PRINCIPLES UNDERLYING ACTUARIAL SCIENCE

BACKGROUND, SCOPE AND LIMITATIONS

BACKGROUND

In October 1991, the Society of Actuaries (SOA) Board of Governors accepted the statement of the SOA Committee on Actuarial Principles entitled "Principles of Actuarial Science," which had been revised in response to the comments received from members during an exposure process that included both a discussion draft and an exposure draft. The Board authorized the statement as an expression of opinion by the Committee. It was not submitted to a vote of the membership and thus was not to be construed as an expression of opinion by the SOA. The statement was published in *Transactions of the Society of Actuaries* XLIV, 1992, along with a note indicating that the statement's application is limited to the areas of actuarial practice that fall within the purview of the SOA and that the paper was not intended to include the areas of property and casualty insurance.

Subsequently, the Casualty Actuarial Society (CAS) and SOA Principles Committees worked together to produce the April 30, 1997 discussion draft of *General Principles of Actuarial Science*, and related companion documents. The SOA Board and the CAS Board authorized the distribution of these documents to members of the actuarial profession and other interested parties. Comments received in response to that discussion draft and its companion documents were considered in the development of a second discussion draft authorized for release in August 1998. Comments received in response to the second discussion draft were considered in the development of this exposure draft.

Comments received in response to this exposure draft will be considered by the Committees in producing a joint statement of principles underlying actuarial science. It will then be presented to the CAS and SOA Boards for acceptance as a statement of opinion of the Committees, and for publication.

SCOPE AND LIMITATIONS

To clarify the scope of this document, it is important to emphasize the distinction between principles and standards.

Principles abstract the key elements of the scientific framework. Principles are not prescriptions that specify how actuarial work is to be done, but are statements grounded in observation and experience. As our experience and understanding continue to develop, the articulation of these principles may change.

In addition to principles, the actuarial profession requires standards. Standards are normative rules, based on the state of the art and science of actuarial practice,

regulatory constraints, and other external conditions. They guide the actuary in the selection of appropriate models and assumptions. Standards are subject to change and new standards may be introduced as actuarial practice evolves. Further discussion of standards is outside the scope of this document.

It is also important to note that this document articulates principles underlying actuarial science, some of which are taken from other disciplines, and is not intended to be a scientific treatise that presents a formal axiomatic structure, but rather an identification and discussion of the significant principles underlying actuarial science.

In the paper "The Methodology of Actuarial Science," presented to the Institute of Actuaries in October 1998, J.M. Pemberton asserts that "Actuarial science is concerned with the development of models which approximate the behaviour of reality and have a degree of predictive power, not the truth."

Pemberton also notes that "simple laws do not adequately describe complex realities" and, thus, "actuarial science deals directly with low-level generalisations, recognising the limited nature of available regularities." Further, there is "need for knowledge of the variations in the specific locality of interest."

The above excerpts summarize well the nature of actuarial science and, thus, the limitations of any document, such as this one, that attempts to articulate principles underlying actuarial science. These excerpts also suggest that any such articulation would include some principle statements with words like "tend" or "generally."

It is also unlikely that principles of the same order of certainty as those used in physics or chemistry can ever be articulated for actuarial science. This means that demanding that the principles be falsifiable is asking too much. It is sufficient that, for now, they have yet to be invalidated.

The statements of principles in this document are drafts developed jointly by the Committee on Principles of the CAS and the Committee on Actuarial Principles of the SOA and do not represent the final deliberations on principles. This exposure draft is being distributed solely for the purpose of review and comment. Members and other interested parties are invited to participate in the process of articulation of principles through submitting comments on this exposure draft.

INTRODUCTION

Actuarial science is an applied science based on concepts and observations distilled from the experience of practitioners and from other sciences. The principles underlying actuarial science are extracted from this experience and from related fields such as mathematics, statistics, economics, and finance.

The objective of *Principles Underlying Actuarial Science* is to articulate the current understanding of the significant principles that form the scientific framework underlying all areas of actuarial practice. The intended audience includes practicing actuaries, researchers, and others, such as representatives of standard-setting organizations. This articulation is not immutable; if fundamental changes occur in our understanding of the world, or if a better expression of the ideas is developed, this statement of principles should be revised.

NATURE OF ACTUARIAL PRACTICE

The primary applications of actuarial science identify and analyze consequences of events involving risk and uncertainty. Actuarial practice involves the analysis and management of these implications and their associated costs. To gain insights about future possibilities, the actuary depends on observation and the wisdom gained through prior experience. Actuaries use these observations and this experience to construct, validate, and apply models. Actuaries continually incorporate additional observations and insights into their models. This feedback cycle systematically addresses discrepancies between these models and observed reality.

Understanding the principles underlying actuarial science enables actuaries to develop models to solve practical problems while recognizing that models do not lead to precise, unique solutions.

Actuarial models are constructed to aid in the assessment of the consequences associated with phenomena that are subject to uncertainty with respect to occurrence, timing, or severity. To construct such models requires:

- understanding the conditions and processes under which past observations were obtained
- anticipating changes in those conditions that will affect future experience
- evaluating the quality of the available data
- bringing judgment to bear on the modeling process
- validating the work as it progresses and revising the model as needed
- estimating the uncertainty inherent in the selection and construction of the model.

Actuarial models are currently used to solve business problems in many different fields, including insurance, investments, healthcare, and retirement systems.

Actuarial models can be developed to solve any problem requiring an analysis of the consequences of risk and uncertainty.

REASONS FOR ARTICULATION OF PRINCIPLES

The reasons for articulating these principles include the following:

- describing and strengthening the intellectual foundation of the actuarial profession
- providing a foundation for the extension of actuarial models to new applications
- providing a basis for formulating sound and consistent standards
- guiding the articulation of practice-specific principles
- furthering actuarial education
- focusing research efforts
- aiding in strategic planning for the profession by providing a foundation upon which actuaries can offer their services in current and potential areas of actuarial practice.

ORGANIZATION OF THIS DOCUMENT

The principles identified in this document are the foundation upon which actuarial science is based. They include principles from mathematics, statistics, economics, and finance. When these principles are considered in conjunction with the actuarial risk variables of occurrence, timing, and severity, models of particular interest to actuaries can be constructed.

Combining these principles with observations about human behavior, actuaries formulate models to assess the implications of future events. In most cases, these models are applied to some aspect of risk management—identification, assessment, control, or financing. Risk financing often involves the transfer of risk through a financial security system.

Thus, the organization of the remainder of this document is:

1. Statistical Framework
2. Economic and Behavioral Framework
3. Principles Underlying Actuarial Modeling and Risk Management
4. Principles Underlying Financial Security Systems.

For reference, glossaries of Principles and Definitions and an index of other significant terms are included at the end of the document.

1. STATISTICAL FRAMEWORK

A fundamental task of the actuary is to use historical observations to draw conclusions about future outcomes. This is similar to the work of the statistician; it is the context that defines the work of the actuary. Therefore, it is appropriate that the initial principles be taken from probability and statistics.

The first two principles state that it is possible to do actuarial work—that, indeed, the probabilities of many events can be estimated. The word "prediction" is avoided because of the uncertainty inherent in future events. However, estimates can be obtained from processes that are reasonably well behaved.

DEFINITIONS

> *Phenomena* are occurrences that can be observed. An *experiment* is an observation of a given phenomenon under specified conditions**.** The result of an experiment is called an *outcome*; an *event* is a set of one or more possible outcomes.

The definition of an event can include a specification of severity and timing; for example, the event could be incurring a $100,000 loss within a particular calendar year.

DEFINITIONS

> *Probability* is a measure that takes on values from zero to one and gives the likelihood of occurrence of an event.
>
> A rule that assigns a numerical value to every possible outcome is called a *random variable*. The probability-weighted average of the numerical values taken on by a random variable, if the average exists, is called the *expected value* of the random variable. The *degree of uncertainty* of a random variable is a measure of the variation of the values taken on by the random variable from its expected value. *Correlation* is a measure of the extent to which a change in one random variable occurs simultaneously with a change in another random variable.

Correlation may be thought of as a tendency for two variables to "move together." A tendency to move in the same direction is referred to as "positive correlation;" a tendency to move in opposite directions is called "negative correlation." Variables that tend to move independently of each other are examples of "uncorrelated" variables.

For certain collections of phenomena, it is of interest to compare the respective expected values of a given random variable. For example, the numbers of sixes for

a die thrown 1,000, 2,000, and 3,000 times are three separate phenomena. However, although the phenomena are separate, the expected number of sixes for the 1,000-throw phenomenon, the 2,000-throw phenomenon, and the 3,000-throw phenomenon would be expected to be in proportions of 1:2:3. For these phenomena, the number of throws acts as a scaling factor that relates the expected values. When such a factor exists, the proportion of occurrences of a specific event observed in experiments on various phenomena can be normalized for comparison through use of the factor. In this way, a wider array of data can be used to develop a specific estimate.

DEFINITION

A scaling factor that relates the expected value of one or more random variables over a collection of phenomena is called an *exposure measure*.

Principle 1.1 is a statement of the law of large numbers. It may appear at first that this law does not apply to a field such as insurance, because the "experiment" whose outcomes are the occurrence or nonoccurrence of the insured event can rarely be precisely repeated. For example, the survival to a specified age or death of a specific individual or the destruction of a particular automobile can be observed but once. But if the experiment is defined as observing whether in the next year a randomly selected 40-year-old nonsmoking male dies or a randomly selected car of a given make is destroyed, this experiment can be repeated. Actuaries believe it is likely that the proportion of deaths or destructions will converge to a limit as the number of observations increases.

1.1 PRINCIPLE (Law of Large Numbers). Phenomena exist such that, if it were possible to conduct a sequence of independent experiments under the same specified conditions, the proportion of occurrences of a given event would converge as the number of experiments becomes large.

DEFINITION

A phenomenon to which Principle 1.1 applies is said to display *statistical regularity*.

If a phenomenon displays statistical regularity, an estimate of the probability of the occurrence of an event associated with the phenomenon is the proportion of occurrences of the event in a long sequence of identical experiments.

DEFINITIONS

A *scientific model* is an abstract and simplified representation of a given phenomenon. A *mathematical model* is a scientific model in which the representation is expressed in mathematical terms. A *stochastic model* is a

mathematical model in which the representation is expressed in terms of probabilities. A *dynamic stochastic model* is a stochastic model that incorporates a systematic process for revising the model in response to observed results. A *deterministic model* of a phenomenon is a stochastic model in which a given event is assumed to occur with certainty.

For statistically regular phenomena, the probabilities needed to construct a stochastic model can be determined by application of the law of large numbers. Alternatively, these probabilities can be selected by using other criteria.

Stochastic models can be based on previous experiments or can utilize prior assumptions about the probabilities of various events, which can be periodically revised as the results of new experiments are obtained.

A stochastic model does not predict the outcome of a single experiment prior to its being carried out. However, it can be used to derive estimates of the expected value and other characteristics of the random variable.

The probabilistic aspect of a model may not be necessary, or feasible, for a given application; in such a situation a simpler version of a stochastic model might be used. A deterministic model can be, but need not be, derived from a stochastic model by replacing random variables with fixed values. A deterministic model can be used to examine the implications of a specific set of assumptions.

Principle 1.1 states that there exist phenomena that can be modeled. Statistical regularity is generally easier to demonstrate for physical phenomena than for biological, social, and behavioral phenomena, where experiments often cannot be replicated and where data numerous enough to be useful have to be gathered from diverse sources over extended periods of time. Thus, models based on the assumption of statistical regularity must be applied with care to actuarial problems. Nevertheless, such models are in widespread use by actuaries and are found to produce useful results in many situations.

Principle 1.2 states that it is possible to construct such a model. Prior observations can be used to determine the nature of the model and also the particulars (often parameters) of the model. Data from related experiments can also be incorporated. For example, experience of drivers in a given city is relevant to the construction of a model of automobile losses in that city. It may be possible to improve the model by incorporating data from similar cities. Judgment can be applied when similar data are modified or adjusted to account for known changes that will affect future results.

1.2 PRINCIPLE (Basis for Model Construction). A stochastic model of a specific phenomenon can be based on the outcomes of experiments performed on that phenomenon, on observations of related phenomena, or on a combination of both.

A model may be developed using:

- only the outcomes of experiments associated with the specific phenomenon of interest
- outcomes of experiments involving related phenomena with characteristics similar to the specific phenomenon of interest
- a priori judgments
- some combination of the above.

When data are collected from several sources, an estimate can be obtained from each set of data. These estimates can then be combined as a weighted average, where each weight represents an assessment of the relative importance of that estimate. This assessment can involve statistical analysis or be based entirely on judgment, and can vary according to the purpose for which the model is to be used.

1.3 PRINCIPLE (Credibility). It is possible to estimate the relative weights to be assigned to each of several estimates so that a given measure of the accuracy of the weighted average is optimized.

DEFINITION

Given an application and a model, *credibility* is the relative weight assigned to one of two or more estimates used to generate a more accurate estimate.

The uncertainty associated with stochastic modeling has three distinct sources:

- the inherent variability of the phenomenon
- incomplete knowledge or inaccurate representation of the probabilities of alternative sets of outcomes
- the risk that the model adopted is not a perfect, or even a good, representation of the underlying situation.

Sometimes these sources of uncertainty are referred to as “process risk,” “parameter risk,” and “model risk,” respectively. The terms “risk” and “uncertainty” have also been used in this context; here, however, risk and uncertainty have been assigned other meanings.

The process of checking the results produced by a model for consistency with available observed information is commonly referred to as “validation.”

DEFINITIONS

A mathematical model is *potentially valid* if it produces results that are consistent with available observations of the modeled phenomena or of similar phenomena and is capable of being validated relative to the specified

observed results when sufficient data are available. A mathematical model is said to be *valid within a specified degree of accuracy* relative to certain observed results if it can reproduce these results within that degree of accuracy.

Observed results involving the phenomena represented by a model might not be available or sufficiently voluminous to allow the model to be validated within a specified degree of accuracy. In this case, the appropriateness of the model can be established initially by comparing its results with those from the observation of similar phenomena. The validity of such "judgmentally validated" models can be tested when sufficient data becomes available.

Not all observable aspects of the modeled phenomena must be reproduced in order for a model to be valid. For example, a model used in the appraisal of an insurance company may be validated with respect to only a few quantities, such as aggregate reserves and total policy count.

2. ECONOMIC AND BEHAVIORAL FRAMEWORK

Economics involves an understanding of human behavior as a series of transactions subject to definable, and often quantifiable, incentives and disincentives. Actuaries have often found this concept of "economically rational behavior" to be useful. However, people do not always act in an economically rational manner, due to non-economic motivations or other factors. As a result, the principles of this section use the words "tend" and "may."

DEFINITIONS

An *economic good* is something that has value to a person and that the person can consider exchanging for something else. *Money* is a means of exchange that can be traded for economic goods. The amount of money a person is willing to trade for an economic good at a specific time is the good's then *current monetary value* to that person.

As defined here, economic goods include services, and "person" indicates either a human being or a corporate or other entity.

Money has been defined in three ways: as a store of value, as a means of exchange, and as a unit of account. Here, the focus is on money as a means of exchange, as reflected in the definition.

Principle 2.1 is a more precise statement of "time is money."

2.1 PRINCIPLE (Time Preference). People tend to prefer receiving money or economic goods at an earlier date, rather than receiving that same amount of money or economic goods at a later date.

Conversely, if a person is obligated to give up money or economic goods, that person will tend to prefer giving them up at a later date, rather than giving up that same amount of money or economic goods at an earlier date.

Time preference is usually represented by a system of interest rates used to discount future receipts or disbursements so that they can be compared in current equivalents.

2.2 PRINCIPLE (Risk Preference). People tend to prefer receiving a given amount of money or economic goods at a specified time with certainty, rather than receiving at the same specified time an amount determined by a random variable having the same expected value as the given amount.

Individuals with such a preference are said to be "risk averse." While some people may be risk-seeking in certain situations, such as in making decisions regarding

buying lottery tickets in which extremely high-return, low-probability outcomes are possible, in the vast majority of cases of concern to actuaries, risk aversion is the preference involved.

Unlike time preference, the ordering of risk preferences is the same whether the outcome is positive or negative. However, in both cases, the degree of preference may be changed if the outcome's signs are changed.

Principle 2.3 indicates that the value assigned to economic goods, the time value of money, and risk preference are not the same for all people at all times.

2.3 PRINCIPLE (Diversity of Preferences). Different people may assign different current monetary values to the receipt at a specified time of a specified amount of money or economic goods.

Principle 2.3 is important for actuarial purposes; for example, the value of an insurance policy (even if personal preference is ignored) can differ from one person to another.

DEFINITIONS

An *economic benefit* (*benefit*) is the receipt at a specific time of money or economic goods. A *cash flow* is an economic benefit for which the economic good received is an amount of money. An economic benefit that depends on an event whose occurrence or timing is not certain is said to be *contingent*. An *option* is a right, but not an obligation, to exchange one set of economic goods for another set at a specified future time or during a specified time interval. An *asset* is money or economic goods held, or the right to receive future economic benefits; an *obligation* is a duty to provide current or future economic benefits. A *contingent cash flow model* is a stochastic model that represents future cash flows as random variables.

The economic benefits associated with an option are contingent on the future actions of the option-holder, which may in turn be dependent on economic and other external conditions, as well as the preferences of the option-holder. Such options are said to be "embedded" in the associated economic benefits. Embedded options often impact cash flows that actuaries model, leading to the frequent use by actuaries of contingent cash flow models.

2.4 PRINCIPLE (Present Value Modeling). A mathematical model exists that can estimate the current monetary value a given person would assign to any future cash flow.

DEFINITIONS

A model described by Principle 2.4 is called a *present value model*. The estimate of the current monetary value of a future cash flow given by a present value model under a particular set of assumptions about future economic or other conditions is called the *present value of the cash flow* relative to those assumptions. A set of assumptions about future conditions is called a *scenario.*

If probabilities can be assigned to the possible scenarios, the present value model can be a stochastic model based on these probabilities. The present value of a series of cash flows is then a random variable with the value assigned to each scenario the current monetary value for that scenario.

The cash flows themselves may depend on the scenario. The present value model takes account of the person's views on such dependence, as well as the person's preferences regarding time of receipt of cash. The cash flows may also exhibit contingencies arising from other phenomena, such as embedded options. In this case, the present value model will incorporate a contingent cash flow model with probabilities, reflecting the person's views, that may depend on the scenario. The present value of an option is the difference between the present value of the cash flows that would occur if the option were available and the present value of the corresponding cash flows that would occur if the option were not available.

DEFINITION

An *economic transaction (transaction)* is an exchange of economic goods or money by two or more persons.

It is reasonable to assume that persons involved in a transaction will tend to make choices that each perceives to be in his or her best interest. In an insurance setting, for example, an insurer must choose among various possible combinations of price and benefits in designing a policy for sale, and the potential purchaser must decide whether to buy that policy. Often, the choices of parties to a transaction are not independent of one another.

2.5 PRINCIPLE (Economic Self Interest). The parties to an economic transaction will tend to act in a manner that each perceives to be most economically advantageous, taking into account the information each has about the environment and about each other.

The decision of an insurer to incorporate a deductible amount into its insurance policy influences the subsequent actions of purchasers of the policy, both in choosing which policy to purchase and in making decisions after the purchase.

The body of economic theory that analyzes transactions and the effect of the structure of transactions on subsequent decisions is called "game theory."

DEFINITIONS

An *economic game (game)* is a model of a transaction that attempts to determine the strategies that the parties to the transaction will adopt, given the information each has at every step in the process, in order to achieve the result that each considers most economically advantageous. A *contract* is a step in a transaction at which the parties make a mutual commitment to carry out certain future actions. *Information asymmetry* exists if one party to an economic transaction has more information than the other party or if one party is not allowed to use all the information available to the other party.

The role of information is central to the game-theoretic analysis of transactions. If all parties to the transaction do not have the same information, the strategies and the outcomes of the game may be significantly affected. If, before the contract is established, asymmetric information exists that could influence the future contractual cash flows, the transaction is an example of adverse selection. The sale of a policy to someone who already knows he or she has a life-threatening disease would be a transaction exhibiting adverse selection.

Another important aspect of transactions is whether the strategies and outcomes of the game are affected by the existence of the transaction. If the existence of a contract contributes to a change in behavior by one of the parties with an impact on the expected outcomes, then moral hazard exists. A specific example of moral hazard is the sale of a homeowner's policy (including theft coverage) to an individual who thereafter is less vigilant about keeping the doors of the house locked, thereby increasing the likelihood of a theft claim.

Classical economic theory describes the interactions of buyers and sellers of goods and services, including capital and labor. These interactions, taken together, are said to form a "market." Markets involving transactions in stocks, bonds, and related securities are called financial markets; the study of such markets is financial economics. Actuaries have adopted several definitions and principles from the field of financial economics.

DEFINITIONS

A *market* for a class of economic goods is an arrangement for facilitating transactions involving such goods by matching willing buyers with willing sellers. The amount of money paid by a buyer to purchase an economic good from a seller is called the *price* of the good. A *financial instrument* is a right to receive, or an obligation to provide, a set of cash flows under specified conditions. A market for financial instruments is called a *financial market.*
The market concept has been applied to the valuation of financial instruments such as stocks, bonds, and related securities. Models have been developed to provide

estimates of the prices that would occur in a given financial market. An important class of models—equilibrium models—attempts to do this by incorporating the optimizing behavior of all market participants. The applicability of such models to a given market depends importantly on the way that information affects prices in the market.

DEFINITIONS

> An *investment portfolio* (*portfolio*) is a set of financial instruments selected from a specified *investment universe* of such instruments. A *market trade* is a transaction involving the sale, purchase, or exchange of financial instruments in a financial market. A *market value* is an estimate of the price at which a market trade would occur; a mathematical model used to produce such estimates is a *market value model.* An *equilibrium pricing model* for a financial market is a market value model that estimates prices of the financial instruments based on the assumption that the participants in the market will enter into market trades until each participant has optimized his or her position relative to his or her preferences and beliefs. A market is *efficient* with respect to a class of information to the extent the prices actually paid in that market fully reflect all information in the specified class.

Each market participant may have a different set of preferences and beliefs, each set, perhaps, represented by a different present value model. Market value is an estimate of the net result of the actions that buyers and sellers are expected to take based on their individual preferences. Equilibria in markets are short lived. Each market participant must reestablish his or her optimum status from instant to instant, as the participants, goods offered and demanded, and available information change. If there has been a recent transaction, the market value will often be close to the price at which that transaction was made. However, this is not always the case. For example, when new information becomes available, prices may adjust instantaneously and may be very different from the prices realized in market trades in the recent past.

In empirical tests of market efficiency, prices in a market are assumed to reflect information to the extent prices correspond to those estimated by an equilibrium pricing model incorporating the information. To the extent that a market is efficient with respect to a class of information, it is unlikely that “excess profits”—that is, profits in excess of the level estimated by using equilibrium pricing models that reflect the information—can be consistently made using such information. Conditions conducive to market efficiency include having a large number of buyers and sellers, information being generally available to buyers and sellers, and buyers and sellers being able to enter or avoid the transaction at their own discretion without undue external constraint.

Buyers and sellers of financial instruments are often numerous, well informed, and able to act on available information. Therefore, the market for transactions involving financial instruments might be expected to be efficient. In fact, empirical tests have tended to show that financial markets are efficient with respect to some kinds of information.

2.6 PRINCIPLE (Efficiency of Financial Markets). Financial markets tend to be efficient with respect to historical price information and other widely available public information.

An implication of Principle 2.6 is that trading strategies based on analyses involving solely the study of series of prices or reactions to publicly available information are unlikely to lead to significant excess profits. While it is not possible to evaluate all potential strategies, empirical tests suggest that any strategy that leads to excess profits would at least have to be singularly difficult to apply (due to complexity or required quickness of reaction). On the other hand, financial markets have been found to be inefficient with respect to material non-public information.

Equilibrium pricing models require extensive information on all market participants. Usually, simplifying assumptions are adopted to make the model more tractable. Such simplifications can, of course, reduce the real-world applicability of the models. Another class of market value models, requiring much less extensive information, is based on the observation that "arbitrage profits" are not usually available in financial markets.

2.7 PRINCIPLE (Law of One Price). In most financial markets, two portfolios that will result in the same future cash flows under all possible scenarios will trade at the same price.

DEFINITION

A market value model that is consistent with Principle 2.7 is called a *no-arbitrage pricing model*.

"Arbitrage" is the extraction of risk-free profits from a series of market trades that requires no net investment. Arbitrage could result from the construction of a portfolio that requires no investment, has no sensitivity to any factor, and generates a positive return. Opportunities for arbitrage are unusual in financial markets. If a market were segmented, arbitrage profits might be earned by simultaneously purchasing and selling the same, or essentially similar, financial instruments in different segments for different prices. Such segmentation is usually transient if it occurs at all. For situations in which opportunities for arbitrage are expected to be entirely absent, no-arbitrage pricing models may be used.

Price estimates obtained from no-arbitrage models are additive. Therefore, the price of any financial instrument can be obtained from the price of a "replicating portfolio" formed from a sufficiently inclusive set of "basic" financial instruments without direct reference to the array of preferences and beliefs of market participants. The information requirements of no-arbitrage models are thus less than those of market equilibrium models.

No-arbitrage models are extensively used for pricing "derivative" financial instruments, that is, financial instruments that pay their owners amounts based on the values of other financial instruments. Options involving the purchase or sale of financial instruments are examples of derivative financial instruments. The assumption of optimality implies that all arbitrage opportunities have been exhausted prior to the establishment of equilibrium; hence, equilibrium models are no-arbitrage models. The reverse is not necessarily true.

Insurance and annuity policies are financial instruments under the definition given above, but the market for such instruments may be neither efficient nor arbitrage free. For example, there is no secondary market for individual life insurance policies that is efficient with respect to information about changes in the insured's health after issue. On the other hand, the reinsurance market may be efficient with respect to information about the block of reinsured policies, although not with respect to individual policies.

If market trades for a class of financial instruments are infrequent, or if the market for such instruments is known to be inefficient, it may be difficult to obtain a market value. In such cases, it may nevertheless be possible to assign a value using information known about the market values of other financial instruments with some similar characteristics. Such a value is called a "fair value."

DEFINITION

> A *fair value* is an estimate of the price of a financial instrument provided by a market value model for another financial instrument that is potentially valid with respect to observations of prices and other market behavior of the first instrument.

The market value, and hence the fair value, of a financial instrument can differ significantly from the price paid for that instrument, even if the transaction occurs immediately before or soon after the market value, or fair value, is determined. This difference is not necessarily an indication that the market value model is inappropriate.

3. PRINCIPLES UNDERLYING ACTUARIAL MODELING AND RISK MANAGEMENT

The concept of actuarial risk underlies actuarial science.

DEFINITIONS

An *actuarial risk* is a phenomenon subject to uncertainty with respect to one or more of the *actuarial risk variables*: occurrence, timing, and severity.

Principle 3.1 provides assurance that actuarial risks can be analyzed and that estimates of future behavior can be obtained. Analysis of actuarial risks frequently focuses on economic consequences.

3.1 PRINCIPLE (Modeling of Actuarial Risks). Actuarial risks can be stochastically modeled based on assumptions about the probabilities that will apply to the actuarial risk variables in the future, including assumptions about the future environment.

DEFINITIONS

A model described by Principle 3.1 is called an *actuarial model*. *Actuarial assumptions* are those upon which an actuarial model is based.

Similar to the more general models discussed earlier, an actuarial model can be constructed using data from prior experiments, data from related phenomena, or judgment. Such a model can be validated by comparing its results to the actual outcomes of the phenomena being modeled. In certain circumstances, the actuary's choice of assumptions may be constrained by regulations or by professional standards.

One form of actuarial model is a simple representation of rates of occurrence associated with the actuarial risk—for example, a mortality table. Alternatively, an actuarial model may reflect the economic consequences of the actuarial risk, either by estimating cash flows contingent on the actuarial risk or by determining the present value of such cash flows to a given person. Thus, an actuarial model may incorporate a contingent cash flow model or a present value model. An actuarial model can reflect the judgment of the actuary constructing the model or that of the actuary's client.

Most actuarial models are representations of collections of related actuarial risks. For example, the actuarial risk of claims under $100,000-life-insurance policies issued to selected 45-year-old males and the actuarial risk of claims under $200,000-policies for similarly selected insureds can usually be represented by the same actuarial model. In this example, the amount of insurance acts as a scaling

factor that relates these separate phenomena and allows the same model to apply to both. In other words, the economic consequences suggest exposure measures. This observation applies to most actuarial models, although the economic consequences and exposure measures may not be in exact proportion.

3.2 PRINCIPLE (Exposure). For many actuarial models, there exist one or more exposure measures that are approximately proportional to the economic consequences of one or more collections of the actuarial risks being modeled.

The degree of accuracy of a mathematical model measures how closely values calculated using the model reproduce known values. As time passes and more known values are available for comparison, the degree of accuracy of the model may change. In the case of a model that was initially validated only judgmentally, it may become possible to determine its degree of accuracy.

3.3 PRINCIPLE (Continued Validity of Actuarial Models). The change over time in the degree of accuracy of an initially valid actuarial model depends upon changes in the:

a. nature of the right to receive or the duty to make a payment
b. various environments (for example, regulatory, judicial, social, financial, economic) within which the modeled events occur
c. sufficiency and quality of the data available to validate the model
d. actuary's understanding of the environments.

Actuarial modeling involves a feedback mechanism. As additional data emerge or the environment changes, the model may need to be changed. Principle 3.3 provides insight into when such updates may be necessary.

Actuarial models may be used to test unlikely scenarios for comparison with likely scenarios or may be used to obtain high, medium and low estimates in situations where the use of a single number based on the validated model may not provide sufficient information to the user. Such models may not currently be capable of being validated.

Much of actuarial science is devoted to the management of actuarial risks, which involves the identification of risk and its quantification. One particular way to manage an actuarial risk is through the exchange of money or other economic goods in return for the transfer of the actuarial risk. The development and management of systems that facilitate this exchange are of special interest to actuaries.

DEFINITIONS

A person or object involved in an event associated with an actuarial risk is called a *risk subject*. *Risk identification* is a process for determining whether a given person or object is a risk subject for a given actuarial risk. *Risk assessment* is the quantification of actuarial risk. *Risk control* is a process that reduces the impact of one or more of the actuarial risk variables associated with the actuarial risk. *Risk financing* is a mechanism that provides cash flows that are contingent upon the occurrence of an event associated with the actuarial risk and that tend to offset undesirable economic consequences. A *risk management system* is an arrangement involving risk identification, risk assessment, risk control, or risk financing.

The *actuarial value*, relative to a given actuarial model of the actuarial risk variables, of a series of future cash flows that are contingent upon such variables is the present value developed by the given actuarial model.

Recall that the present value—and hence the actuarial value—is generally a random variable, and the degree of uncertainty of a random variable is a measure of its variation relative to its expected value. The sources of such variation include process risk, parameter risk, and model risk. The actuarial value of any asset or obligation is determined by the actuarial value of the associated cash flows, including money currently held. The cash flows need not be independent of one another, and the actuarial value of a series of cash flows need not be the sum of the actuarial values of the individual cash flows.

A risk management system that is primarily concerned with contingent cash flows is said to be managing "financial risk." Strategies for controlling or financing financial risk often involve development of a risk management system that results in a combination of cash flows, the degree of uncertainty of which is less than the sum of the degrees of uncertainty of the component cash flows.

3.4 PRINCIPLE (Combinations of Cash Flows). The degree of uncertainty of the actuarial value of a combination of sets of cash flows reflects both the degree of uncertainty underlying each actuarial risk variable and the correlation of the variables.

Note that Principle 3.4 does not indicate that uncertainty must be reduced when cash flows are combined.

DEFINITIONS

Pooling is the aggregation of sets of future cash flows contingent upon the same or similar actuarial risk variables. *Diversification* is the aggregation of sets of future cash flows contingent upon actuarial risk variables that are not

perfectly positively correlated. *Hedging* is the aggregation of sets of future cash flows that are negatively correlated.

Pooling, diversification, and hedging are common risk management strategies. Aggregation of sets of cash flows generally can result in a decrease in the degree of uncertainty when the cash flows are not perfectly positively correlated. When pooling is employed to control risk, as in insurance systems, care is usually taken to ensure that the pooled risks are diversified.

Cash flows can arise from both assets and obligations. Aggregation strategies can involve sets of assets, sets of obligations, or mixed sets of assets and obligations. Asset-liability management often uses such strategies.

In addition to identifying, assessing, and controlling financial risk, some financial risk management systems provide for its financing.

DEFINITIONS

The *actuarial value of a risk management system* relative to a given actuarial model is the actuarial value, developed by that model, of the combination of cash flows associated with the system. If the actuarial value can be expressed as a function of any variable associated with the risk management system and independent of the actuarial model, that variable is called a *financial parameter* of the risk management system. The amount by which the value of a financial parameter can be changed without reducing the actuarial value of the risk management system below zero is called the *margin* with respect to that parameter.

For example, the financial parameters could be the premium rates.

Actuaries are often called upon to place a value on future contingent cash flows related to the operations of a risk management system. Because the actuarial value is usually a random variable, the actuary often states the conditions under which the actuarial value can be expected to fall within a given range.

When setting financial parameters, actuaries often must consider and respond to other than purely actuarial criteria. For example, the risk management system may have to meet criteria set by regulators, rating agencies, creditors, or accounting requirements to be deemed acceptable. As one example, casualty actuaries might estimate the value of claim obligations by calculating the aggregate amount of claims expected over a given period using a valid actuarial model but without regard to the timing of claim payments.

Principles 3.5 and 3.6 address evaluation of the potential success of a risk management system. The likelihood of attaining success or avoiding failure

depends on the goals of the system. Certain goals are central to the purpose of the risk management system. Most risk management systems, for example, would be considered fundamentally flawed if the likelihood of meeting their obligations as they came due was not high. For analytic purposes, it is convenient to focus on the likelihood of the avoidance of failure, defined as the first occurrence of a pre-specified adverse condition, such as the inability to meet all obligations.

DEFINITIONS

Failure occurs when a risk management system first fails to satisfy one or more of a set of required conditions fundamental to the system's purpose. The required conditions are called the *success criteria*. The probability that failure will occur within a specified period of time is called the *failure probability* of the risk management system relative to that model within that period of time. The probability that a risk management system will be able to meet the success criterion of being able to pay all obligations as promised is called the *degree of actuarial soundness* of the risk management system.

The following two principles indicate that changing the financial parameters can control the failure probability and the degree of actuarial soundness.

3.5 PRINCIPLE (Avoidance of Failure). For most risk management systems with specified success criteria, there is a set of financial parameters such that a combination of values of the financial parameters reduces the failure probability, as estimated by a valid actuarial model, to below a specified positive level.

3.6 PRINCIPLE (Degree of Actuarial Soundness). For most risk management systems, there is a set of financial parameters such that a combination of values of the financial parameters produces a degree of actuarial soundness, as estimated by a valid actuarial model, that exceeds a specified level less than one.

Note that actuarial soundness is defined relative to a risk management system. It can be quite different for a subsystem. For example, a governmental pension plan may be designed to be funded through participant contributions, but may enjoy a governmental guarantee of solvency. This system can be analyzed with and without taking into account the guarantee; the degrees of actuarial soundness could differ significantly.

In practical situations, the level of margins (and thus the degree of actuarial soundness attainable) may be constrained by market conditions.

DEFINITIONS

The *experience* of a risk management system is the data obtained in the operation of the system. Estimates, based on such data, of rates of occurrence or amounts of payment related to an actuarial risk are called *experience rates*.

Establishment of a risk management system implies that various steps have been taken to manage the risk. In developing and validating a model, it is important to recognize that the existence of the risk management system may, by itself, change the experience rates and, as a result, the model. Principle 3.7 indicates that experience rates are critical in developing and validating models.

3.7 PRINCIPLE (Induced Experience). The economic costs and consequent experience rates for events associated with a risk management system tend to differ from those for the same events occurring in the absence of any such system.

In the absence of other factors, the availability of certain insurance coverages, such as medical expense insurance, causes both unit costs and utilization to increase. For example, the risks associated with dental health may be managed by an insurance contract that pays in full for periodic checkups, but only in part for other dental procedures; it is very likely that the frequency of checkups would increase if this system were put in place.

For certain forms of insurance, such as workers' compensation, the economic costs are so closely tied to the coverage that it would be hard to estimate what the costs would be in the absence of the risk management system.

4. PRINCIPLES UNDERLYING FINANCIAL SECURITY SYSTEMS

Certain risk management systems provide benefits related to the actuarial risk in return for one or more payments to the system. Such an arrangement is called a financial security system. Additional principles apply to financial security systems. They relate to characteristics of the risk subject as well as the risk subject's behavior under such a system.

DEFINITIONS

> A *financial security system* is an arrangement for risk financing in which one person assumes the obligation to provide benefits to offset undesirable economic consequences that may be experienced by a second person, in return for the payment, by or on behalf of the second person, of amounts called *considerations*. A financial security system is *mandatory* if all persons in a group or in society are required to participate; otherwise, it is *voluntary*.

Examples of a financial security system include insurance, annuity, retirement, and health-care financing systems.

In general, there is a period of time between the date a consideration is received under a financial security system and the date a benefit is paid. During this period, at least part of the consideration may be invested in one or more types of assets.

In operating a risk management system, it is often necessary to find a systematic way to assign to each risk subject the probabilities of occurrence, timing, and severity associated with an actuarial risk. In the case of financial security systems, in particular, it is necessary to determine considerations, usually based on these probabilities, for each risk subject. One way to do this is to group "similar" risk subjects into "risk classes" and to assign the probabilities to these classes. More generally, "characteristics" of the risk subjects may be identified that allow the probabilities to be assigned in a systematic way.

DEFINITION

> A *risk characteristic (characteristic)* is a quality that can be identified for each risk subject in a specified group and to which a numeric value can be assigned.

Characteristics used in risk classification are usually related to the associated actuarial risk, but may not exhibit an identifiable cause and effect relationship. One characteristic that is always relevant is the potential financial obligation undertaken by the financial security system with respect to each risk subject. For voluntary

financial security systems, this obligation is usually described in a contract. For social insurance systems, the obligation may be specified in a law or regulation.

DEFINITIONS

A *rate structure for a financial security system* is a rule that assigns numeric values called *exposures* to each covered risk subject for each future time period, and a set of numbers called *rates*, such that the consideration for or cost related to that risk subject for each such time period is the product of the appropriate rate and exposure.

4.1 PRINCIPLE (Risk Classification). For a group of risk subjects associated with a given actuarial risk, it is possible to identify a set of characteristics and a relationship between the sets of values assigned to the characteristics corresponding to each risk subject and probabilities of occurrence, timing and severity so that:

a. each risk subject is assigned to one and only one set of probabilities
b. all risk subjects that have the same values for each of the identified characteristics are assigned the same sets of probabilities
c. the probabilities result in an actuarial model for the actuarial risk that is valid for some degree of accuracy or is potentially valid.

DEFINITION

A set of characteristics and a relationship assigning probabilities to risk subjects that together satisfy Principle 4.1 is called a *risk classification system*.

Several risk classification systems may be possible for a group of risk subjects. Additional considerations or criteria may be applied in order to determine an appropriate system to be used. These may include such factors as marketing strategy, possible antiselection (Principle 4.2), and perceived social policy, and may be affected by legal or regulatory constraints.

There may be several ways to assign values to a risk characteristic. For example, if the risk characteristic is systolic blood pressure, one way to assign a value would be to use the measurement itself. Alternatively, a grouping of measurements into low, medium, and high ranges could be used. A third alternative is a "membership function" that assigns, for example, membership value 0 if the reading is below 100 and membership value $(x\text{-}100)/x$ if the reading x is at or above 100. All three alternatives satisfy the definition of a risk classification system, but only the second alternative actually results in risk classes. Risk classification systems that do not have risk classes are becoming more common as the technology necessary to handle such structures is improved.

A risk classification system is established at a given time. Its continued appropriateness for a specific use depends on the continued availability of a valid associated actuarial model.

DEFINITIONS

A *refinement of a risk classification system* is a risk classification system formed from an existing risk classification system either by introducing a new characteristic or by changing the assignment of values to an existing characteristic in such a way that the original assignment is a special case of the new one. The refinement is said to be *more homogeneous* than the existing system if there are one or more risk subjects that are assigned different probabilities of occurrence, timing, or severity under the refinement than under the existing system.

A change in the assignment of values could be accomplished through the creation of additional groups formed by splitting the range into subintervals. For example, the value "high" for systolic blood pressure might be assigned to readings of 140 and above. Instead, two values, "slightly high" and "very high" could be assigned to readings of 140-175 and 175 and above respectively, thereby splitting the original range. The original system is now a special case of the new system where risk subjects with values "slightly high" and "very high" are treated identically. The new assignment of probabilities of death may be the same for risk subjects with "slightly high" and "very high" values. If these probabilities differ, then the refinement is more homogeneous than the original system.

It would appear that making a risk classification system more and more homogeneous implies greater accuracy. However, the credibility of estimated quantities for the refined system may be lower because the amount of information per group will be smaller. This tradeoff between model error and estimation error implies that some heterogeneity can be advantageous.

Risk classification systems often play an important role in the construction of rate structures. While rate structures have been defined in general terms, many rate structures are, in fact, based on risk classification systems.

DEFINITIONS

A rate structure is said to be *based on a given risk classification system* if the rule that assigns exposures under the rate structure is an exposure measure for the actuarial model associated with the risk classification system. A *refinement of a rate structure* based on a risk classification system is a rate structure based on a refinement of the risk classification system of the original rate structure.

Actuarial models often must change in order to remain valid for a given degree of accuracy. Correspondingly, the rate structure of a financial security system may need to reflect such changes.

DEFINITION

> An *experience adjustment* is a change in considerations or benefits applicable to the various risk subjects to reflect the experience of the financial security system.

The use of experience adjustments may be appropriate in order to maintain or improve a given degree of actuarial soundness of the financial security system. Experience adjustments can reflect the experience of the current period or can involve a recalculation of future considerations or benefits.

A financial security system can provide for experience adjustments (sometimes referred to as dividends or experience refunds) that can be applied as offsets to considerations. The considerations that define a rate structure for such a system are then net of such experience adjustments.

DEFINITION

> *Experience rating* is a refinement of a rate structure that prospectively or retrospectively adjusts the rates of a participant (or group of participants) in a financial security system based on the individual experience of the participant(s).

Experience rating is a technique for recognizing those individual or group risk attributes not adequately addressed by an existing rate structure. It is a method of introducing experience adjustments to the rate structure. The technique can simultaneously introduce incentives, perhaps to adopt preventive or safety measures, into the rate structure and thereby contribute to the management of the risk. The degree of experience adjustment may be affected by the credibility assigned to the experience of the risk subject.

The general observations about economic self interest set forth in Principle 2.5 can be helpful in developing rate structures. For example, actuaries have frequently observed that if one voluntary financial security system offers more rate classes than another such system, and if this results in significant differences in considerations, the risk subjects required to pay higher considerations tend to participate in the system with fewer risk classes. Principle 4.2 formalizes this observation.

4.2 PRINCIPLE (Antiselection). If the rate structure of a voluntary financial security system is based on a risk classification system such that a refinement of the system could result in significant differences in

considerations among risks originally assigned to the same class, there will be a tendency for relatively greater participation by those whose considerations would increase if the refinement were put in place.

If a voluntary financial security system is unable to obtain or utilize information about a characteristic used to define its risk classification system, there will be a tendency for relatively greater participation by those who would have been assigned the same values with higher considerations had the information been available. If, for example, an insurer is unable to use age or sex as a classification variable and if experience varies by age or sex, that insurer may encounter an increase in business from the ages or sex in which the higher claim costs would be expected. This is an example of antiselection based on information asymmetry.

DEFINITION

Selection is the process by which a financial security system determines whether to accept a specific risk subject and the set of probabilities to which the risk will be assigned.

Selection is intended to ensure that similar risk subjects pay similar considerations. Thus, selection acts as a counterbalance to antiselection. The effectiveness of the selection process depends on the availability of necessary information.

A mandatory financial security system does not reject participants, because prospective participants cannot choose to avoid participation. For a voluntary financial security system, on the other hand, selection may be found to be essential to the system's actuarial soundness.

Each party to a voluntary financial security system has the option of participating or not. Thus, for a voluntary financial security system, the set of individuals who participate may not be representative of the universe of individuals subject to the particular actuarial risk.

4.3 PRINCIPLE (Select Experience). The processes of antiselection and selection tend to create differences in the experience of a financial security system, compared with the experience for the same events among all those subject to a given actuarial risk.

The observation described by Principle 4.3 appears on the surface to be similar to that described by Principle 3.7, yet the cause is different. Principle 4.3 observes that the selection and antiselection processes redistribute the overall experience, whereas Principle 3.7 observes that the existence of a risk management system may change the experience for the same events occurring in the absence of any such system.

GLOSSARY
PRINCIPLES UNDERLYING ACTUARIAL SCIENCE

1.1 PRINCIPLE (Law of Large Numbers). Phenomena exist such that, if it were possible to conduct a sequence of independent experiments under the same specified conditions, the proportion of occurrences of a given event would converge as the number of experiments becomes large.

1.2 PRINCIPLE (Basis for Model Construction). A stochastic model of a specific phenomenon can be based on the outcomes of experiments performed on that phenomenon, on observations of related phenomena, or on a combination of both.

1.3 PRINCIPLE (Credibility). It is possible to estimate the relative weights to be assigned to each of several estimates so that a given measure of the accuracy of the weighted average is optimized.

2.1 PRINCIPLE (Time Preference). People tend to prefer receiving money or economic goods at an earlier date, rather than receiving that same amount of money or economic goods at a later date.

2.2 PRINCIPLE (Risk Preference). People tend to prefer receiving a given amount of money or economic goods at a specified time with certainty, rather than receiving at the same specified time an amount determined by a random variable having the same expected value as the given amount.

2.3 PRINCIPLE (Diversity of Preferences). Different people may assign different current monetary values to the receipt at a specified time of a specified amount of money or economic goods.

2.4 PRINCIPLE (Present Value Modeling). A mathematical model exists that can estimate the current monetary value a given person would assign to any future cash flow.

2.5 PRINCIPLE (Economic Self Interest). The parties to an economic transaction will tend to act in a manner that each perceives to be most economically advantageous, taking into account the information each has about the environment and about each other.

2.6 PRINCIPLE (Efficiency of Financial Markets). Financial markets tend to be efficient with respect to historical price information and other widely available public information.

2.7 PRINCIPLE (Law of One Price). In most financial markets, two portfolios that will result in the same future cash flows under all possible scenarios will trade at the same price.

3.1 PRINCIPLE (Modeling of Actuarial Risks). Actuarial risks can be stochastically modeled based on assumptions about the probabilities that will apply to the actuarial risk variables in the future, including assumptions about the future environment.

3.2 PRINCIPLE (Exposure). For most actuarial models, there exist one or more exposure measures that are approximately proportional to the economic consequences of one or more collections of the actuarial risks being modeled.

3.3 PRINCIPLE (Continued Validity of Actuarial Models). The change over time in the degree of accuracy of an initially valid actuarial model depends upon changes in the:

- **a. nature of the right to receive or the duty to make a payment**
- **b. various environments (for example, regulatory, judicial, social, financial, economic) within which the modeled events occur**
- **c. sufficiency and quality of the data available to validate the model**
- **d. actuary's understanding of the environments.**

3.4 PRINCIPLE (Combinations of Cash Flows). The degree of uncertainty of the actuarial value of a combination of sets of cash flows reflects both the degree of uncertainty underlying each actuarial risk variable and the correlation of the variables.

3.5 PRINCIPLE (Avoidance of Failure). For most risk management systems with specified success criteria, there is a set of financial parameters such that a combination of values of the financial parameters reduces the failure probability, as estimated by a valid actuarial model, to below a specified positive level.

3.6 PRINCIPLE (Degree of Actuarial Soundness). For most risk management systems, there is a set of financial parameters such that a combination of values of the financial parameters produces a degree of actuarial soundness, as estimated by a valid actuarial model, that exceeds a specified level less than one.

3.7 PRINCIPLE (Induced Experience). The economic costs and consequent experience rates for events associated with a risk management system tend to differ from those for the same events occurring in the absence of any such system.

4.1 PRINCIPLE (Risk Classification). For a group of risk subjects associated with a given actuarial risk, it is possible to identify a set of characteristics and a relationship between the sets of values assigned to the characteristics corresponding to each risk subject and probabilities of occurrence, timing and severity so that:

a. each risk subject is assigned to one and only one set of probabilities
b. all risk subjects that have the same values for each of the identified characteristics are assigned the same sets of probabilities
c. the probabilities result in an actuarial model for the actuarial risk that is valid for some degree of accuracy or is potentially valid.

4.2 PRINCIPLE (Antiselection). If the rate structure of a voluntary financial security system is based on a risk classification system such that a refinement of the system could result in significant differences in considerations among risks originally assigned to the same class, there will be a tendency for relatively greater participation by those whose considerations would increase if the refinement were put in place.

4.3 PRINCIPLE (Select Experience). The processes of antiselection and selection tend to create differences in the experience of a financial security system, compared with the experience for the same events among all those subject to a given actuarial risk.

GLOSSARY
DEFINITIONS

Note: In this glossary, the parenthetical reference at the end of each paragraph gives the closest relative location of the definition(s) in the main body of the paper: "p. P4.1" indicates that the definition can be found preceding Principle 4.1, and "f. P4.1" indicates that the definition can be found following Principle 4.1.

Actuarial assumptions are those upon which an actuarial model is based. (f. P3.1)

A model described by Principle 3.1 is called an **actuarial model**. (f. P3.1)

An **actuarial risk** is a phenomenon subject to uncertainty with respect to one or more of the *actuarial risk variables*: occurrence, timing, and severity. (p. P3.1)

An *actuarial risk* is a phenomenon subject to uncertainty with respect to one or more of the **actuarial risk variables**: occurrence, timing, and severity. (p. P3.1)

The **actuarial value**, relative to a given actuarial model of the actuarial risk variables, of a series of future cash flows that are contingent upon such variables is the present value developed by the given actuarial model. (p. P3.4)

The **actuarial value of a risk management system** relative to a given actuarial model is the actuarial value, developed by that model, of the combination of cash flows associated with the system. (f. P3.4)

An **asset** is money or economic goods held, or the right to receive future economic benefits; an *obligation* is a duty to provide current or future economic benefits. (f. P2.3)

A rate structure is said to be **based on a given risk classification system** if the rule that assigns exposures under the rate structure is an exposure measure for the actuarial model associated with the risk classification system. (f. P4.1)

An *economic benefit* **(benefit)** is the receipt at a specific time of money or economic goods. (f. P2.3)

A **cash flow** is an economic benefit for which the economic good received is an amount of money. (f. P2.3)

A *risk characteristic* **(characteristic)** is a quality that can be identified for each risk subject in a specified group and to which a numeric value can be assigned. (p. P4.1)

A *financial security system* is an arrangement for risk financing in which one person assumes the obligation to provide benefits to offset undesirable economic

consequences that may be experienced by a second person, in return for the payment, by or on behalf of the second person, of amounts called **considerations**. (p. P4.1)

An economic benefit that depends on an event whose occurrence or timing is not certain is said to be **contingent**. (f. P2.3)

A **contingent cash flow model** is a stochastic model that represents future cash flows as random variables. (f. P2.3)

A **contract** is a step in a transaction at which the parties make a mutual commitment to carry out certain future actions. (f. P2.5)

Correlation is a measure of the extent to which a change in one random variable occurs simultaneously with a change in another random variable. (p. P1.1)

Given an application and a model, **credibility** is the relative weight assigned to one of two or more estimates used to generate a more accurate estimate**.** (f. P1.3)

The amount of money a person is willing to trade for an economic good at a specific time is the good's then **current monetary value** to that person. (p. P2.1)

The probability that a risk management system will be able to meet the success criterion of being able to pay all obligations as promised is called the **degree of actuarial soundness** of the risk management system. (p. P3.5)

The **degree of uncertainty** of a random variable is a measure of the variation of the values taken on by the random variable from its expected value. (p. P1.1)

A **deterministic model** of a phenomenon is a stochastic model in which a given event is assumed to occur with certainty. (p. P1.2)

Diversification is the aggregation of sets of future cash flows contingent upon actuarial risk variables that are not perfectly positively correlated. (f. P3.4)

A **dynamic stochastic model** is a stochastic model that incorporates a systematic process for revising the model in response to observed results. (p. P1.2)

An **economic benefit** *(benefit)* is the receipt at a specific time of money or economic goods. (f. P2.3)

An **economic game** *(game)* is a model of a transaction that attempts to determine the strategies that the parties to the transaction will adopt, given the information each has at every step in the process, in order to achieve the result that each considers most economically advantageous. (f. P2.5)

An **economic good** is something that has value to a person and that the person can consider exchanging for something else. (p. P2.1)

An **economic transaction** *(transaction)* is an exchange of economic goods or money by two or more persons. (p. P2.5)

A market is **efficient** with respect to a class of information to the extent the prices actually paid in that market fully reflect all information in the specified class. (p. P2.6)

An **equilibrium pricing model** for a financial market is a market value model that estimates prices of the financial instruments based on the assumption that the participants in the market will enter into market trades until each participant has optimized his or her position relative to his or her preferences and beliefs. (p. P2.6)

The result of an experiment is called an *outcome*; an **event** is a set of one or more possible outcomes. (p. P1.1)

The probability-weighted average of the numerical values taken on by a random variable, if the average exists, is called the **expected value** of the random variable. (p. P1.1)

The **experience** of a risk management system is the data obtained in the operation of the system. (p. P3.7)

An **experience adjustment** is a change in considerations or benefits applicable to the various risk subjects to reflect the experience of the financial security system. (p. P4.2)

The *experience* of a risk management system is the data obtained in the operation of the system. Estimates, based on such data, of rates of occurrence or amounts of payment related to an actuarial risk are called **experience rates**. (p. P3.7)

Experience rating is a refinement of a rate structure that prospectively or retrospectively adjusts the rates of a participant (or group of participants) in a financial security system based on the individual experience of the participant(s). (p. P4.2)

An **experiment** is an observation of a given phenomenon under specified conditions**.** (p. P1.1)

A scaling factor that relates the expected value of one or more random variables over a collection of phenomena is called an **exposure measure**. (p. P1.1)

A *rate structure for a financial security system* is a rule that assigns numeric values called **exposures** to each covered risk subject for each future time period, and a set of numbers called *rates*, such that the consideration for or cost related to that risk subject for each such time period is the product of the appropriate rate and exposure. (p. P4.1)

Failure occurs when a risk management system first fails to satisfy one or more of a set of required conditions fundamental to the system's purpose. (p. P3.5)

The probability that failure will occur within a specified period of time is call the **failure probability** of the risk management system relative to that model within that period of time. (p. P3.5)

A **fair value** is an estimate of the price of a financial instrument provided by a market value model for another financial instrument that is potentially valid with respect to observations of prices and other market behavior of the first instrument. (f. P2.7)

A **financial instrument** is a right to receive, or an obligation to provide, a set of cash flows under specified conditions. (p. P2.6)

A market for financial instruments is called a **financial market**. (p. P2.6)

If the actuarial value can be expressed as a function of any variable associated with the risk management system and independent of the actuarial model, that variable is called a **financial parameter** of the risk management system. (f. P3.4)

A **financial security system** is an arrangement for risk financing in which one person assumes the obligation to provide benefits to offset undesirable economic consequences that may be experienced by a second person, in return for the payment, by or on behalf of the second person, of amounts called *considerations*. (p. P4.1)

An *economic game* **(game)** is a model of a transaction that attempts to determine the strategies that the parties to the transaction will adopt, given the information each has at every step in the process, in order to achieve the result that each considers most economically advantageous. (f. P2.5)

Hedging is the aggregation of sets of future cash flows that are negatively correlated. (f. P3.4)

Information asymmetry exists if one party to an economic transaction has more information than the other party or if one party is not allowed to use all the information available to the other party. (f. P2.5)

An **investment portfolio** *(portfolio)* is a set of financial instruments selected from a specified *investment universe* of such instruments. (p. P2.6)

An *investment portfolio (portfolio)* is a set of financial instruments selected from a specified **investment universe** of such instruments. (p. P2.6)

A financial security system is **mandatory** if all persons in a group or in society are required to participate; otherwise, it is *voluntary*. (p. P4.1)

The amount by which the value of a financial parameter can be changed without reducing the actuarial value of the risk management system below zero is called the **margin** with respect to that parameter. (f. P3.4)

A **market** for a class of economic goods is an arrangement for facilitating transactions involving such goods by matching willing buyers with willing sellers. (p. P2.6)

A **market trade** is a transaction involving the sale, purchase, or exchange of financial instruments in a financial market. (p. P2.6)

A **market value** is an estimate of the price at which a market trade would occur; a mathematical model used to produce such estimates is a *market value model*. (p. P2.6)

A *market value* is an estimate of the price at which a market trade would occur; a mathematical model used to produce such estimates is a **market value model**. (p. P2.6)

A **mathematical model** is a scientific model in which the representation is expressed in mathematical terms. (p. P1.2)

Money is a means of exchange that can be traded for economic goods. (p. P2.1)

The refinement is said to be **more homogeneous** than the existing system if the probabilities of occurrence, timing, or severity for some risk subjects are changed. (f. P4.1) (also see “refinement of risk classification system” definition)

A market value model that is consistent with Principle 2.7 is called a **no-arbitrage pricing model**. (f. P2.7)

As *asset* is money or economic goods held, or the right to receive future economic benefits; an **obligation** is a duty to provide current or future economic benefits. (f. P2.3)

An **option** is a right, but not an obligation, to exchange one set of economic goods for another set at a specified future time or during a specified time interval. (f. P2.3)

The result of an experiment is called an **outcome**; an *event* is a set of one or more possible outcomes. (p. P1.1)

Phenomena are occurrences that can be observed. (p. P1.1)

Pooling is the aggregation of sets of future cash flows contingent upon the same or similar actuarial risk variables. (f. P3.4)

An *investment portfolio* **(portfolio)** is a set of financial instruments selected from a specified *investment universe* of such instruments. (p. P2.6)

A mathematical model is **potentially valid** if it produces results that are consistent with available observations of the modeled phenomena or of similar phenomena and is capable of being validated relative to the specified observed results when sufficient data are available. (f. P1.3)

A model described by Principle 2.4 is called a **present value model**. (f. P2.4)

The estimate of the current monetary value of a future cash flow given by a present value model under a particular set of assumptions about future economic or other conditions is called the **present value of the cash flow** relative to those assumptions. (f. P2.4)

The amount of money paid by a buyer to purchase an economic good from a seller is called the **price** of the good. (p. P2.6)

Probability is a measure that takes on values from zero to one and gives the likelihood of occurrence of an event. (p. P1.1)

A rule that assigns a numerical value to every possible outcome is called a **random variable**. (p. P1.1)

A *rate structure for a financial security system* is a rule that assigns numeric values called *exposures* to each covered risk subject for each future time period, and a set of numbers called **rates**, such that the consideration for or cost related to that risk subject for each such time period is the product of the appropriate rate and exposure. (p. P4.1)

A **rate structure for a financial security system** is a rule that assigns numeric values called *exposures* to each covered risk subject for each future time period, and a set of numbers called *rates*, such that the consideration for or cost related to that

risk subject for each such time period is the product of the appropriate rate and exposure. (p. P4.1)

A **refinement of a rate structure** based on a risk classification system is a rate structure based on a refinement of the risk classification system of the original rate structure. (f. P4.1)

A **refinement of a risk classification system** is a risk classification system formed from an existing risk classification system either by introducing a new characteristic or by changing the assignment of values to an existing characteristic in such a way that the original assignment is a special case of the new one. (f. P4.1)

Risk assessment is the quantification of actuarial risk. (p. P3.4)

A **risk characteristic** *(characteristic)* is a quality that can be identified for each risk subject in a specified group and to which a numeric value can be assigned. (p. P4.1)

A set of characteristics and a relationship assigning probabilities to risk subjects that together satisfy Principle 4.1 is called a **risk classification system**. (f. P4.1)

Risk control is a process that reduces the impact of one or more of the actuarial risk variables associated with the actuarial risk. (p. P3.4)

Risk financing is a mechanism that provides cash flows that are contingent upon the occurrence of an event associated with the actuarial risk and that tend to offset undesirable economic consequences. (p. P3.4)

Risk identification is a process for determining whether a given person or object is a risk subject for a given actuarial risk. (p. P3.4)

A **risk management system** is an arrangement involving risk identification, risk assessment, risk control, or risk financing. (p. P3.4)

A person or object involved in an event associated with an actuarial risk is called a **risk subject**. (p. P3.4)

A set of assumptions about future conditions is called a **scenario**. (f. P2.4)

A **scientific model** is an abstract and simplified representation of a given phenomenon. (p. P1.2)

Selection is the process by which a financial security system determines whether to accept a specific risk subject and the set of probabilities to which the risk will be assigned. (f. P4.2)

A phenomenon to which Principle 1.1 applies is said to display **statistical regularity**. (f. P1.1)

A **stochastic model** is a mathematical model in which the representation is expressed in terms of probabilities. (p. P1.2)

Failure occurs when a risk management system first fails to satisfy one or more of a set of required conditions fundamental to the system's purpose. The required conditions are called the **success criteria**. (p. P3.5)

An *economic transaction* **(transaction)** is an exchange of economic goods or money by two or more persons. (p. P2.5)

A mathematical model is said to be **valid within a specified degree of accuracy** relative to certain observed results if it can reproduce these results within that degree of accuracy. (f. P1.3)

A financial security system is *mandatory* if all persons in a group or in society are required to participate; otherwise, it is **voluntary**. (p. P4.1)

INDEX
OTHER SIGNFICANT TERMS

1 uncertainty (page 8, f. P1.3)

2 uncorrelated (page 5, p. P1.1)

3 validation (page 8, f. P1.3)