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An Introduction to Loss Reserving: Concepts, Origins and Development of the Models

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Abstract: *Loss reserving is a fundamental topic for a non-life insurance company. It includes several activities from claims management to set actuarial models. Differently from the past when it was a heuristic ancillary part of risk theory and non-life insurance mathematic today has become a great actuarial research field. From nineties every year a lot of paper are published in actuarial journals. This work is originated from the experience of an introductory university lecture kept many times from the author. Some examples are taken from Italian regulation.*

Keywords: *Loss reserving; Technical provisions; Claims handlers; Stochastic models; Solvency II.*

JEL Classification Numbers: *C13, G22, M40.*

1. INTRODUCTION

Insurance companies are characterized by the reversal of the production cycle, the length of the settlement processes and the investment of the funds. This is due to the typical activity carried out: insuring against a certain event means protecting you or your property from the negative effects caused by the event itself. The function and purpose of the insurer can be traced precisely in the offer of property guarantees for policyholders, through future and eventual benefits. In general, therefore, solvency consists in the availability of sufficient financial resourcesto meet the present and future commitments towards policyholders on a reference period. This occurs with a predetermined level of confidence, corresponding to the probability of the percentile of the distribution of the random variable "overall damage value", taken as the safety target. The chanceof economic survival can be examined mainly accordingtwo perspectives. The first focuses on the overall exposure of the company to sources of risk (technical or financial). The second looks at the availability of safetycapital sufficient to face unexpected losses and to overcome possible crises. It is fundamental to pay attention to the fact thatthe inversion of the production cycle, whereby

revenues (premiums) precede costs (compensations), involve greater elements of risk if compared withindustrial companies. In this regard, the companies, in order to face future reimbursements deriving from claims or management costs, constitute the so-called technical reserves.

Technical reserves are the first measure to safeguard the solvency of insurance companies, well before the safety margin: constant monitoring and an assessment of reserves as correct as possible are undoubtedly of primary importance.

Therefore, the premiums issued will have to meet the compensations, expenses and liquidity funds for phase-outs ofexpected cash flows. What remains is the profit of the company.

The technical provisions - through the assets covering them - therefore represent the provisions that an insurance company holds to meet the technical obligations towards its policyholders, as far as reasonably foreseeable. In the field of non-life insurance, the legislation distinguishes between the premium reserve and the claims reserve based on the purpose of the provisions.

The establishment of the premium reserve responds to the need for correct management of the premium collected by the insurer; its assessment, which is possible at any time in the life of a generic contract, is normally based on the assumption of uniform distribution of the occurrence of claims and compensationand of expenses. Italian legislation allows a contract-by-contract method, called pro rata temporis, or, alternatively and under certain conditions, a flat rate method.

The establishment of the claimsreserve is necessary for the claims settlement process, which, given an accident year of claims, may take place for more than one year. The Italian Insurance Code specifies that the claims reserve must be sufficient to cover both claims, that occurred in the reference year or in previous years and still not closed, and settlement costs,from the occurrence of the accident until its closure, i.e. the moment that determines the end of the company's commitments. There are in fact distinct phases, which can cover periodsmore or less extended, depending on the branch, onthe characteristics of the company, on the speed of liquidation, on the contractual conditions as well as on the emergence of disputes.

2. CLAIMS MANAGEMENT

The discussion now addresses the determination of the cost of the damage originating from the uncertain event. The following diagram highlights the

three fundamental moments of the opening of a claim (event, report to the company and subsequent registration).

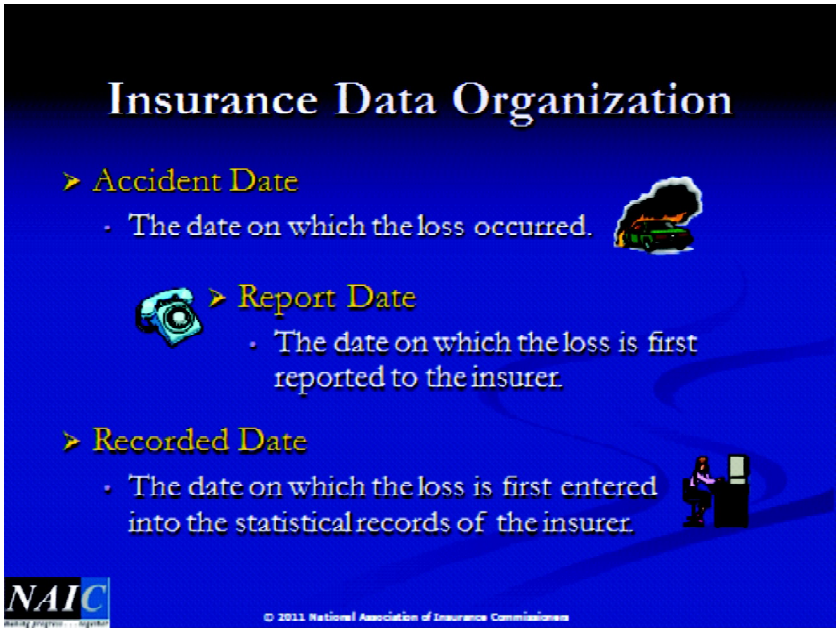


Figure 1: Key dates for a claim

The typical course of a claim can be summarized with the following diagram, while taking into account possible operational anomalies (e.g. delay in registering with respect to the report, reopening of a claim closed due to litigation):

The time of a single claim

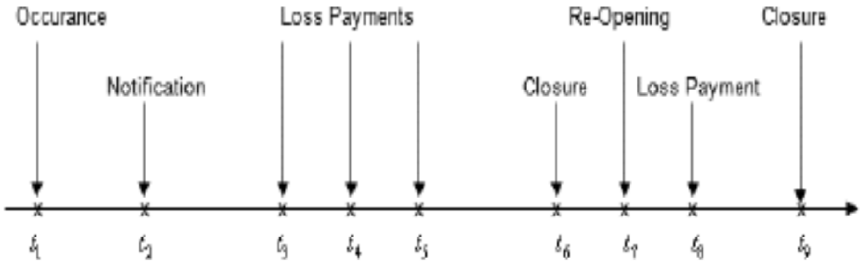


Figure 2: Claim life

The number of liquidations that precede a final payment, the so-called partial payments, is influenced by the company's liquidation policies and

contractual conditions. From an actuarial point of view, the further distinction between claims settled and claims paid (due to timing related to accounting procedures) is irrelevant; in fact, claims settled and unpaid constitute a real debt due to policyholders, for which there is therefore no actuarial valuation problem. The insurer must also put in reserve not only the amounts necessary to cover the claims for which, following the claims reported, the liquidation process began, but also appropriate provisions for claims that have occurred but are still unknown to the company. The latter are commonly known with the abbreviation IBNR (Incurred But Not Reported) or also IBNYR (Incurred But Not Yet Reported). Claims not yet known to the company require an assessment based on experience, regarding the frequency and average cost of late claims. Otherwise, the reported claims for which a specific reserve is established are indicated as IBNER (Incurred But Not Enough Reported) or as RBNS (Reported But Not Settled). The recourse to historical data held by the company requires to evaluate with particular caution past claims which are exceptional in nature. The current provisions on the preparation of the financial statements provide that the procedure by which these large claims, which are generally particularly expensive, be dealt with in detail in the explanatory notes.

Another example that highlights the complexity of managing a single claim is taken from the NAIC or the United States Insurance Supervisory Institute.

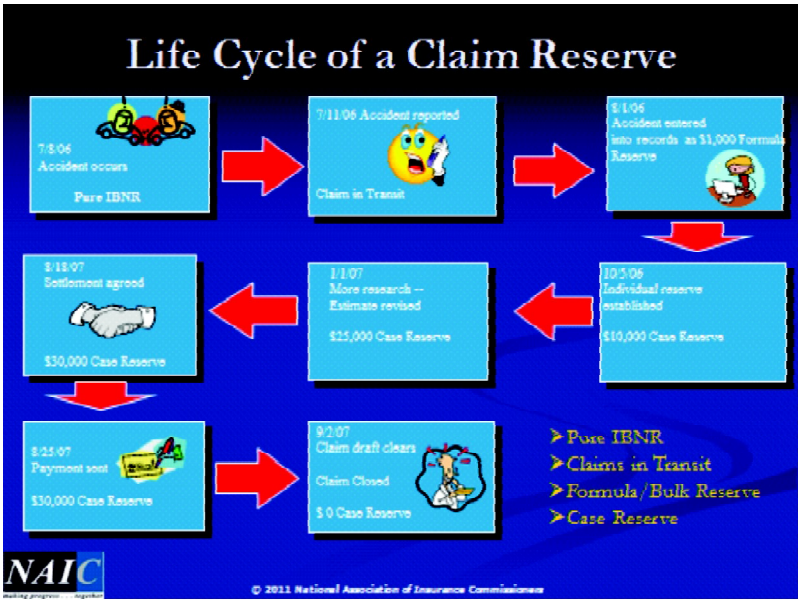


Figure 3: Life Cycle of a claim (NAIC)

The reserve represents the amount of the aggregate of claims still to be paid; in Italy, several million claims are managed every year and the corresponding reserves amount to more than 40 billion euros.

3. CASE BY CASE CLAIMS RESERVING APPROACH

In general, the evaluation of the reserve as a whole can follow two alternative logics. One monitors the individual claim, dynamically quantifying its final cost by periodically updating the estimated amount based on new information that becomes available. The other, with a collective approach, analyses a sufficiently large portfolio of claims in terms of compensations occurred and expected.

The first approach finds expression in the inventory (case by case) method, ideally preferable because it is considered more adherent to the principle of prudent evaluation; the second (actuarial method) leads to the use of deterministic and stochastic statistical methods, the object of subsequent study. The evaluation of the reserve must be based on objective and prudent elements;therefore, the reference method is that of the inventory. However, with the exclusion of the Credit and Surety classes and limited to the generation of the financial year, it is allowed to estimate the ultimate cost by using the average cost criterion for sufficiently large homogeneous groups of claims.

- ✓ In the inventory:
  - a file is opened for each accident report;
  - estimates are made, and updated, when new information is added;
  - all payments are recorded;
  - when the claim is defined, the file is closed;
  - the IBNR reserve is not taken into account;
  - uses all the information available on a claim;
  - can be altered by managers' attitude in terms of directives to liquidators;
  - the procedures are easy to implement.

An article entitled "Why are reserves often inaccurate?", Recently published in the American magazine Claim Journal, states that outside the normal and expected daily changes that occur during the liquidation process, there are rarer but worrying reasons for which inventory reserves are often inaccurate, including:

Claims Staff Turnover - Due to the burnout, or also due to the attraction represented by a work alternative characterized by a shorter commute or a

higher salary, a company could lose an expert liquidator resulting in problems in handling the files. While temporary employees can help fill in the gaps, they are not a long-term solution. There are opportunity costs inherent in each claim file in the event of the liquidator's turnover, which equate to higher repayments and problems of adequacy of the reserves. It is considered that it typically takes 90 days to recruit and hire a new liquidator. Once the new liquidator finishes training on systems and procedures, it usually takes another 90 days before reviewing the claims inventory. Lurking in the dark could be that claim that destroys a portfolio's profitability.

Lack of Training & Experience - The education and training of assessor employees is an investment and not just an expense, because it helps companies retain quality talents. If a company invests in the continuous training of a liquidator, it is natural that employee satisfaction increases because the liquidator has the opportunity to hone existing skills and develop new ones.

High Caseloads - Too often companies increase workloads in an attempt to reduce operating expenses. Although there may be an initial reduction in expenses, there are likely to be oversights in critical areas of the long-term settlement process because the workloads are not manageable. To avoid high workloads, claims management contracts should limit the number of claims that a liquidator can handle at any given time.

Outdated Claims Systems - Many claims departments work with old systems, tools and methods that are no longer effective or efficient. Having web-based, real-time information helps liquidators to sort and analyze files more efficiently. The business rules of the systems can be configured to support the reservation process by asking the liquidators to set or modify the reserve or reserve authorization levels.

4. ACTUARIAL MODELS

The correctness of the estimates according to a collective approach is subordinated not only to the number and homogeneity of the claims in the portfolio, which are also delicate aspects of the evaluation process, but also to the stability of the contractual conditions and the regularity of the settlement speed. As said, in actuarial practice we often resort to mixed approaches, favoring a collective logic for medium-low claims, also due to the fact that there will normally be a more substantial database, and adopting an individual approach for large claims. In this regard, methods based on historical experience are more reliable (with particular reference to the frequency of occurrence), at least for the branches that enjoy regular

technical trends. Whatever the calculation procedure adopted the centrality of the available information remains, an essential starting point for estimating future charges.

An example of how the reservation process involves the participation of many business units of the company (IT systems workers, actuaries, liquidators, auditors, accountants and managers) is well exemplified by the following wheel of the process itself.

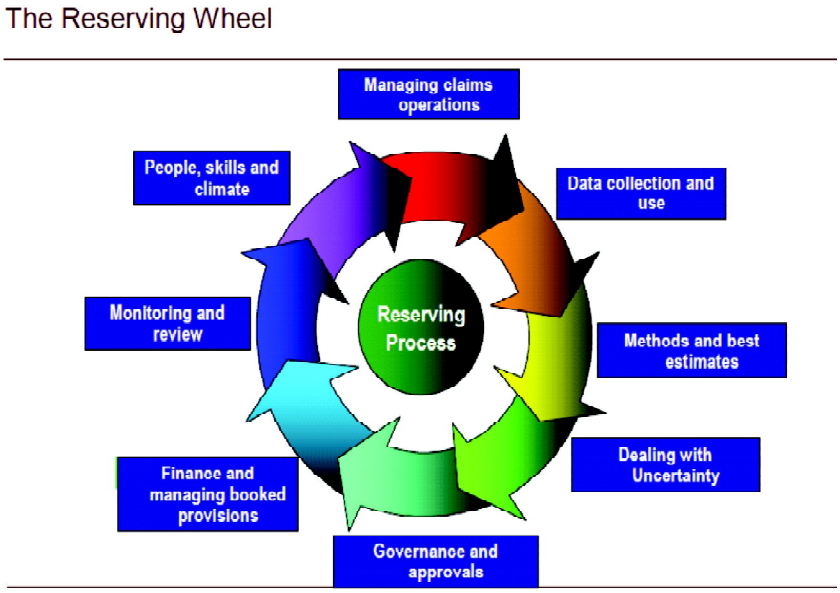


Figure 4

The Friendland manual [5] published by CAS in 2010 provides useful tips on how to properly develop this interaction process within the company and, very interestingly, a series of questions that those who have the burden of evaluating this process independently and externally must ask themselves.

5. CLAIMS COMPETENCE

The claims reserve is the most important item in the financial statements of a company that carries out non-life business.The assessment is based on strict accounting principles. As regards claims, a principle for thepreparation of the financial statements particularlyrelevantis that of competence. It requires costs and revenues to be accounted for by attributing them to the financial years to which they compete economically, regardless of their

financial manifestation. Here, then, we will talkaboutrelevant claims, meaning the overall burden relating to claims that occurred in the current year. The amount of the relevant claims is calculated based on the financial flow generated by the amounts paid, adjusted with the provision for the remaining claims reserve. The first data is present in the technical account of the non-life classes, while the second is in the passive side of the balance sheet.

The overall charge relating to the claims pertaining to the current year is therefore equal to the sum of the payments made to settle the claims in the year and the change of thereserve during the year. Depending on the date of occurrence of an accident, four cases can be distinguished

- Claim occurred and closed in the current year.
- Claim occurred in the current year but still open.
- Claim occurred in previous years and closed in the current year.
- Claim occurred in previous years but still open.

In the first two cases, the accident is to be considered as of competence; if it was closed during the year, then the relative cost is valued among the amounts paid, otherwise the evaluation of the coverage amount appears in the claims reserve of the current year. However, in the third case, there may be a difference between the amount actually paid and the provision already madeat the end of the previous year. Similarly, in the latter case, a non-zero balance may occur between the amount set aside in the reserve at the end of the current year and the provision made at the end of the previous year.

The late claims mentioned above fall into the third or fourth case, even if only those that occurred in the current year are as of competence. In all the cases commented upon, the relevant claims are quantified in the technical account of the non-life business, net of the reinsurance assignments and recoveries and gross of the directly attributable liquidation costs (*allocated loss expenses* ALAE)and of the nondirectly attributable liquidation costs (*unallocated loss expenses* ULAE).

6. THE VALUATION AT THE ULTIMATE COST OF THE CLAIMS RESERVE

The claims reserve includes the total amount that, according toa prudent assessment made based on objective elements, isnecessary to meet the payment of the claims. We consider the claimsnot yet paid, which occurred in the same year or in the previous onesregardless of the date of reporting, as well as the related settlement costs, regardless of their origin. Schematizing local principles:

- The companies estimatethe claims reserve separately for each claim occurred and reported, whose liquidation process has not yet been completed at the end of the year andfor which compensation for damages anddirect expenses has not been fully paid. Limited to the current generation, companies maydetermine the claims reserve using the average cost criterion.
- Companies determine the reserve for claims that have occurred but have not yet been reported at the end of the year, by number and amount, based on the experience acquired in previous years, having regard to the frequency and average cost of claims reported late.
- For long dismantling branches, as motor third party liability, actuarial methods must be implemented to integrate the estimates at the ultimate cost.
- Italy has decided not to allow the discount of reserves according to an option of the European directive.
- IVASS has issued provisions (nowincorporated into ISVAP Regulation 22/2008) on the methodologies for calculating claims reserves. The documentsused for the analysis are: annual and half-yearly financial statements, supervisory information, report of the auditing company.

The reference criterion for the evaluation of the claims reserve is the ultimate cost, specified in art. 37 of the Legislative Decree 209/2005. This principle requires that the company estimatesprovisions equal to the foreseeable future cost of the claims still to be paid, including, as already mentioned, the settlement costs. Therefore, when estimating the reserve, inflation of the cost of claims must be taken into account. This magnitude can be divided into two parts: a partexogenousto the company and an endogenous one. The term exogenous inflation indicates inflation linked to the reference economic system, which is the subject of studies ofthe national Statistical Institutes.It reflects the average variation in consumer prices and, in a broad sense, the purchasing power of the national currency. It is an external variable therefore in a certain sense suffered by market operators. In this context, endogenous inflation capturesthe effect of the company's internal factorson the average cost of claims.

These factorsinclude, among others, the efficiency of the internal structures responsible for the settlement of the claims and for the underwriting policies, on which the limitation of anti-selection phenomena depends.

Of course, an evaluation at the ultimate cost cannot ignore a careful statistical analysis of past data; for this purpose, the actuary needs specific information on homogeneous claims classes to improve the assessment. It is also required by the regulation to provide evidence of the assessment carried out to quantify the claims settlement costs. These include the specific costs of a particular claim, the branch indirect costs and the costs common to all branches. The first ones should be correctly attributed to the claims to which they refer, the indirect costs of the branch are attributed to the claims pertaining to the specific branch and finally the common costs are distributed.

7. THE IAS PRINCIPLES AND SOLVENCY II

The European Union has adopted, with EU Regulation 1606/2002, the IAS / IFRS international accounting standards issued by the IASB (International Accounting Standard Board), obliging all EU listed companies to prepare their consolidated accountsin conformity with theinternational accounting standards . The rules and the scope of application of international accounting standards in our Regulation havebeen defined with Legislative Decree 38/ 2005.The decree extends the scope of application of IAS/IFRS to consolidated accounts of all insurance groups, listed or not(article 2 and 3). To date, insurance companies do not adopt international accounting standardsfor the preparation of their annual accounts: instead, they have to use local principles (Local GAAP – Generally Accepted Accounting Principles). The international accounting standard forinsurance contracts(IFRS 4) was issued in 2004. IFRS 4 is only an interim standard, which will be replaced, starting from the 2023financial statements by anew and completeaccounting standard (IFRS17). The Private Insurance Code also establishes that ISVAP (now IVASS) has the power to draw up the schemes for annual and consolidated financial statements in accordance with international accounting standards.

A general principle-based footprint characterizes IAS/IFRS. Assets and liabilities are evaluated at their fair value instead of the historical cost, preferable in a context of prudence. The change in the valuation perspective makes it possible not only to make the financial statements afaithful representation of the company's economic situation, but also to improve the auditing activity of the Supervisor. The valuation principles of insurance liabilities are fundamental for the determination of the own funds available to companies to face unexpected future losses. The solvency systems of insurance companies aim to define a capital requirement, in monetary terms, to be compared with the own funds.

The new European solvency regime known as Solvency II mainly consists of the introduction of minimum capital requirements more adherent to the risks (not only technical) borne by the companies. This regime, in force since the 2016 financial statements, provides for calculating these requirements using a standard formula (SF) or, alternatively, through internal risk assessment models (IM) or undertaking specific parameters (USP). Like the system in use for the banking sector, Solvency II has a three-pillar structure. The first pillar representsthe financial requirements, as well as the provisions relating to the valuation criteria of assets and liabilities, the calculation of the Solvency Capital Requirement (SCR) using the standard formula and the conditions for using internal models and undertaking specific parameters. In this context, a minimum solvency threshold is also introduced, the so-called Minimum Capital Requirement (MCR), the ideal evolution of the concept of guaranteed quota previouslyin force in the Italian regulation. The second pillar concerns the qualitative requirements to which companies are required to comply with and, in particular, the provisions to be adopted on the valuation of reserves and on the management of investments. The third pillar is aimed at ensuring market discipline, transparency and correct information of stakeholders. It should be noted that the valuation criteria for Solvency II technical provisions are defined by EU legislation and not by international accounting standards.

With regard to the valuation of assets and liabilities in Solvency II, the principle of economic valuation is the guide. This is expressed, on the asset side, in the fair value measurement according to IFRS 9. On the liabilities side, a cost-based evaluation is clearly not possible. Since there is no reference market for the insurance liabilities, two components are calculated: the best estimate (BE) of the liabilities and the risk margin (RM). The best estimate of the liabilities requires the projection of all expected future cash flows generated by current production and the discounting of them using an appropriate term structure of risk free rates.

The estimate so calculated is intended to be the most faithful representation of the company's liabilities, based on the principle of correctness. The risk margin responds instead to the principle of risk aversion. In general, the non-discounted risk margin provides the loading necessary to transform the expected values into certain equivalents. The basic concept is that fair valuation (BE) should bemarket consistent. Then, given that risk-averse agents set market prices, expectation (BE) is required to be correct with a risk margin. In this way, the technical provision is a discounted certainty equivalent.

Solvency II eliminates prudence from the estimate of reserves andtransfers it to the calculationof the SCR. According to the previous framework the margin was implicitly present in the valuations of assets and liabilities themselves; it is explained according to the cost of capital criterion, that is, ideally based on the cost of capital necessary to meet the commitments towards policyholders. The valuation of the liabilities according to the economic approach is quite operationally challenging for companies; inSolvency II, indeed, theapplication of any statistical techniques for estimating reserves must be accompanied by a certain variety of actuarial models. These modelsare mainly aimed at testing the consistency of the technique chosen by the company with the characteristics of the portfolio. In this regard, particular attention must be paid to the distortions caused by mergers and acquisitions, changes in liquidation practices and exceptional claims.

The quantitative requirements of the first pillar also aim to make companies comparable about the technical liabilities. This was previously impossible due to the subjectivity used in the implementation of the principle of prudence. Must be said that Solvency II principles are similar but in same waysdifferent from the international accounting ones: the sum of the best estimate and the risk margin constitutes the technical provisions (TP), the most relevantliability of a Solvency II balance sheet. Assets that must meet specific criteria cover TP. The assets in excess of the TP are free assets "covering" other liabilities and the so-called own funds. The own funds are subject to specific rules that determine the properties of those who are qualified to cover the SCR, i.e. the capital required over a one-year time horizon, calculated usingSF, USPorIM. The connection of the TP with own funds is this: if the TP are underestimated, the insurer may appear more solvent than it is.

TPscan also be defined as follows: TPs represent the amount that the insurer should pay, net of the costs and benefits borne by the reinsurer, in order to transfer to a third party the obligations deriving from thecontracts. In particular, the best estimate is defined by the directive as "probability weighted average of future cash flows taking into account the time value of the money using the relevant risk free interest rate term structure". This estimate is different from that of the IAS/IFRS principles "average mean of the range of potential outcomes"because the former also refers to rare (high-value) events and fits wellwiththe use of stochastic models. In addition, a greater excess could characterize the risk margin in the IAS/IFRSframework, if the relative reserve assessments are not calculated on a best estimate basis and need to be recalibrated on the latter.

In thecontext of Solvency IItherefore:

- the inventory methodhas a different, less fundamental,rolefor the purposes of the financial statements;
- the Lines of Business (LOBs) replace the previousbranches;
- the discount of reserves is allowed;
- the concept of risk margin has been explicitly introduced;
- IVASS has issued provisions in this regard (Regulation 18/2016).

8. STOCHASTIC AND DETERMINISTIC MODELS

The classical deterministic models are limited to providing a punctual value of the random compensation commitments; the use of stochastic methods instead allows obtaining, in addition to this item, ranges of variation of the same, according to predetermined levels of probability of error. This is determined in harmony with the methodological system required by the most recent regulations and directives, such as Solvency II. The bootstrap technique or other simulation approaches are used in the same vein. The solvency to whom Solvency II aspires to is not static but dynamic, that is, in line with sudden changes in the market, which underlies the natural dynamism of the company's business. It is in fact to achieve this particular type of solvency that it is fundamental to base the assessments of the relevant quantities on stochastic rather than deterministic models. Before reviewing some of the main models currently in use in the insurance business of the non-life business, we will focus below on the main differences between these two macro-categories. The use of calculation methods of one or the other type for the evaluation of the claims reserve plays a pre-eminent role and constitutes one of the most debated topics in recent years, in the actuarial literature relating to non-life insurance. Deterministic techniques, which constitute the most classic and traditional evaluation approaches, have the undisputed advantage of being rapidly implementable from a computational point of view. Lower constraints on the basic data confer a certain degree of ease of use; moreover, they are immediately understandable at the managerial level of the company.

For this reason, the actuaries, both in Italy and abroad, have generally preferred deterministic methods to stochastic ones. Among the weaknesses, however, there is the fact that these evaluations return only a punctual value of the forecast, neglecting any possible evaluation on the probability of its realization. In other words, they can on the one hand produce the "best estimate" in the range of possible results, but on the other, they are unable to measure the goodness of this estimate. Then deterministic models are often used without a clear knowledge of the assumptions that are taking

place, which does not happen with stochastic models, since they are based on completely explicit hypotheses and verifiable with a great variety of techniques. In any case, the regulatory framework that is emerging is increasingly requiring the diffusion of stochastic methodologies. Only the stochastic models, although evidently characterized by a greater application complexity and by more demanding hypotheses on the basic data, allow obtaining, in addition to the precise estimate of the reserve, intervals of variation of the same according to a predetermined level of probability. In fact, they are able to provide a measure of precision of the estimate, treating the process that leads to the determination of the reserve as a data analysis exercise on which to base itself.

Another important question is precisely that of the estimate: the best estimate is simply a punctual value of future disbursements. On the contrary, it is clear that real payments may differ from those expected and, while with deterministic models, we have no idea how significant this deviation can be, stochastic methods instead provide an interval within which limits can be expected to fall there amount of future disbursements with a certain level of confidence. Stochastic methods also have some disadvantages. Think, for example, of the fact that they model a very large series of events through a relatively small number of parameters. A further criticism concerns the assumptions, defined too simplistic and sometimes unreal due to the rigidity of these models. Indeed, these do not easily allow for the incorporation of external judgments or factors. In addition, even the practical and computational application is frequently complex to implement, sometimes requiring significant statistical and calculation skills. Despite this, the stochastic models are effective: the utility that most interests them is that deriving from the greater information provided, which can be useful to the company not only in the process of establishing the reserve and the risk capital requirement but also in its management overall. Lastly, an important aspect and objective is the fitting-of-the-model concept: a stochastic method for estimating the claims reserve, after choosing an appropriate parametric structure, combines this structure with the available data (in the present case: at the upper triangle of the run-off, known). The typical approach, for example with GLMs, is to estimate the parameters of the structure, true but unknown, with the maximum likelihood method.

9. CLAIMS RESERVING WORKING PARTY PAPER (INSTITUTE AND FACULTY OF ACTUARIES UK)

The purpose of the work that led to the publication of the notebook in 2002 was to provide a practical guide to the process of reserving claims in non-

life insurance.In examining the data underlying the application of the reservation models, contained a list of aspects characterizing the business context as well as a series of practical indications to be followed in the projections with the chain ladder method, the most common to carry out the assessments. This list is schematically represented below to remind you how many aspects you need to check when implementing the models.

a) Claims settlement process:
   - Period of occurrence of claims (for example in property risks, the adverse weather experience experienced in the final phase of a year could increase the percentage of payments made in the first quarter after the end of the year
   - Direct settlement costs (changes in the allocation of the ALAE)
   - Change in settlement procedures (advances, liquidator skills, etc.)
   - Claims points (the irregularity alters the time series of compensation)
   - Claim frequency (a change in frequency without a change in the mix or type of claims will not affect most of the projection methods, but a change deriving from the awareness of the increase in claims or from the introduction of bonuses to protect the motor policies can affect the development of payments
   - Partial payments (the increase of which can affect the speed)
   - Exceptional payments (attitude towards border cases)
   - Null claims (impact on medium cost methods)
   - Legal disputes (special judgments)

b) Nature of the business:
   - Change in portfolio volume (structure, lack of resources)
   - Change in business mix
   - Change of policy conditions
   - Aggregated deductibles
   - Charging

c) Constraints on data:
   - Informative system
   - Data availability
   - Data reliability
   - Defective processes

- Heterogeneity of data

d) Exogenous factors:

- Legislative changes
- Social conditionings
- Environmental conditions
- Foreign exchange movements
- Miscellaneous (e.g. changes in assessment approaches)

e) Transfers in reinsurance:

- Calculation of net liabilities
- Catastrophic coverage / major claims

10. MAIN USED MODELS

The most used evaluation method is based on a triangular data organization (someone called the reservation as the art of squaring triangles) and is called chain ladder.It implies the use of the development pattern observed over time in relation to the payment of claims of the older generations, assuming that the same pattern can be applied to more recent generations using average development coefficients per generation. It was originally developed as a simple numerical algorithm for projecting reserves but was later formulated in terms of a statistical model. Incremental payments are reported in a few example steps:

Incremental claims loss settlements		Development year							
		0	1	2	3	4	5	6	7
Claims occurrence year	2005	1232	946	520	722	316	165	48	14
	2006	1469	1201	708	845	461	235	56	
	2007	1652	1416	959	954	605	287		
	2008	1831	1634	1124	1087	725			
	2009	2074	1919	1330	1240				
	2010	2434	2263	1661					
	2011	2810	4108						
	2012	3072							

Figure 5: Incremental payments

Cumulative payments - from the origin - are reported with an example of calculation of the development coefficients.

Cumulative claims loss settlements		Development year							
		0	1	2	3	4	5	6	7
Claims occurrence year	2005	1232	2178	2698	3420	3736	3901	3949	3963
	2006	1469	2670	3378	4223	4684	4919	4975	
	2007	1652	3068	4027	4981	5586	5873		
	2008	1831	3465	4589	5676	6401			
	2009	2074	3993	5323	6563				
	2010	2434	4697	6358					
	2011	2810	4918						
	2012	3072							
CLM estimator for claims loss settlement factor			1,8508	1,3140	1,2422	1,1151	1,0491	1,0118	1,0035

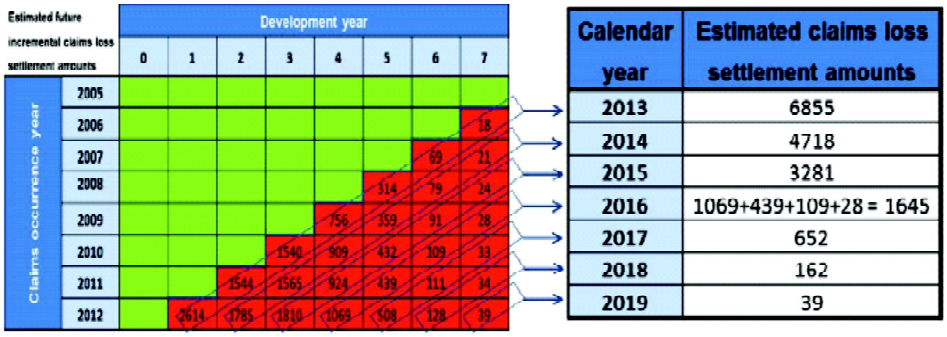
3736+4684+5586+6401 = 20407

3420+4223+4981+5676 = 18300

20407/18300 = 1,1151

Figure 6: Development factors calculation

The projections produce payment flows which, added together, constitute the reserve estimate.



Calendar year	Estimated claims loss settlement amounts
2013	6855
2014	4718
2015	3281
2016	1069+439+109+28 = 1645
2017	652
2018	162
2019	39

Figure 7: Reserve estimates

The origins of the method date back at least to the seventies of the last century and the name seems attributable to Professor R.E. Beard who worked as a consultant to the UK Department of Trade. David Skurnick already called it a projection method by recalling a 1960s accounting paper. With many references, it is possible to get to the instructions for the guidance of the auditors of the London Lloyd's of 1908, which described a method to evaluate the budget liabilities as a simple average of the development coefficients.

In practice, awareness of the limits of this approach has always accompanied the interpretation of the relative results. It is not surprising that many analyzes have been carried out to build a stochastic model equivalent - in terms of expected value - to the deterministic chain ladder. In fact, first the Mack model without distribution hypotheses - then the Overdispersed Poisson (ODP) of Renshaw and Verrall in GLM form [16] - represented the main models developed on the subject and such as to provide a central best estimate equal to the chain reserve estimate ladder, both in the analytical version and in that simulated through bootstrapping techniques. GLP ODP has the advantage of producing extensive statistical diagnostics, however compared to Mack's model [10], it hypothesizes the independence of payments between different payment years in relation to the same generation and entails the necessary verification to be used.

In the transition from the final view of the total dismantling of the reserves to the one year, required in Solvency II for the calculation of the capital requirement relating to the reserve risk, the Merz and Wüthrich model (2008) [12] was particularly recognized. This is the version to measure the volatility, in the annual horizon, of the Mack model, which instead produces the volatility of the entire run off. Of particular note was the introduction of the Bayesian chain ladder made by Gisler and Wüthrich (2008) [7] in the vision of ultimate volatility and by Bühlmann, De Felice, Gisler, Moriconi and Wüthrich (2009) [3] in the one year vision, because through the mathematical power of credibility theory has made it possible to achieve some results obtained in subsequent years.

Other deterministic methods widely used in practice are: Bornuhetter-Ferguson (1972), which incorporates a priori information on the target loss ratio and Fisher-Lange (1973) of the frequency-severity family, for which some authors have recently obtained the their stochastic versions (see [4], [13] and [17]). In addition,we recall the method of Taylor's separations from 1977, an author who also wrote two important monographs on the subject in 1986 and 2000.

A little-known model in Italy that has taken root in the Netherlands and Germany in recent years is the one presented in 2001 by P. ter Berg [1] and developed in the best-known 2008 article by Posthuma et al. [15]. In which a two-dimensional model is determined, for the generations (autoregressive process) and for the year of payment development (theoretical distribution), which is then recombined into a multivariate matrix structure. The following graph represents its logic; the model for generations constitutes the prototype of the premium risk capital model then used in the USP.

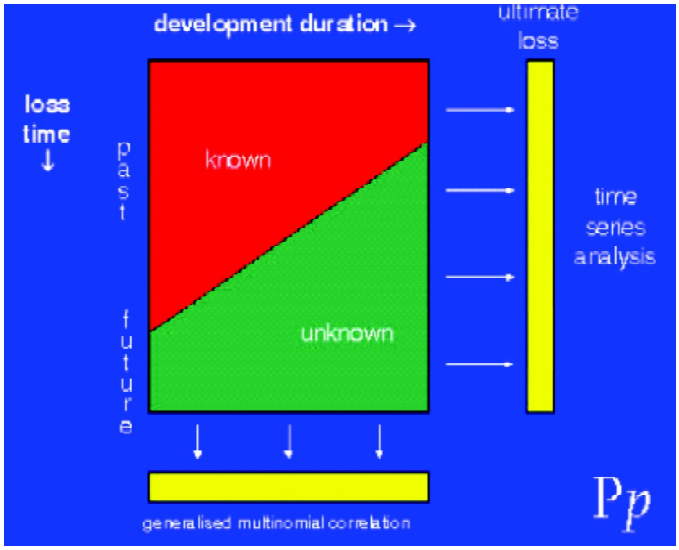


Figure 8: The integral financial model

In addition to Merz and Wüthrich theoretical book [11], Hindley's book was published in 2017 [see 9]: it represents a complete and accessible reference source that documents the theoretical and practical aspects of all the deterministic and stochastic reservation methods that have been developed in the context of non-life insurance . Work examples and mathematical details are included, along with many of the broader topics associated with reserving in practice. It also discusses the main features of the reservation in a variety of different contexts, in the UK and elsewhere. The book contains material that is aimed at anyone with an interest in reserving claims. It can be used as a learning resource for actuarial science students who are studying the relevant parts of their professional course exams, as well as others who are new to the topic. Employees of a more experienced insurance company and industry professionals can also use the book to update or expand their knowledge in a wide range of topical topics covered in the book.

The computational power of current calculators has found expression in the application of very advanced simulation techniques such as Markov Monte Carlo chains (MCMC) to Bayesian reserving models well represented in the 2018 Guangyuan Gao book [6].

In 2016, the CAS also set up a Reserving Research Hall of Fame to reward, through a voting system for members, the best works published on loss reserving, according to the criteria of originality, full application,

inspiration for other studies. , legibility and today's validity. In 2018, for the second edition, the following were awarded:

- Hans Bühlmann and James N. Stanard for their work in developing the Stanard-Bühlmann / Cape Cod method.
- "On the Accuracy of Loss Reserving Methodology," written by Tapio N. Boles and Andrew Jon Staudt and published in Casualty Actuarial Society E-Forum, Fall 2010, Volume 1.

11. INDIVIDUAL CLAIMS RESERVING MODELS

With the growing need to create increasingly accurate reserving models, the use of the information incorporated in the individual accident data in the same models is a promising alternative compared to the use of traditional aggregate loss development triangles. While not without implementation challenges, the future of individual reserving is expanded by the innovative opportunities offered by these alternative individual reserving models.

The current reservation practice consists, in most cases, in using methods based on claims development triangles both for projection of point estimates and for calculations of capital requirements. Triangles as already stated are organized by origin period (e.g. event, subscription) and development period. In recent decades, there has been a widespread diffusion of deterministic and stochastic accident reserve models still to be paid, based on triangles, such as those relating to the popular chain ladder model or many others developed in the huge amount of related actuarial literature. These models, particularly in their stochastic form, have been used to measure and manage the reserve risk for business lines.

Traditional reservation methods have worked well in several circumstances in the past and will likely continue to do so in similar circumstances in the future. Today, however, awareness of the insurance market regarding some possible limitations of traditional aggregate models as a provider of robust and realistic estimates in more variable contexts, has reached a level that for some researchers (Boumezoued and Devinau in 2017 [2]) should be evident. The same have already highlighted several potential limitations of the aggregate models based on triangles from both a practical and a theoretical point of view. These limits are mainly the following:

- over / under-estimated distribution when retrospective tests are carried out between the amounts realized and the forecasts;
- huge estimate error for the last development periods due to the small amount of aggregate amounts observed;

- uncertainty about the ability of these models to capture correctly the development of claims settlement, combined with the limited interpretative and predictive power of the generation and development year parameters.

Overall, these limits are due to the loss of information that occurs when the details of the individual claim data are aggregated (e.g. the time of occurrence, the delay in reporting, the date and the amount of payments, along with many other features) in the blocks in years of origin and basic development in the triangle.

Recent developments in data collection, storage and analysis techniques indicate that correct modeling of individual claims is now achievable. On this basis, it has become crucial to implement flexible models for operational uses (e.g. claims management, underwriting and reinsurance.). This to take into account key aspects such as the following:

- acquisition of the analytical development models of the claims, including their events, complaints and cash flow characteristics;
- taking into account any changes in the product mix, in the legal context or in the liquidation process over time, to avoid potential errors in the estimate and forecast;
- implementation of an advanced risk assessment and monitoring (e.g. that allows to detect changes in the trend);
- separate and consistent treatment of claims reported late;
- inclusion of the key characteristics of the claims (i.e. explanatory variables) to capture the heterogeneity of the same and take advantage of large data sets, additional and combined with big data and analysis technologies;
- collection of these characteristics in a rigorous statistical framework that allows the analysis of goodness and adaptation of the models.

However, compared to aggregate approaches, so far few academic contributions reveal the power to use individual claims data. As a result, few practical implementations have been made in the insurance market. As noted in the report on damage reservation practices worldwide by the ASTIN working group on the claims reserve (June 2016), there is "an increase in the need to move to individual and big data reservations, to better link the reservation process with the pricing process and in order to better evaluate non-proportional reinsurance". The limited diffusion of individual reservation approaches on the market seems to be due to the lack of an innovative solution.

The point of view of the individual claim requires methodologies that are capable of acquiring the detailed development of the individual indication. In this context, a modeling framework based on the claim is necessary, with a precise temporal description throughout its history from the moment it occurs, its delay in reporting, the various payment amounts and the reserve in the event of changes with the related associated timings, as well as the closing date. This modeling framework can be made flexible enough to take into account the specificities of the business line, such as recoveries and reopening.

Continuous analytical time modeling provides a more precise description of the portfolio model. The mathematical tools at the center of the model specification lie in the family of continuous time stochastic processes, known as point processes and multistate dynamics, which model all types of events relating to the history of claims. It is interesting to note that the stochastic models for the reserve of unpaid claims appeared more or less in the same period with reference both to those based on single claims and to triangular ones. In fact, those of Norberg (1993) [14] and Hesselager (1994) [8] are among the first documents that introduced an appropriate probabilistic approach for the reserve of individual claims, recently applied by Antonio and Plat (2014).

To date, one might think that the most successful triangle-based models could be due to their relative ease of use and the lack of electronic processing power in the same introduction period of the other models.

In the parametric model, taken here as an example, by Boumezoued and Devinau (2017) [2] which draws on the contributions of the pioneers just mentioned, in order to estimate the parameters for a single accident model, a calibration procedure is performed based on the maximization of likelihood. Deriving the probability associated with the data set on the observed claims is a demanding phase, as the reported but not settled claims (RBNS) are observed only partially, while the so-called IBNR are not observed at all. This introduces a sampling distortion in the observation process, which, from a statistical point of view, refers to censorship and truncation. Since the individual claims model involves a reasonable number of parameters, often less than a triangle-based approach and since the number of individual claims records is large, probability maximization provides an efficient procedure that estimates the model parameters almost instantly.

As an added bonus, the estimated parameters generally show natural explanatory powers (e.g. occurrence and reporting frequencies, average settlement delays, etc.). Furthermore, specifications relating to the

distribution of separate payments can provide information on the building blocks of the overall compensation development pattern. In this way, the parameters allow a detailed monitoring of the main risk indicators, which, with triangular approaches, are hidden in the aggregate development factors and in the related volatilities.

As regards the forecasts, the simulation procedures are based on stochastic patterns of the development of the RBNS and IBNR claims, as well as on new claims that will arise in the future. The procedure allows the user to predict future events in a very efficient way, while the patterns in terms of arrival of claims and time-to-event frequencies (such as reporting and settlement times) can be set as generally as possible. In addition, the simulation procedure can explicitly include anticipated changes in the parameters (e.g. product mix, frequency trend, etc.), which help avoid potential errors in the forecast. In its standard parameterization, the model also makes it possible to obtain closed formulas in a simple way that provide estimates of the overall claims reserve and the relative confidence intervals. The key components of the individual reservation methodology are shown in Figure 9.

The authors developed these models as a new way of efficiently measuring and managing risks. To meet the challenge, they designed an

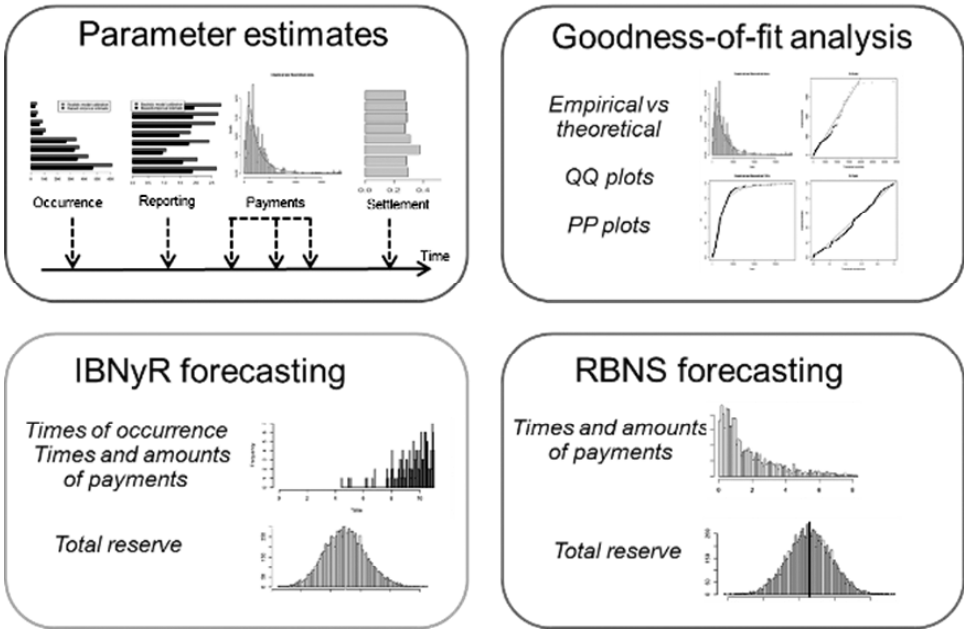


Figure 9: Analytic claims reserving model

integrated reservation process that covers the data needs, modeling and risk monitoring to which the following stages refer:

- ✓ Data collection and preparation: organization of a standardized collection strategy that focuses only on the claims data used by the individual claims model and performs the data transformation necessary to feed this model.
- ✓ Model specification and calibration: identification of the model components based on the business lines to be managed and the transformed data and estimate of the model parameters using advanced optimization procedures, combined with analysis of the goodness of the adaptation.
- ✓ Model simulation and validation: prediction of the individual trajectories of IBNR and RBNS using efficient simulation algorithms and execution of a model validation process based on back-testing procedures and comparisons with classic models based on triangles.
- ✓ Reserve risk dashboard: display of parameters through an automatic dashboard in order to periodically monitor the key indicators and exploit information to improve management actions.

This framework allows users to evaluate why things materialized in anobserveddetermination, which is to identify the underlying drivers that caused changes in aggregate payments. This can also lead to a reassessment of what will happen by improving forecasts and their associated uncertainty. Two building blocks will ensure a successful implementation: a strong modeling experience combined with an optimized and rigorous data collection process. Although the integration of reservation techniques based on individual claims within the context of the reservation is neither immediate nor obvious, there is no doubt that these models will become a strong paradigm towards which to evolve in the near future.

From a non-parametric point of view machine learning has garnered increasing interest in recent years due to successful applications in many fields and has recently made its way into the loss reserving literature. Wüthrich augments the traditional chain ladder method with neural networks to incorporate claims features, Gabrielli and Wüthrich utilize neural networks to synthesize claims data, and Gabrielli et al. embed classical parametric loss reserving models into neural networks. More specifically, the development in Gabrielli et al. proposes initializing a neural network so that, before training, it corresponds exactly to a classical model, such as the over-dispersed Poisson model. The training iterations then adjust the weights of the neural network to minimize the prediction errors, which

can be interpreted as a boosting procedure. In addition, De Felice and Moriconi implemented in 2019 regression and classification tree models (CART) to claims reserving problem.

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