009	372 907	985 838	4 120 617	9 610 390	16 686 438	23 337 975	29 405 359	34 460 997	39 862 508	44 843 108	49 190 403	52 860 163	55 639 667	58 152 473	60 360 761	62 426 759	63 280 894	64 406 200	64 859 196	65 295 912	65 448 327	65 563 951	65 601 963	31 140 967
2010	66 268	136 381	420 236	973 357	2 375 480	3 809 040	4 463 242	5 184 612	5 713 411	6 165 255	6 549 508	6 872 908	7 129 893	7 331 401	7 488 432	7 628 426	7 750 880	7 870 489	7 965 257	8 054 632	8 097 473	8 118 242	8 118 242	3 655 000
Total																								298 949 261

2014

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 978 607	24 928 807	1 739 515
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	58 236 481	60 788 955	63 390 406	7 742 825
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	69 244 206	72 526 020	75 380 971	77 830 803	12 234 210
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 117 957	75 654 124	80 624 677	84 675 625	88 120 607	23 553 542
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	70 783 986	75 199 803	79 709 244	83 434 725	86 793 561	89 553 150	23 395 310
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	75 902 793	81 597 024	87 326 712	92 739 074	97 079 413	100 847 307	104 264 101	34 356 995
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	75 997 334	81 931 241	87 253 063	92 251 539	96 873 436	101 078 618	104 997 247	108 327 725	38 395 429
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 396 567	94 181 560	100 985 543	107 188 711	112 591 765	117 307 387	121 323 495	124 787 590	127 836 293	49 216 267
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	89 942 964	97 001 489	103 669 188	109 966 337	115 193 809	119 945 775	124 113 607	128 009 637	130 975 004	133 510 822	50 795 579
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 429 317	81 078 489	86 700 447	92 046 048	96 826 526	101 153 834	104 819 272	108 019 089	110 954 474	113 352 262	115 407 232	46 121 444
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	87 450 962	94 845 239	101 757 970	108 516 237	114 938 408	120 492 494	124 847 765	128 744 694	131 915 161	134 462 895	136 641 715	138 424 551	59 316 672
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	74 843 492	84 121 420	92 153 788	99 847 421	107 263 390	114 425 573	120 659 417	125 826 369	130 135 733	133 910 228	137 164 559	139 645 989	141 788 058	77 820 868
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	70 426 534	79 710 529	87 837 612	95 011 701	101 867 582	108 431 055	114 776 448	120 294 522	124 754 388	128 337 859	131 210 089	133 732 830	135 716 209	137 279 266	76 993 235
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	56 226 870	65 585 726	73 614 061	80 219 777	85 963 621	91 354 682	96 679 862	101 651 238	105 734 940	108 696 772	110 994 871	112 848 405	114 501 562	115 703 376	116 522 138	70 278 686
2008	437 577																							

Machine Learning & Traditional Methods Synergy in Non-Life reserving

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9.4.2.2.2. Forecasts of incurred

2016

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 406 914	25 439 358	1 254 293
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	64 619 050	64 916 166	63 757 222	6 753 113
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	77 469 194	76 457 402	75 194 028	6 092 812
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	79 527 139	78 377 819	76 877 218	5 257 378
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463	83 337 809	82 545 511	81 490 063	79 567 055	8 405 950
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	88 884 019	88 083 219	87 101 230	86 281 411	85 369 056	9 747 298
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	83 886 650	82 813 978	81 203 193	79 672 295	78 274 763	76 837 548	2 105 889
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	101 044 605	98 282 722	96 816 916	95 560 897	93 884 980	93 146 268	92 853 769	5 192 471
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	103 513 048	100 782 170	99 053 505	97 663 292	96 507 195	95 174 546	94 748 077	94 091 533	6 357 601
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	93 103 257	89 877 514	87 601 576	85 507 216	84 289 254	83 539 053	81 884 883	81 205 057	80 671 215	1 974 164
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	103 202 450	100 018 292	97 112 136	94 380 566	92 384 409	91 506 827	91 148 451	90 151 039	89 522 083	88 918 424	2 222 976
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	90 479 617	86 331 507	82 993 086	80 191 648	78 076 853	76 858 795	75 916 191	75 469 255	74 513 794	73 782 608	72 836 971	2 120 495
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	89 437 987	84 817 712	81 946 286	79 304 372	77 035 955	75 418 990	74 153 296	73 598 169	73 109 674	72 389 516	72 002 608	71 623 127	567 750
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 468 291	88 623 800	84 067 004	79 336 371	76 462 859	74 070 156	72 137 424	70 413 823	69 244 164	68 512 784	67 943 255	67 304 311	66 909 873	66 514 808	4 416 010
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 094 805	83 207 042	79 449 123	84 834 047	89 292 714	84 827 381	79 633 353	74 703 581	66 660 079	62 784 700	60 181 886	57 950 705	55 686 842	54 597 064	53 867 955	53 259 743	52 558 669	52 208 581	51 718 089	750 910
2009	17 193 212	38 002 433	50 937 746	48 829 445	58 044 114	58 744 756	62 895 252	69 006 711	63 189 354	58 896 112	55 342 084	51 518 832	46 282 717	44 555 893	42 815 955	41 399 889	39 780 886	39 088 529	38 775 866	38 605 295	38 570 841	38 544 042	38 509 457	4 048 460
2010	1 136 121	2 133 857	1 612 655	4 909 603	6 539 149	6 426 980	7 370 584	6 951 485	6 503 980	6 217 414	5 953 701	5 637 754	5 482 893	5 386 969	5 325 527	5 258 504	5 199 486	5 198 447	5 190 358	5 188 362	5 195 097	5 205 464	5 205 464	742 222
Total																								62 266 980

2014

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	24 295 010	19 532 917	3 656 374
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	58 694 975	53 760 720	49 303 868	6 343 713
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	70 513 632	65 779 261	60 967 483	56 098 651	9 497 943
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	75 334 206	70 559 430	65 191 634	59 002 391	52 591 351	11 975 714
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	71 498 551	67 556 236	63 215 121	58 231 137	52 086 982	47 537 163	18 620 677
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	88 884 019	88 083 219	87 101 230	86 281 411	85 369 056	14 103 706
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	83 886 650	82 813 978	81 203 193	79 672 295	78 274 763	76 837 548	2 105 889
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	101 044 605	98 282 722	96 816 916	95 560 897	93 884 980	93 146 268	92 853 769	5 192 471
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	103 513 048	100 782 170	99 053 505	97 663 292	96 507 195	95 174 546	94 748 077	94 091 533	6 357 601
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	93 103 257	89 877 514	87 601 576	85 507 216	84 289 254	83 539 053	81 884 883	81 205 057	80 671 215	1 974 164
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	103 202 450	100 018 292	97 112 136	94 380 566	92 384 409	91 506 827	91 148 451	90 151 039	89 522 083	88 918 424	2 222 976
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	90 479 617	86 331 507	82 993 086	80 191 648	78 076 853	76 858 795	75 916 191	75 469 255	74 513 794	73 782 608	72 836 971	2 120 495
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	89 437 987	84 817 712	81 946 286	79 304 372	77 035 955	75 418 990	74 153 296	73 598 169	73 109 674	72 389 516	72 002 608	71 623 127	567 750
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 468 291	88 623 800	84 067 004	79 336 371	76 462 859	74 070 156	72 137 424	70 413 823	69 244 164	68 512 784</					

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.2.3. Neural Networks

9.4.2.3.1. Forecasts of paid

2016

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 604 122	24 185 065	-
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	56 471 294	57 004 109	59 298 484	2 294 375
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	66 459 669	69 101 217	71 617 093	73 720 442	4 619 226
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 619 839	74 535 712	76 946 603	78 945 775	7 325 935
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	71 161 106	74 726 708	77 662 812	80 081 336	82 084 833	10 923 728
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758	79 156 670	82 023 645	84 350 971	86 243 905	87 794 630	12 172 873
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660	79 131 589	82 604 460	85 410 117	87 655 699	89 474 510	90 963 549	16 231 890
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298	92 840 100	96 833 334	99 934 536	102 401 133	104 349 225	105 894 657	107 111 956	19 450 659
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933	93 520 807	98 307 448	101 890 807	104 653 008	106 841 997	108 543 416	109 880 969	110 911 680	23 177 748
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	78 697 051	84 356 658	89 073 967	92 967 188	95 849 885	98 054 285	99 792 885	101 156 577	102 222 869	103 007 618	24 310 567
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	86 695 449	92 636 350	97 555 520	101 606 665	104 928 650	107 369 767	109 223 356	110 657 217	111 756 357	112 548 379	113 125 057	26 429 608
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	74 957 466	81 237 661	86 434 461	90 715 880	94 228 046	97 081 655	99 217 296	100 854 915	102 108 082	103 052 597	103 741 871	104 198 794	29 241 329
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	68 279 969	71 055 378	77 246 707	82 300 078	86 434 217	89 816 758	92 591 785	94 860 583	96 495 887	97 706 811	98 603 053	99 228 607	99 653 918	99 902 965	28 847 587
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	62 098 797	69 104 242	74 828 899	79 505 998	83 335 210	86 468 606	89 027 298	91 100 418	92 610 126	93 659 917	94 397 904	94 911 289	95 250 308	95 459 427	33 360 630
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	32 541 630	39 719 013	47 251 511	52 468 999	60 471 311	66 965 666	72 252 106	76 549 999	80 028 078	82 828 880	85 086 497	86 882 265	88 121 415	88 976 849	89 569 054	89 941 320	90 127 460	90 215 300	37 746 301
2009	372 907	985 838	4 120 617	9 610 390	16 686 438	23 337 975	29 405 359	34 460 997	41 301 302	46 695 268	50 923 732	54 269 711	56 918 879	59 019 596	60 675 385	61 961 242	62 944 031	63 532 543	63 835 126	63 988 797	64 051 501	64 048 479	64 031 065	29 570 069
2010	66 268	136 381	420 236	973 357	2 375 480	3 809 040	4 463 242	5 728 749	6 717 894	7 473 078	8 040 086	8 451 830	8 741 716	8 944 523	9 079 536	9 168 662	9 224 301	9 250 258	9 251 979	9 239 189	9 220 211	9 203 374	9 203 374	4 740 132
Total																								310 442 657

2014

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	24 002 573	24 679 300	1 490 008
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	57 714 502	59 411 713	60 802 622	5 155 041
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	67 969 402	69 930 757	71 533 944	72 810 085	7 213 942
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	67 529 835	69 981 887	72 002 322	73 634 826	74 896 794	10 329 729
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 438 865	72 161 869	74 424 508	76 266 118	77 721 400	78 845 259	12 687 419
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 392 826	76 166 050	78 418 410	80 213 425	81 608 169	82 669 656	83 472 249	13 565 143
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	74 283 328	77 694 616	80 401 940	82 604 799	84 335 694	85 681 021	86 715 781	87 488 171	17 555 875
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	83 343 379	87 369 053	90 474 277	92 875 371	94 780 843	96 252 106	97 376 488	98 202 960	98 819 008	20 198 982
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 677 564	91 895 823	95 418 867	98 033 738	99 991 519	101 526 864	102 680 254	103 551 548	104 168 363	104 594 165	21 878 922
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	74 161 216	78 365 449	81 949 068	84 930 445	87 103 483	88 722 904	89 965 650	90 905 494	91 621 505	92 124 534	92 460 074	23 174 286
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	84 129 818	88 431 804	92 080 205	95 134 303	97 643 304	99 444 255	100 751 619	101 733 325	102 454 233	102 927 467	103 244 588	103 437 782	24 329 904
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	69 324 200	73 922 794	77 843 901	81 155 558	83 918 987	86 185 395	87 842 001	89 078 447	89 998 103	90 683 242	91 189 474	91 509 749	91 691 311	27 724 121
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	65 577 783	70 123 651	74 017 577	77 320 945	80 108 123	82 441 305	84 335 144	85 700 272	86 686 380	87 400 798	87 905 957	88 253 976	88 452 962	88 555 111	28 269 079
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	56 291 587	60 150 692	63 378 586	66 060 622	68 288 620	70 120 798	71 594 856	72 674 714	73 397 805	73 888 859	74 219 907	74 437 847	74 566 518	74 610 435	28 366 983
2008	437 577	1 458 651	4 020 558	12 065 305																				

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2011

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	21 225 949	22 111 966	22 892 961	23 596 230	24 220 636	3 975 764
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	51 895 865	54 548 667	56 886 576	59 026 526	60 930 109	62 590 766	13 617 079
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	57 652 691	60 773 696	63 612 642	66 209 165	68 487 717	70 530 814	72 302 500	18 136 406
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	57 919 139	61 537 536	64 743 982	67 689 071	70 328 291	72 666 346	74 690 306	76 405 407	22 564 475
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	61 363 661	65 430 008	68 951 906	72 057 714	74 843 566	77 374 212	79 614 935	81 577 010	83 180 228	26 134 247
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	61 925 875	66 337 818	70 498 813	74 083 342	77 164 740	79 873 115	82 256 451	84 345 760	86 073 790	87 507 656	30 249 223
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 969 414	65 621 948	69 991 143	74 081 914	77 532 055	80 423 035	82 975 511	85 182 801	87 069 497	88 669 548	89 883 740	33 853 491
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	66 400 166	71 343 678	76 001 770	80 377 315	84 477 088	87 900 663	90 756 085	93 235 887	95 321 801	97 027 900	98 361 585	99 411 198	38 238 806
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	66 846 171	72 224 633	77 305 768	82 090 544	86 583 462	90 789 553	94 234 802	96 998 587	99 391 756	101 363 712	103 018 303	104 301 351	105 278 244	44 108 504
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	54 485 187	59 591 055	64 428 227	68 998 489	73 301 201	77 339 692	81 122 329	84 071 617	86 451 556	88 437 026	90 110 374	91 506 229	92 599 162	93 352 390	44 243 206
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	53 202 120	57 904 298	62 340 652	66 514 763	70 428 176	74 082 189	77 478 673	80 623 324	82 977 092	84 815 487	86 310 440	87 499 861	88 341 752	88 947 300	89 292 575	41 062 013
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	34 365 651	38 796 957	42 978 513	46 913 933	50 607 183	54 063 743	57 285 527	60 278 774	63 053 656	64 990 706	66 381 729	67 421 913	68 200 068	68 746 235	69 003 755	69 003 755	39 320 240
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	33 963 040	38 862 241	43 488 022	47 844 289	51 936 696	55 772 394	59 360 126	62 707 669	65 831 430	68 750 573	70 573 638	71 818 221	72 712 124	73 266 194	73 558 532	73 558 532	74 575 273	44 775 273
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	20 016 442	24 155 056	28 055 151	31 721 858	35 158 031	38 367 108	41 352 030	44 119 045	46 675 266	49 034 876	51 218 594	52 603 553	53 385 432	54 023 876	54 023 876	54 023 876	54 023 876	54 023 876	38 390 923
2008	437 577	1 458 651	4 020 558	12 065 305	15 761 822	19 243 920	22 517 315	25 587 223	28 462 890	31 146 206	33 641 713	35 954 098	38 087 227	40 047 200	41 846 771	43 503 872	44 372 587	44 847 214	45 060 464	45 060 464	45 060 464	45 060 464	45 060 464	32 995 159
2009	372 907	985 838	4 120 617	6 469 816	8 677 163	10 749 210	12 694 629	14 518 685	16 227 899	17 824 981	19 314 120	20 700 347	21 987 108	23 176 073	24 272 861	25 285 407	25 820 406	25 982 075	25 982 075	25 982 075	25 982 075	25 982 075	25 982 075	21 861 458
2010	66 268	136 381	261 048	373 705	475 243	566 658	648 957	722 658	788 102	845 183	894 654	937 326	973 459	1 003 114	1 026 306	1 043 860	1 049 058	1 049 058	1 049 058	1 049 058	1 049 058	1 049 058	1 049 058	912 677
Total																							494 438 944	

2006

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	19 051 118	21 151 873	23 108 798	24 789 249	26 076 696	27 086 572	27 908 919	28 564 519	29 107 669	29 544 970	12 791 791
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	42 826 278	48 207 169	53 154 721	57 710 393	61 521 938	64 644 901	67 281 697	69 451 852	71 226 775	72 676 046	73 857 891	36 877 006
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 996 959	46 394 875	51 360 662	55 918 038	60 141 431	63 538 497	66 269 945	68 536 831	70 430 183	71 990 506	73 248 537	74 206 686	39 154 666
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 664 478	44 735 221	50 267 486	55 307 591	59 904 253	64 139 891	67 500 955	70 251 757	72 619 428	74 565 546	76 180 578	77 441 489	78 372 089	46 333 259
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	32 466 944	38 543 668	44 056 093	49 052 168	53 589 980	57 701 559	61 463 782	64 391 447	66 747 571	68 750 163	70 415 361	71 799 980	72 937 279	73 681 498	47 913 282
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 647 262	38 364 194	44 411 828	49 889 299	54 749 324	59 119 662	63 027 629	66 591 039	69 332 439	71 470 444	73 251 113	74 701 071	75 828 343	76 596 260	77 031 497	52 764 439
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	27 259 356	35 904 755	43 620 268	50 399 862	56 372 516	61 634 243	66 287 035	70 512 478	74 467 582	77 350 076	79 313 950	80 863 565	82 026 482	82 786 175	83 151 298	83 151 298	65 457 811
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	29 770 647	39 458 251	48 031 381	55 529 122	62 006 576	67 668 679	72 606 973	77 021 458	81 075 201	84 895 376	87 514 732	89 114 536	90 256 035	90 980 877	91 328 488	91 328 488	91 328 488	72 137 391
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	26 221 710	35 827 174	44 574 812	52 258 889	58 911 975	64 595 103	69 453 462	73 716 599	77 525 033	81 028 872	84 335 232	86 510 650	87 748 195	88 509 404	88 862 800	88 862 800	88 862 800	88 862 800	72 632 051
2003	769 845	2 212 022	3 772 127	7 521 103	16 671 602	25 780 892	34 468 780	42 304 762	49 133 131	54 953 646	59 838 276	64 057 330	67 723 765	70 984 004	73 999 571	76 860 120	78 604 850	79 434 246	79 792 090	79 792 090	79 792 090	79 792 090	79 792 090	72 270 987
2004	812 119	2 246 467	5 061 713	12 461 143	19 959 185	27 389 300	34 394 389	40 585 812	45 857 202	50 267 017	53 989 487	57 190 524	59 965 308	62 470 880	64 826 218	67 085 723	68 241 910	68 609 052	68 609 052	68 609 052	68 609 052	68 609 052	68 609 052	63 547 339
2005	509 627	1 351 807	6 240 891	11 207 776	16 247 125	21 224 710	25 866 151	29 896 922	33 251 046	36 066 493	38 410 244	40 442 263	42 212 541	43 832 731	45 366 876	46 857 712	47 455 995	47 455 995	47 455 995	47 455 995	47 455 995	47 455 995	47 455 995	46 104 189
2006	526 864	3 785 491	7 097 277	10 463 240	13 878 099	17 197 033	20 262 637	22 835 530	24 986 908	26 774 163	28 261 518	29 579 302	30 725 429	31 777 092	32 790 880	33 783 897	33 783 897	33 783 897	33 783 897	33 783 897	33 783 897	33 783 897	33 783 897	33 257 033
2007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																							661 241 244	

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.2.4. Gradient Boosting Machine (GBM)

9.4.2.4.1. Forecasts of paid

2016

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 604 122	24 185 065	-
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	56 471 294	57 004 109	58 161 127	1 157 018
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	66 459 669	69 101 217	70 320 750	71 340 429	2 239 212
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 619 839	73 132 663	74 439 243	75 479 523	3 859 684
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	71 161 106	72 990 716	74 521 089	75 846 227	76 950 463	5 789 357
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758	77 553 926	79 160 606	80 456 362	81 532 270	82 379 798	6 758 041
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660	77 083 488	78 793 832	80 113 555	81 158 501	82 140 989	82 931 856	8 200 196
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298	91 788 841	94 731 076	96 705 619	98 243 738	99 453 939	100 571 569	101 509 779	13 848 481
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933	92 223 334	96 558 620	99 495 811	101 542 599	103 130 853	104 411 019	105 535 501	106 473 591	18 739 659
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	78 697 051	83 246 716	87 632 698	91 633 425	94 300 243	96 174 376	97 640 885	98 867 144	99 890 491	100 732 260	22 035 209
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	86 695 449	91 223 252	95 316 977	99 120 655	102 745 868	105 079 078	106 736 900	108 049 904	109 097 978	110 035 844	110 819 179	24 123 730
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	74 957 466	79 226 791	83 150 780	86 569 450	89 818 517	92 910 245	95 026 186	96 673 857	98 008 526	99 074 845	99 935 795	100 632 297	25 674 831
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	68 279 969	71 055 378	75 404 823	79 375 292	83 040 696	86 345 041	89 486 347	92 538 074	94 548 001	95 989 156	97 057 092	97 847 771	98 537 628	99 065 644	28 010 266
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	62 098 797	66 646 087	70 740 571	74 347 819	77 643 759	80 708 507	83 661 020	86 579 576	88 661 794	90 076 613	91 205 671	92 104 810	93 392 348	93 293 551	31 293 551
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	32 541 630	39 719 013	47 251 511	52 468 999	57 027 864	61 198 332	64 878 938	68 092 828	71 080 993	73 786 683	76 462 536	79 100 141	80 819 069	82 101 486	83 083 778	83 849 211	84 506 112	85 020 682	32 551 683
2009	372 907	985 838	4 120 617	9 610 390	16 686 438	23 337 975	29 405 359	34 460 997	38 544 796	42 338 534	45 740 405	48 792 310	51 697 335	54 484 920	57 032 700	59 534 469	61 977 142	63 615 828	64 606 651	65 281 891	65 707 669	66 099 535	66 295 606	31 834 610
2010	66 268	136 381	420 236	973 357	2 375 480	3 809 040	4 463 242	5 095 595	5 686 905	6 236 905	6 730 184	7 191 088	7 629 504	8 048 021	8 451 450	8 842 342	9 233 234	9 550 120	9 792 385	9 981 676	10 092 782	10 149 040	10 149 040	5 685 798
Total																								261 801 326

2014

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 796 060	24 347 167	1 157 876
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	57 505 902	59 153 703	60 581 708	4 934 127
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	67 792 609	69 684 116	71 293 462	72 637 453	7 040 859
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 619 839	73 132 663	74 439 243	75 966 568	11 399 504
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	71 161 106	72 990 716	74 521 089	75 846 227	76 950 463	5 789 357
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758	77 553 926	79 160 606	80 456 362	81 532 270	82 379 798	6 758 041
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660	77 083 488	78 793 832	80 113 555	81 158 501	82 140 989	82 931 856	8 200 196
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298	91 788 841	94 731 076	96 705 619	98 243 738	99 453 939	100 571 569	101 509 779	13 848 481
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933	92 223 334	96 558 620	99 495 811	101 542 599	103 130 853	104 411 019	105 535 501	106 473 591	18 739 659
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	78 697 051	83 246 716	87 632 698	91 633 425	94 300 243	96 174 376	97 640 885	98 867 144	99 890 491	100 732 260	22 035 209
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	86 695 449	91 223 252	95 316 977	99 120 655	102 745 868	105 079 078	106 736 900	108 049 904	109 097 978	110 035 844	110 819 179	24 123 730
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	74 957 466	79 226 791	83 150 780	86 569 450	89 818 517	92 910 245	95 026 186	96 673 857	98 008 526	99 074 845	99 935 795	100 632 297	25 674 831
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	68 279 969	71 055 378	75 404 823	79 375 292	83 040 696	86 345 041	89 486 347	92 538 074	94 548 001	95 989 156	97 057 092	97 847 771	98 537 628	99 065 644	28 010 266
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	62 098 797	66 646 087	70 740 571	74 347 819	77 643 759	80 708 507	83 661 020	86 579 576	88 661 794	90 076 613	91 205 671	92 104 810	93 392 348	93 293 551	31 293 551
2008	437 577	1 458 651	4 020 558	12 065 305	2																			

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2011

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	20 972 563	21 626 492	22 144 644	22 590 694	22 981 083	2 736 212
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	51 230 761	53 187 804	54 881 735	56 372 603	57 658 947	58 760 929	9 787 242
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	57 181 455	59 682 444	61 803 507	63 665 433	65 213 727	66 507 572	67 605 491	13 439 398
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	58 076 679	61 433 456	64 225 018	66 650 951	68 738 715	70 575 552	72 137 275	73 460 902	19 619 970
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	61 611 222	65 966 975	69 234 761	71 927 932	74 212 677	76 251 670	78 123 488	79 779 622	81 134 319	24 088 338
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 096 802	66 768 343	71 220 569	74 603 325	77 285 442	79 624 082	81 664 038	83 437 822	84 916 946	86 153 861	28 895 429
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	61 321 900	66 413 737	71 279 812	75 967 994	79 529 496	82 261 658	84 650 861	86 766 797	88 591 891	90 118 298	91 311 103	35 280 854
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	66 989 156	72 653 358	77 969 426	83 272 034	88 437 025	92 425 483	95 595 094	98 343 250	100 661 219	102 665 482	104 340 101	105 665 370	44 492 978
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	67 912 057	74 312 239	80 694 387	86 838 135	92 988 450	99 026 280	103 639 151	107 216 883	110 337 411	112 975 063	115 318 497	117 249 823	118 789 359	57 619 619
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	56 154 757	63 108 422	69 758 509	76 255 688	82 600 047	88 881 470	95 113 138	99 655 663	103 274 996	106 392 193	109 098 993	111 496 962	113 441 376	114 844 142	65 734 958
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	54 689 915	61 234 523	67 617 764	73 982 637	80 381 254	86 827 345	93 230 515	99 564 632	104 162 512	107 847 238	110 982 450	113 608 643	115 571 372	117 010 402	117 917 275	69 686 713
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	36 679 474	43 664 952	50 606 157	57 466 052	64 189 513	70 810 777	77 349 488	83 876 890	90 395 300	94 957 172	98 256 291	100 789 126	102 587 725	103 851 548	104 441 515	104 441 515	74 758 000
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	37 040 073	45 302 285	53 708 254	61 700 031	69 828 339	77 723 544	85 580 463	93 384 402	101 177 923	108 971 445	113 649 212	116 773 620	119 081 030	120 504 089	121 290 186	121 290 186	121 290 186	92 506 927
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	22 410 253	29 318 025	36 097 013	42 846 625	49 539 543	56 139 483	62 711 316	69 250 060	75 764 328	82 278 595	88 792 863	92 656 258	94 722 949	95 940 547	96 531 353	96 531 353	96 531 353	96 531 353	80 898 400
2008	437 577	1 458 651	4 020 558	12 065 305	18 303 891	24 576 148	30 505 385	36 326 690	42 172 721	47 940 849	53 672 253	59 374 757	65 052 876	70 730 996	76 409 116	82 087 235	85 047 236	86 418 522	87 062 638	87 062 638	87 062 638	87 062 638	87 062 638	74 997 333
2009	372 907	985 838	4 120 617	8 391 380	12 628 147	16 781 132	21 028 716	25 214 449	29 380 760	33 452 956	37 458 263	41 442 844	45 427 425	49 412 006	53 396 586	57 381 167	59 555 323	60 224 967	60 224 967	60 224 967	60 224 967	60 224 967	60 224 967	56 104 350
2010	66 268	136 381	402 729	669 077	931 624	1 167 236	1 417 341	1 650 767	1 884 194	2 111 939	2 340 998	2 570 058	2 799 118	3 028 178	3 257 238	3 486 298	3 596 744	3 596 744	3 596 744	3 596 744	3 596 744	3 596 744	3 596 744	3 460 363
Total																							754 107 082	

2006

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	18 056 185	19 404 094	20 761 478	22 015 174	23 036 623	23 864 766	24 603 865	25 222 960	25 732 015	26 135 761	9 382 582
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 652 316	44 429 235	48 268 076	52 190 818	55 780 254	59 002 461	61 811 696	64 332 448	66 689 412	68 686 280	70 333 152	33 352 267
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	38 556 113	42 059 406	45 624 119	49 289 248	53 029 083	56 346 610	59 238 715	61 805 795	64 157 186	66 056 870	67 536 720	68 524 630	33 472 610
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	35 678 684	39 354 528	43 169 220	47 141 424	51 177 343	55 223 434	58 794 422	61 962 273	64 863 696	67 352 613	69 568 086	71 246 294	72 383 041	40 344 211
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	29 367 145	33 035 220	36 892 196	40 865 750	44 962 771	49 104 656	53 314 198	56 848 065	59 869 256	62 480 817	64 703 741	66 688 849	68 282 846	69 416 151	43 647 935
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	27 868 120	31 515 858	35 294 393	39 085 421	43 040 384	47 062 217	51 136 736	55 234 298	58 447 571	60 945 885	63 016 633	64 711 761	65 991 280	66 887 846	67 496 871	43 229 813
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	22 002 342	26 290 499	30 650 539	35 159 073	39 828 664	44 576 409	49 345 812	54 197 073	59 048 335	62 725 113	65 250 940	67 260 549	68 833 034	69 941 109	70 582 898	70 582 898	52 889 411
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 410 770	29 704 607	35 014 480	40 316 671	45 777 220	51 232 571	56 756 994	62 349 985	67 942 976	73 535 967	77 391 396	79 860 643	81 622 134	82 767 094	83 411 259	83 411 259	83 411 259	64 220 162
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	21 085 404	25 920 117	30 764 092	35 650 073	40 629 795	45 656 392	50 804 384	55 992 428	61 180 472	66 368 515	71 556 559	74 822 530	76 712 853	77 830 395	78 229 563	78 229 563	78 229 563	78 229 563	61 998 814
2003	769 845	2 212 022	3 772 127	7 521 103	11 928 059	16 279 217	20 717 720	25 168 475	29 612 046	34 035 461	38 525 803	43 096 233	47 666 663	52 237 093	56 807 523	61 377 953	63 954 858	65 194 209	65 740 457	65 740 457	65 740 457	65 740 457	65 740 457	58 219 354
2004	812 119	2 246 467	5 061 713	8 991 453	12 996 811	16 945 104	20 912 418	24 873 986	28 845 130	32 932 331	37 012 238	41 092 145	45 172 052	49 251 959	53 331 866	57 411 773	59 328 259	59 935 673	59 935 673	59 935 673	59 935 673	59 935 673	59 935 673	54 873 960
2005	509 627	1 351 807	3 971 774	6 645 751	9 319 729	11 993 706	14 695 906	17 393 659	20 137 417	22 997 042	25 856 667	28 716 291	31 575 916	34 435 541	37 295 166	40 154 790	41 285 175	41 285 175	41 285 175	41 285 175	41 285 175	41 285 175	41 285 175	39 933 368
2006	526 864	2 666 013	4 815 945	6 965 876	9 115 807	11 226 793	13 354 470	15 485 828	17 651 177	19 816 526	21 981 875	24 147 224	26 312 573	28 477 923	30 643 272	32 808 621	32 808 621	32 808 621	32 808 621	32 808 621	32 808 621	32 808 621	32 808 621	32 281 757
2007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																							567 846 243	

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.2.4.2. Forecasts of incurred

2016

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 406 914	25 439 358	1 254 293
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	64 619 050	64 916 166	63 896 473	6 892 364
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	77 469 194	76 319 762	75 202 811	6 101 594
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	79 570 557	78 158 782	76 938 544	5 318 705
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463	82 490 766	80 867 306	79 411 647	78 132 190	6 971 085
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	87 337 726	85 654 190	84 216 931	82 981 253	81 916 558	6 294 801
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	82 846 284	80 875 335	79 196 166	77 751 565	76 512 485	75 416 778	6 851 118
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	101 104 627	98 232 273	95 984 764	94 058 069	92 455 320	91 043 357	89 856 420	2 195 122
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	101 773 192	98 069 394	95 278 497	93 201 779	91 444 551	89 957 643	88 638 100	87 557 754	176 179
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	92 197 623	88 647 128	85 346 222	82 871 361	80 905 064	79 250 315	77 880 078	76 760 961	75 801 985	2 895 065
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	102 473 709	98 856 119	95 480 145	92 338 146	90 042 236	88 228 794	86 707 465	85 478 396	84 464 096	83 585 825	3 109 624
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	90 108 358	86 608 413	83 402 589	80 392 336	77 658 962	75 526 072	73 776 736	72 372 440	71 231 475	70 323 550	69 573 421	5 384 045
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	90 063 211	86 499 955	83 213 661	80 141 201	77 231 855	74 487 499	72 524 688	71 047 360	69 839 943	68 940 539	68 229 106	67 739 428	3 315 949
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 468 291	88 904 536	85 383 840	82 112 459	79 106 536	76 328 798	73 674 083	71 201 554	69 333 127	67 988 960	66 896 893	66 032 886	65 372 779	64 830 723	2 731 926
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 094 805	83 207 042	79 449 123	84 834 047	89 292 714	85 700 702	81 811 474	78 316 705	75 045 408	72 075 938	69 258 086	66 582 608	64 186 830	62 506 602	61 258 574	60 266 656	59 549 163	58 994 671	58 528 376	6 059 378
2009	17 193 212	38 002 433	50 937 746	48 829 445	58 044 114	58 744 756	62 895 252	69 006 711	65 556 660	61 950 621	58 970 912	56 402 835	54 000 144	51 785 867	49 743 562	47 858 474	46 009 500	44 725 663	44 028 427	43 555 734	43 218 224	42 993 959	42 881 992	8 420 996
2010	1 136 121	2 133 857	1 612 655	4 909 603	6 539 149	6 426 980	7 370 584	7 057 968	6 582 860	6 144 600	5 771 660	5 450 673	5 165 913	4 913 419	4 692 815	4 475 554	4 263 718	4 091 115	3 971 873	3 876 747	3 821 869	3 793 165	3 793 165	670 077
Total																							37 374 440	

2014

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 604 407	25 589 446	2 400 154	
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	62 809 468	62 764 309	62 725 465	7 077 884	
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	74 495 320	74 426 359	74 365 220	74 320 582	8 723 988	
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	78 429 447	78 311 225	78 202 611	78 142 297	13 575 232
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463	82 490 766	80 867 306	79 411 647	78 132 190	8 555 896	
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	87 337 726	85 654 190	84 216 931	82 981 253	81 916 558	13 227 109	
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	82 846 284	80 875 335	79 196 166	77 751 565	76 512 485	75 416 778	7 961 855	
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	101 104 627	98 232 273	95 984 764	94 058 069	92 455 320	91 043 357	89 856 420	13 877 274	
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	101 773 192	98 069 394	95 278 497	93 201 779	91 444 551	89 957 643	88 638 100	87 557 754	9 212 715	
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	92 197 623	88 647 128	85 346 222	82 871 361	80 905 064	79 250 315	77 880 078	76 760 961	75 801 985	14 336 868	
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	102 473 709	98 856 119	95 480 145	92 338 146	90 042 236	88 228 794	86 707 465	85 478 396	84 464 096	83 585 825	16 787 799	
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	90 108 358	86 608 413	83 402 589	80 392 336	77 658 962	75 526 072	73 776 736	72 372 440	71 231 475	70 323 550	69 573 421	22 459 979	
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	90 063 211	86 499 955	83 213 661	80 141 201	77 231 855	74 487 499	72 524 688	71 047 360	69 839 943	68 940 539	68 229 106	67 739 428	24 879 229	
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 468 291	88 904 536	85 383 840	82 112 459	79 106 536	76 328 798	73 674 083	71 201 554	69 333 127	67 988 960	66 896 893	66 032 886	65 372 779	64 830 723	3	

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2011

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	27 926 904	27 906 041	27 888 883	27 873 648	27 860 333	7 615 462
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	62 376 390	62 270 305	62 214 028	62 166 399	62 124 947	62 090 083	13 116 395
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	72 605 952	72 459 426	72 326 076	72 201 100	72 133 510	72 074 019	72 030 891	17 864 798
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	76 618 163	76 083 185	75 752 604	75 433 553	75 308 194	75 192 580	75 087 260	75 031 338	21 190 406
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	81 672 177	81 472 927	81 325 836	81 216 657	81 128 919	81 053 535	80 987 073	80 927 336	80 878 992	23 833 011
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	82 607 536	82 180 413	81 931 686	81 754 089	81 613 826	81 490 308	81 380 242	81 282 255	81 196 621	81 120 733	23 862 300
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	79 382 901	78 756 709	78 130 516	77 685 799	77 498 462	77 356 283	77 232 085	77 121 750	77 025 828	76 942 945	76 881 366	20 851 117
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	95 644 362	94 935 189	94 407 491	94 061 268	93 715 045	93 447 472	93 240 734	93 096 021	93 009 489	92 937 096	92 877 056	92 828 134	31 655 742
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	98 811 479	97 624 650	96 976 089	96 505 924	96 035 760	95 565 595	95 238 879	94 971 459	94 732 040	94 512 112	94 308 106	94 126 914	93 965 653	32 795 913
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	96 290 317	95 214 776	94 317 632	93 964 913	93 612 194	93 259 475	92 906 757	92 670 737	92 495 112	92 347 899	92 218 667	92 105 770	92 004 539	91 956 961	42 847 776
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	101 567 947	101 251 689	100 935 431	100 619 172	100 302 914	99 986 655	99 670 397	99 354 138	99 186 790	99 075 444	98 991 001	98 928 107	98 891 047	98 864 968	98 848 908	50 618 347
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	84 908 408	84 219 683	83 530 959	83 205 184	82 879 410	82 553 636	82 227 862	81 902 087	81 576 313	81 386 014	81 275 737	81 197 441	81 140 009	81 100 146	81 089 303	81 089 303	51 405 788
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	103 884 655	103 489 759	102 699 969	102 305 074	101 910 178	101 515 283	101 120 388	100 725 493	100 330 598	100 145 023	100 053 059	99 997 195	99 966 037	99 952 311	99 952 311	99 952 311	99 952 311	71 169 052
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	83 922 790	83 377 104	83 009 814	82 642 524	82 275 234	81 907 944	81 540 654	81 173 364	80 806 073	80 438 783	80 071 493	79 869 326	79 754 456	79 714 376	79 696 807	79 696 807	79 696 807	79 696 807	64 063 855
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 422 665	82 706 010	82 346 148	81 986 286	81 626 424	81 266 562	80 906 700	80 546 838	80 186 976	79 827 113	79 467 251	79 107 389	78 904 415	78 853 080	78 832 354	78 832 354	78 832 354	78 832 354	78 832 354	66 767 049
2009	17 193 212	38 002 433	50 937 746	50 583 361	49 829 802	49 439 194	49 230 062	49 020 929	48 811 796	48 602 664	48 393 531	48 184 399	47 975 266	47 766 133	47 557 001	47 347 868	47 253 130	47 224 306	47 224 306	47 224 306	47 224 306	47 224 306	47 224 306	43 103 688
2010	1 136 121	2 133 857	2 208 920	2 194 645	2 180 370	2 166 095	2 151 820	2 137 545	2 123 270	2 108 995	2 094 721	2 080 446	2 066 171	2 051 896	2 037 621	2 023 346	2 016 894	2 016 894	2 016 894	2 016 894	2 016 894	2 016 894	2 016 894	1 880 513
Total																							584 641 211	

2006

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	23 746 651	22 305 311	20 794 889	19 487 066	18 611 966	17 964 827	17 371 480	16 924 514	16 581 116	16 311 549	441 630
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	50 949 079	47 430 800	43 675 685	39 953 558	36 982 650	34 650 839	32 635 881	30 964 556	29 473 612	28 259 012	27 277 130	9 703 755
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	53 110 521	49 236 905	45 149 803	40 988 073	36 704 524	33 267 597	30 472 338	28 062 337	25 873 078	24 213 266	22 881 168	21 925 697	13 126 323
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	57 983 837	54 409 263	50 554 117	46 368 199	42 166 472	38 018 333	34 808 956	32 199 274	29 898 941	27 957 293	26 249 432	24 904 284	24 099 071	7 939 760
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	55 060 994	51 357 908	47 563 329	43 245 067	38 479 309	33 652 922	29 013 010	25 571 999	22 934 728	20 844 980	19 027 894	17 509 857	16 177 503	15 235 491	10 532 725
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	56 684 903	52 820 379	48 619 790	44 256 862	39 458 281	34 457 101	29 497 684	24 683 888	21 255 188	18 758 766	16 764 731	15 122 973	13 931 178	13 100 478	12 562 714	11 704 344
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	56 760 158	50 775 733	44 824 356	38 646 278	32 044 452	25 349 611	18 757 153	12 279 099	5 801 045	1 594 493	- 756 591	- 2 476 107	- 3 862 693	- 4 859 550	- 5 468 491	- 5 468 491	- 23 161 978
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	76 032 291	67 615 087	59 327 672	51 102 898	42 551 830	33 994 193	25 590 627	17 279 625	8 968 623	657 620	- 4 284 420	- 6 636 473	- 7 996 118	- 8 762 835	- 9 204 557	- 9 204 557	- 9 204 557	- 28 395 654
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	75 799 362	70 732 051	62 899 268	54 906 537	46 974 206	38 950 755	31 084 196	23 358 938	15 633 679	7 908 421	183 163	- 3 873 041	- 5 552 286	- 6 288 414	- 6 567 168	- 6 567 168	- 6 567 168	- 6 567 168	- 22 797 917
2003	23 272 575	46 129 306	55 251 952	67 031 626	69 214 251	68 803 498	63 831 498	55 868 793	47 808 042	40 260 463	32 954 244	25 786 076	18 617 908	11 449 740	4 281 572	- 2 886 596	- 6 345 096	- 7 400 686	- 7 665 304	- 7 665 304	- 7 665 304	- 7 665 304	- 7 665 304	- 15 186 407
2004	21 393 949	48 047 041	62 660 447	65 444 293	66 528 456	66 546 305	62 019 668	55 009 447	48 427 453	42 512 878	36 802 723	31 092 568	25 382 413	19 672 258	13 962 103	8 251 948	5 828 165	5 217 231	5 217 231	5 217 231	5 217 231	5 217 231	5 217 231	155 518
2005	13 296 154	35 928 219	41 114 968	42 528 497	43 773 859	44 167 737	40 775 826	35 686 399	31 392 944	27 605 430	23 817 916	20 030 402	16 242 889	12 455 375	8 667 861	4 880 347	3 476 161	3 476 161	3 476 161	3 476 161	3 476 161	3 476 161	3 476 161	2 124 355
2006	22 256 213	34 903 108	35 769 515	36 348 345	36 989 745	36 458 479	32 191 115	27 936 715	24 809 380	21 682 044	18 554 709	15 427 373	12 300 037	9 172 702	6 045 366	2 918 031	2 918 031	2 918 031	2 918 031	2 918 031	2 918 031	2 918 031	2 918 031	2 391 167
2007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-																			

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.2.5. Gradient Boosting Machine (GBM) combined

9.4.2.5.1. Forecasts of paid

2016

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 604 122	24 185 065	-
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	56 471 294	57 004 109	58 196 474	1 192 365
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	66 459 669	69 101 217	70 135 970	70 763 205	1 661 989
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 687	64 567 065	70 293 819	71 619 839	73 189 940	74 610 636	75 991 720	4 371 881
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	71 161 106	73 414 198	75 742 647	77 930 052	79 724 321	8 563 216
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758	77 656 054	1 255 004 994	26 733 710 758	52 219 917 875	77 698 814 915	77 623 193 157
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660	80 067 054	98 069 715	126 077 994	161 382 735	202 118 839	247 504 691	172 773 031
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298	90 504 145	96 352 622	109 841 635	133 076 953	162 609 104	355 045 877	2 897 539 886	2 809 878 588
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933	90 899 019	92 870 285	94 960 379	103 087 604	117 444 670	135 244 513	166 059 918	204 659 741	116 925 808
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	78 697 051	81 124 911	82 094 555	79 968 344	76 124 407	76 196 538	88 019 916	107 591 322	140 947 343	179 002 164	100 305 114
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	86 695 449	90 855 966	93 384 454	93 871 105	92 410 441	90 256 912	108 290 202	131 755 353	166 288 547	188 847 458	218 735 410	132 039 961
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	74 957 466	79 232 555	82 574 304	83 676 044	82 458 656	83 687 684	83 448 723	93 148 815	117 272 587	153 074 770	199 538 223	250 833 450	175 875 985
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	68 279 969	71 055 378	75 881 646	79 980 994	83 521 717	84 851 625	83 754 655	80 765 432	78 504 271	80 093 667	100 474 613	130 457 341	177 877 073	236 389 325	165 333 948
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	62 098 797	67 386 823	71 945 124	75 290 601	77 549 635	77 718 940	76 050 849	72 395 293	68 610 041	69 973 870	77 034 860	94 361 363	135 422 837	225 018 495	162 919 698
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	32 541 630	39 719 013	47 251 511	52 468 999	57 802 255	62 987 507	67 597 894	71 380 388	74 103 220	74 311 810	72 015 017	67 117 371	61 888 983	73 248 675	93 948 180	149 866 928	459 341 435	801 996 664	749 527 665
2009	372 907	985 838	4 120 617	9 610 390	16 686 438	23 337 975	29 405 359	34 460 997	38 787 323	42 949 875	46 699 763	49 594 393	51 887 806	53 567 353	53 806 570	50 179 226	43 868 070	57 474 644	304 236 503	762 790 124	1 243 286 799	1 515 931 208	1 562 145 220	1 527 684 223
2010	66 268	136 381	420 236	973 357	2 375 480	3 809 040	4 463 242	4 953 167	5 398 285	5 805 633	6 167 504	6 435 870	6 671 761	6 848 816	6 894 284	6 794 128	6 482 475	6 125 093	7 774 585	9 320 278	12 750 001	14 444 215	16 126 047	11 662 805
Total																							83 763 909 433	

2014

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 963 254	24 865 687	1 676 395
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	59 209 766	63 906 566	69 876 099	14 228 518
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	69 373 361	74 647 928	80 507 622	86 276 065	20 679 472
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 687	64 567 065	69 394 349	74 558 954	82 023 403	90 262 226	99 698 177	35 131 112
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 890 020	73 706 345	77 455 477	82 175 870	88 436 120	93 009 114	26 851 274
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758	77 656 054	1 255 004 994	26 733 710 758	52 219 917 875	77 698 814 915	77 623 193 157
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660	80 067 054	98 069 715	126 077 994	161 382 735	202 118 839	247 504 691	172 773 031
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298	90 504 145	96 352 622	109 841 635	133 076 953	162 609 104	355 045 877	2 897 539 886	2 809 878 588
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933	90 899 019	92 870 285	94 960 379	103 087 604	117 444 670	135 244 513	166 059 918	204 659 741	116 925 808
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	78 697 051	81 124 911	82 094 555	79 968 344	76 124 407	76 196 538	88 019 916	107 591 322	140 947 343	179 002 164	100 305 114
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	86 695 449	90 855 966	93 384 454	93 871 105	92 410 441	90 256 912	108 290 202	131 755 353	166 288 547	188 847 458	218 735 410	132 039 961
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	74 957 466	79 232 555	82 574 304	83 676 044	82 458 656	83 687 684	83 448 723	93 148 815	117 272 587	153 074 770	199 538 223	250 833 450	175 875 985
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	68 279 969	71 055 378	75 881 646	79 980 994	83 521 717	84 851 625	83 754 655	80 765 432	78 504 271	80 093 667	100 474 613	130 457 341	177 877 073	236 389 325	165 333 948
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	62 098 797	67 386 823	71 945 124	75 290 601	77 549 635	77 718 940	76 050 849	72 395 293	68 610 041	69 973 870	77 034 860	94 361 363	135 422 837	225 018 495	162 919 698
2008	437 577																							

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.2.5.2. Forecasts of incurred

2016

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 406 914	25 439 358	1 254 293
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	64 619 050	64 916 166	64 524 707	7 520 598
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	77 469 194	77 240 032	76 718 130	7 616 913
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	80 196 255	79 171 249	78 098 693	6 478 853
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463	83 345 931	82 047 915	80 753 324	79 557 795	8 396 690
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	88 624 654	87 847 526	87 161 925	86 542 519	85 977 116	10 355 358
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	84 454 716	83 684 098	83 515 494	83 340 642	83 219 040	83 169 099	8 437 440
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	102 972 655	101 477 790	100 260 895	99 348 571	98 597 866	97 897 345	97 363 564	9 702 267
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	104 247 414	102 761 106	100 997 666	98 768 372	96 975 366	95 530 973	94 164 585	92 843 109	5 109 176
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	94 437 963	92 785 131	91 307 033	90 276 064	89 493 021	88 762 090	88 177 700	87 745 269	87 411 358	8 714 307
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	104 210 360	102 007 944	99 884 075	97 974 919	96 421 945	95 080 709	93 907 320	92 944 263	92 193 414	91 554 254	4 858 806
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	91 924 618	89 844 693	87 745 703	85 817 817	84 205 178	82 904 149	81 765 028	80 776 881	80 071 739	79 460 884	79 000 092	4 042 627
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	91 593 346	89 261 535	86 984 850	84 793 724	82 697 623	80 849 668	79 421 768	78 304 800	77 406 965	76 638 579	75 965 991	75 377 334	4 321 957
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 468 291	90 411 064	87 659 626	84 978 094	82 571 221	80 349 116	78 299 372	76 431 085	74 989 228	73 798 664	72 741 436	71 774 254	70 898 831	70 100 595	8 001 797
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 094 805	83 207 042	79 449 123	84 834 047	89 292 714	87 812 555	85 635 262	82 911 665	80 155 265	77 757 485	75 488 434	73 339 618	71 500 564	70 118 754	69 058 770	68 159 586	67 429 247	66 821 976	66 279 008	13 810 009
2009	17 193 212	38 002 433	50 937 746	48 829 445	58 044 114	58 744 756	62 895 252	69 006 711	67 590 061	65 933 307	64 219 063	62 549 880	60 920 835	59 432 274	58 181 003	57 075 393	56 142 815	55 108 402	54 219 306	53 457 836	52 898 273	52 461 057	52 135 234	17 674 237
2010	1 136 121	2 133 857	1 612 655	4 909 603	6 539 149	6 426 980	7 370 584	7 207 042	6 876 499	6 520 489	6 185 503	5 887 931	5 612 088	5 374 838	5 165 402	4 984 859	4 809 414	4 648 779	4 542 970	4 430 021	4 322 839	4 228 642	4 145 275	317 968
Total																							125 977 360	

2014

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 078 301	24 701 160	1 511 869
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	62 171 019	61 102 523	59 461 515	3 813 933
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	74 887 192	76 650 871	79 115 835	83 366 621	17 770 028
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	80 196 255	79 171 249	78 098 693	6 478 853
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463	83 345 931	82 047 915	80 753 324	79 557 795	8 396 690
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	88 624 654	87 847 526	87 161 925	86 542 519	85 977 116	10 355 358
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	84 454 716	83 684 098	83 515 494	83 340 642	83 219 040	83 169 099	8 437 440
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	102 972 655	101 477 790	100 260 895	99 348 571	98 597 866	97 897 345	97 363 564	9 702 267
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	104 247 414	102 761 106	100 997 666	98 768 372	96 975 366	95 530 973	94 164 585	92 843 109	5 109 176
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	94 437 963	92 785 131	91 307 033	90 276 064	89 493 021	88 762 090	88 177 700	87 745 269	87 411 358	8 714 307
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	104 210 360	102 007 944	99 884 075	97 974 919	96 421 945	95 080 709	93 907 320	92 944 263	92 193 414	91 554 254	4 858 806
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	91 924 618	89 844 693	87 745 703	85 817 817	84 205 178	82 904 149	81 765 028	80 776 881	80 071 739	79 460 884	79 000 092	4 042 627
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	91 593 346	89 261 535	86 984 850	84 793 724	82 697 623	80 849 668	79 421 768	78 304 800	77 406 965	76 638 579	75 965 991	75 377 334	4 321 957
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 468 291	90 411 064	87 659 626	84 978 094	82 571 221	80 349 116	78 299 372	76 431 085	74 989 228	73 798 664	72 741 436	71 774 254	70 898 831	70 100 595	8 001

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.2.6. TD Boost

9.4.2.6.1. Forecasts of paid

2016

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	23 604 122	24 185 065	-	
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	56 471 294	57 004 109	58 606 126	1 602 017	
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	66 459 669	69 101 217	70 840 306	72 577 348	3 476 131	
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 619 839	73 286 786	75 248 167	76 949 004	5 329 165	
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	71 161 106	73 248 578	75 847 409	77 728 871	79 507 003	8 345 897	
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758	76 473 014	77 227 317	77 630 638	77 963 152	78 262 366	2 640 608	
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660	77 279 996	78 158 855	78 109 628	77 471 840	76 964 585	76 620 394	1 888 734	
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298	90 469 956	92 490 842	94 969 543	97 875 355	100 259 843	101 681 016	103 270 134	15 608 836	
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933	91 789 105	95 783 437	98 139 840	100 659 711	102 782 088	103 753 244	105 288 614	106 980 902	19 246 969	
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	75 625 896	78 697 051	83 000 621	87 393 878	90 993 075	93 273 717	94 691 588	95 920 569	97 603 793	98 825 445	100 132 708	21 435 657	
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	83 624 466	86 695 449	91 592 665	96 428 980	100 615 048	102 615 740	105 474 341	107 026 782	108 933 510	110 145 035	110 763 409	111 103 193	24 407 744	
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 611 719	74 957 466	79 997 817	84 808 555	88 617 692	92 042 383	95 247 471	96 146 008	98 008 086	98 894 431	100 048 380	100 882 185	100 522 711	25 565 245	
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	68 279 969	71 055 378	76 127 305	80 802 972	84 613 828	88 180 122	91 422 542	93 739 228	95 250 749	97 285 161	98 136 252	98 407 103	97 488 231	97 488 231	26 432 854	
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	57 750 310	62 098 797	67 374 648	72 092 843	76 028 879	79 536 654	82 493 029	85 280 440	88 333 923	90 207 318	91 764 984	91 989 979	91 239 016	90 791 207	90 190 298	28 091 501	
2008	437 577	1 458 651	4 020 558	12 065 305	22 025 266	32 541 630	39 719 013	47 251 511	52 468 999	58 036 966	63 052 708	67 188 209	70 170 296	73 448 340	75 994 638	79 108 560	80 929 309	82 969 365	83 636 792	82 518 276	81 642 729	80 652 680	79 680 744	27 211 745	
2009	372 907	985 838	4 120 617	9 610 390	16 686 438	23 337 975	29 405 359	34 460 997	38 822 504	42 714 549	45 979 385	48 737 341	51 150 382	53 218 595	55 373 240	57 672 840	57 808 692	58 740 617	59 782 042	60 834 942	61 499 475	61 648 735	61 443 811	26 982 814	
2010	66 268	136 381	420 236	973 357	2 375 480	3 809 040	4 463 242	5 077 465	5 604 177	6 050 690	6 405 779	6 712 404	6 976 677	7 211 135	7 425 822	7 660 207	7 783 472	7 896 220	7 985 657	8 052 504	8 035 223	8 059 512	8 059 512	3 596 270	
Total																									241 862 188

2014

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	22 627 307	22 880 927	23 189 292	24 035 305	24 816 383	1 627 091	
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	50 598 039	51 130 306	55 647 581	58 087 283	60 259 145	62 149 711	6 502 129	
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	58 986 679	61 783 053	65 596 594	66 459 669	68 408 201	70 905 075	73 095 022	75 001 293	9 404 700
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	56 974 118	62 897 987	64 567 065	70 293 819	71 619 839	73 286 786	75 248 167	76 949 004	16 158 678	
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	60 545 603	63 786 147	66 157 840	69 351 883	71 161 106	73 248 578	75 847 409	77 728 871	79 507 003	21 447 335	
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 570 270	68 754 065	69 907 106	73 900 427	75 621 758	76 473 014	77 227 317	77 630 638	77 963 152	78 262 366	2 640 608	
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	60 859 676	67 244 556	69 932 296	73 072 285	74 731 660	77 279 996	78 158 855	78 109 628	77 471 840	76 964 585	76 620 394	1 888 734	
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	69 571 747	74 466 479	78 620 026	86 232 355	87 661 298	90 469 956	92 490 842	94 969 543	97 875 355	100 259 843	101 681 016	103 270 134	15 608 836	
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	71 066 389	79 775 327	82 715 242	87 322 036	87 733 933	91 789 105	95 783 437	98 139 840	100 659 711	102 782 088	103 753 244	105 288 614	106 980 902	19 246 969	
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	57 134 413	63 035 749	69 285 788	76 182 087	82 923 466	89 262 691	95 218 593	99 964 948	104 030 101	107 600 974	110 720 920	113 575 309	116 099 228	118 078 815	48 793 027	
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	61 727 550	72 501 748	79 107 878	86 238 682	93 122 379	99 728 189	106 028 229	112 029 607	116 781 390	120 915 022	124 612 803	127 852 120	130 612 380	132 955 245	134 756 490	55 648 612	
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	41 055 309	53 575 798	63 967 190	71 814 000	79 287 662	86 286 676	93 000 253	99 354 038	105 389 054	110 576 151	115 150 224	119 242 338	122 859 711	126 068 150	128 687 561	130 772 565	66 805 375	
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	39 648 750	48 094 227	60 286 032	67 614 063	74 673 900	81 290 574	87 618 447	93 697 188	99 544 404	105 174 406	109 839 146	113 932 234	117 462 207	120 400 204	122 940 892	124 783 355	126 151 322	65 865 290	
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	23 294 188	35 522 475	46 243 452	52 882 193	59 288 827	65 344 050	71 147 235	76 632 404	82 029 133	87 237 983	92 261 950	96 575 015	100 145 320	103 116 886	105 659 647	107 832 891	109 462 277	110 456 736	64 213 284	
2008	437 577																								

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

2011

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	17 634 099	18 287 400	19 081 590	20 065 206	20 244 872	21 152 851	21 955 635	22 641 226	23 278 724	23 836 086	3 591 214	
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	40 027 741	41 976 969	44 964 580	46 686 287	48 973 688	51 643 940	53 987 310	56 061 153	57 916 766	59 565 993	60 999 160	12 025 472	
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	40 451 031	44 564 474	46 812 391	51 905 400	54 166 094	57 792 842	60 931 987	63 611 271	65 919 130	67 901 243	69 637 413	71 139 350	16 973 256	
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	38 585 132	42 382 228	46 843 884	50 028 721	53 840 932	58 672 335	62 726 842	66 280 296	69 407 013	72 208 072	74 717 232	76 895 464	78 747 709	24 906 777	
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 470 617	36 814 660	44 876 426	50 699 027	57 045 981	62 441 374	67 609 493	71 788 908	75 427 048	78 632 679	81 518 527	84 157 746	86 547 607	88 535 494	31 489 513	
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	31 782 385	36 649 905	44 427 004	49 754 466	57 258 433	62 942 935	68 428 855	73 520 455	77 672 017	81 280 132	84 557 903	87 410 502	89 886 363	91 988 162	93 761 177	36 502 745	
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	23 922 094	31 746 044	41 161 488	47 302 069	56 030 249	61 754 541	67 180 926	72 353 239	77 388 810	81 506 333	84 963 669	88 041 167	90 766 600	93 131 365	95 151 381	96 773 660	40 743 411	
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 946 646	30 618 074	41 661 838	53 613 209	61 172 392	68 050 580	74 575 685	80 804 562	86 812 600	92 505 205	97 257 018	101 245 437	104 710 799	107 655 156	110 223 804	112 406 238	114 150 205	52 977 813	
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	23 866 174	32 358 907	37 460 021	50 201 114	61 169 740	68 336 993	75 285 995	81 826 169	88 150 360	94 292 068	100 186 943	104 972 475	108 832 420	112 254 735	115 174 831	117 782 243	119 941 610	121 581 984	60 412 244	
2003	769 845	2 212 022	3 772 127	7 521 103	14 918 550	22 334 592	28 990 287	38 513 052	49 109 185	56 816 012	64 120 543	70 990 830	77 620 704	84 075 010	90 223 304	96 014 828	100 339 508	103 919 952	107 016 391	109 663 811	112 000 007	113 964 102	115 339 851	66 230 667	
2004	812 119	2 246 467	5 061 713	11 334 302	19 487 406	27 548 810	40 376 945	48 230 562	55 238 509	62 118 612	68 634 017	74 787 974	80 721 977	86 506 807	92 036 620	97 331 294	101 252 430	104 525 660	107 344 663	109 673 045	111 455 479	112 779 479	113 548 453	65 317 891	
2005	509 627	1 351 807	2 936 518	8 051 538	12 881 737	21 428 300	29 683 515	36 830 424	43 908 750	50 457 871	56 699 233	62 593 674	68 263 258	73 742 402	78 997 069	84 181 666	88 039 187	90 969 841	93 331 482	95 126 071	96 452 010	97 064 150	97 064 150	67 380 635	
2006	526 864	1 841 235	5 043 862	10 860 470	22 317 030	28 783 259	37 338 545	45 642 405	53 394 159	60 455 750	67 278 586	73 807 237	80 140 499	86 353 930	92 486 300	98 597 377	102 541 494	105 432 734	107 582 849	108 990 784	109 859 276	109 859 276	109 859 276	81 076 017	
2007	670 926	2 512 008	4 701 870	9 787 798	15 632 953	22 273 643	28 740 106	34 851 760	40 605 065	45 974 603	51 042 754	55 972 164	60 750 309	65 484 189	70 202 019	74 913 450	77 923 109	79 760 099	80 801 645	81 282 844	81 282 844	81 282 844	81 282 844	65 649 892	
2008	437 577	1 458 651	4 020 558	12 065 305	18 175 923	24 176 567	29 713 151	35 005 684	39 765 273	44 231 645	48 517 396	52 664 282	56 757 235	60 848 813	64 915 902	68 982 992	71 294 941	72 432 745	72 996 864	72 996 864	72 996 864	72 996 864	72 996 864	60 931 559	
2009	372 907	985 838	4 120 617	8 403 944	12 735 164	16 854 755	20 704 916	24 234 341	27 387 446	30 242 315	32 967 492	35 640 286	38 272 664	40 885 675	43 498 685	46 111 696	47 556 151	48 107 817	48 107 817	48 107 817	48 107 817	48 107 817	48 107 817	43 987 199	
2010	66 268	136 381	369 578	607 230	838 128	1 051 548	1 260 754	1 450 185	1 615 085	1 776 375	1 936 074	2 095 774	2 250 392	2 405 010	2 559 628	2 714 247	2 787 465	2 787 465	2 787 465	2 787 465	2 787 465	2 787 465	2 787 465	2 787 465	2 651 084
Total																							732 847 388		

2006

Accident year	Total claims paid (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	65 646	339 110	945 684	2 036 174	4 231 519	4 792 346	6 412 067	9 075 367	11 962 186	14 301 145	15 483 078	16 650 151	16 753 180	18 781 529	20 912 252	23 147 782	25 334 757	27 370 877	29 149 652	30 734 358	32 009 803	33 147 443	34 111 680	17 358 501
1995	217 706	1 008 637	1 962 762	5 639 279	7 325 899	13 024 579	15 897 613	19 000 301	22 616 967	26 254 305	30 257 697	36 980 886	43 290 107	49 904 129	56 715 567	63 649 922	70 370 475	76 685 058	82 323 757	87 528 625	92 512 663	96 815 144	100 511 575	63 530 690
1996	296 990	1 041 467	2 191 783	5 241 453	7 625 208	9 434 910	11 689 699	16 600 787	22 622 248	28 193 253	35 052 020	39 746 499	44 846 290	50 103 001	55 652 321	61 207 385	66 561 277	71 438 461	76 009 859	80 379 567	83 922 247	86 916 696	89 059 667	54 007 647
1997	296 898	827 534	2 473 538	5 173 058	7 241 624	10 222 896	15 102 328	19 749 656	25 689 779	32 038 830	36 980 721	42 059 209	47 463 854	53 196 773	59 058 483	64 949 042	70 420 741	75 355 428	79 991 535	84 104 221	87 624 824	90 265 824	92 087 151	60 048 321
1998	373 884	1 380 324	2 443 138	3 954 886	6 638 787	11 387 956	14 586 849	20 046 382	25 768 216	30 225 105	35 057 308	40 451 926	46 186 019	52 082 925	57 909 748	63 929 221	69 359 151	74 147 175	78 424 519	82 152 621	85 447 820	87 996 730	89 753 925	63 985 709
1999	634 584	2 350 067	3 858 717	6 345 662	9 920 195	14 443 688	20 214 501	24 267 058	28 731 194	33 539 979	39 098 691	44 956 828	51 260 186	57 738 435	64 405 243	71 178 647	76 973 037	81 843 385	85 981 681	89 484 068	92 149 230	93 919 563	95 003 284	70 736 226
2000	404 734	1 742 023	3 317 961	6 445 612	10 304 137	13 749 429	17 693 487	21 907 533	26 224 577	31 013 712	36 128 655	41 697 796	47 615 622	53 711 868	59 976 945	66 270 946	71 729 042	75 884 362	79 438 145	82 275 432	84 150 093	85 279 872	85 279 872	67 586 385
2001	471 632	1 806 288	3 938 349	9 499 575	13 580 894	19 191 096	24 621 818	30 309 055	36 024 090	41 806 344	48 200 985	54 704 016	61 448 883	68 349 390	75 259 226	82 169 062	87 622 987	91 635 912	94 587 437	96 714 654	97 765 131	97 765 131	97 765 131	78 574 035
2002	701 296	2 221 124	6 096 116	12 269 782	16 230 749	21 177 241	26 340 368	31 453 788	36 568 824	42 235 499	48 264 523	54 622 282	61 208 264	67 833 520	74 458 776	81 084 031	86 097 657	89 294 164	91 456 922	92 241 646	92 241 646	92 241 646	92 241 646	76 010 897
2003	769 845	2 212 022	3 772 127	7 521 103	11 575 232	15 642 158	19 732 585	23 844 457	28 099 168	32 392 772	36 897 124	41 567 809	46 275 914	50 984 019	55 692 124	60 400 229	63 404 343	65 273 128	66 227 616	66 227 616	66 227 616	66 227 616	66 227 616	58 706 513
2004	812 119	2 246 467	5 061 713	8 554 161	12 205 259	15 782 588	19 278 595	22 787 317	26 333 404	30 266 571	34 300 727	38 320 804	42 340 882	46 360 959	50 381 037	54 401 114	56 545 659	57 217 558	57 217 558	57 217 558	57 217 558	57 217 558	57 217 558	52 155 845
2005	509 627	1 351 807	3 390 882	5 563 613	7 740 170	9 970 190	12 227 163	14 475 201	16 893 861	19 830 917	22 878 498	25 926 080	28 973 661	32 021 242	35 068 824	38 116 405	39 635 717	39 635 717	39 635 717	39 635 717	39 635 717	39 635 717	39 635 717	38 283 910
2006	526 864	2 133 191	3 940 045	5 772 534	7 564 254	9 349 150	11 093 142	12 847 173	14 868 684	16 969 028	19 069 372	21 169 717	23 270 061	25 370 405	27 470 750	29 571 094	29 571 094	29 571 094	29 571 094	29 571 094	29 571 094	29 571 094	29 571 094	29 044 230
2007	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total																							730 028 909	

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.2.6.2. Forecasts of incurred

2016

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 406 914	25 439 358	1 254 293
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	64 619 050	64 916 166	64 731 148	7 727 038
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	77 469 194	76 882 379	76 183 439	7 082 223
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	80 298 086	79 675 841	79 171 322	7 551 482
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463	83 546 251	83 139 269	82 942 854	82 954 471	11 793 366
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	88 879 849	89 285 340	89 765 411	90 133 397	90 989 902	15 368 144
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	84 947 447	85 041 612	85 162 868	85 760 013	86 623 991	87 399 182	12 667 523
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	104 076 419	103 659 915	103 668 949	104 269 201	104 400 108	105 406 209	106 384 176	18 722 878
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	104 755 996	103 928 019	104 287 252	104 360 876	104 235 696	105 024 692	105 418 634	105 960 675	18 226 742
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	94 766 341	93 753 431	93 274 052	92 862 135	92 745 234	93 161 600	93 310 037	94 237 987	95 235 030	16 537 979
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	103 567 715	101 979 518	100 634 028	99 834 816	99 317 918	99 118 972	99 392 734	100 098 701	100 921 195	100 400 259	13 704 811
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	91 351 824	88 821 114	87 426 158	86 385 884	86 679 957	87 345 047	88 524 444	89 453 274	90 252 671	90 953 003	91 597 399	16 639 933
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	89 428 555	85 670 885	83 060 060	81 255 042	80 042 620	79 238 348	78 820 798	78 973 732	79 580 054	79 175 903	79 489 189	79 619 480	8 564 102
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 468 291	88 317 334	84 517 546	82 356 590	80 729 246	79 420 307	78 500 892	77 920 996	78 138 554	78 698 042	79 286 829	80 281 205	81 447 042	82 800 050	20 701 252
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 094 805	83 207 042	79 449 123	84 834 047	89 292 714	85 221 196	81 320 687	78 212 252	75 425 294	73 607 552	72 396 095	71 635 312	71 432 089	72 561 824	72 178 831	73 081 921	74 008 856	75 560 827	76 955 362	24 486 364
2009	17 193 212	38 002 433	50 937 746	48 829 445	58 044 114	58 744 756	62 895 252	69 006 711	66 095 588	63 411 499	61 767 036	60 310 869	59 322 292	59 368 883	59 698 234	60 736 001	61 804 001	62 975 611	63 605 296	64 207 179	64 833 971	65 453 716	65 575 850	31 296 854
2010	1 136 121	2 133 857	1 612 655	4 909 603	6 539 149	6 426 980	7 370 584	6 941 500	6 347 350	5 813 866	5 320 901	4 883 038	4 598 231	4 379 864	4 245 505	4 121 544	3 997 582	3 896 458	3 872 419	3 863 462	3 863 061	3 859 001	3 859 001	604 242
Total																								231 720 742

2014

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	22 854 760	18 486 473	4 702 819
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	57 271 295	49 434 769	41 672 589	13 974 993
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	65 990 266	55 750 103	45 539 005	35 495 262	30 101 331
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	80 298 086	79 675 841	79 171 322	7 551 482
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463	83 546 251	83 139 269	82 942 854	82 954 471	11 793 366
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	88 879 849	89 285 340	89 765 411	90 133 397	90 989 902	15 368 144
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	84 947 447	85 041 612	85 162 868	85 760 013	86 623 991	87 399 182	12 667 523
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	104 076 419	103 659 915	103 668 949	104 269 201	104 400 108	105 406 209	106 384 176	18 722 878
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	104 755 996	103 928 019	104 287 252	104 360 876	104 235 696	105 024 692	105 418 634	105 960 675	18 226 742
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	94 766 341	93 753 431	93 274 052	92 862 135	92 745 234	93 161 600	93 310 037	94 237 987	95 235 030	16 537 979
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	103 567 715	101 979 518	100 634 028	99 834 816	99 317 918	99 118 972	99 392 734	100 098 701	100 921 195	100 400 259	13 704 811
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	91 351 824	88 821 114	87 426 158	86 385 884	86 679 957	87 345 047	88 524 444	89 453 274	90 252 671	90 953 003	91 597 399	16 639 933
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	89 428 555	85 670 885	83 060 060	81 255 042	80 042 620	79 238 348	78 820 798	78 973 732	79 580 054	79 175 903	79 489 189	79 619 480	8 564 102
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 468 291	88 317 334	84 517 546	82 356 590	80 729 246	79 420 307									

Machine Learning & Traditional Methods Synergy in Non-Life reserving

ASTIN 2018 Working Party

9.4.2.6.3. Forecasts of incurred

2016

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 406 914	25 439 358	1 254 293
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	64 619 050	64 916 166	64 621 259	7 617 150
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	77 469 194	77 094 672	76 783 424	7 682 208
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	80 469 824	80 029 498	79 664 680	8 044 840
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463	83 557 325	83 075 813	82 665 766	82 315 979	11 154 874
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	88 420 919	87 856 926	87 396 924	87 029 662	86 732 135	11 110 377
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	84 142 302	83 419 199	82 827 303	82 337 943	81 931 558	81 592 292	6 860 632
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	103 011 739	101 938 571	101 151 652	100 523 804	100 028 953	99 620 793	99 302 213	11 640 916
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	103 696 243	102 069 942	100 974 567	100 194 862	99 579 690	99 092 842	98 695 172	98 383 670	10 649 737
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	94 100 041	92 608 307	91 217 971	90 276 755	89 614 697	89 107 264	88 699 975	88 370 348	88 106 811	9 409 761
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	104 409 895	102 931 792	101 568 351	100 301 621	99 468 132	98 889 885	98 450 522	98 104 726	97 856 538	97 654 483	10 959 034
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	92 072 448	90 696 243	89 429 161	88 261 013	87 178 280	86 437 491	85 896 010	85 480 874	85 154 846	84 901 768	84 706 357	9 748 891
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	92 041 381	90 634 320	89 337 519	88 143 487	87 042 490	86 023 093	85 367 591	84 913 499	84 581 035	84 343 480	84 160 896	84 033 777	12 978 399
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 468 291	90 923 125	89 513 943	88 224 659	87 043 283	85 961 523	84 967 789	84 049 289	83 382 447	82 952 916	82 647 000	82 418 748	82 241 120	82 105 346	20 006 549
2008	23 441 702	61 042 168	73 074 376	83 852 295	83 094 805	83 207 042	79 449 123	84 834 047	89 292 714	87 711 873	86 273 153	84 960 905	83 762 286	82 665 230	81 657 316	80 733 489	79 881 201	79 322 462	78 943 278	78 663 481	78 452 549	78 302 903	78 189 823	25 720 824
2009	17 193 212	38 002 433	50 937 746	48 829 445	58 044 114	58 744 756	62 895 252	69 006 711	67 389 973	65 918 157	64 589 703	63 387 946	62 295 551	61 297 603	60 386 042	59 546 991	58 768 968	58 264 623	57 966 610	57 756 734	57 613 915	57 529 558	57 489 769	23 028 773
2010	1 136 121	2 133 857	1 612 655	4 909 603	6 539 149	6 426 980	7 370 584	7 117 271	6 889 890	6 690 343	6 516 907	6 364 703	6 228 630	6 106 060	5 994 482	5 891 652	5 795 051	5 723 537	5 672 137	5 634 333	5 611 662	5 600 690	5 600 690	1 137 448
Total																							189 004 705	

2014

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	25 066 395	24 432 426	25 594 678	25 498 919	25 376 157	2 186 866
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	59 231 158	61 085 905	62 813 008	62 218 139	61 604 721	60 989 747	5 342 166
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	66 534 324	72 092 968	74 596 410	77 414 724	77 038 295	76 190 428	75 400 573	6 231 896
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	71 599 617	74 604 751	78 832 768	81 134 716	80 992 013	80 469 824	80 029 498	79 664 680	10 121 484
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	74 757 578	75 258 337	75 124 198	82 043 829	84 125 463	83 557 325	83 075 813	82 665 766	82 315 979	3 740 031
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	78 453 449	82 044 480	83 606 990	88 541 498	89 111 012	88 420 919	87 856 926	87 396 924	87 029 662	86 732 135	6 746 791
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	77 500 087	78 051 510	79 068 949	84 718 535	85 134 396	84 142 302	83 419 199	82 827 303	82 337 943	81 931 558	81 592 292	6 746 791
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	87 811 406	90 407 519	93 950 595	102 675 617	104 516 066	103 011 739	101 938 571	101 151 652	100 523 804	100 028 953	99 620 793	99 302 213	6 746 791
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	91 208 509	92 826 509	94 825 982	102 458 598	105 439 493	103 696 243	102 069 942	100 974 567	100 194 862	99 579 690	99 092 842	98 695 172	98 383 670	6 860 632
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	84 590 684	86 237 834	85 764 419	93 047 109	95 710 615	94 100 041	92 608 307	91 217 971	90 276 755	89 614 697	89 107 264	88 699 975	88 370 348	88 106 811	9 409 761
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	95 818 006	96 621 687	97 787 807	104 403 799	106 014 692	104 409 895	102 931 792	101 568 351	100 301 621	99 468 132	98 889 885	98 450 522	98 104 726	97 856 538	97 654 483	10 959 034
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	77 265 401	85 015 842	88 176 759	91 469 746	93 564 492	92 072 448	90 696 243	89 429 161	88 261 013	87 178 280	86 437 491	85 896 010	85 480 874	85 154 846	84 901 768	84 706 357	9 748 891
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	87 405 357	86 172 259	86 916 292	91 463 741	93 572 601	92 041 381	90 634 320	89 337 519	88 143 487	87 042 490	86 023 093	85 367 591	84 913 499	84 581 035	84 343 480	84 160 896	84 033 777	12 978 399
2007	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	85 973 038	79 791 545	79 610 555	89 264 285	92 468 291	90 923 125	89 513 943	88 224 659	87 043 283	85 961 523	84 967 789	84 049 289	83 382 447	82 952 916	82 647 000	82 418 748	8		

Machine Learning & Traditional Methods Synergy in Non-Life reserving

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2011

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	24 387 934	25 165 890	25 602 334	26 620 987	27 941 558	27 811 486	27 655 227	27 490 041	27 304 872	27 116 004	6 871 132
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	57 263 654	59 974 035	65 135 092	65 429 517	62 472 685	61 926 481	61 356 982	60 767 503	60 190 155	59 635 857	59 145 791	10 172 103
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	59 352 533	66 542 690	67 687 083	70 334 891	72 742 675	72 233 711	71 759 541	71 270 225	70 756 993	70 238 657	69 739 306	69 306 504	15 140 411
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	76 084 594	75 290 410	74 599 080	73 929 656	73 297 680	72 710 726	72 198 339	71 765 016	17 924 084
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	80 865 251	79 487 219	78 507 560	77 736 574	77 029 208	76 401 585	75 837 719	75 328 827	74 927 966	17 881 985
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	81 676 869	80 118 917	78 390 535	77 247 169	76 406 567	75 689 145	75 057 733	74 522 845	74 096 420	73 762 278	16 503 845
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	78 635 973	76 964 216	75 136 863	73 199 017	71 949 407	71 107 257	70 407 625	69 809 476	69 328 472	68 953 751	68 673 739	12 643 490
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	94 987 025	93 446 696	91 772 920	89 996 119	88 154 983	86 983 378	86 238 092	85 633 575	85 161 709	84 785 642	84 492 332	84 278 145	23 105 753
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	98 753 685	97 228 750	95 540 808	93 768 501	91 920 437	90 020 532	88 823 836	88 085 320	87 552 605	87 140 524	86 830 661	86 611 752	86 451 322	25 281 582
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	96 070 697	94 706 102	93 258 666	91 748 131	90 214 647	88 645 205	87 055 486	86 134 314	85 565 130	85 159 651	84 856 130	84 636 699	84 472 832	84 369 807	35 260 622
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	101 227 692	100 164 204	98 988 822	97 793 018	96 565 171	95 337 438	94 109 195	92 888 122	92 176 649	91 737 690	91 423 309	91 200 962	91 046 555	90 937 270	90 871 577	42 641 015
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	84 664 084	83 618 671	82 357 509	81 126 292	79 927 812	78 725 902	77 527 277	76 334 962	75 158 208	74 542 675	74 240 069	74 042 456	73 907 117	73 825 009	73 785 844	73 785 844	44 102 329
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	103 179 993	102 502 873	101 554 913	100 441 791	99 436 861	98 521 273	97 615 920	96 722 241	95 848 508	95 001 025	94 612 386	94 397 554	94 257 460	94 174 753	94 135 286	94 135 286	94 135 286	65 352 027
1998	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	84 527 047	83 818 450	83 230 363	82 453 207	81 571 404	80 774 788	80 086 750	79 448 946	78 859 417	78 301 874	77 770 042	77 495 103	77 352 351	77 269 893	77 231 566	77 231 566	77 231 566	77 231 566	61 598 613
2008	23 441 702	61 042 168	73 074 376	83 852 295	85 232 066	85 147 739	84 254 399	83 542 642	82 749 136	81 942 564	81 274 318	80 701 707	80 188 915	79 727 413	79 298 034	78 891 507	78 706 829	78 622 915	78 584 819	78 584 819	78 584 819	78 584 819	78 584 819	66 519 514
2009	17 193 212	38 002 433	50 937 746	53 099 757	53 805 232	53 546 871	52 801 329	52 251 840	51 699 306	51 158 272	50 710 990	50 339 411	50 016 951	49 732 206	49 469 789	49 221 254	49 101 302	49 058 192	49 058 192	49 058 192	49 058 192	49 058 192	49 058 192	44 937 575
2010	1 136 121	2 133 857	2 354 970	2 431 962	2 401 544	2 304 840	2 185 763	2 103 100	2 046 215	2 008 244	1 980 405	1 958 000	1 939 660	1 924 708	1 911 611	1 899 974	1 895 325	1 895 325	1 895 325	1 895 325	1 895 325	1 895 325	1 895 325	1 758 944
Total																							507 695 023	

2006

Accident year	Total claims incurred (\$) to the end of development year - actual and forecast																						Estimated loss reserve	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22
1994	3 349 291	12 636 268	15 528 994	16 853 432	19 486 003	23 638 743	26 049 777	22 302 587	24 397 608	24 933 717	24 911 070	24 621 799	25 052 897	22 726 957	20 010 951	16 914 317	14 155 373	12 139 735	10 523 495	9 120 866	7 955 104	6 893 069	5 996 750	10 756 430
1995	15 419 283	33 114 401	38 965 892	44 346 883	47 827 439	50 605 938	51 443 543	48 901 125	50 610 693	53 132 498	55 163 766	54 100 332	49 655 354	44 194 605	37 752 748	30 356 579	24 290 095	19 301 449	14 779 821	10 622 979	6 933 716	3 699 898	942 595	36 038 291
1996	17 050 090	32 717 244	37 631 768	43 438 143	53 308 928	59 875 376	61 934 993	55 356 013	55 174 437	54 449 055	56 455 203	51 938 099	46 304 855	39 582 183	31 797 639	22 978 721	16 360 406	11 055 057	6 428 239	2 203 687	1 553 919	4 651 060	7 037 527	42 089 547
1997	18 109 382	36 311 893	42 193 245	47 942 155	54 385 836	62 809 117	64 505 637	57 849 342	59 040 249	61 069 922	63 718 647	65 514 138	70 358 924	75 164 139	77 160 609	76 084 594	75 290 410	74 599 080	73 929 656	73 297 680	72 710 726	72 198 339	71 765 016	17 924 084
1998	23 224 197	40 547 829	49 915 629	53 369 060	57 961 887	63 655 294	65 452 004	54 825 999	57 955 603	60 559 700	75 246 730	80 495 913	83 517 519	82 014 886	80 865 251	79 487 219	78 507 560	77 736 574	77 029 208	76 401 585	75 837 719	75 328 827	74 927 966	17 881 985
1999	20 665 821	41 786 198	50 543 856	56 933 371	64 536 569	69 340 364	66 099 963	59 456 547	64 952 799	74 388 405	85 785 796	87 893 067	83 004 246	81 676 869	80 118 917	78 390 535	77 247 169	76 406 567	75 689 145	75 057 733	74 522 845	74 096 420	73 762 278	16 503 845
2000	19 961 458	41 954 468	52 016 559	56 266 583	60 314 760	61 464 735	61 332 185	60 911 821	72 758 312	80 898 584	80 758 390	80 152 740	78 635 973	76 964 216	75 136 863	73 199 017	71 949 407	71 107 257	70 407 625	69 809 476	69 328 472	68 953 751	68 673 739	12 643 490
2001	18 756 606	45 065 326	57 924 080	67 158 163	72 664 016	80 639 724	81 425 754	82 361 209	96 238 127	99 601 436	96 311 717	94 987 025	93 446 696	91 772 920	89 996 119	88 154 983	86 983 378	86 238 092	85 633 575	85 161 709	84 785 642	84 492 332	84 278 145	23 105 753
2002	20 604 971	46 534 770	58 164 792	67 168 870	75 388 954	81 217 520	83 228 525	94 574 915	101 665 869	100 099 948	98 753 685	97 228 750	95 540 808	93 768 501	91 920 437	90 020 532	88 823 836	88 085 320	87 552 605	87 140 524	86 830 661	86 611 752	86 451 322	25 281 582
2003	23 272 575	46 129 306	55 251 952	67 031 626	72 819 485	85 460 733	95 738 649	101 964 701	97 287 924	96 070 697	94 706 102	93 258 666	91 748 131	90 214 647	88 645 205	87 055 486	86 134 314	85 565 130	85 159 651	84 856 130	84 636 699	84 472 832	84 369 807	35 260 622
2004	21 393 949	48 047 041	62 660 447	73 738 929	93 583 614	111 397 008	110 585 142	101 843 285	101 227 692	100 164 204	98 988 822	97 793 018	96 565 171	95 337 438	94 109 195	92 888 122	92 176 649	91 737 690	91 423 309	91 200 962	91 046 555	90 937 270	90 871 577	42 641 015
2005	13 296 154	35 928 219	49 225 566	63 527 170	80 880 226	91 624 723	85 446 968	84 664 084	83 618 671	82 357 509	81 126 292	79 927 812	78 725 902	77 527 277	76 334 962	75 158 208	74 542 675	74 240 069	74 042 456	73 907 117	73 825 009	73 785 844	73 785 844	44 102 329
2006	22 256 213	48 097 250	62 743 804	83 357 713	96 147 273	104 089 468	103 179 993	102 502 873	101 554 913	100 441 791	99 436 861	98 521 273	97 615 920	96 722 241	95 848 508	95 001 025	94 612 386	94 397 554	94 257 460	94 174 753	94 135 286	94 135 286	94 135 286	65 352 027
1998	19 586 963	47 169 049	66 896 340	76 261 682	84 225 171	84 527 047	83 818 450	83 230 363	82 453 207	81 571 404	80 774 788	80 086 750	79 448 946	78 859 417	78 301 874	77 770 042	77 495 103	77 352 351	77 269 893	77 231 566	77 231 566	77 231 566	77 231 566	61 598 613
2008	23 441 702	61 042 168	73																					

Machine Learning & Traditional Methods Synergy in Non-Life reserving

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9.4.2.7. Pure IBNR

9.4.2.7.1. On Payments

2016

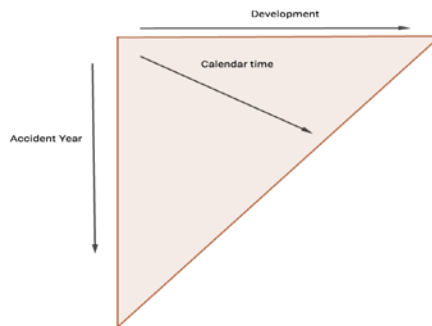
Accident year	Total IBNR (\$) to the end of development year															Pure IBNR		
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
1995																		
1996																		
1997																		
1998																		
1999																		
2000																		
2001																		
2002																	2 222 000,26	
2003																2 272 171,30	5 886 384,36	
2004																3 614 130,60	9 505 642,49	
2005																3 619 392,43	10 964 018,50	
2006																2 222 000,26	13 776 205,73	
2007																2 272 171,30	15 018 357,28	
2008																3 614 130,60	17 123 283,50	
2009																3 619 392,43	16 983 628,14	
2010																2 222 000,26	3 495 448,67	
																	Total	94 974 969

2014

Accident year	Total IBNR (\$) to the end of development year															Pure IBNR		
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16			
1996																		
1997																		
1998																		
1999																		
2000																		
2001																		
2002																	2 053 288,84	
2003																	6 060 309,87	
2004																	9 865 134,69	
2005																	13 982 585,44	
2006																	16 529 384,25	
2007																	21 541 728,57	
2008																	22 727 916,60	
2009																	25 395 596,79	
2010																	24 875 562,97	
																	Total	163 934 338

9.5. Models validation and comparison for reserving

▪ **The reserving problem**



Chain ladder	Machine Learning
$X_{ij} = \alpha_i \times \beta_j \times (1 + \varepsilon_{ij})$	$X_{ij} = A(i, j) + \psi_{ij}$
$\log X_{ij} = a_i + b_j + \tilde{\varepsilon}_{ij}$	

Chain Ladder does not account for calendar time effects (or any other non-multiplicative effect). If calendar time effects are present, (ε_{ij}) will be correlated.

If we sum the up the payments per calendar year we have

Chain ladder	Machine Learning
$\sum_{i+j=c} X_{ij}$	$\sum_{i+j=c} X_{ij}$
$= \sum_{i+j=c} \alpha_i \times \beta_j + \sum_{i+j=c} \tilde{\varepsilon}_{ij}$	$= \sum_{i+j=c} A(i, j) + \sum_{i+j=c} \psi_{ij}$

This might be helpful because the interest is also in the errors per calendar year

▪ **Errors along calendar time**

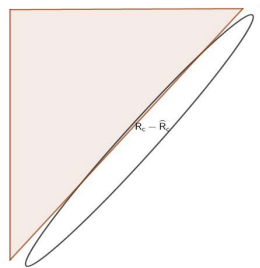
Good measures for model validation are the infeasible quantities

$$\mathbb{E} \left[(R_c - \hat{R}_c)^2 \right],$$

$$1 - \frac{\mathbb{E} \left[(R_c - \hat{R}_c)^2 \right]}{\mathbb{E} \left[(R_c - \bar{R}_c)^2 \right]}$$

where R_c are all payments for calendar year c .

- **What will be the error for the next year?**



- **Errors along AY**

Let's say we are interested in

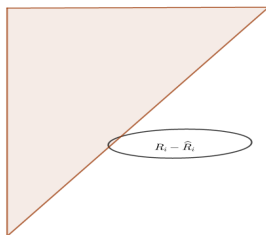
$$\mathbb{E} \left[(R_i - \hat{R}_i)^2 \right],$$

$$1 - \frac{\mathbb{E} \left[(R_i - \hat{R}_i)^2 \right]}{\mathbb{E} \left[(R_i - \bar{R}_i)^2 \right]}$$

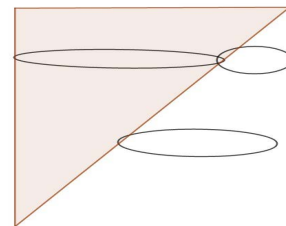
where R_i are all payments for accident year i .

With calendar effects we might have problems that the residuals/errors are correlated. Also recent rows are not fully observed.

- **Row errors**



- **Which error are we mimicking?**



Generally, if errors (residuals) are iid, then any validation method will work well. The problem arises when this is not the case.

(If errors are iid, then a method estimating R_i well will also estimate R_c well)

To estimate a mean $\mathbb{E}[X]$ - by the law of large number- we need many independent observations X_i with mean $\mathbb{E}[X]$ and then take the average.