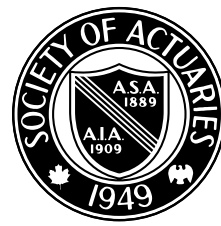


# GENERAL PRINCIPLES OF ACTUARIAL SCIENCE

DISCUSSION DRAFT  
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**Casualty Actuarial Society**  
1100 N. Glebe Rd., Suite 600  
Arlington, VA 22201-0425  
Phone: 703-276-3100  
Fax: 703-276-3108



**Society of Actuaries**  
475 N. Martingale Rd., Suite 800  
Schaumburg, IL 60173-2226  
Phone: 847-706-3500  
Fax: 847-706-3599

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COMMITTEE ON PRINCIPLES**

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# GENERAL PRINCIPLES OF ACTUARIAL SCIENCE

## INTRODUCTION

Actuarial science is an applied science based on concepts and observations distilled from the experience of practitioners and from other sciences. The principles of actuarial science are extracted from this experience. Because actuarial science is an applied science, many of the principles are drawn from related fields such as mathematics, statistics, economics, and finance. The *General Principles of Actuarial Science* represents the current articulation of the scientific framework that underlies the actuary's work.

## NATURE OF ACTUARIAL PRACTICE

The primary focus of actuarial work is on the financial and economic consequences of events involving risk and uncertainty. Actuarial practice involves the management of these implications and their associated uncertainties. To gain insights about future possibilities, the actuary depends on observation and the wisdom gained through prior experience. The actuary uses these observations and this experience when constructing, validating, and applying models.

Actuarial models are constructed to aid in the assessment of the financial and economic consequences associated with phenomena that are subject to uncertainty with respect to occurrence, timing, or severity. This 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
- Estimating the uncertainty inherent in the modeling process itself.

## 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. The objective of this document is to articulate the current understanding of the general principles that form the scientific framework underlying all areas of actuarial practice. Some of the principles also apply in other fields. The intended audience includes practicing actuaries,

1 researchers, and others, such as representatives of standard-setting organizations.  
2 This articulation is not immutable. If fundamental changes occur in our  
3 understanding of the world, or if a better expression of the ideas is developed, the  
4 statements of principles will be revised.

5 In addition to principles, actuarial practice requires standards. Standards are  
6 normative rules, based on the state of the art and science of actuarial practice,  
7 regulatory constraints, and other external conditions. They guide the actuary in the  
8 selection of appropriate models and assumptions. Standards are subject to change,  
9 and new standards may be introduced as actuarial practice expands into new areas.  
10 Further discussion of standards is outside the scope of this document.

## 11 REASONS FOR ARTICULATION OF GENERAL PRINCIPLES

12 The reasons for articulating these principles include the following:

- 13 ● Describing and strengthening the intellectual foundation of the actuarial  
14 profession
- 15 ● Aiding in strategic planning for the profession by identifying the areas in  
16 which actuaries can practice
- 17 ● Providing a foundation for the extension of actuarial models to new  
18 applications
- 19 ● Providing a basis for formulating sound and consistent standards of practice
- 20 ● Guiding the articulation of practice-specific principles
- 21 ● Furthering actuarial education
- 22 ● Focusing research efforts.

## 23 ORGANIZATION OF THIS DOCUMENT

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

29 Combining these principles with observations about human behavior, actuaries  
30 formulate models to assess the financial implications of future events. In most  
31 cases, these models are applied to some aspect of risk management—identification,  
32 assessment, control, or financing, with a major area of risk financing being the  
33 transfer of risk through a financial security system.

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

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

1           **1.     STATISTICAL FRAMEWORK**

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

6           The first three principles state that it is possible to do actuarial work—that, indeed,  
7           the probabilities of many events are estimable. The word “prediction” is avoided  
8           because of the uncertainty inherent in future events. However, estimates of most  
9           likely outcomes and of ranges of possibility can be applied to processes that are  
10          reasonably well behaved.

11          DEFINITIONS

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

16                 *Probability* is a measure that takes on values from zero to one and gives the  
17                 likelihood of occurrence of an event.

18                 A rule that assigns a numerical value to every possible outcome is called a  
19                 *random variable*. The probability-weighted average of the numerical values  
20                 taken on by a random variable, if the average exists, is called the *expected*  
21                 *value* of the random variable. *Correlation* is a measure of the extent to  
22                 which a change in one random variable occurs simultaneously with a change  
23                 in another random variable, that is, of how two variables “move together.”  
24                 *Positive correlation* indicates a tendency to move in the same direction.  
25                 *Negative correlation* indicates a tendency to move in opposite directions.  
26                 *Uncorrelated* variables tend to move independently of each other.

27                 Principle 1.1 is a statement of the law of large numbers. It may appear at first that  
28                 this law does not apply to a field such as insurance, because the “experiment” whose  
29                 outcomes are the occurrence or nonoccurrence of the insured-for claim can rarely be  
30                 precisely repeated. For example, the survival to a specified age or death of a specific  
31                 individual or the theft of a particular automobile can be observed but once. But if  
32                 the experiment is defined as observing whether in the next year a randomly selected  
33                 40-year-old nonsmoking male dies or a randomly selected car of a given make is  
34                 stolen, this experiment can be repeated. Actuaries believe it is likely that the  
35                 proportion of deaths or thefts will converge to a limit as the number of observations  
36                 37

1 increases.

2 **1.1 PRINCIPLE (Law of Large Numbers). Phenomena exist such that, if it**  
3 **were possible to conduct a sequence of independent experiments under**  
4 **the same specified conditions, the proportion of occurrences of a given**  
5 **event would converge as the number of experiments becomes large.**

6 DEFINITION

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

9 If a phenomenon displays statistical regularity, an estimate of the probability of the  
10 occurrence of an event associated with the phenomenon is the proportion of  
11 occurrences of the event in a long sequence of identical experiments. Alternatively,  
12 the probability of an event can be estimated subjectively by using other criteria. The  
13 definition of an event can include a specification of severity and timing; for example,  
14 the event could be the incurring of a \$100,000 loss.

15 For certain collections of phenomena, it is of interest to compare the respective  
16 expected values of a given random variable. For example, the numbers of sixes for a  
17 die thrown 1000, 2000, and 3000 times are three separate phenomena. However,  
18 although the phenomena are separate, the expected number of sixes for the 1000-  
19 throw phenomenon, the 2000-throw phenomenon, and the 3000-throw phenomenon,  
20 would be expected to be in proportions of 1:2:3. For these phenomena, the number  
21 of throws acts as a scaling factor that relates the expected values. When such a  
22 factor exists, the proportion of occurrences of a specific event observed in  
23 experiments on various phenomena can be normalized for comparison through use  
24 of the factor. In this way, a wider array of data can be used to develop a specific  
25 estimate.

26 DEFINITIONS

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

29 A *scientific model* is an abstract and simplified representation of a given  
30 phenomenon. A *mathematical model* is a scientific model in which the  
31 representation is expressed in mathematical terms. A *stochastic model* is a  
32 mathematical model in which the representation is expressed in terms of  
33 probabilities.

1 The law of large numbers applies to probabilities of specified events. When an  
2 experiment has several possible outcomes, a probability distribution is required.

3 **1.2 PRINCIPLE (Stochastic Modeling). A phenomenon that displays**  
4 **statistical regularity can be described by a stochastic model.**

5 A stochastic model does not predict the outcome of a single experiment prior to its  
6 being carried out. However, it can be used to derive an estimate of the expected  
7 value (and other characteristics) of a random variable, provided the sequence of  
8 estimated values arising from the sequence of experiments converges.

9  
10 Stochastic models can be based on previous experiments or can utilize prior  
11 assumptions about the probabilities of various events, which can be periodically  
12 revised as the results of new experiments are obtained. A dynamic model is a  
13 stochastic model that incorporates a systematic process for revising the model in  
14 response to observed results.

15 The stochastic aspect of a model may not be necessary for a given application; in  
16 such a situation a simpler version of a stochastic model might be used.

17 **DEFINITION**

18 *A deterministic model* is a simplification of a stochastic model in which the  
19 proportion of occurrences of a given event estimated by the stochastic model  
20 is assumed to occur with probability one.

21 A deterministic model can be derived from a stochastic model by replacing random  
22 variables with fixed values. A deterministic model can be used to examine the  
23 implications of a specific set of assumptions.

24 Principles 1.1 and 1.2 state that there exist phenomena that can be modeled.  
25 Principle 1.3 states that it is possible to construct such a model. Prior observations  
26 can be used to determine the nature of the model and also the particulars (often  
27 parameters) of the model. Data from related experiments can also be incorporated.  
28 For example, experience of drivers in a given city is relevant to the construction of a  
29 model of automobile losses in that city. It may be possible to make the model more  
30 accurate by incorporating data from similar cities. Judgment can be applied when  
31 similar data are modified or adjusted to account for known changes that will affect  
32 future results.

1       **1.3 PRINCIPLE (Construction of Models). A stochastic model of a specific**  
2       **phenomenon can be based on the outcomes of experiments performed**  
3       **on that phenomenon, on observations of related phenomena, or on a**  
4       **combination of both.**

5       In some cases, a model may be developed using only the outcomes of experiments  
6       associated with the specific phenomenon of interest. In other cases, outcomes of  
7       experiments involving related phenomena with characteristics similar to the specific  
8       phenomenon of interest or a priori judgments may be incorporated. The  
9       incorporation process may involve a simple weighting of the various outcomes, a  
10      weighting of the relevant stochastic models, or some other combination process.

11      One approach to constructing a model from data obtained from several sources  
12      involves attaching to each set of data a weight that represents an assessment of its  
13      usefulness for making a particular statistical estimate. This assessment can involve  
14      statistical calculation or be based entirely on judgment and can vary according to the  
15      purpose for which the model is to be used.

16      **1.4 PRINCIPLE (Credibility). It is possible to estimate the relative weights**  
17      **that must be assigned to each of two or more sets of data so that a given**  
18      **statistical measure of the accuracy of an estimate based on the**  
19      **combined data is optimized.**

20      DEFINITION

21              *Credibility* is the set of relative weights assigned to sets of data for a given  
22              application and model.

23      The uncertainty associated with a stochastic model has two distinct sources:

- 24      •       The inherent variability of the phenomenon  
25      •       Incomplete knowledge or inaccurate representation of the probabilities of  
26              alternative sets of outcomes.

27      Sometimes these sources of uncertainty are referred to as “process risk” and  
28      “parameter risk,” respectively. The terms “risk” and “uncertainty” have also been  
29      used; however, in this paper, risk and uncertainty have been assigned other  
30      meanings. The process of checking the results produced by a model for consistency  
31      with available observed information is commonly referred to as “validation.”

1           DEFINITIONS

2                   A mathematical model is said to be *valid within a specified degree of*  
3                   *accuracy* relative to certain observed results if it can reproduce these results  
4                   within that degree of accuracy. A mathematical model is *potentially valid* if  
5                   it produces results that are consistent with available observations of the  
6                   modeled phenomena or of similar phenomena and is capable of being  
7                   validated relative to the specified observed results when sufficient data are  
8                   available.

9           Observed results involving the phenomena represented by a model might not be  
10           available or sufficiently voluminous to allow the model to be validated within a  
11           specified degree of accuracy. In this case, the usefulness of the model can be  
12           established initially by comparing its results with those from the observation of some  
13           similar phenomenon. Such “judgmentally validated” models could be validated if  
14           sufficient data were available.

15           Not all observable aspects of the modeled phenomena must be reproduced in order  
16           for a model to be valid. For example, a model used in the appraisal of an insurance  
17           company may be validated only with respect to a few quantities, such as aggregate  
18           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.

Principle 2.1 is a more precise statement of “time is money.” This principle indicates that actuarial models usually reflect the time at which payments are made.

**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.**

Principle 2.2 indicates that the value assigned to economic goods, as well as the time value of money, is not the same for all people at all times.

**2.2 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.**

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

It is reasonable to assume that individuals will act in their own interest. In an insurance setting there may be choices—for example, buying or not buying a particular insurance policy. Although Principle 2.3 may seem obvious, it is necessary for actuarial purposes because the value of an insurance policy (even if personal preference is ignored) can differ from one person to another.

1           DEFINITIONS

2                    A *cash flow* is the receipt or disbursement at a specific time of an amount of  
3                    money or of an economic good. A cash flow whose occurrence or amount  
4                    depends on the occurrence of an event that is not certain to occur is said to  
5                    be *contingent*. An *asset* is money or economic goods held, or a right to  
6                    receive future cash flows; an *obligation* is a duty to provide current or future  
7                    cash flows.

8           **2.3   PRINCIPLE (Present Value Modeling). A mathematical model exists**  
9           **that can estimate the current monetary value a person would assign to**  
10           **any future cash flow.**

11           DEFINITIONS

12                   A model described by Principle 2.3 is called a *present value model*. The  
13                   estimate of the current monetary value of a future cash flow given by a  
14                   present value model under a particular set of assumptions about future  
15                   economic or other conditions is called the *present value of the cash flow*  
16                   relative to those assumptions. A set of assumptions about future conditions  
17                   is called a *scenario*.

18           If the mathematical model is a stochastic model, then the model produces a  
19           probability distribution of the present values of the cash flow. Alternative scenarios  
20           could be the source of the possible present values, and the respective likelihoods of  
21           the scenarios could provide the probabilities. Nevertheless, if a stochastic model is  
22           used, the present value is a random variable and the current monetary value is an  
23           expected value.

24           Economists use their insights into human behavior to describe interactions between  
25           persons.  
26

27           DEFINITION

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

30           Economic goods, as defined here, include services, and persons include both  
31           individuals and firms, so the hiring of an individual by a firm is a transaction. It is  
32           reasonable to assume that individuals involved in a transaction will tend to make  
33           choices that each perceives to be in his or her best interest. In an insurance setting,  
34           for example, an insurer must choose among various possible combinations of price

1 and benefits in designing a policy for sale, and the potential purchaser must decide  
2 whether to buy that policy. Often, the choices of parties to a transaction are not  
3 independent of one another.

4 **2.4 PRINCIPLE (Economic Self-Interest). The parties to an economic**  
5 **transaction will tend to act in the manner that each perceives to be most**  
6 **economically advantageous, taking into account the information each**  
7 **has about the environment and about each other.**

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

12 **DEFINITIONS**

13 *An economic game (game)* is a model of a transaction that attempts to  
14 determine the strategies that the parties to the transaction will adopt, given  
15 the information each has at every step in the process, in order to achieve the  
16 result that each considers most economically advantageous. A *contract* is a  
17 step in a transaction at which the parties make a mutual commitment to carry  
18 out certain future actions.

19 The role of information is central to the game-theoretic analysis of transactions. If  
20 all parties to the transaction do not have the same information, the strategies and the  
21 outcomes of the game may be significantly affected. In transactions involving  
22 several steps (for example, the purchase of a life insurance policy and the later  
23 decision of the purchaser to begin smoking), it is important to determine at what  
24 point the information available to the parties becomes “asymmetric.”

25 If the parties to a transaction involving a contract have the same information before  
26 but different information after the contract is established, the transaction is an  
27 example of moral hazard. If the parties have different information before the  
28 contract is established, the transaction is an example of adverse selection.

29 A specific example of moral hazard is the sale of a nonsmoker life insurance policy to  
30 a current nonsmoker. If, subsequent to the sale, the insured begins to smoke, this  
31 fact will be known to the insured but not the insurer. The sale of a policy to  
32 someone who already knows he or she has a life-threatening disease would, on the  
33 other hand, be a transaction exhibiting adverse selection.

1           **3.     FINANCIAL PRINCIPLES**

2           Classical economic theory describes the interactions of buyers and sellers of goods  
3           and services, including capital and labor. These interactions, taken together, are said  
4           to form a “market.” This market concept has been applied to the valuation of  
5           financial instruments such as stocks, bonds, and related securities. Actuaries have  
6           adopted several definitions and principles from the field of financial economics.

7           DEFINITIONS

8                     The amount of money paid by a buyer to purchase an economic good from a  
9                     seller is called the *price* of the good. An *efficient market* is a market in  
10                    which the prices paid fully reflect all information available to the buyers and  
11                    sellers.

12           Conditions that make it more likely that a market will be efficient can be specified.  
13           These include, for example, the number of buyers and sellers being large, all  
14           interested parties having sufficient information to establish their current monetary  
15           value for the good, and buyers and sellers being able to enter or avoid the transaction  
16           at their own discretion without undue external constraint.

17           **3.1     PRINCIPLE (Existence of Market Value). In an efficient market, the**  
18           **price at which willing buyers and sellers are likely to conclude a**  
19           **transaction can be estimated.**

20           DEFINITIONS

21                     A *financial instrument* is a right to receive, or an obligation to provide, a set  
22                     of cash flows under specified conditions. An *investment portfolio (portfolio)*  
23                     is a set of financial instruments selected from a specified *investment universe*  
24                     of such instruments. A *market trade* is a transaction involving the sale,  
25                     purchase, or exchange of financial instruments in an efficient market. *Market*  
26                     *value* is an estimate of the price at which a market trade for a portfolio would  
27                     occur.

28  
29           Note that the definition of market value is prospective. If there has been a recent  
30           transaction, the market value will often be close to the price at which that transaction  
31           was made. However, this is not always the case. For example, when new  
32           information becomes available to an efficient market, prices adjust instantaneously  
33           and may be far removed from the prices realized in recent market trades.

1 Investors (buyers and sellers of financial instruments) are often numerous, well  
2 informed, and able to act on available information. In such cases, the market for  
3 transactions involving financial instruments is likely to be efficient. In such a market,  
4 market values have been observed to be additive.

5 **3.2 PRINCIPLE (Additivity of Market Values). The market value of an**  
6 **investment portfolio is equal to the sum of the market values of the**  
7 **financial instruments in the portfolio.**

8 By definition, a market value is an estimate of the price at which a market trade  
9 would occur. In many cases, this estimate is made using a valid mathematical model.  
10 Mathematical models are particularly useful when market values need to be  
11 determined for a set of financial instruments for which there is not an efficient  
12 market—for example, private placements, new forms of financial instruments, and  
13 financial instruments with thin or nonexistent markets. Such models are particularly  
14 useful when the quantity estimated may be assumed to be continuous.

15 **3.3 PRINCIPLE (Continuity of Market Values). The market value of a**  
16 **financial instrument with cash flows that are anticipated to be similar**  
17 **to those of a portfolio whose market value is known is close to the**  
18 **market value of that portfolio.**

19  
20 Principles 3.2 and 3.3 together lead to a law of one price for financial instruments: If  
21 two sets of financial instruments are anticipated to have the same (or similar) cash  
22 flows, they have the same (or similar) market values. This means a financial  
23 instrument can be valued through the use of a “replicating portfolio.” Moreover, this  
24 means the model can be used to obtain the market value of financial instruments for  
25 which no efficient market exists.

26 DEFINITION

27 The *fair value* of a financial instrument is the financial instrument’s market  
28 value obtained through the use of a valid mathematical model.

29 Investors are generally concerned primarily with the performance of their portfolios,  
30 rather than with the performance of individual financial instruments. Two aspects of  
31 portfolio performance are measured by the rate of return and the degree of volatility.

32 DEFINITIONS

33 The *return* on a portfolio for a given time period during which the only cash  
34 flows into or out of the portfolio are cash flows generated by the instruments

1 in the portfolio or resulting from market trades is the excess of the market  
2 value of the portfolio at the end of the period over the market value of the  
3 portfolio at the beginning of the period. The *rate of return* on a portfolio for  
4 such a period is the return expressed as a percentage of the market value at  
5 the beginning of the period. The *degree of volatility* of the portfolio is a  
6 measure of the variability of the rate of return of the portfolio over a series of  
7 such periods.

8 In a stable (that is, with respect to legal, regulatory, economic, and similar forces)  
9 environment, many financial markets, particularly those involving a large number of  
10 buyers and sellers, are relatively efficient. In such markets, it is difficult to achieve  
11 “arbitrage profits” merely by trading financial instruments.

12 **3.4 PRINCIPLE (Absence of Arbitrage). In an efficient market, it is**  
13 **impossible to construct a portfolio that requires no initial investment,**  
14 **and that results in an immediate positive cash flow and only non-**  
15 **negative future returns under all possible circumstances.**

1           **4.     ACTUARIAL MODELING PRINCIPLES**

2           The concept of actuarial risk defines the subject matter of actuarial science.

3           DEFINITIONS

4                     An *actuarial risk* is a phenomenon that has economic consequences and is  
5                     subject to uncertainty with respect to one or more of the *actuarial risk*  
6                     *variables*: occurrence, timing, and severity.

7           Principle 4.1 provides assurance that actuarial risks can be analyzed and that  
8           estimates of future behavior can be obtained.

9           **4.1     PRINCIPLE (Modeling of Actuarial Risks). Actuarial risks can be**  
10           **stochastically modeled based on assumptions about the probabilities**  
11           **that will apply to the actuarial risk variables in the future, including**  
12           **assumptions about the future environment.**

13           DEFINITIONS

14                     A model described by Principle 4.1, together with a present value model, if  
15                     applicable, is called an *actuarial model*. *Actuarial assumptions* are those  
16                     upon which an actuarial model is based.

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

23           In general, an actuarial model utilizes a present value model if it is intended to  
24           determine economic values. A present value model included in an actuarial model is  
25           often based on assumptions concerning aspects of the future environment, such as  
26           interest rates and inflation rates. The present value model can reflect the judgment  
27           of the actuary constructing the model or that of the actuary's client. Although all  
28           actuarial risk is subject to timing considerations, a present value model directly  
29           addresses timing risk and is used if the time dimension is significant.

30           Most actuarial models are representations of collections of related actuarial risks.  
31           For example, the actuarial risk of claims under \$100,000-life-insurance policies  
32           issued to selected 45-year-old males and the actuarial risk of claims under

1 \$200,000-policies for similarly selected insureds can usually be represented by the  
2 same actuarial model. The economic consequences in effect act as a scaling factor  
3 that relates these separate phenomena and allows the same model to apply to both.  
4 In other words, the economic consequences suggest exposure measures. This  
5 observation applies to most actuarial models, although the economic consequences  
6 and exposure measures may not be in exact proportion.

7 **4.2 PRINCIPLE (Exposure). For most actuarial models, there exist one or**  
8 **more exposure measures that are approximately proportional to the**  
9 **economic consequences of one or more collections of the actuarial risks**  
10 **being modeled.**

11 The degree of accuracy of a mathematical model is based on a comparison of values  
12 calculated using the model with known values. As time passes and more known  
13 values are available for comparison, the degree of accuracy of the model may  
14 change. In the case of a model that was initially validated only judgmentally, it may  
15 become possible to determine the degree of accuracy.

16 Actuarial modeling involves a feedback mechanism. As additional data emerge or  
17 the environment changes, the model may need to be changed. Principle 4.3 provides  
18 insight into when such updates may be necessary.

19 **4.3 PRINCIPLE (Continued Validity of Actuarial Models). The change**  
20 **over time in the degree of accuracy of an initially valid actuarial model**  
21 **depends upon changes in the:**

- 22 a. Nature of the right to receive or the duty to make a payment
- 23 b. Various environments (for example, regulatory, judicial, social,  
24 financial, economic) within which the modeled events occur
- 25 c. Sufficiency and quality of the data available to validate the  
26 model
- 27 d. Actuary's understanding of the environments.

1           **5.     PRINCIPLES UNDERLYING RISK MANAGEMENT AND**  
2           **FINANCIAL SECURITY SYSTEMS**

3           In previous sections, the actuarial problem was broadly defined. Much, but not all,  
4           of actuarial science is devoted to managing actuarial risks, which, in turn, involves  
5           the identification of the risk and its quantification. One particular way to manage an  
6           actuarial risk is through the exchange of fixed amounts of money in return for the  
7           transfer of the actuarial risk. The development and management of systems that  
8           facilitate this exchange are of special interest to actuaries.

9           DEFINITIONS

10           A person or object involved in an event associated with an actuarial risk is  
11           called a *risk subject*. *Risk identification* is a process for determining whether  
12           a given person or object is a risk subject for a given actuarial risk. *Risk*  
13           *assessment* is quantification of the actuarial risk. *Risk control* is a process  
14           that reduces the impact of one or more of the actuarial risk variables  
15           associated with the actuarial risk. *Risk financing* is a mechanism that  
16           provides cash flows that are contingent upon the occurrence of an event  
17           associated with the actuarial risk and that tend to offset undesirable economic  
18           consequences.

19           A *risk management system* is an arrangement involving risk identification,  
20           risk assessment, risk control, or risk financing. *Obligations of a risk*  
21           *management system* are payments promised by a risk management system in  
22           connection with risk financing.

23           The *actuarial value of a future cash flow* that is contingent upon actuarial  
24           risk variables is the present value developed by an actuarial model associated  
25           with the actuarial risk variables. The *degree of uncertainty* of the actuarial  
26           value of a future cash flow is a measure of its variation due to uncertainties  
27           such as process and parameter risk.

28           Recall that the present value, and hence the actuarial value, of a future cash flow is  
29           generally a random variable. The actuarial value of any asset or obligation is  
30           determined by the actuarial value of the associated cash flows, including money  
31           currently held. In general, the component cash flows not only have uncertain values  
32           but also are not independent of one another. A risk management system that is  
33           primarily concerned with contingent cash flows is said to be managing “financial  
34           risk.”

35           Strategies for controlling or financing financial risk often involve development of a

1 risk management system that results in a combination of cash flows, the degree of  
2 uncertainty of which is less than the degrees of uncertainty of some of the  
3 component cash flows.

4 One of the guiding principles of risk management is that combining cash flows can  
5 reduce uncertainty. This can be done in a variety of ways, such as pooling  
6 (increasing the exposure to reduce process variance) and hedging (combining cash  
7 flows that tend to offset each other). While it is possible to do this in an insurance  
8 context, that context is not necessary.

9 Note that Principle 5.1 does not indicate that uncertainty must be reduced when cash  
10 flows are combined.

11 **5.1 PRINCIPLE (Combinations of Cash Flows). The degree of uncertainty**  
12 **of the actuarial value of a combination of cash flows reflects both the**  
13 **uncertainties affecting each underlying actuarial risk variable and the**  
14 **degree of correlation of the variables.**

15 DEFINITIONS

16 *Pooling* is the aggregation of sets of future cash flows contingent upon the  
17 same or similar actuarial risk variables. *Diversification* is the aggregation of  
18 sets of future cash flows contingent upon actuarial risk variables that are not  
19 perfectly positively correlated. *Hedging* is the aggregation of sets of future  
20 cash flows that are negatively correlated.

21 Pooling, diversification, and hedging are common risk management strategies.  
22 Aggregation of sets of cash flows generally can result in a decrease in the degree of  
23 uncertainty when the cash flows are not perfectly positively correlated. When  
24 pooling is employed to control risk, as in insurance systems, care is usually taken to  
25 ensure that the pooled risks are also relatively diversified. Because cash flows arise  
26 from both assets and obligations, aggregation strategies can involve sets of assets,  
27 sets of obligations, or mixed sets of assets and obligations.

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

30 DEFINITIONS

31 The *actuarial value of a risk management system* relative to a given actuarial  
32 model is the actuarial value, developed by that model, of the combination of  
33 cash flows associated with the system. If the actuarial value can be

1           expressed as a function of any variable associated with the risk management  
2           system and independent of the actuarial model, that variable is called a  
3           *financial parameter* of the risk management system. The amount by which  
4           the value of a financial parameter can be changed without reducing the  
5           actuarial value of the risk management system below zero is called the  
6           *margin* with respect to that parameter.

7           Actuaries are often called upon to place a value on future contingent cash flows  
8           related to the operations of a risk management system. Because the actuarial value  
9           is, in general, a random variable, the actuary often states the conditions under which  
10          the actuarial value can be expected to fall within a given range. Actuaries working in  
11          certain defined contexts have sometimes developed approaches that are deemed to  
12          produce appropriate values. For example, casualty actuaries often estimate an  
13          appropriate or “sound” actuarial value for claim obligations by calculating the  
14          aggregate amount of claims expected over a given period using a valid actuarial  
15          model, but without regard to times of receipt of the claims.

16          When setting financial parameters, actuaries consider other information in addition to  
17          the actuarial value. For example, the risk management system may have to meet  
18          criteria set by regulators, rating agencies, or creditors to be allowed to continue  
19          operations, to maintain a rating, or to borrow money.

20          Principles 5.2 and 5.3 address evaluation of the potential success of the risk  
21          management system. In general, “success” is the avoidance of “failure,” the first  
22          occurrence of a pre-specified adverse condition. One specific type of failure is the  
23          inability to meet all obligations. These two principles indicate that the probability of  
24          success can be controlled by changing the financial parameters.

## 25          DEFINITIONS

26                 *Failure* occurs when a risk management system first fails to satisfy one or  
27                 more of a set of required conditions. The required conditions are called the  
28                 *failure criteria*. The probability that failure will occur within a specified  
29                 period of time, as calculated by using an actuarial model, is called the *failure*  
30                 *probability* of the risk management system relative to that model within that  
31                 period of time.

32          **5.2    PRINCIPLE (Avoidance of Failure). For most failure criteria, there are**  
33          **combinations of values of the financial parameters that will reduce, to**  
34          **below a given specified positive level, the failure probability relative to**  
35          **an actuarial model.**

1 Actuaries are often asked to opine about the soundness of risk management systems.

2 DEFINITION

3 The probability that a risk management system will be able to pay all  
4 obligations as promised is called the *degree of actuarial soundness* of the  
5 risk management system.

6 The degree of actuarial soundness is the complement of the failure probability, where  
7 the failure criterion is the inability to pay obligations as promised.

8 **5.3 PRINCIPLE (Actuarial Soundness). For most risk management**  
9 **systems, there are combinations of margins that will produce, relative to**  
10 **a valid actuarial model, a degree of actuarial soundness that exceeds a**  
11 **given level.**

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

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

20 DEFINITIONS

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

25 When a risk management system is established, it implies that various steps have  
26 been taken to manage the risk. In developing and validating a model, it is important  
27 to recognize that the existence of the risk management system may, by itself, change  
28 the experience rates and, as a result, the model. Principle 5.4 indicates that  
29 experience rates are critical in validating models.

1       **5.4 PRINCIPLE (Induced Experience). The economic costs and consequent**  
2       **experience rates for events associated with a risk management system**  
3       **tend to differ from those for the same events occurring in the absence of**  
4       **any such system.**

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

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

14      Risk management systems may involve a contractual relationship that provides for  
15      the payment of premiums (considerations) in return for benefits related to the  
16      actuarial risk. Such an arrangement is called a financial security system. When  
17      premiums are introduced, additional principles apply. They relate to characteristics  
18      of the risk subject as well as the risk subject's behavior under such a system.

19      DEFINITIONS

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

27      “Person” indicates either a human being or a corporate or other entity. The term  
28      “financial security system” applies to systems such as insurance, annuity, retirement,  
29      and health care financing systems.

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

33      In operating a risk management system, it is often necessary to find a systematic way  
34      to assign to each risk subject the probabilities of occurrence, timing, and severity

1 associated with an actuarial risk. In the case of financial security systems, in  
2 particular, it is necessary to determine considerations, which are usually based on  
3 these probabilities, for each risk subject. One way to do this is to group “similar”  
4 risk subjects into “risk classes” and to assign the probabilities to these classes. More  
5 generally, “characteristics” of the risk subjects may be identified that allow the  
6 probabilities to be assigned in a systematic way.

#### 7 DEFINITION

8  
9 *A characteristic* is a quality that can be identified for each risk subject in a  
10 specified group and to which a numeric value can be assigned.

11 Characteristics used in risk classification are usually relevant to the protection  
12 provided, but may not exhibit an identifiable cause and effect relationship. One  
13 characteristic that is always relevant is the potential financial obligation undertaken  
14 by the financial security system with respect to each risk subject. For voluntary  
15 financial security systems, this obligation is usually described in a contract. For  
16 social insurance systems, the obligation may be specified in a law or regulation.

#### 17 DEFINITIONS

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

23 **5.5 PRINCIPLE (Risk Classification).** For a group of risk subjects  
24 associated with a given actuarial risk, it is possible to identify a set of  
25 characteristics and a relationship between the sets of values assigned to  
26 the characteristics corresponding to each risk subject and probabilities  
27 of occurrence, timing and severity so that:

- 28 a. Each risk subject is assigned to one and only one set of  
29 probabilities
- 30 b. All risk subjects that have the same values for each of the  
31 identified characteristics are assigned the same sets of  
32 probabilities
- 33 c. The probabilities result in an actuarial model for the actuarial  
34 risk that, for some degree of accuracy, is valid or potentially  
35 valid.

1           DEFINITION

2                   A set of characteristics and a relationship assigning probabilities to risk  
3                   subjects that together satisfy Principle 5.5 is called a *risk classification*  
4                   *system*.

5           A characteristic, such as systolic blood pressure, could be used as is (that is, the  
6           value is the measurement), could produce a value by grouping (for example, values  
7           of low, medium, and high defined by ranges), or could be a membership function  
8           such as “is high with membership value 0” if the reading is below 100 and “is high  
9           with membership value  $(x - 100)/x$ ” if the reading,  $x$ , is at or above 100. All three  
10           alternatives can be part of a risk classification system, but only the second one would  
11           allow for the construction of risk classes.

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

15           DEFINITIONS

16                   A *refinement of a risk classification system* is a risk classification system  
17                   formed from an existing risk classification system either by introducing a new  
18                   characteristic or by changing the assignment of values to an existing  
19                   characteristic in such a way that the new assignment generalizes the existing  
20                   one. The refinement is said to be *more homogeneous* than the existing  
21                   system if the probabilities of occurrence, timing, or severity for some risk  
22                   subjects are changed.

23           A generalization of the assignment of values could occur by creating additional  
24           groups by splitting the range into subintervals. For example, the value “high for  
25           systolic blood pressure” might be 140 and above. A generalization could create two  
26           values, high (140–175), and very high (175 or more). For functional value  
27           assignments, the generalization might be a change from a linear function to a  
28           quadratic function. To be a generalization, it must be possible that the relationship  
29           of the financial consequences to the values will not change. For example, it is  
30           possible that the probabilities of death are the same for the newly created high and  
31           very high blood pressure groups as they were for the original high group. If they  
32           differ, then the refinement is more homogeneous than the original system.

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

1           DEFINITIONS

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

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

11          DEFINITION

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

15          The use of experience adjustments may be appropriate in order to maintain or  
16          improve a given degree of actuarial soundness of the financial security system.  
17          Experience adjustments can reflect the experience of the current period or can  
18          involve a recalculation of the considerations or benefits based on the assumption that  
19          the future experience rates of the financial security system will be more like its past  
20          experience rates than the rates previously assumed.

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

25          DEFINITION

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

30          Experience rating is a technique for recognizing those individual or group risk  
31          attributes not adequately addressed by an existing rate structure. It is a method of  
32          introducing experience adjustments to the rate structure. The technique can  
33          simultaneously introduce an element of risk management incentive to the rate

1 structure. The degree of experience adjustment may be affected by the credibility  
2 assigned to the experience of the risk subject.

3 Principle 5.6 indicates that if one financial security system offers more rate classes  
4 than another and if this results in significant differences in considerations, the risk  
5 subjects required to pay higher considerations tend to participate in the financial  
6 security system with fewer risk classes.

7 **5.6 PRINCIPLE (Antiselection). If the rate structure of a voluntary**  
8 **financial security system is based on a risk classification system such**  
9 **that a refinement of the system could result in significant differences in**  
10 **considerations among risks originally assigned to the same class, there**  
11 **will be a tendency for relatively greater participation by those whose**  
12 **considerations would increase if the refinement were put in place.**

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

## 21 DEFINITIONS

22 *Information asymmetry* exists if one party to an economic transaction has  
23 more information than the other party or if one party is not allowed to use all  
24 the information available to the other party. *Selection* is the process by  
25 which a financial security system determines whether to accept a specific risk  
26 subject and the class to which the risk should be assigned.

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

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

1 Both parties to a voluntary financial security system have the option of participating  
2 or not. Through these choices, the set of individuals who participate may not be  
3 representative of the universe of individuals subject to the particular actuarial risk.  
4

5 **5.7 PRINCIPLE (Select Experience). The processes of antiselection and**  
6 **selection tend to create differences in the experience of a financial**  
7 **security system, compared with the experience for the same events**  
8 **among all those subject to a given actuarial risk.**

9 The observation described by Principle 5.7 appears on the surface to be similar to  
10 that described by Principle 5.4, yet the cause is different. Principle 5.7 observes that  
11 the selection and antiselection processes redistribute the overall experience, whereas  
12 Principle 5.4 observes that the existence of a risk management system may change  
13 the experience for the same events occurring in the absence of any such system.