Dynamic Financial Models of Property-Casualty Insurers

The CAS Committee on
Dynamic Financial Analysis

DYNAMIC FINANCIAL MODELS OF PROPERTY-CASUALTY INSURERS

Prepared by
the Dynamic Financial Analysis Committee
of the Casualty Actuarial Society

Charles C. Emma, Chairman

Donald F. Behan
Roger W. Bovard
Richard Derrig
Owen M. Gleeson
Philip E. Heckman
Gerald S. Kirschner
Pierre Lepage
Eduardo P. Marchena
Glenn G. Meyers
Raymond S. Nichols
Marc B. Pearl
Mark R. Shapland
William R. Van Ark
Thomas V. Warthen
Peter G. Wick

January, 2000

TABLE OF CONTENTS

Chapter

Appendices

CHAPTER 1[1]
PURPOSE

The purpose of this paper is to discuss and provide guidance on the important issues and considerations that confront actuaries when designing, building or selecting dynamic financial models of property-casualty risks. The Casualty Actuarial Society's Dynamic Financial Analysis Committee has prepared it as a part of the Society's ongoing educational efforts on issues affecting actuaries responsible for the strategic and dynamic financial analysis of insurers.[2]

This paper should not be interpreted as placing requirements on actuaries or the models used by actuaries. Such requirements have been and will continue to be addressed by the Actuarial Standards Board.

1 This document is an update to "Dynamic Financial Models of Property-Casualty Insurers" prepared by the Subcommittee on Dynamic Financial Models of the Casualty Actuarial Society's Valuation and Financial Analysis Committee on September 22, 1995.

2 Other sources of information regarding dynamic financial models are included in Appendix A.

CHAPTER 2
INTRODUCTION AND BACKGROUND

What is Dynamic Financial Analysis?

One of the early works related to dynamic financial analysis comes from Jay W. Forrester in Industrial Dynamics. He defines it as ". . . a way of studying the behavior of industrial systems to show how policies, decisions, structure, and delays are interrelated to influence growth and stability. It integrates the separate functional areas of management -- marketing, investment, research, personnel, production, accounting, etc. Each of these functions is reduced to a common basis by recognizing that any economic or corporate activity consists of flows of money, orders, materials, personnel, and capital equipment. These five flows are integrated by an information network."[3]

Models are the key tools in dynamic financial analysis. Such models are ". . . a systematic way to express our wealth of descriptive knowledge about industrial activity. The model tells us how the behavior of the system results from the interactions of its component parts."[4]

For insurance applications[5], the underlying system differs from an industrial one in the degree to which the functioning of the system manifests itself as pure flows of cash. Additionally, the many processes that can affect the amount and timing of the insurance cash flows are complex: some are stochastic, some allow for varying degrees of management control, and some may be imposed as constraints by either the marketplace or external regulatory entities.

This paper discusses the use of dynamic financial analysis as it applies to insurance. In this context, a systematic approach to analyzing all the major flows of cash is key.

---

[3] MIT Press, 1961, p. vii.

[4] Ibid.

[5] Throughout this paper, the application of dynamic financial models to insurers is discussed. These models are equally useful for captives, risk retention groups, self-insurance pools and large self-insureds, as well as conventional insurers. Dynamic financial models are used in other financial sectors as well, e.g., the banking and investment industries.

The Actuary's Changing Role

Historically, casualty actuaries have primarily focused on rates and loss and loss adjustment expense reserves. Since 1980, property-casualty actuaries have had increasing responsibility to provide opinions on the loss and loss adjustment expense reserves of property-casualty insurance companies in the U.S.

In more recent years, regulatory and competitive pressures, as well as the desire for a broader understanding of the insurance process, have led and continue to lead to expansion of the casualty actuary's role. To meet the demands of this expanded role, actuaries now need a more complete understanding of insurance company cash flows: both assets and liabilities and their associated risks as well as their interrelationships.

This broader role will also increase the number of situations where the actuary must function in an interdisciplinary setting, communicating with the other major functional specialists of a company: those in investments, underwriting, claims, accounting and finance. This will bring new challenges in that it is likely that what is "normal" in terms of language or quantitative measures for the individual specialties may need to be described or measured differently for purposes of the dynamic financial model. However, if done effectively, this interdisciplinary communication network among specialists, and ultimately the company's management, can be one of the most valuable end results of building a dynamic financial model.

Why Use Dynamic Financial Models?

Dynamic financial models generally reflect the interplay between assets and liabilities and the resultant risks to income and cash flows. The explicit recognition of all of the insurer's operations gives dynamic financial models the power to illustrate the links between strategies and results. Therefore, these models make a unique contribution to the analytical tools available for performing financial analysis.

Dynamic financial models are valuable in effectively dealing with the complex interrelationships of variables relevant to an insurer's future results. Uncertainty related to contingent events occurring during the potentially long delay between writing a property-casualty insurance policy and the payment of claims against that policy make it difficult or impossible to evaluate strategies and decisions without explicit consideration of their effects on the flows of funds. Indeed, the results of management decisions or the effects of outside forces may be counter-intuitive. Use of a dynamic financial model can provide the insights necessary to clarify situations such as these.[6]

The explicit consideration of time delays, alternative outcomes of contingent events and interrelationships between different aspects of an insurers' operations gives dynamic financial models a unique role in helping management to identify profit opportunities, avoid negative outcomes and encourage investment in the company. Such explicit considerations can also assist both management and regulators in identifying and understanding problems early, before they grow to crisis size. Furthermore, in the event that problems do arise, these considerations can assist regulators in distinguishing short-term problems that do not warrant intervention from long-term problems that require action.

[6] These types of situations may be most common when a company changes strategy, either entering or exiting a line of business that has different characteristics from its existing book. A dynamic financial model can provide insight into the changing mix of the company's cash flows, both assets and liabilities, and the timing of profit recognition in published financial statements.

CHAPTER 3
USES, USERS AND RESOURCES

The design and/or selection of a dynamic financial model will depend heavily upon the question(s) to be addressed, the users of the model and its expected results, and the available resources.[7] Also, an effective design and selection process will solicit the expertise of a company's various major functional units. In and of itself, this communication network can be a significant benefit to company management as it will tend to reduce instances where actions might be taken that have not considered the ramifications to all areas of the company.

Uses

Dynamic financial models have a variety of applications, including:

- Determination of the value of an insurance company or a block of policies to a potential buyer or seller;
- Assessment of how an insurer might fare in a range of future economic, competitive, and regulatory environments;
- Strategic planning, including asset-liability management, claims management and settlement strategy, tax planning, reinsurance planning and costing, and market strategy;
- Tactical decision-making, including product pricing;
- Capital adequacy and capital allocation decisions;
- Liquidity analysis;
- Identification of the kinds of risks that most threaten the solvency of the insurer; and
- Support for company discussions with rating agencies.

[7] These considerations, along with the others identified in this report, are summarized in Appendix B.

The application will be a key determinant of many of the model's requirements. Examples include:

- The complexity of the model should reflect the question(s) being investigated. For example, if modeling long term capital needs, the underwriting experience may not need to be modeled by state and by coverage;
- The model output should reflect an appropriate time horizon and accounting basis. For example, if the question(s) being addressed only require statutory results, there may not be a need to include a GAAP module;
- The application may determine whether a deterministic or stochastic model[8] is more appropriate. This decision in turn will greatly affect the resources and data needed, the model structure, and the form that output will take. As an example, if the goal is to develop probability distributions of results, then an actuary will be more likely to use a stochastic model.

The development of a model must balance the need for complexity with usability and cost issues. Indeed, if a model is too complex, it could add unnecessarily to the development time and cost, it could mask errors in the model, and it could make results from the model harder to interpret. On the other hand, if a model is too simple, it may miss an important source of variation in results, it may not answer one or more of the questions being addressed, and it may lead to incorrect conclusions and actions.

<u>Users</u>

Users of dynamic financial models include insurers that employ such models as tools for tactical and strategic decision-making, including pricing decisions. Other users of the results of dynamic financial models can include regulators, reinsurers, investment bankers, financial intermediaries, institutional investors, securities rating organizations, and financial analysts.

The intended users' needs are the primary consideration in designing and selecting the model. The type of model used and its structure depend on users and their needs. As an example, regulators may focus mainly on the insurer in total. Company management may focus on the total corporation as well as individual products.

[8] A stochastic model will reflect the uncertainty in a company's estimated cash flows by treating one or more components of the cash flows as random variables from specified probability distributions. A deterministic model will treat all estimated cash flows as though they are certain.

As a practical matter, the model design should also take into consideration the expertise of the end user. At one end of the spectrum, it may be that a model with a limited number of user-specified scenario options and input variables provides the best fit to the user's needs. At the other end of the spectrum, a user may want the control and flexibility to address almost any situation. In the former case, if the user is applying the model almost like a "black box," it becomes more important to have a plan of periodic review and update to the internal workings of the model. Otherwise, the user may continue producing results when in fact the model's parameters have become outdated.

Resources

The choice of dynamic financial model will depend on the available resources:

- people available for system design and programming;
- data from which to derive assumptions and with which to initialize the model;
- money available to purchase an existing software package; and
- computer architecture.

Detailed dynamic financial models require a significant investment of time for research to determine assumptions, for validation of results, and for maintenance to keep the model's logic current and to revise assumptions in light of new data. Such models also require a significant expenditure of time to interpret the results.

The purpose of the analysis and the level of detail of the projections often determine the choice of computer architecture. A simple spreadsheet might be appropriate if the purpose of the study is to highlight the effects on financial results of one particular risk, such as adverse development of loss reserves. At the other extreme, complex, report-generating software with a user-friendly front-end and efficient coding of the detailed calculations might be appropriate if the model is intended to cope with a wide range of different problems and be used by a wide range of users.

CHAPTER 4
TYPES OF MODELS

In many disciplines, mathematical models have become important tools in the study of the behavior of systems. The systems are diverse, almost unlimited, ranging from the biology of the human body to the weather to insurance. For any of these applications, the type of mathematical model employed will depend upon the nature of the system, how broadly the system is defined, and what needs to be learned about the system's behavior. Considerations for building a model include:

- the extent to which the system is described by stochastic versus deterministic mathematical relationships;
- the length of time horizons if predictions of future behavior are important;
- the ability of the system to adapt to changing environments; and
- the nature of the system's interrelationships with external factors or other systems.

These considerations, and the extent to which a model must emulate all facets of the real system, will determine how simple or sophisticated a model must be.

In the context of property-casualty insurance, dynamic financial models will incorporate different features depending on the application and the types of risks that must be measured. The extent that certain features are emphasized will determine what might be called the "type" of model (i.e., is it primarily stochastic or deterministic; does it include feedback loops, etc.). However, different models may include any or all of these features to different degrees. Therefore, the spectrum of types of models can be viewed as a continuum rather than a collection of discrete categories. At one end of the spectrum, sophisticated models may incorporate many features, emulating an entire company and most of its interrelationships. At the other end of the spectrum, simpler models may incorporate few of these features and may be designed for specific narrowly defined problems. A key consideration in the design of a dynamic financial model is its ability to evaluate the material sources of risk for the problem at hand.

Primary Modeling Considerations

Stochastic vs. Deterministic

If material random fluctuations in a variable are significant for a particular application, then stochastic features can be added to a model. Random fluctuations around projected losses, for example, may be incorporated into a model by introducing probability distributions about loss costs or loss ratios, by modeling the collective risk process, or by modeling the underlying claim settlement process.

A simple model of the collective risk process may assume probability distributions for the frequency and severity of losses. A more complicated model of the collective risk process may include estimates of parameter uncertainty for frequency and size-of-loss, and may include a number of different kinds of losses, each with its own frequency and size-of-loss assumptions. A model of the underlying claim settlement process may be a multi-state Markov chain model or some other appropriate model.

Identifying and modeling the interactions among variables is important when either stochastic or deterministic variables are used. However, when assumptions are stochastically generated, a model that does not reflect these interactions may generate scenarios that are meaningless. At best, the results of such models would be difficult to interpret.

Time Horizon

The time frame for the analysis is an important consideration in the choice and design of a dynamic financial model. For example, the choice of time frame may reflect whether the model includes only the run-off of current business, a going concern for some stated period, or a going concern in a long-range projection valuation.

In addition to the time horizon of the model, the model also reflects a choice about the length of time intervals under study. While annual time intervals may be appropriate for some purposes, quarterly or even monthly time intervals might be appropriate for other purposes. The user must consider the procedures to be carried out over various time frames and their suitability for the use of the model. For example, a model might generate cash flows on a monthly basis, but test statutory solvency on an annual basis.

Feedback Loops/Adapting to Change

Dynamic financial models may employ feedback loops (automatic conditional decisions) which are algorithms that make calculations for each modeled time period dependent on values calculated for earlier periods. Feedback loops provide for reactions to specific conditions. For example, if a given scenario shows a loss ratio that is unacceptably high for a certain line of business, then the model could assume that rate level and other underwriting decisions will be made by management to mitigate the unacceptable results.

Models without feedback loops may be under-determined, showing excessive income under favorable scenarios and excessive loss under unfavorable scenarios. Models with feedback loops, however, may be over determined, showing little risk regardless of the scenario because the model builder often assumes that management will respond quickly to increased risk with appropriate strategic or operational responses. The issues of feedback loops and strategy specification are closely related.

Interrelationships with External Systems

The insurance process is subject to constraints imposed by the choice of available investments, underwriting commitments, laws and regulations, rating agencies, and income tax laws. Comprehensive models, for example, a model designed to determine the value of an insurance company, will reflect all or most of these constraints. Less comprehensive models, for example, a model designed to price a specific product, may be appropriate, however, for specific applications.

Other Modeling Considerations

Generalized vs. Tailor-Made

Generalized models usually permit the user to specify several different types of insurance products or lines of business and a range of different investments. Other models are often tailor-made, such as one that addresses the unique characteristics of a company or one developed for a situation in which a simple model is sufficient.

If a generalized model is used, it is important to consider whether results may be distorted by features inconsistent with a particular application or because a characteristic of the particular company is not addressed. For example, if a general-purpose model is used for an insurer that plans to invest only in bonds and cash equivalents, the model does not need to include a strategy that involves investment in other assets. If it does, care should be taken so that the ramifications of that logic do not distort the projections.

Logic vs. Input

There are always tradeoffs between the coding of logic versus the selection of parameters. Dynamic financial models differ in the choices the developers make about which assumptions will be represented by variables and which will be fixed by the software. Also, the user will be able to determine the values of certain variables used by the model, whereas others will have been pre-set by the developer. The mix between input and logic will be determined in part by the users of the model (both the operator and the decision-maker). Models with extremely large numbers of variables can be daunting to use and difficult to interpret, while models with too many decisions incorporated into logic may not be flexible enough.

In selecting or building a dynamic financial model, decisions must also be made about the level of detail to be captured. For example, some choices include the detail of the insurance coverage (by broad product group, statutory line of business, individual form, etc.), the factual context (including the level of detail about accounting and tax rules), and the precision with which strategies are defined.

Strategies are inevitably a part of the logic of a model. The strategies incorporated in the model should be reasonably consistent with its purpose. Some models allow the user to build in explicit recognition of management strategies. Other models assume certain strategies, even to the extent of letting presumptions about strategies affect the architecture or design of the model.

Relationship between Parent and Subsidiaries

Parents and subsidiaries have a number of different effects on an enterprise. A consolidated model of the entire organization can be developed, or the existence of the parent and subsidiaries might simply show up as assumptions about flows of funds, tax calculations, and income. A model may explicitly reflect a range of scenarios regarding the availability of or drain on surplus due to external influences. Alternatively, each entity may be modeled separately, with output from one model serving as input for other models.

CHAPTER 5
PROPERTY CASUALTY RISKS AND MODELING CONSIDERATIONS

Evaluation of risk is the focus of dynamic financial models. The relative importance of each type of risk will determine the detail of assumptions and analyses built into any model. Ultimately, a model must provide a quantitative evaluation of risk in terms of its effects on the amount and timing of flows of cash. This chapter describes the risks affecting the property-casualty insurance business and addresses the related modeling considerations.

Property-casualty insurance risks can be divided into many categories.[9] In this paper, we will follow the definitions originated by the Committee on Valuation and Related Matters of the Society of Actuaries and will discuss these risks in the following four categories:

> **Asset Risk** – The risk that the amount or timing of items of cash flow connected with assets will differ from expectations or assumptions as of the valuation date for reasons other than a change in interest rates.
>
> **Obligation Risk** – The risk that the amount or timing of items of cash flow connected with the obligations[10] considered will differ from expectations or assumptions for reasons other than a change in interest rates.
>
> **Interest Rate Risk** – The risk that the amount or timing of items of cash flow connected with assets or obligations will differ from expectations or assumptions because of changes in interest rates.
>
> **Mismanagement Risks** – Uncertainty from taking incorrect or fraudulent actions in light of the available information.

As do many discussions of insurance risks, this paper will focus on the first three of these risks. At present, measuring Mismanagement Risk is beyond the scope of most actuarial analysis.

---

[9] For example, the NAIC's risk-based capital formula divides risk into 5 categories: asset risk, credit risk, reserve risk, premium risk, and off balance sheet risk (e.g., growth).

[10] Any tangible or intangible commitment by, requirement of, or liability of a plan or an insurer that can reduce receipts or generate disbursements.

Asset Risk

Asset risk encompasses uncertainty regarding:

- Default rates;
- Future market value of equity assets; and
- Liquidity of assets.

In addition to these inherent asset risks, model builders should take care to look beyond the general description of the various asset classes to make sure that all relevant risk characteristics are incorporated in the model. This precaution increases in importance as capital markets develop a greater range of non-equity investments that have many of the risk characteristics of equity investments.

Appropriate data and methods are critical to the development of ranges of assumptions to reflect asset risk in the projected performance of the insurer. Historical data developed for investment managers is readily available, including time series of default rates of various classes of assets as a function of age.

Dynamic financial models can be used to estimate the effects of these risks alone on the projected performance of the insurer and can also be used to estimate the interrelationships between these risks and other risks. In modeling, asset risks may be assumed to correlate with inflation or some other variable or to be autoregressive.

Obligation Risk

Obligation risk encompasses:

- **Reserve Risk** - the risk that the actual cost of losses for obligations incurred before the valuation date will differ from expectations or assumptions for reasons other than a change in interest rates;
- **Premium Risk** - the risk that premium for future obligations will differ from expectations or assumptions;
- **Loss Projection risk** - the uncertainty regarding assumptions (other than interest rates) about future loss costs (including LAE);

- **Catastrophe risk** - the uncertainty regarding the costs of natural disasters and other catastrophes;
- **Reinsurance Risk** - the uncertainty regarding the cost, value, availability and collectibility of reinsurance; and
- **Expense Risk** - the risk that expenses and taxes will differ from those projected.

Dynamic financial models can be used to estimate the effects of these risks individually on the projected performance of the insurer and to evaluate the interrelationships between these risks and other risks.

Reserve risk may be a function of:

- Inflation in claim costs (other than that related to interest rates);
- The legal environment in which claims will be resolved, including the environment in which claims are pursued by policyholders or third parties;
- The possibility of a breakdown in some basic premise underlying the reserves for a particular coverage (such as has occurred with environmental impairment liability);
- Past patterns of pricing adequacy which affect case reserves or financial reserves;
- Corporate culture, training, and incentives that affect the payment of claims or the adequacy of case reserves;
- Currency fluctuations which affect the costs of losses when expressed in local currency;
- The randomness of the claims process itself;[11] and
- Incompleteness of databases.

Premium risk may be a function of:

- Competitive pressures that do not allow the insurer to achieve assumed levels of exposure and/or rate adequacy;
- Regulatory intervention that restrains premium increases or decreases or requires business to be underwritten that would not be underwritten in the absence of such intervention;

[11] The randomness of the claims process itself can be studied by modeling the patterns of loss development or by more detailed analysis of the claims process. Inevitably, however, data for such models always include the effects of other factors affecting the claims process.

- Premiums for involuntary business underwritten at premium rates and in volumes that differ from assumptions;
- Retrospective premiums or dividends that differ from assumptions; and
- Amounts collectible from agents that differ from assumptions.

Loss projection risk is a function of the factors that affect reserve risk and also of the uncertainty regarding:

- Unanticipated changes in loss costs and exposures from the historical experience period;
- Loss costs for the mix of new policies being underwritten, including the effect of adverse selection; and
- Loss adjustment practices in the future that may differ from those in the past.

Catastrophe risk can be considered a component of loss projection risk. It is a function of:

- The coverages being written;
- The concentration of insured values in specific geographic areas or legal jurisdictions; and
- Uncertainty regarding the frequency, severity, and nature of catastrophic events.

Computerized models of the damage arising out of certain types of catastrophes are available and may be of value in determining assumptions about the probabilities and sizes of catastrophic losses. Output from these catastrophe models may be used in a variety of ways. A link between models could be constructed to feed catastrophe simulations directly into the Dynamic Financial Analysis (DFA) model. Alternatively, the output could be used as an input table to a DFA model to generate catastrophe risk scenarios. Further, the output could be analyzed to obtain values to parameterize catastrophe risk within the DFA model.

Reinsurance risk is a function of changes in the price and availability of desired reinsurance, and of uncertainty regarding the collectibility of reinsurance recoverables arising from the financial condition of the reinsurer or ambiguity about the coverage provided. Reinsurance risk exists in each of the four obligation risks identified thus far. In many models, projections are made on a net of reinsurance basis. Such projections incorporate implicit assumptions regarding reinsurance risks, whereas projections made on a gross of reinsurance basis require explicit instructions regarding the reinsurance mechanism. Reinsurance risk recognizes how reinsurance responds under stress, such as a large catastrophe or other strain on collectibility, aggregates, reinstatements and other reinsurance parameters.

Expense risks, those associated with expenses (other than loss adjustment expenses) and taxes, include uncertainty regarding:

- Contingent commissions to agents;
- Marginal expenses of adding new business;
- Overhead costs, including the risk that overhead costs will be changed by regulatory intervention, and the risk that there may be periods of changing premium during which overhead costs will not change in proportion to premium;
- Assigned risk overburdens, second injury funds and other assessments;
- Policyholder dividends; and
- Federal and local income taxes, both in interpreting the current Internal Revenue Code and in anticipating changes to the code.

These lists of uncertainties regarding the major components of obligation risk are illustrative. Other factors may also affect obligation risk.

Interest Rate Risk

Interest rate risk is the risk of financial loss caused by changes in future interest rates. It encompasses:

- The risk of a change in the economic value of asset cash flows caused by changes in interest rates – this includes cash inflows such as those from bonds, mortgages, real estate, and dividends from equity investments; and
- The risk of a change in the economic value of obligation cash flows caused by changes in interest rates – this includes both cash outflows (such as those related to loss reserves) and cash inflows (such as expected future premium receipts).

A dynamic financial model is an important tool in measuring the financial effects of these components of interest rate risk, both individually and in combination. The model's ability to measure interest rate effects on all cash flows - cash inflows, cash outflows and net cash flow - will also enable a company to develop management strategies that mitigate the potential adverse financial effects related to interest rate changes.

Asset Cash Flows – Asset cash flows may be fixed or may change in response to interest rate changes. If cash flows are fixed (e.g.. some types of bonds) an increase in interest rates produces a reduction in market value and possibly a reduction in earnings if conditions force the insurer to sell the bond in the high interest rate environment (see disinvestment risk below). If the cash flows are interest sensitive (e.g., a bond with fixed payments but having a prepayment option), then both the timing and amount of the flows may change in response to an interest rate change. For example, a bond that has a prepayment option would tend to be called in times of declining interest rates. In this situation, the borrower would prepay the bond in order to take advantage of more favorable borrowing costs elsewhere. On the opposite side of the transaction, the insurer would realize an adverse economic impact in the loss of future investment income from the higher yielding asset after reinvestment at the lower prevailing rates. The same effects can occur when cash flows are not fixed as in these examples, unless the variable cash flows change in concert with interest rate changes (such as with debt with interest linked to a market index).

Cash flows from other assets may also be fixed or interest sensitive. Generally, the sophistication with which the effects of interest rate risk on assets need to be modeled is directly related to the asset's importance to the insurer. For most property casualty insurers, more effort would be made to appropriately model the effects of interest rate changes on bonds than on real estate and equities.

Obligation Cash Flows – Obligation cash flows may also be fixed or may change in response to interest rate changes.

By far, the largest obligation cash outflows for property-casualty insurers are payments for losses and loss adjustment expenses. The degree to which interest rate risk is an issue and the degree to which these cash flows are fixed or interest sensitive will vary by line. At one end of the spectrum, if the cash flow for losses incurred prior to the valuation date is fixed relative to interest rates (i.e., excluding reserve risk), then a decrease in interest rates would produce an adverse financial impact (measured on an economic basis). To the extent that the loss payments are interest sensitive, the economic impact will be reduced, provided that they move in the same direction that interest rates move. Generally, interest rate risk will be more significant for the longer tail lines of business because of the longer duration of the cash flows.

On the premium side, an increase in interest rates could produce a decrease in future premium cash inflows to the extent that insurance companies in the marketplace rely on investment income to maintain overall profitability. Other components of underwriting income could also show varying degrees of sensitivity to interest rate changes.

Again, the needed degree of effort and sophistication applied to modeling the effects of interest rate changes on each component of the obligation cash flows will depend on the relative importance of each component. This will vary in each situation according to the specific characteristics of the insurance operations being modeled.

Net Cash Flows – Differences in timing and amount between cash inflows and cash outflows produce risks and opportunities with respect to the potential financial loss associated with interest rate changes. The risks include reinvestment risk when cash inflows exceed outflows and disinvestment risk when cash outflows exceed inflows. Opportunities exist to the extent that these risks can be mitigated by managing cash inflows and cash outflows in such a way that the economic value of the net cash flow is immunized, to some extent, from changes in interest rates. The degree of immunization may be limited by the available choice of investments if the optimal asset cash flow is not produced by any readily available asset. Such differences could arise from the interaction of economic factors with assets or liabilities.

Reinvestment and disinvestment risks are components of interest rate risk that arise when differences in the timing and amount of cash inflows and outflows cause the insurer's net cash flow in a period to be substantially different from zero.

Reinvestment risk relates to the uncertainty regarding investment returns that will be available upon the reinvestment of excess cash flow related to proceeds from investments. If interest rates have decreased, then the excess cash flow will have to be reinvested at rates below those on the existing or maturing assets.

Disinvestment risk arises when fixed-income assets must be sold prior to maturity to meet cash flow needs, typically because the net cash flow is negative absent the sale of these assets. If interest rates have increased, then the market value of these assets has decreased and they will be sold at a relative loss.

Interest rate risk includes the portion of market value uncertainty due only to changes in interest rates. The portion of market value uncertainty related to changes in perceived credit or default risk is a component of Asset Risk. Also, the reinvestment rate assumption in a dynamic financial model determines both reinvestment risk and disinvestment risk for fixed-income assets.

Consequently, the reinvestment rate can have a significant impact on the results of a dynamic financial model.

CHAPTER 6
POTENTIAL DANGERS/PITFALLS INHERENT IN THE MODELING PROCESS

Once the risks to be incorporated in the model have been identified and the model built, there are a number of dangers inherent in the modeling process to consider, including:

- The range of scenarios may not reflect the user's intent;
- The model may be incorrectly or incompletely specified for the intended purpose; and
- The model may quickly become obsolete if it is not adaptable to change.

Importance of Scenario Testing and Selection of Assumptions

For a particular application, proper use of a model depends on the selection of appropriate scenarios[12] to evaluate and the development of consistent assumptions within each scenario, which, in turn, will influence the data and methods used to provide assumptions for understanding the projected performance of the insurer. Scenarios permit links between assumptions for various parts of the model. For example, a high interest rate scenario might include assumptions of high bond yields, low common stock values with high dividends, high inflation in medical costs, and a low level of unemployment.

Scenarios provide a useful tool for determining the implications of risks on the projected performance of an insurer. Observing the results for a variety of scenarios yields information about the company's response to risk. Careful selection of scenarios is essential.

Often times, the scenarios to be studied will be specified by company management. There may also be times when scenarios are specified by external sources. For example, the Canadian regulations provide general guidance on the choice of scenarios. By whatever means, the range of scenarios is selected, its choice will impact the results that the model produces. It may be appropriate to observe the model under scenarios other than those specified by regulators or management to adequately understand the implications of the scenarios that were specified.

---

[12] A scenario is a description (set of assumptions) of a group of variables (such as interest rates or combined ratios) that can reasonably be expected to impact an insurance enterprise. The description of the group of variables constitutes the environment within which the insurance enterprise will operate.

When the range of scenarios has been selected using only retrospective tests as a guide, the model may be prone to under-determination. For example, the danger that the probability distributions in a stochastic model are incorrectly specified can be reduced by choosing probability distributions that have greater uncertainty (dispersion and skewness) than historical data.

Model Specification and Validation

A model that is incorrectly or insufficiently specified will fail in its intended purpose and could lead to costly mistakes. To reduce this danger, model validation is crucial, i.e., matching the model to the insurer's own history over some period of time. A well-specified model will reasonably reproduce past actual results. Actual results varying from projections may not be an indication of a poor model. Rather, it is generally appropriate to investigate such differences and reconcile the model's results with the actual results. This process of reconciliation may identify weaknesses in the model, or clarify ways in which the enterprise's activities departed from what would have been reasonably expected (e.g., writing more, rather than less, unprofitable business to cover up poor experience).

Keeping the Model Relevant[13]

Work does not end once a model is built. Change is constant and a model must keep pace with this change to stay relevant. Examples of continuing change include:

Proliferation of Insurance Products: Although regulation and custom tend to slow the creation of insurance products by entrepreneurs, changes in the markets served by insurance enterprises constantly press for new products and services. Dynamic financial models may need to be refined to adapt to these changes.

Competitive Pressures: In the past, pressures were perceived to arise from competition at the point of sale of the insurance product. Since at least 1970, competitive pressure has increasingly come to mean competition at the point that capital is being raised. Dynamic financial models are playing an increasingly visible role in corporate decisions regarding purchases and sales of business units, means to tap capital markets, and trade-off between

[13] The following subsection was adopted from R. Blanchard, Actuarial Digest, Volume 15, No. 5, Oct./Nov. 1996: "A Mechanics Perspective to Model Building".

trend is expected to continue.

Innovation in Assets: Recent innovations in asset design make it difficult to understand the riskiness of many investments by looking at their financial designations for accounting purposes. For example, some bonds have the risks of stock investments or mortgages, and mortgages are often backed by a wide range of securities. Existing accounting classifications may be misleading to tabulate information about assets for input into dynamic financial models.

New types of asset classes are emerging, some with purposes other than purely generation of investment returns. For example, some assets, such as catastrophe futures, can hedge risks undertaken by the insurer's underwriting activities. More innovation can be expected, along with the need to model these kinds of investments.

Regulatory, Accounting, and Tax Requirements: Dynamic financial models may need to be revised from time to time to reflect the latest developments in regulation. Such changes may be as simple as adding a set of calculations, or they may require modeling of the corporate response to the impact of the regulations (e.g., a shift in marketing or investment strategy to accommodate surplus constraints of risk-based capital). Projections of cash flow may react to changes in these constraints differently from projections of statutory results. Dynamic financial models with feedback loops may react differently from static models.

In a changing environment, to keep a model from rapidly becoming a dinosaur, it should be designed with change in mind. A structured model comprised of smaller interrelated program modules will tend to be much more adaptable than one big monster.

CHAPTER 7
MEASURING RESULTS

In order to be an effective analytical tool, a dynamic financial model should be capable of producing various types of output, both financial and analytical. Financial summaries could range from high level, e.g., the overall company balance sheet and income statement, to detailed financial statements at the level that a company would manage and plan its business strategies. Analytical output could include various statistics including graphic representations such as plots of results in a risk vs. reward format (e.g., the asset/liability efficient frontier). A comprehensive model would also generally be capable of producing these results under various bases of accounting.

In addition to the appropriate output summaries, a model must also be designed to maintain whatever additional detail might be needed – either at still lower levels of detail or at intermediate calculation points – that would be needed in order to analyze and interpret output. This "drill down" capability is crucial to successfully reconcile model output with expectations or to diagnose those situations where the model output appears either counter-intuitive or even unreasonable.

- **Basis of Accounting** - Comprehensive dynamic financial models will usually include accounts on at least four bases simultaneously: cash (or economic), statutory, GAAP, and tax.[14] This is the only way to reflect the details of the interrelationships among constraints imposed by investment opportunities, underwriting commitments, laws and regulations, generally accepted accounting principles, and income tax laws. However, less comprehensive models may be appropriate depending on the use.

- **Interpreting Output/Drill Down** – Proper interpretation of output is possibly the most important aspect of using a dynamic financial model. The danger of inappropriate interpretation can be reduced by communicating the possibly limited extent of variation among modeled scenarios in comparison to the potential range of variation in the year to year results of the insurer's operations.

[14] Financial reporting, and therefore modeling, may be more complex for international users.

Additionally, developing conceptual interpretations of model results is crucial to communicating these results. This can be a challenge and may entail an intensive drill down through model output in order to identify major "drivers" of the results. Because the volume of output data generated by a detailed model can be overwhelming, the task will be made easier if the model design includes drill down and diagnostic capabilities on its output. These may include:[15]

- Expectation and distribution of selected output variables;
- Identification and categorization of scenarios that resulted in extreme values;
- Determination of explanatory variables relative to selected output variables (e.g., regression techniques);
- Evaluation of decision rules, reinsurance programs, etc. relative to selected output variables (e.g., "on/off" switches); and
- "Good vs. bad" analyses (e.g., risk vs. reward types comparisons).

The results of the model could suggest that either one or more assumptions are incorrect (in which case the assumptions will likely be revised before results are presented) or that the insurer's strategies could be improved. As an example of the latter, the results of the model may suggest that the insurer may be particularly at peril due to one or more sources of risk.

[15] Adapted from "Dynamic Financial Modeling - Issues and Approaches," Thomas V. Warthen III and David B. Sommer; CAS Forum, Spring, 1996.

APPENDIX A
BIBLIOGRAPHY

Adelberger, Otto L., "SIMULFIN: A General Financial Simulation Model of the Firm for Teaching and Research Purposes," Journal of Financial Education, Vol. 3, 1974, pp. 96-104.

Arvan, Lanny and Leon N. Moses, "A Model of the Firm in Time and Space," Journal of Economic Dynamics and Control, Vol. 9, No. 1, 1985, pp. 77-100.

Chalke, Shane, "Heuristic Modeling," The Chalke Perspective, 3rd Quarter, 1993.

Cho, Dongsae, "The Impact of Risk Management Decisions on Firm Value: Gordon's Growth Model Approach," Journal of Risk and Insurance, Vol. 55, No. 1, 1988, pp. 118-131.

Clouse, Maclyn L., "A Simulation Model to Link the Economic Environment with Corporate Financial Decisions," Journal of Financial Education, Vol. 8, 1979, pp. 94-96.

Elliott, J. Walter, "Forecasting and Analysis of Corporate Financial Performance with an Economic Model of the Firm," Journal of Financial and Quantitative Analysis, Vol. 7, No. 2, 1972, pp. 1499-1526.

Forrester, Jay W., Industrial Dynamics, MIT Press, 1961.

Francis, Jack Clark and Dexter R. Rowell, "A Simultaneous Equation Model of the Firm for Financial Analysis and Planning," Financial Management, Vol. 7, No. 1, 1978, pp. 29-44.

Herendeen, James B., "A Financial Model of the Regulated Firm," Southern Economic Journal, Vol. 42, No. 2, 1975, pp. 279-284.

MacMinn, Richard D. and John D. Martin, "Uncertainty, The Fisher Model, and Corporate Financial Theory," Research in Finance, Vol. 7, 1988, pp. 227-264.

Myers, S. C., "A Simple Model of Firm Behavior Under Regulation and Uncertainty," Bell Journal of Economics, Vol. 4, No. 1, 1973, pp. 304-315.

Prisman, Eliezer Z., Myron B. Slovin and Marie E. Sushka, "A General Model of the Banking Firm Under Conditions of Monopoly, Uncertainty, and Recourse," Journal of Monetary Economics, Vol. 17, No. 2, 1986, pp. 293-304.

Taggart, Robert A., Jr., "A Model of Corporate Financing Decisions," Journal of Finance, Vol. 32, No. 5, 1977, pp. 1467-1484.

Walker, Kenton B. and Lawrence A. McClelland, "Management Forecasts and Statistical Prediction Model Forecasts in Corporate Budgeting," Journal of Accounting Research, Vol. 29, No. 2, 1991, pp. 371-381.

APPENDIX B
CHECKLIST OF CONSIDERATIONS[16]

1. Is the model appropriate for the intended use?

2. Are the model and related communications appropriate for the expected users of its results?

3. Can the model be developed, purchased, maintained and/or used within the personnel, time, hardware, software and budget resources available?

4. Does the model contain input, output and processing regarding each of the risks to be evaluated in appropriate detail? Are the available historical data regarding these risks sufficient to use to derive the assumptions needed by the model? These risks include:

   - Asset risk
   - Obligation risk
     - Reserve risk
     - Premium risk
     - Loss projection risk
     - Catastrophe risk
     - Reinsurance risk
     - Expense risk
   - Interest rate risk

5. Is the range of scenarios broad enough to reasonably address the questions at hand?

6. Is the model specification accurate and appropriately complete?

7. Are the measures used to summarize and interpret the range of results reasonable for the application?

[16] This is an abbreviated list of considerations. A more comprehensive list is contained in the CAS Handbook for Dynamic Financial Analysis.

8. Have the limitations of the model and range of scenarios been communicated clearly to reduce the risk of misinterpretation?

9. Is a generalized model reasonable for the application or would a tailor-made model better address specific issues?

10. Does the model have a reasonable balance between input assumptions and hard-coded logic?

11. Is the model's time horizon appropriate to the application?

12. Are the accounting bases upon which the model makes forecasts of appropriate breadth to the application?

13. Does the model provide sufficient detail (input and output) with respect to interactions with parents, subsidiaries and affiliates?

14. Will the value of the model results be enhanced enough by the presence of feedback loops (automatic conditional decisions) to warrant a model with such features?

15. Is a deterministic or stochastic model better suited for the application?