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Estimation of Technical Reserves in Automobile Insurance Using Deterministic and Stochastic Methods

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Abstract: Insurance companies bear the responsibility of maintaining their financial stability on an ongoing basis. One of the most significant challenges they face in this regard is the inaccuracy of technical reserve estimates for outstanding claims. For this reason, numerous research studies have focused on developing methods to improve the accuracy of these estimates. In this paper, we will present and apply several methods for calculating technical reserve provisions, whether deterministic or stochastic, such as the chain ladder method, the Mack method, the bootstrap method, and generalized linear models (GLMs). These statistical and analytical methods will be applied to a dataset of bodily injury claims in the civil liability arising from automobile accidents, covering the period from 2012 to 2022, and issued by one of the leading insurance companies in the Algerian market. Each method will be described and implemented to provide more accurate reserve estimates. Finally, we will compare the results obtained from each of these methods.

Key words: Reserves, Automobile insurance, Deterministic Methods, Stochastic Methods.
JEL Classification Codes : G22 ; G32;C52

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تقدير الأرصدة التقنية في تأمين السيارات باستخدام الطرق الحتمية والعشوائية

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ملخص: تقع على عاتق شركات التأمين مسؤولية الحفاظ على استقرارها المالي بصورة مستمرة، ومن أبرز التحديات التي تواجهها في هذا الصدد هو عدم دقة تقدير الأرصدة التقنية المتعلقة بمطالبات التعويض العالقة. لهذا السبب ركزت العديد من الدراسات البحثية على تطوير طرق لتحسين دقة هذه التقديرات. في هذه المقال، سنقدم ونطبق عدة طرق لحساب الأرصدة التقنية، سواء كانت حتمية أو عشوائية، مثل طريقة السلم المتسلسل(Chain Ladder) ، وطريقة ماك(Mack) ، وطريقة بوتستراب(Bootstrap) ، ونماذج الانحدار العام(GLMs) . سيتم تطبيق هذه الطرق الإحصائية التحليلية على مجموعة البيانات المتعلقة بمطالبات التعويض عن الإصابات الجسدية (المسؤولية المدنية) الناتجة عن حوادث السيارات، والتي تغطي الفترة الممتدة من 2012 إلى 2022، والصادرة عن إحدى كبرى شركات التأمين الرائدة في السوق الجزائري. سيتم وصف كل طريقة وتنفيذها لتوفير تقديرات أكثر دقة للاحتياطيات. وفي الاخير، سنقوم بمقارنة النتائج التي تم الحصول عليها من كل من هذه الطرق.

الكلمات المفتاحية: الأرصدة التقنية ؛تامين السيارات ؛الطرق الحتمية؛الطرق العشوائية.

تصنيف JEL: G22؛ G32؛ C52

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1. INTRODUCTION :

Insurancec ompanies play a crucial role in the economic and social fabric by providing essential services that protect individuals and companies, while contributing to economic development.Given their economic role, it is imperative that they constantly monitor their financial performance, which requires an accurate estimation of technical reserves.

Technical reserves in insurance represent financial reserves that companies establish to meet their future commitments to policyholders. They are primarily intended to cover reported but unpaid claims, as well as incurred but not reported (IBNR) claims. These provisions are essential to ensure the solvency of insurers and play a fundamental role in the long-term sustainability of the company.

Numerous studies have been conducted to develop methods for calculating technical reserves in insurance, such as the work of Mack (1993), Wüthrich, M. V. (2003), Verrall, R. J. (2006), and Fia Fridayanti Adam (2017). These studies have helped to explain reserving methods, highlight the limitations of each approach, and present the advantages of each.

The insurance activity in Algeria contributes to socio-economic development by protecting the assets of individuals and companies, while also playing a role in financing the economy. It is regulated by Law 06/04 of February 20, 2006, which amends and complements Ordinance 95/07 of January 25, 1995.

Algerian insurance companies continuously seek to improve their estimates of reserves, which are regulated by the aforementioned law. Three calculation methods are specifically mentioned: the method of average claim cost settled by the company over the past three years, the evaluation based on the settlement pattern observed over the past five years, and a third method based on the calculation of the loss ratio on earned premiums (flat-rate method or premium balancing). However, the most commonly applied method within insurance companies is generally the average cost method, which can lead to under-reserving, there by negatively impacting the financial performance of the companies.

The objective of this work is to gather and apply methods beyond the average cost, both deterministic and stochastic, in order to improve the accuracy of reserve estimates for bodily injury claims settlements in the civil liability branch, using data from an Algerian insurance company for the period from 2012 to 2022. The methods we will use will include a mix of deterministic and stochastic techniques, such as the Chain Ladder, Mack's method, Bootstrap, and GLM (Generalized Linear Models).

This paper will begin with a literature review covering previous studies on reserve estimation, followed by a presentation of the methodological approach, which will include the description and explanation of the methods we will apply. Subsequently, we will apply the methods and analyze the results by comparing the outcomes obtained from each approach.

2.1 Estimation of technical reserves in Automobile Insurance: Literature Review:

Given the importance of reserve calculation in insurance, researchers have focused on this topic, presenting several articles highlighting the use of both deterministic and stochastic methods. (Fia Fridayant, 2017) attempted to estimate loss reserves using the Chain Ladder method, applying this technique to real data from an insurance company in Indonesia. The data used, provided by the Financial Services Authority (FSA), concerns the year 2014 . The data waspre-processed using MS-Excel and then presented in the form of development triangles, summarizing the incremental claims paid over a 12-month period. The calculation of reserves was performed using the R software, version 3.2.3, which allows the application of the algorithms necessary for the Chain Ladder method. This approach does not require distribution al assumptions, making it a widely accessible and practical method in the insurance field.

The application of the Chain Ladder method highlighted its simplicity and logic. However, this method has significant limitations. It does not differentiate between IBNR (Incurred But Not Reported) reserves and RBNS (Reported But Not Settled) reserves, and its predictions are limited to a maximum period of 2m-1, which reduces the scope of its estimates in long-term projections.The study conducted by (Verdonck, Van Wouwe, & Dhaene, 2009) focused on improving the Chain Ladder method by introducing robust techniques to better handle outliers in actuarial data. The main objective is to make this method more resilient to anomalies present in the run-off triangles used to estimate loss reserves. This study presents two approaches to strengthen the robustness of the Chain Ladder method. The first approach consists of the detection and adjustment of outliers, while the second proposes the use of a robust generalized linear model. To complement these techniques, the authors applied the bootstrap method to estimate the standard errors associated with the reserves. Both techniques were tested on several sets of run-off triangles, with and without outliers, to evaluate their effectiveness. The results show that the robust Chain Ladder method offers superior performance, especially in environments where the data contains extreme values. This method allows insurers to obtain reserve estimates similar to those obtained in the absence of anomalies. In addition, robustification makes it possible to identify outliers, thus facilitating their in-depth analysis for adjustments or future studies.

On the other hand, (Busse, Müller, & Dacorogna, 2010) examine the practical challenges associated with reserve risk estimation in insurance using Mack's method.

The study focuses on the difficulties encountered when applying this method, particularly in detecting outliers and significant data fluctuations. To address these challenges, the authors propose a filter to identify anomalies and develop a robust version of Mack's variance estimator, even in conditions where the data are deficient or noisy. The article also demonstrates the effectiveness of these methods by applying them to real data, highlighting their relevance in addressing common issues encountered in the insurance field. This robust approach thus enhances reserve risk assessment by taking into account the inherent uncertainties in the data, providing a more reliable alternative to the traditional method.

(Antonin & Benjamin, 2003) explore the impact of correlation between different lines of insurance on reserve estimation. The study highlights that traditional methods, which often assume independence between lines, can lead to biased estimates. To address this limitation, the authors propose the use of advanced statistical methods, such as copulas and generalized linear models (GLM), to better capture the dependence between these lines. Their results show that by accounting for these dependencies, insurers can reduce the risk of under-reserving, thereby strengthening the financial stability of insurance companies. This approach allows for more accurate reserve estimation and contributes to a more robust risk management in insurance. In conclusion, this study underscores the importance of modeling the interactions between different lines of insurance to achieve more precise and reliable reserve calculations.

The study conducted by (Yulita & Adhitya, 2022) focuses on estimating IBNR (Incurred But Not Reported) and RBNS (Reported But Not Settled) claims reserves using the Detailed Conditioning Reserve (DCR) method combined with a Gamma Generalized Linear Model (GLM). The researchers worked with data from liability insurance claims from a non-life insurance company in Sweden, comprising 1,710,629 records over the period from January 2011 to December 2012.This research stands out for its attempt to overcome the instability of the Detailed Conditioning Reserve (DCR) method, which arises from the complexity of the numerous possible calculation combinations. By integrating a Gamma Generalized Linear Model (GLM), the study stabilizes the reserve estimation while improving the accuracy of the forecasts. The results show that the combined use of the DCR method and the Gamma GLM, coupled with a bootstrap technique on individual claims, minimizes the Mean Squared Prediction Error (MSEP). Compared to other approaches such as the Chain Ladder method or a Poisson GLM associated with the DCR, this method has proven to be more effective, with a lower MSEP, indicating a reserve estimation closer to the actual value.

3. Methodological Approach:

3.1 Sampling and Data Collection:

To meet their future commitments, insurance companies must establish reserves as soon as a claim is reported. The evaluation of these reserves varies from one insurer to another, leading to the adoption of different approaches. Due to their importance, researchers have continuously sought to improve reserve calculation methods to preserve the financial stability of insurance companies.

Our study aims to estimate reserves for claims to be paid by applying several deterministic and stochastic methods specific to bodily injury liability branches. To achieve this, we utilized settlement data from a large Algerian insurance company, covering the period rom 2012 to 2022, to construct the claims settlement triangle for bodily injury within the liability branch.

3.2 Deterministic and Stochastic Methods Used:

Before presenting the various methods, it is essential to begin with the run-off triangles, which serve as the indispensable tool for their application. These triangles illustrate the evolution of claims and can include various data, such as payments, provisions, or the number of claims, thus providing a better understanding of claims dynamics. We establish the following definitions and notations:

- $i \in [0,n]$ represents the year of occurrence of the claim,
- $j \in [0,n]$ indicates the year of development of the claim.
- $C_{i,j,k}$ denotes the payments made during the development year j for the k-th claim that occurred in year i.

Fig01: Descriptive Diagram of the Cumulative Run-Off Triangle

	0	...	j	...	$n-i$	...	n	Rèserves
0	$C_{0,i}$	...	$C_{0,j}$	...	$C_{0,n-i}$	...	$C_{0,n}$	
...	...	...	...	...	...	...	...	...
i	$C_{i,0}$	...	$C_{i,j}$		$C_{i,n-i}$		$C_{i,n}$	$R_i = C_{i,n} - C_{i,n-i}$
...	...	...	...	...	...	...	...	...
$n-j$	$C_{n-j,0}$		$C_{n-j,j}$				$C_{n-j,n}$	$R_{n-j,n} = C_{n-j,n} - C_{n-j,j}$
...	...	...	...	...	...	...	...	...
n	$C_{0,n}$						$C_{n,n}$	$R_n = C_{n,n} - C_{0,n}$

Source : (Belgada, Lahlou, & EL ouardirhi, 2017)

3.2.1 Chain Ladder:

According to (P. D & Verrall, 2002) the Chain-Ladder method, also known as the settlement pattern method, is an old technique with its earliest references appearing in insurance law literature from the 1930s. It is now the most widely adopted method among actuaries due to its simplicity, both in terms of calculation and interpretation. This method allows for the estimation of the final value of cumulative payments for a given accident year based on historical data. It utilizes cumulative triangles and development factors, known as "link ratios," to transpose data from one development year to another.

The Chain-Ladder (CL) algorithm is a non-parametric deterministic reserving method designed for a cumulative run-off triangle. It relies on two assumptions:

H1: The accident years are independent.
H2: The development years are explanatory variables for the behavior of future payments.

3.2.2 The Mack Method:

In (Mack, 1993) 's article, the variability of reserve estimates using the Chain-Ladder method is assessed without relying on a predefined distribution of claim amounts. To achieve this, a formula is developed to calculate the standard error, which corresponds to an estimate of the standard deviation of reserves for unpaid claims. This formula is based solely on the traditional Chain-Ladder equations. This tool allows for the determination of a confidence interval for the reserves to be established and the final amount of claims.

Following (Kesar & Minge, 2008) ,the Mack model "is one of the first stochastic models for the Chain-Ladder method. It is therefore interesting to quantify the variability of the estimated reserves, particularly to determine if the difference between the results obtained by Chain-Ladder and those obtained by another method is significant, and also to construct confidence intervals for the estimates made to forecast the ultimate amount of claims.

The model is based on three main assumptions: the first two are the same as those of the Chain-Ladder method, but this model includes a third additional assumption as mentioned in the article by (Haxhi, Llaga, raço, & Zaçaj, 2022) , which is:

H3: the conditional variance of Cij is given by: $V(C_{ij}+1|C_{j,1},\ldots,C_{i,n})=\sigma_j 2C_{ij}$

This means that, for fixed j, the plot of the residuals should not exhibit any non-random structure.

3.2.3 Bootstrap:

In the field of insurance, the Chain Ladder method is the most commonly used to estimate outstanding claims reserves, particularly in long-tail business. It is non-parametric and provides a point estimate of reserves but does not allow for measuring the risk that this estimate differs from the actual reserves.

To analyze the variability of reserves, the Mack model is frequently used. It calculates the standard error and confidence intervals based on the results of the Chain Ladder, but it does not predict the underlying distribution of the data. It is limited to the analysis of the first two moments (mean and variance)

In contrast, and as stated by (Wanat, Papież, & miech, 2016) bootstrap techniques provide a powerful alternative to the Mack model for estimating the distribution of claims and reserves while calculating the standard error. Unlike Mack, the bootstrap simulates the adjusted distribution of the data by repeatedly sampling the claims experience, allowing for a better understanding of the variability of reserves while accounting for the uncertainties present in the data .This method was initially developed by Efron (1971).The Bootstrap method is primarily based on two assumptions:

H1: The non-causality assumption, i.e., the independence of observations.

H2: The uniqueness of the distribution law for each element that composes the initial sample.

3.2.4 Generalized Linear Model: GLM

(Ticconi, 2018) Shows that GLMs (Generalized Linear Models) are widely regarded as a standard tool for actuaries. They are frequently used and have already been suggested for more detail dreserving processes, as demonstrated by the work of Zhou and Taylor. Due to their efficiency and simplicity in modeling different underlying relationships in the data, GLMs are considered a reliable benchmark for analysis.

(Zhou & Garrido, 2009) adds that Generalized Linear Models (GLMs) have become a commonly used statistical method for data analysis in the property and casualty insurance field. Haberman and Renshaw (1996) provide an in-depth analysis of the application of GLMs to various actuarial problems, particularly in reserve estimation. Taylor and McGuire (2004) focus specifically on claims reserving models based on GLMs. Hoedemakers and colleagues (2005) define bounds for discounted claims reserves within the GLM framework. Verrall (2004) employs a Bayesian parametric model using GLMs to estimate reserves, while Venter (2008) extends the application of GLMs beyond the exponential family to apply them to claims reserves.

4. Results and Discussions:

Our study will focus on the motor insurance branch, specifically on bodily injury claims under civil liability. It is based on a claims payment triangle, which compiles the amounts of payments made for these claims. This data is presented in the form of triangles expressed in Algerian dinars, categorized by year of occurrence and development year, covering the period from 2012 to 2022, and sourced from a major Algerian insurance company. The tools used for this study are the R and Excel software. The table below presents the payment triangle used for our analyses:

Table 01.Bodily Injury Claims Payment Triangle

	1	2	3	4	5	6	7	8	9	10	11
1	1 599 916,25	9 546 953,44	9 774 174,66	3 596 898,45	621 879,92	196 260,00	2 758 746,20	8 899 016,18	5 237 560,34	3 561 158,62	2 855 982,29
2	639 300,00	7 292 450,00	5 054 466,02	2 325 576,11	4 900,00	10 358 910,03	6 461 930,18	3 506 486,07	3 824 607,41	3 457 197,94	
3	1 286 400,00	7 665 292,36	7 635 447,39	1 168 324,71	7 637 821,54	12 595 153,08	8 284 619,23	9 379 938,52	1 745 398,51		
4	265 200,00	6 374 127,74	1 963 866,20	30 398 712,62	28 025 232,20	18 006 056,79	9 106 364,80	4 293 991,96			
5	3 828 426,80	7 411 963,88	61 994 068,97	60 445 705,27	31 662 158,42	17 338 790,68	10 329 864,99				
6	808 820,00	79 559 899,48	110 994 667,07	42 053 761,20	31 678 847,65	15 726 130,86					
7	14 213 311,06	147 192 529,52	95 633 180,71	74 105 646,29	27 261 739,96						
8	20 014 385,52	73 190 608,51	112 221 708,18	70 126 191,65							
9	14 495 779,55	76 771 336,52	80 072 335,40								
10	21 816 134,43	114 001 415,31									
11	17 636 977,40										

Source: Prepared by us using Excel

Our payment triangle allows us to visualize the evolution of bodily injury claims payments over several years (11 years), based on their year of occurrence and development. It consists of 66 observations (bodily injury claims) occurring over 11 years, with a cumulative payment amount of 1,679,992,698.04 Algerian dinars.

4.1 Descriptive Data Analysis:

Table. 02 Statistical description

Min	Max	Nb obs	Mean	Variance
4 900,00	147 192 529,52	66	25 454 434,82	1,19977E+15

Source: Prepared by us using Excel

The data shows a minimum payment of 4,900.00 and a maximum of 147,192,529.52 Algerian dinars (DA), with a total of 66 observations. The average amount paid is 25,454,434.82 DA, while the variance, which measures the dispersion of values around the mean, reaches 1.19977E+15.

4.1.1Chain Ladder Method:

The first step of the Chain Ladder method is to establish the triangle of cumulative payments, which is presented in the following table:

Table3. Cumulative Payments Table

	1	2	3	4	5	6	7	8	9	10	11
1	1 599 916,25	11 146 869,69	20 921 044,35	24 517 942,80	25 139 822,72	25 336 082,72	28 094 828,92	36 993 845,10	42 231 405,44	45 792 564,06	48 648 546,35
2	639 300,00	7 931 750,00	12 986 216,02	15 311 792,13	15 316 692,13	25 675 602,16	32 137 532,34	35 644 018,41	39 468 625,82	42 925 823,76	
3	1 286 400,00	8 951 692,36	16 587 139,75	17 755 464,46	25 393 286,00	37 988 439,08	46 273 058,31	55 652 996,83	57 398 395,34		
4	265 200,00	6 639 327,74	8 603 193,94	39 001 906,56	67 027 138,76	85 033 195,55	94 139 560,35	98 433 552,31			
5	3 828 426,80	11 240 390,68	73 234 459,65	133 680 164,92	165 342 323,34	182 681 114,02	193 010 979,01				
6	808 820,00	80 368 719,48	191 363 386,55	233 417 147,75	265 095 995,40	280 822 126,26					
7	14 213 311,06	161 405 840,58	257 039 021,29	331 144 667,58	358 406 407,54						
8	20 014 385,52	93 204 994,03	205 426 697,21	275 552 888,86							
9	14 495 779,55	91 267 116,07	171 339 451,47								
10	21 816 134,43	135 817 549,74									
11	17 636 977,40										

Source: Prepared by us using Excel

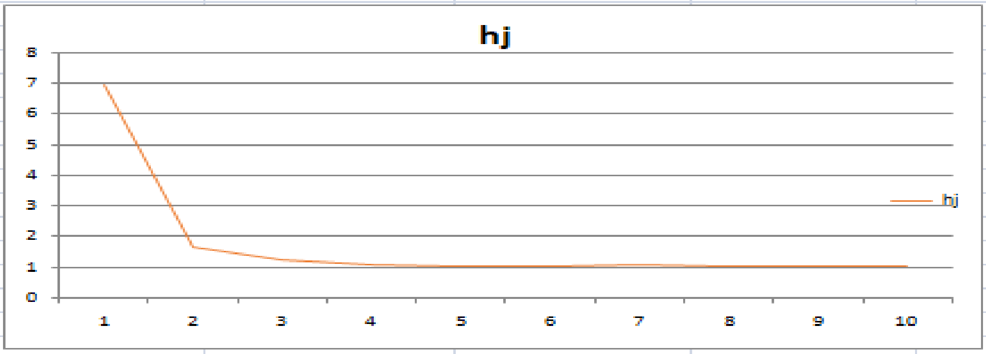
Next, it is essential to calculate the development factors, which represent the ratio between the cumulative payments of one occurrence year and those of the previous year. These factors are used to forecast future payments based on the claims payment history. The development factors in our study are presented as follows:

Table 04.Development Factors

j	1	2	3	4	5	6	7	8	9	10
hj	7,6990	2,0279	1,3615	1,1596	1,1317	1,1035	1,1299	1,0842	1,0859	1,0623

Source: Prepared by us using Excel

Fig 2 . Graphical Representation of Development Factors



Source: Prepared by us using Excel

The curve illustrates the evolution of claims payments over time. It is observed that from the fourth year onwards, almost all insured claims will be settled.

After determining the development factors hj , it is possible to complete the lower part of the triangle using the following formula:

$$C_{i,j+1} = h_j * C_{i,j}$$

Table 05. Estimation of Future Payments

	1	2	3	4	5	6	7	8	9	10	11
1	1 599 916,25	11 146 869,69	20 921 044,35	24 517 942,80	25 139 822,72	25 336 082,72	28 094 828,92	36 993 845,10	42 231 405,44	45 792 564,06	48 648 546,35
2	639 300,00	7 931 750,00	12 986 216,02	15 311 792,13	15 316 692,13	25 675 602,16	32 137 532,34	35 644 018,41	39 468 625,82	42 925 823,76	45 603 013,71
3	1 286 400,00	8 951 692,36	16 587 139,75	17 755 464,46	25 393 286,00	37 988 439,08	46 273 058,31	55 652 996,83	57 398 395,34	62 329 145,04	66 216 477,80
4	265 200,00	6 639 327,74	8 603 193,94	39 001 906,56	67 027 138,76	85 033 195,55	94 139 560,35	98 433 552,31	106 725 858,84	115 894 033,20	123 122 091,14
5	3 828 426,80	11 240 390,68	73 234 459,65	133 680 164,92	165 342 323,34	182 681 114,02	193 010 979,01	218 098 159,59	236 471 333,68	256 785 158,66	272 800 288,63
6	808 820,00	80 368 719,48	191 363 386,55	233 417 147,75	265 095 995,40	280 822 126,26	309 904 206,31	350 184 934,51	379 685 452,89	412 301 938,44	438 016 310,59
7	14 213 311,06	161 405 840,58	257 039 021,29	331 144 667,58	358 406 407,54	405 629 325,11	447 636 501,18	505 819 397,29	548 430 980,35	595 543 375,65	632 686 116,37
8	20 014 385,52	93 204 994,03	205 426 697,21	275 552 888,86	319 544 254,44	361 646 771,78	399 099 092,60	450 973 193,53	488 964 385,24	530 968 364,29	564 083 702,47
9	14 495 779,55	91 267 116,07	171 339 451,47	233 283 797,38	270 527 002,70	306 171 104,15	337 878 337,04	381 795 086,74	413 958 529,15	449 519 207,81	477 554 739,84
10	21 816 134,43	135 817 549,74	275 428 446,92	375 004 083,72	434 872 596,85	492 170 547,89	543 139 976,34	613 736 222,92	665 439 008,90	722 602 857,69	767 670 021,03
11	17 636 977,40	135 787 565,00	275 367 639,98	374 921 293,26	434 776 589,08	492 061 890,33	543 020 066,15	613 600 727,04	665 292 098,48	722 443 327,09	767 500 540,85

Source: Prepared by us using Excel

From this table, we can draw the following summary:

Table 06 . Estimation of Future Payments

Year of occurance	Total settlements	Estimated final cost	Provision for claims to be established
2012	48 648 546,35	48 648 546,35	-
2013	42 925 823,76	45 603 013,71	2 677 189,95
2014	57 398 395,34	66 216 477,80	8 818 082,46
2015	98 433 552,31	123 122 091,14	24 688 538,83
2016	193 010 979,01	272 800 288,63	79 789 309,62
2017	280 822 126,26	438 016 310,59	157 194 184,33
2018	358 406 407,54	632 686 116,37	274 279 708,83
2019	275 552 888,86	564 083 702,47	288 530 813,61
2020	171 339 451,47	477 554 739,84	306 215 288,37
2021	135 817 549,74	767 670 021,03	631 852 471,29
2022	17 636 977,40	767 500 540,85	749 863 563,45
Total	1 679 992 698,04	4 203 901 848,78	2 523 909 150,74

Source: Prepared by us using Excel

In conclusion, after several calculation steps, we determine that using the Chain Ladder method, the reserve to be established for bodily injury claims amounts to: 2,523,909,150.74 Algerian Dinars (DA).

4-1-2 Mack Method:

The stochastic Mack model (1993) is a semi-parametric model based on the Chain Ladder method.It is conditional on the available information and applies to the triangle of cumulative amounts (Mack, 1993). This model allows for the estimation of the volatility of the technical reserve estimates, that is, the prediction errors. It is termed semi-parametric because it does not rely on any distributional assumptions regarding the data in the triangle.

To establish a confidence interval, several steps need to be followed: first, calculate the volatility of the triangle for each development year using the unbiased estimator σ_j^2, σ_{j-1}^2. Next, assess the uncertainty in the estimation of Ci,j using the means quared error (MSE). After that, determine the standard error and the coefficient of variation. The results of applying the Mack method to our sample can be summarized as follows:

Table 07.Summary of MSE Calculation, Standard Error (SE), and Coefficient of Variation

Year of occurance	(Ri)	MSE	SE(Ri)	**Coefficient of Variation**
2012	0,00	0,00	0,00	0,00
2013	2677189,953	2,66819E+07	5165,448058	0,001929429
2014	8818082,457	2,40977E+10	155234,302	0,017604088
2015	24688538,83	5,95755E+02	24,40809565	9,88641E-07
2016	79789309,62	1,07245E+05	327,4834836	4,10435E-06
2017	157194184,3	2,07098E+05	455,0799519	2,89502E-06
2018	274279708,8	5,55490E+05	745,3123078	2,71734E-06
2019	288530813,6	9,05396E+05	951,5231783	3,29782E-06
2020	306215288,4	4,81727E+06	2194,827464	7,1676E-06
2021	631852471,3	2,49619E+07	4996,193037	7,90721E-06
2022	749863563,4	2,98495E+09	54634,74011	7,28596E-05

Source: Prepared by us using Excel

Based on the previous calculations, the confidence interval according to the Mack method is as follows:

Table 08 . Confidence Interval of the Technical Reserves According to the Mack Method

	Normal distribution				Log -normal distribution	
Years	Lower bound	Upper bound	Yi	6i*2	Lower bound	Upper bound
2012	0,00	0,00	-	-	0,00	0,00
2013	2667065,68	2687314,23	14,80	3,72269E-06	2 677 165,44	2 677204,50
2014	8513823,23	9122341,69	15,99	0,00030985	8 811 363,47	8822072,57
2015	24 688490,99	24688586,7	17,02	9,7744E-13	24 688 538,83	24688538,83
2016	79 788 667,76	79789951,9	18,19	1,68456E-11	79 789 309,62	79789309,63
2017	157193292,38	157195076,29	18,87	8,38107E-12	157194184,3	157194184,33
2018	274278248,02	274 281169,64	19,43	7,38387E-12	274279708,2	274279708,83
2019	288528948,62	288 532 678,59	19,48	1,08755E-11	288530813,0	288530813,61
2020	306210986,51	306 219 590,24	19,54	5,13745E-11	306215288,4	306215288,40
2021	631842678,75	631 862 263,83	20,26	6,2524E-11	631852471,9	631852471,35
2022	749756479,36	749 970 647,54	20,44	5,30852E-09	749863553,6	749863569,26
TOTAL	2 523 468681,28	2524 349620,21			2523902397,29	2523913161,31

Source: Prepared by us using Excel

Using the normal distribution, the amount of the reserves is between 2,523,468,681.28 Algerian Dinars (DA) and 2,524,349,620.21 Algerian Dinars (DA). However, with the log-normal distribution, it ranges between 2,523,902,397.29 Algerian Dinars (DA) and 2,523,913,161.31 Algerian Dinars (DA). We have favored the log-normal distribution because the normal distribution can result in a negative lower bound, which is unrealistic given that reserves can not be negative.

4.1.3 Bootstrap Method:

Bootstrap is a stochastic method used to estimate the distribution of a statistic from a sample by generating multiple samples through resampling with replacement. In our study, we performed 999 simulations using the Boot Chain Ladder function in R. The results obtained are as follows:

Table 9.Results of the Bootstrap Method Application

	IBNR	IBNR.S.E	IBNR 75%	IBNR 95%
2012	0	0	0	0
2013	4 010 000,00	26 700 000,00	4 680 000,00	17 900 000,00
2014	10 900 000,00	23 200 000,00	16 200 000,00	39 800 000,00
2015	30 500 000,00	58 900 000,00	41 300 000,00	85 700 000,00
2016	93 400 000,00	127 000 000,00	121 000 000,00	218 000 000,00
2017	179 000 000,00	174 000 000,00	225 000 000,00	363 000 000,00
2018	307 000 000,00	286 000 000,00	373 000 000,00	582 000 000,00
2019	325 000 000,00	309 000 000,00	388 000 000,00	575 000 000,00
2020	335 000 000,00	232 000 000,00	391 000 000,00	585 000 000,00
2021	683 000 000,00	387 000 000,00	802 000 000,00	1 170 000 000,00
2022	842 000 000,00	723 000 000,00	1 080 000000,00	2 120 000 000,00
Total	2 809 810 000,00	2 346 800 000,00	3 442 180 000,00	5 756 400 000,00

Source: Prepared by us using R

The results obtained show that the standard error (SE), which evaluates the prediction error, is 2,346,800,000 Algerian Dinars (DA). Furthermore, the estimated amount of reserves is 2,809,810,000 Algerian Dinars (DA), according to the calculations performed with R.

4.1.4 Generalized Linear Model (GLM): The generalized linear models (GLM) method is an extension of classical linear models designed to handle situations where the relationships between variables are not strictly linear. It allows for the analysis of both discrete and continuous data, even when the normal distribution is no longer appropriate. The software used to apply this method is R, which facilitates its implementation. The results obtained are as follows:

Table 10.Reserves According to the GLM Method

Year of occurrence	Total settlement	Estimated final cost	Provision for claims to be established
2012	48 648 546,35	48 648 546,35	-
2013	42 925 823,76	44 921 512,94	1 995 689,18
2014	57 398 395,34	69 799 076,90	12 400 681,56
2015	98 433 552,31	121 917 509,58	23 483 957,27
2016	193 010 979,01	301 225 412,55	108 214 433,54
2017	280 822 126,26	466 466 426,51	185 644 300,25
2018	358 406 407,54	873 677 327,51	515 270 919,97
2019	275 552 888,86	794 372 519,71	518 819 630,85
2020	171 339 451,47	695 770 338,49	524 430 887,02
2021	135 817 549,74	1 176 916 327,15	1 041 098 777,41
2022	17 636 977,40	1 240 180 283,53	1 222 543 306,13
Total	1 679 992 698,04	5 833 895 281,20	4 153 902 583,16

Source: Prepared by us usingR

After applying the GLM method to the entire data set, the amount of reserves is estimated at 3,610,332,010.07 Algerian Dinars (DA). This result reflects the model's fit to the available data.After applying several methods to estimate the amount of reserves, we noted the following points:

- **Chain Ladder Method:** The required reserve is estimated at 2,523,909,150.74 DA. This method, both simple and deterministic, provides a result that falls within the average of the estimates obtained by other approaches.
- **Mack Method:** Using the normal distribution, the reserve estimates range between 2,523,468,681.28 DA and 2,524,349,620.21 DA. When applying the log-normal distribution, these amounts vary between 2,523,902,397.29 DA and 2,523,913,161.31 DA. The narrow confidence intervals indicate consistency in these results, which are comparable to those from the Chain Ladder and highlight a stochastic approach to uncertainties.
- **Bootstrap Method:** The reserve estimate reaches 2,809,810,000 DA, representing a significantly higher amount. This method, which is more complex and capable of accounting for data variability, partly explains this difference compared to the previous approaches.
- **GLM Method:** After adjusting the data, the reserve estimate amounts to 3,610,332,010.07 DA, making it the highest estimate. This method, being more sophisticated and adaptable, appears to integrate more factors and subtleties in the claims evaluation, justifying the significant difference observed.

In summary, the Chain Ladder and Mack methods provide similar estimates, while the Bootstrap and GLM methods yield much higher reserve amounts. This difference can be attributed to the robustness and stochastic adjustments offered by these latter methods.

5. Conclusion:

The evaluation of reserves in automobile insurance is a major issue for the solvency and performance of insurance companies. According to Algerian regulations, this evaluation is conducted on a case-by-case basis, distinguishing between property claims and bodily injury claims. Once approval from the regulatory authority is obtained, insurers have the option to use three methods (the average cost method, the payment pattern method, or the premium blocking method) and retain the highest estimate. However, these approaches can often lead to under-reserving situations, prompting insurance companies to explore other methods to obtain more accurate reserves and avoid such scenarios.

In our study, which focused on bodily injury claims in the automobile insurance sector, particularly regarding civil liability, we examined the payments made by a large Algerian insurance company covering the period from 2012 to 2022. We calculated the reserves using the Chain Ladder, Mack, Bootstrap, and GLM methods. The results indicate that the Chain Ladder and Mack methods provide similar estimates, while the Bootstrap and GLM methods yield significantly higher reserve amounts. This difference can be attributed to the reliability and stochastic adjustments incorporated into these latter methods.These results highlight the necessity of adopting appropriate estimation techniques to ensure the sustainability of insurance companies and optimize their risk management. However, while these traditional methods are reliable, they have certain limitations. Other approaches, such as the copula method, could provide more accurate results by taking additional parameters into account, particularly the dependence between property and bodily injury claims when evaluating reserves. Moreover, with technological advancements and the emergence of artificial intelligence, tools such as neural networks and machine learning could also enhance reserve estimation.

In conclusion, it is crucial for insurance companies to continue exploring and integrating new reserve estimation methods while building on the solid foundations of traditional approaches. This will not only improve their performance but also strengthen policy holders' trust in their risk and claims management.

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