LECTURE NOTES: EMGT 234

RISK ANALYSIS AND RISK MANAGEMENT:
A Historical Perspective - Pre 20-th Century

SOURCE:

Vincent T. Covello and Jeryl Mumpower
Risk Analysis, Vol. 5, No. 2, 1985, 103-120

INTRODUCTION

3200 B.C. : Asipu in the Tigris-Euphrates valley.
Consultants for risky, uncertain, or difficult decisions e.g.:

- risky venture
- proposed marriage
- suitable building site.

Primary tasks:

- Identify Alternatives
- Collect data on likely outcomes.

Best available data:

- Signs from the gods.

Report:

- A clay tablet prepared to the client.

Similarities between **Asipu** and practices and procedures of **modern day risk analysts** underscore that people have been dealing with problems of risk for a long time, often in a sophisticated and quantitative way.

This lecture\paper reviews history or risk analysis\risk management **prior** to 20-th century to:

- Shed light on the intellectual antecedents of current thinking about risk.
- To provide a basis for anticipating future directions in risk analysis and management.

FOUR SECTIONS

1. **Early antecedents of Risk Analysis, with an emphasis on the development of probability theory.**

Note:
Contemporary Risk Analysis relies heavily on probability theory. Risk Analysis, however, can be traced back to Mesopotamia, whereas probability theory can only be traced back to the 17-th century.

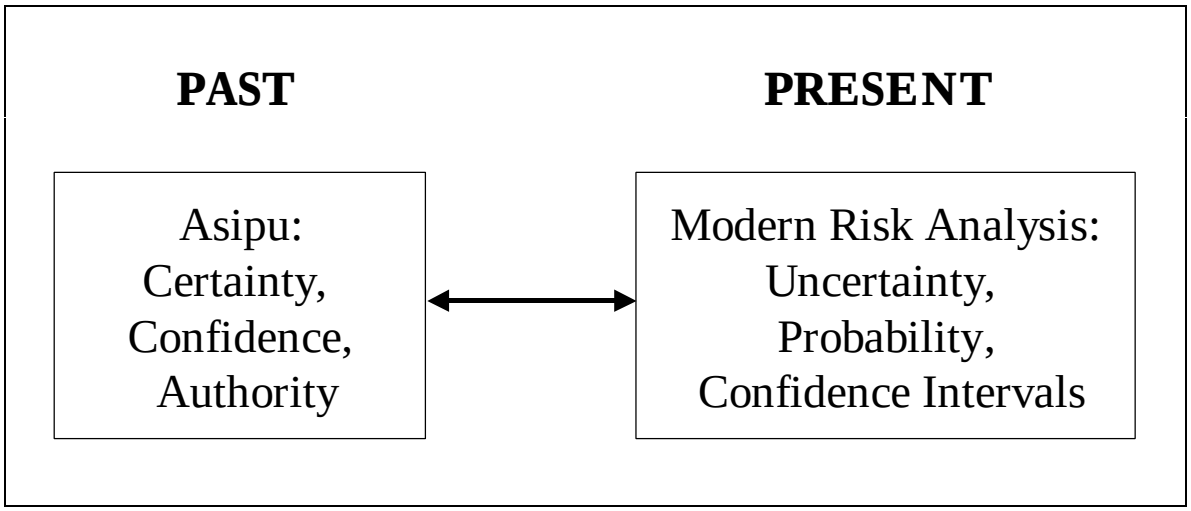
2. **The developments of scientific methods to establish causal links.**

Note:
Methods for establishing causal link are as important to modern risk analysis as probability theory.

3. **Early antecedents of contemporary risk management techniques.**

4. **Nine changes between the past end the present which may be considered important for current risk analysis and risk management techniques \developments.**

SECTION 1.
QUANTITATIVE RISK ANALYSIS AND PROBABILITY



Modern quantitative risk analysis can be traced to religious ideas concerning **the probability of an after life**.

400 B.C. : Plato's Phaedo and numerous treaties have been written discussing the risk to one's soul in the afterlife based on current behavior.

400 A.D. : Arnobius a Pagan wanted to convert to Christianity. Initially, a strong believer of the Pagan church his request to baptism was refused. To demonstrate his authenticity, he wrote an eight-volume monograph "Against the Pagans" including an argument relevant to probabilistic risk assessment today.

Arnobius' Risk Analysis Table:

	GOD exists	GOD does not exist
Accept Christianity	Risk Low	Risk Low
Remain a Pagan	Risk High	Risk Low

Based on dominance, best decision is to accept Christianity.

Above table is first recorded appearance of:

"Dominance Principle".

Lactinius (Arnobius Student), St. Jerome and St. Augustine introduced this argument in the mainstream of Christian Theology and intellectual thought.

- **Dominance and making decisions under uncertainty**

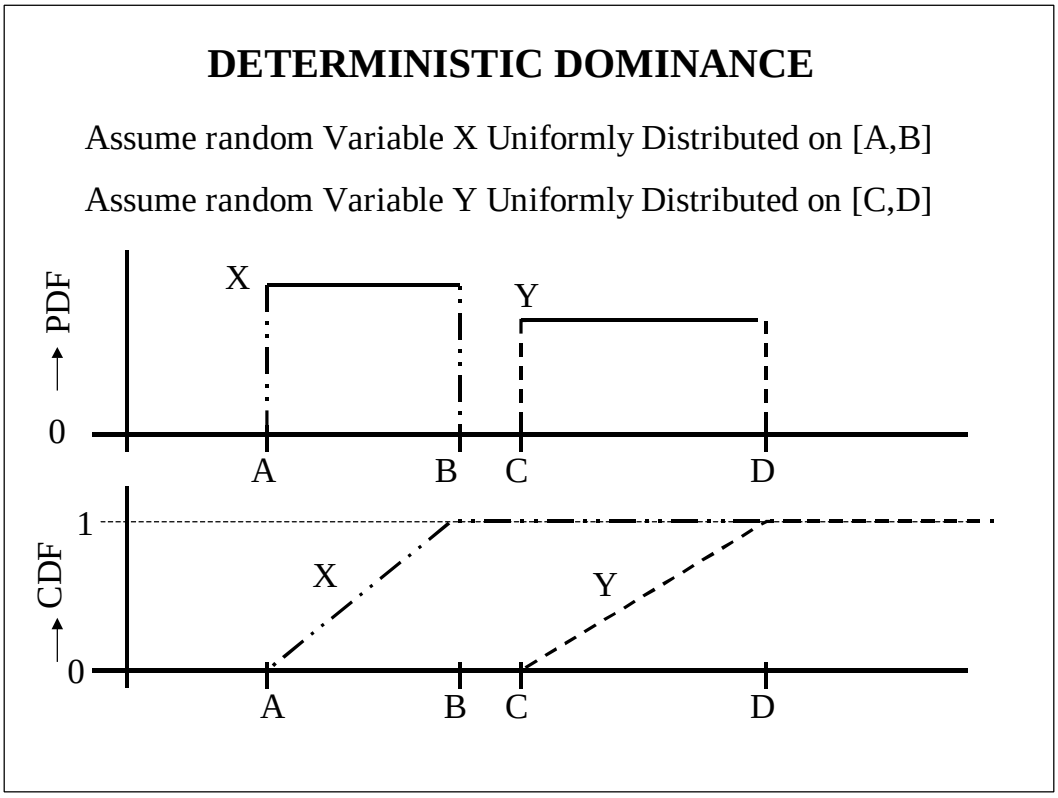
Suppose you have to choose between two lottery tickets and the only information you have is that the expected pay-off of the first lottery ticket is lower than the second. Which one would you choose?

You picked your ticket and the lotteries are played and you learn your outcome. Is your pay-off higher than the pay-off of the first lottery-ticket?

Conclusion: There is a chance of an **unlucky outcome.** In other words there is no dominance (=deterministic dominance.

SITUATION 1:

You are given more information about both lotteries. The pay-off X of lottery 1 falls in the range from [A,B]. The pay-off from lottery 2 falls in the range from [C,D].



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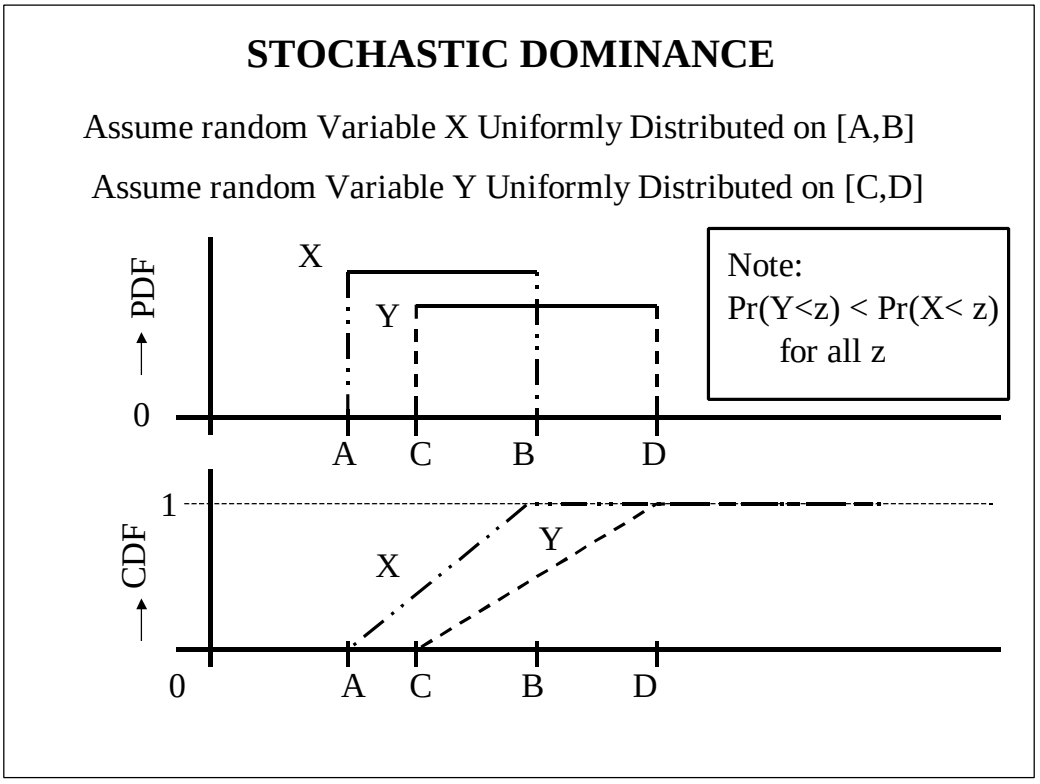
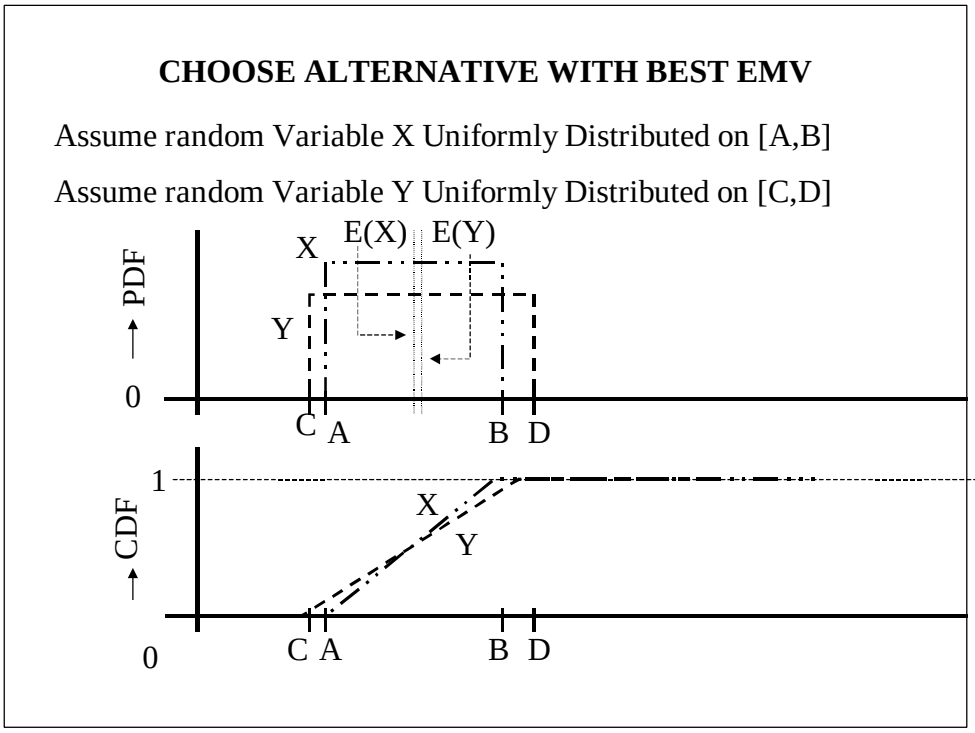


You picked your ticket and the lotteries are played and you learn your outcome. Is your pay-off higher than the pay-off of the first lottery-ticket?

Conclusion: There is a a chance of an **unlucky outcome.** In this case there is stochastic dominance, but no deterministic dominance.

SITUATION 3:

You are given more information about both lotteries. The pay-off X of lottery 1 falls in the range from [A,B]. The pay-off from lottery 2 falls in the range from [C,D].



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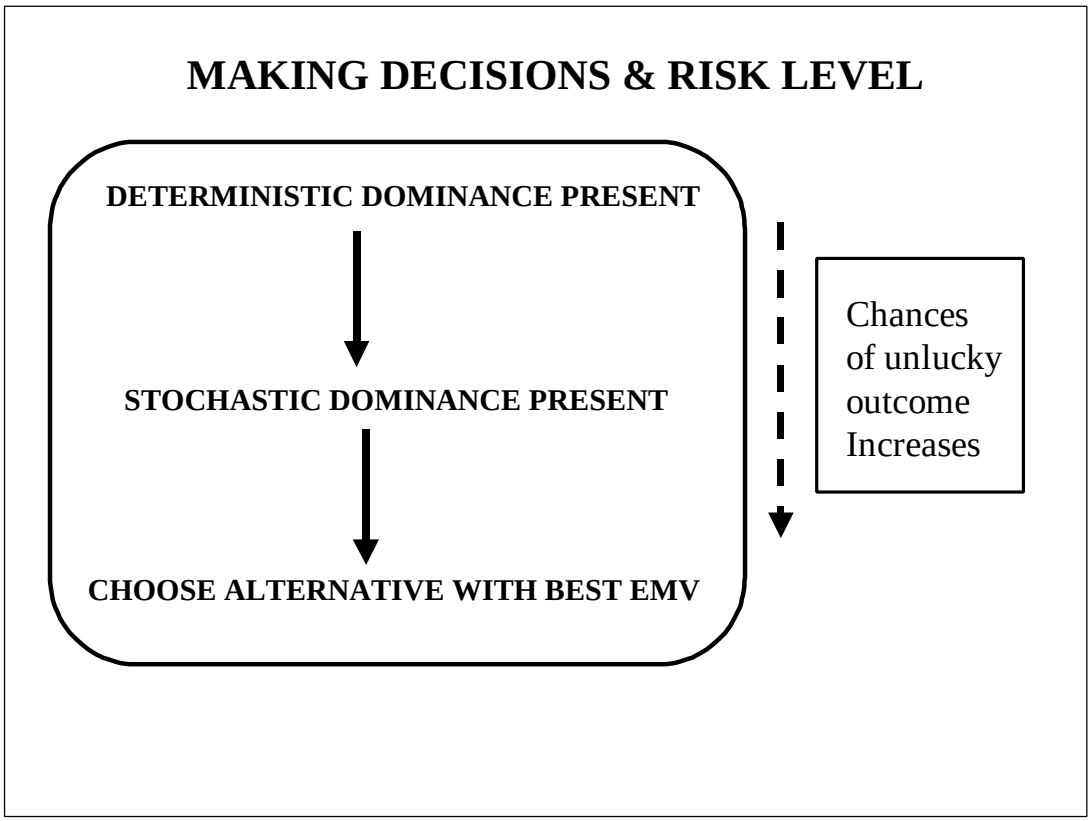


What is the type of dominance in case of the Arnobius' Risk Analysis Table?

17-th Century:
Given the probability distribution for God's Existence, **Pascal** concluded that the expected value of being a Christian outweighed the expected value of atheism.

What decision situation is associated with the above statement?

17-th Cent, 18-th. Century:

Remarkable spurt in development of probability theory, e.g.:

1. Arbuthnot (1692) argued that probabilities of causal events can be calculated,
2. Halley (1693) proposed improved life expectancy tables,
3. Hutchinson (1728) analyzed the tradeoff between probability and utility in risky decisions
4. Laplace (1793) developed a prototype of modern day risk assessment - An analysis of the probability of death with and without smallpox vaccination.

WHY OCCURRED THIS ACTIVITY IN DEVELOPMENT OF THEORY OF PROBABILITY AND WHY SO LATE?

- There was no substantial understanding of probability theory prior to Pascal.
- Games of chance have been one of the first inventions of primitive man!

For example:

- Archeologists have uncovered a large number of tali, a predecessor of the modern dice, in the shape of "knucklebones" or heel of deer, oxen, or sheep.
- Well polished tali are regularly found in ancient Egyptian, Sumerian, and Assyrian sites
- In the Roman era, Marcus Aurelius was so obsessed with throwing dice that he was regularly accompanied with his own master of games.

Given these examples, it would seem **that the mathematical calculation of relative frequencies** and **averages** should be as old as **the rolling of ancient devices**.

Mathematical theories of relative frequency, betting, randomness, and probability only appear **1500 years later** in the work of Pascal, Bernoulli and others. WHY?

Argument 1: Mathematical probability developed in response to specific economic needs. Hence, probability theory development can be traced back to the rice of capitalism.
Counter Argument: Early probability theorists were generally not involved in commerce, nor was their work readily applicable to business.

Argument 2: The development of mathematical probability was related to the growths of firms dealing in life annuities.
Counter Argument: the selling of annuities was common practice in Rome in the third century A.D.

Argument 3: Mathematics was not sufficiently rich prior the 17-th century.
Counter Argument: The concept of probability requires simple arithmetic (addition, multiplication and subtraction).

Argument 4: The conditions leading to the emergence of probability are the same as those leading to the emergence of modern science in the 16-th and 17-th century.

Argument 5: The preconditions for the emergence of probability theory occurred a century and a half before Pascal, largely because of a chance in attitude of the Catholic Church.

Two conflicting objectives:

- money was needed for church construction under growing population pressure.
- money was needed to pay massive debts due to the Crusades.

Solution: Church searched for ways to generate money and allowed to charge interest in the event of risky loans (interest was previously considered sinful). Even though this principle was revoked, the 68 years of sin-free interest rate were enough to stir-up intellectual thought about probability and made risk a legitimate topic of discussion.

After Pascal's introduction of theory of Probability:

1662: Graunt publishes his **life expectancy tables**.

> "It may now be asked, to what purpose tends all this laborious puzzling and groping? ... I might answer: That there is much pleasure in deducing so many abstruse and unexpected inferences out of these poor despised Bills of Mortality ... But, I answer more seriously,... that a clear knowledge of these particulars, and many more, ... , is necessary in order for good, certain, and easy Government, and even to balance parties and factions both in Church and State. But whether the knowledge thereof be necessary to many, or fit for others, than the Sovereign, and his chief Ministers, I leave to consideration."

Prior to Graunt only life expectancy tables of note were of the Roman Domitius Ulpianus in 230 A.D. This large gap is most likely explained by philosophical objections.

Davids Points out:

> "... seems to have been a taboo on speculations with regard to health, philosophers implying that to count the sick or even the number of boys born was impious in that it probed the inscrutable purpose of God."

17-th Cent.: Halley (Related to Comet Name): Publishes article containing probabilistic analysis **disproving** popular theories about the effect of phases of the moon on health.

19-th Cent.: Von Bortkiewicz build on previous work of Poison to show that a streak of soldiers dying of Horse Kicks represented a random event and not a change in circumstance, requiring action (e.g. carelessness of soldiers).

SECTION 2.
METHODS FOR ESTABLISHING CAUSALITY

Modern Risk Analysis has its twin roots in:

- mathematical theories of probabilities
- scientific methods for identifying causal links between adverse health effects and different types of hazardous activities.

Three different types of methods to establish causal links:

1. Experience based Trial and Error studies:

Used throughout the history of primitive man either on humans or on a surrogate e.g. animals.

2. Indirect observational methods:

1st Cent. A.D.:

Burn tests of Pliny the Elder to detect food adulteration.

3. Epidemiological Observational Methods:

5th Cent B.C:

The association between malaria and swamps was established even though the precise reason remained obscure.

1st Cent B.C.:

The Greeks and the Romans had observed the adverse effect of exposure to lead through various mediums.

"We can take by example the workers in lead who have complexions affected by pallor. For when, in casting, the lead receives the current of air, the fumes from it occupy the members of the body, and burning them thereon, rob the limbs from the virtues of the blood. Therefore it seems that water should not be brought in lead pipes if we desire to have it wholesome."

16-th, 17-th and 18-th Century:

- **Agricola:** linked adverse health effect to various mining and metallurgical practices.
- **Evelyn:** linked smoke in London to various types of acute and chronic respiratory problems.
- **Ramazinni:** indicated that nuns living in Appenine monasteries appeared to have higher frequencies of breast cancer.
- **Hill:** linked the usage of tobacco snuffing with cancer of the nasal passage
- **Sir Percival Pot:** indicated that juvenile chimney sweeps in England were susceptible to scrotal cancer at puberty.
- **Ayrton Paris / Hutchinson:** indicated that occupational and medical exposure to arsenic can lead to cancer.
- **Chadwick:** linked nutrition and sanitary conditions in English slums to various type of ailments.
- **Snow:** linked cholera outbreaks to contaminated water pumps.
- **Unna and Dubreuilh:** linked sunlight exposure to skin cancer.
- **Rehn:** linked aromatic amines with bladder cancer.

Despite these studies, progress in establishing causal links was slow. Two major obstacles may have impeded the progress:

1. The scarcity of scientific models of biological, chemical and physical processes. Related to this was the lack of instrumentation and the lack of rigorous observational and experimental techniques for collecting data and testing hypotheses.
2. The belief, rooted in ancient traditions, that most illnesses, injuries, misfortunes, and disasters could be best explained in social, religious, or magical terms.

Examples:

- **In 16-th Cent, 17-th Cent. Europe:** witch hunting resulted in death by fire for an estimated half-million people, as the Church attempted to eliminate a perceived source of crop failures, disease, death, and other ill fortune.
- **1721:** An influential critic of medical experimentation in Boston insisted that smallpox is " a judgment of God on the sins of the people".
- **Mid 19-th century:** critics opposed to health reform blamed symptoms of disease among factory workers on the workers "improvident" style of life.

SECTION 3:
SOCIETAL RISK MANAGEMENT

In response to **identified risk**, individual and groups have historically employed a number of techniques for reducing or mitigating adverse health effects.

Examples of Techniques:

- **Avoiding or eliminating the risk**, such as prohibiting the use of a potentially dangerous object or substance.

- **Regulating or modifying the activity** to reduce the magnitude and/or frequency of adverse health effects, e.g., by constructing dams, levees, and seawalls.

- **Reducing the vulnerability of exposed persons and property**, e.g., by requiring the use of safety devices, by elevating buildings in flood plains, by immunizing the population, by implementing quarantine laws, or by establishing disaster warning systems.

- **Developing and implementing post-event mitigation and recovery procedures**, e.g., by establishing search and rescue team, stock piling food, providing first aid training, or providing fire extinguishing equipment and services.

- **Instituting loss-reimbursement and loss-distribution schemes** through such mechanisms as insurance systems or incentive pay schedules for high risk activities.

Most of our current ideas about societal risk management are rooted in four basis strategies of mechanism of control: Insurance, Common Law, Government intervention, Private sector self-regulation.

3.1 Societal Risk Management – Insurance

Insurance is one of the oldest strategies for coping with risk. Its origins trace back to setting interest rates:

3000 B.C.:
Mesopotamia - farmer loaned a portion of excess production in exchange for a share of the return. At first, loaned goods were returned, later barley and silver became the media of exchange. Interest rates varied from 0% to 33% for riskier agricultural loans.

Interest Rates may reflect the perceived riskyness of the loan, and as such are the earliest attempts to quantify and manage risk.

Pre-Greek Period:
Ancient Babylon served as trade center of the world economy. Imports and exports flowed through Babylon. Traders faced numerous hazards in the form of bandits, pirates, fires, storms, etc. Loans on cargo ordinarily included risk premiums as large as 200% in excess of interest!

Under these conditions, trade declined, until **insurance emerged** as a more effective risk management technique.

- **1950 B.C.:**

The code of Hammurabi, formalized the concept of bottomry, which formed the basis for maritime contracts on the vessel, cargo, or freight. Contracts had three elements:

1. The loan on the vessel, cargo, or freight;
2. an interest rate;
3. A risk premium for the chance of loss and consequent cancellation of debt.

By 750 B.C. Almost all voyages were covered by bottomry contracts, with 10-25% risk premiums, depending of riskiness of the venture. In this period the concept of **general average** was developed, which called for **all parties to share proportionally** in any loss suffered during a venture.

- **Romans:**

Instituted a form of life and health insurance in the form of collegia. Members made regular contributions, a fund was maintained, and burial expenses were paid by the collegia.

- **1000 A.D.:**

Marine Insurance reappeared in Italian port cities and by 12-th/14-th century becoming progressively more widespread and better developed.

- **1688:**

Lloyd's detailed set of regulations pertaining to Marine Insurance was developed and London emerged as the nucleus of the global marine insurance market.

- **16-th & 17-th Cent:**

The insurance industry flourished in England.

- **1583:**

First recorded life insurance policy in England. Life insurance resembling its modern form emerged in England, France, and Holland.

- **1666:**

Fire insurance emerged in response to the Great Fire in London.

Estimates on failure rates used in insurance were initially exceedingly high as methods of probabilistic risk assessments were not known or not utilized and comprehensive sets of vital statistics were not available.

Note:

- Life insurance foreshadowed the modern debate whether it is acceptable to place a monetary value on the loss of a human life. The Church raised serious questions about the morality of life insurance. For the Church life insurance was an immoral-or at least highly suspect wager on human life. Life insurance was prohibited in France until 1820.
- Debate about the morality of life insurance has long since died out, but similar issues are still discussed in debates about the moral status of cost-benefit analyses addressing risks to human life.

3.3 Societal Risk Management – Common Law

English and American legal systems:

The common law (i.e. judge made law) permitted a citizen to recover damages from nuisance, negligence and the pursuit of abnormal dangerous activities.

Common Law is a form of Risk Management

People must conform to a standard of reasonable conduct (e.g. cleaning their chimneys, disposing of waste products) or face the prospects of being liable.

Common law provides two risk management functions:

- Compensation
- Deterrence.

Definition:

Strict Liability = the concept that the manufacturer of a product is liable for injuries due to defects **regardless** of negligence or fault. Originates to the code of Hammurabi and the Old Testament.

Industrial Revolution ⟶ use strict liability declined.

- **By 1850:**

"The plaintiff must come prepared with evidence to show that **intention was unlawful**, or that **the defendant was at fault**; for if the injury was unavoidable, and the conduct of the defendant was free of blame, he will not be liable."

- **1916:**

In Macpherson vs Buick Motor Company this narrow concept of liability was broadened, to require manufactures to inspect for defects.

- **1960's:**

The ancient notion of strict liability began to be reinstated through a series of court decisions.

3.3. Societal Risk Management – Direct Government Intervention

Since Ancient times, government authorities have directly intervened to **reduce, mitigate, or control risks**. Many of the earliest efforts relied heavily on **magico-religious practices**.

- **500 B.C.:**

Provincial officials and priest required the annual sacrifice of a **maiden** to please the **Yellow River gods** and thereby **control** the ravages of **annual** flooding.

> "Adorend in Ceremonial regalia, the victim was flung into the stream, where she was swiftly dragged beneath the surface by her heavy accouterments. Needless to say, the maiden was invariably selected from a peasant family rather than from the local gentry, and Chinese historians record that as years passed, farmers who had eligible daughters deserted the district in increasing numbers. Eventually, around 400 B.C. a magistrate named Hsimen Pao stepped forth and put an end to the practice with one final, highly appropriate sacrifice: He had the priests and officials hurled to their deaths in the swirling yellow waters."

Paralleling with these **magico/religious techniques** were direct government interventions based on a firmer ground related to:

1. Natural Disasters
2. Epidemic Disease
3. Pollution
4. Food Contamination and Adulteration
5. Building and Fire Codes
6. Transportation Accidents
7. Occupational Injuries

3.3.1. Natural Disasters

- Troughout History, all great ancient civilizations (e.g. China, Maya, Egypt and Mesopotamia) **directly intervened** to reduce the effects of natural disasters.

Historical records show that governments financed elaborate systems of **flood control, including dams, dikes, and canals**.

- In addition to attempts to prevent or control disasters, government authorities have responded **by providing relief after the disasters** occur.

- **1803:**

U.S. Congress passed legislation to assist victims of a fire in Portsmouth, New Hampshire. In following years Congress approved on ad hoc basis 100 separate acts granting relief after specific disasters had occurred.

- **20-th century:**

First US Agency was authorized to make loans to grant relief after disaster occurrence.

3.3.2. Epidemic Disease

Throughout history, governments have attempted to mitigate the effects of epidemic disease.

- **1348 to 1349:**

Black Death (bubonic plague), killed over a quarter of the population of Europe (25 million). Given the lack of causes government adopted the oldest and most direct technique-**quarantine and isolation**.

- Fear of leprosy caused wide-scale adoption of isolating the infected and the cleansing and burning of their garments.

- Fear of infection also prompted the adoption in preventing entry of goods and persons from infected communities.

3.3.3. Pollution

Pollution of the air, water, and land has long been recognized as a problem, but efforts at pollution control have been highly sporadic.

- **1285:**

First act of government of King Edward I concerning **Air pollution**. He responded to a petition from members of the nobility concerning **offensive coal smoke** in London and

did what is now commonly practiced, he formed a **commission to study the problem**. Commission's Study resulted in **voluntary** efforts that were not sufficient upon which Edward **prohibited** the use of soft coal. He next, had to form a commission why his royal proclamation was not observed.

Examples of **water and land pollution control**:

- Governments of Minoa and Crete built some community sewage draining systems.

- Athens and other Greek cities built sewage disposal systems and enacted laws requiring waste matter to be carried outside the walls of the city with a minimum distance. Fines were frequently given and pollution of the city water supply was **punishable by death**.

- Ancient Romans can be accredited with most extensive system, consisting of paved streets, gutters, and a complex of tunnels and aqueducts. Roman authorities enacted strict laws to control foul smells and the disposal of waste products.

- **14-th,15-th Century:**

In response to the spread of contagious diseases, public officials in Europe created a rudimentary system of pollution and sanitary control, e.g.:

1. Colonial New Amsterdam " ... prohibiting the throwing of rubbish and filth into the streets or canals, ...",

2. 1671 a law requiring that each peasant coming into Berlin had to leave with a load of filth.

The effectiveness of these efforts was questionable.

- **1848:**

Formation of the General Board of Health in response to government sponsored research documents.

- **1869:**

Formation of the State's board of health in US. Similar bodies were created in Europe leading to major improvements in street paving, water purification, water distribution, and sewage disposal.

- **1855:**

English Nuisance Removal Act to clean the Thames River.

Effective Control, however, only occurred **after** the outbreak of infectious diseases.

3.3.4. Food Contamination and Adulteration

Most societies have been concerned about the safety of the food supply.

Biblical abominations of Leviticus, particularly the prohibition against the eating of pork, are often cited as an early attempt of controlling food safety.

Food Control?
or
Affirmation of Ethical Norms?

1262: English Assize of Bread,
First important law regulating food, which made it **unlawful to sell** any food **unwholesome** for man's body.

Early 1800's:
The English Assize of Bread and other statutes regulating food were **repealed** at the height of the industrial revolution and **a laissez fair** philosophy of the government was adopted.

Late 1900's:
Medieval Laws were reinstated, culminating in US federal legislation such as the US Biologies Act of 1902, and the Federal Meat inspection Act of 1906.

3.3.5. Building and Fire Codes

- **1950 B.C.:**

Code of Hammurabi decreed that should **a house collapse and kill the occupants**, the builder of the house must forfeit **his own life**.

- Romans also enacted laws regulating the quality of building construction.

Aside from **construction risks**, virtually all societies have been concerned with **the risks of fire**.

Examples:

- **1626:**

Plymouth Colony enacted a law that houses should not be thatched, roofed with board or other materials.

- **1648:**

New Amsterdam prohibited the construction of wooden or plaster chimneys on new homes, and required that existing chimneys be inspected regularly.

- **1666:**

Great London Fire (destroyed over three quarters of the city's buildings) stimulated all large cities in Europe and America to establish municipal firing companies during the next 100 years.

- **1745:**

City of Charleston required that "... all buildings should be of brick or stone, that all **tall** wooden houses must **be pulled down by 1745**, and that the use of wood should be confined to window frames, shutters, and to interior work".

3.3.6. Transportation Accidents

Transportation System Regulation, in the interest of safety, substantially predates modern mechanized transportation technologies.

- **Ancient Rome:**

Julius Caesar prohibited all wheeled vehicles in Rome between sunrise and 2 hours before sunset, except for essential public service traffic. This regulation was largely for the benefit of pedestrians, for whom the combination of narrow streets and heavy traffic created a genuine hazard.

- **1838:**

1st Regulation of **Technological Risk** in the United States, when Congress passes legislation governing boiler testing, inspection, and liability. This legislation was enacted in response to a series of **boiler explosions on steamboats** with lead to **thousands of injuries and fatalities**.

- **1858:**

Replaces above regulation as previous regulation was **too lax** to foster **risk reduction**. This law specified engineering safety criteria, gave inspectors authority **to examine boats and refuse licenses,** and created a regulatory agency - The Board of Directors of Inspectors.

- **Turn of the 20-th century:**

Intrinsic risk with railroads, automobiles and later airplanes led to the development of regulatory schemes.

3.3.7. Occupational Injuries

Pre 18th and 19th Century:

Occupational health and safety issues were only minor concern to government authorities. Most of the first efforts were focussed on **the conditions of child labor**.

> " ... No Dickens novel did full justice to the dismal conditions of child labor, length of working day, and conditions of safety and sanitation in the early 19th century factories. A **workweek of 84 hours** was the prevailing rule, with time out at the bench for breakfast and sometimes supper, as well as lunch. **A good deal of work could be got out of a six year old child**, and **if a man lost two fingers in a machine, he still has eight left."**

Most effort at reform were initially **strongly resisted** by mine and factory owners.

- **Late 1900's:**

Bismarck, Germany, instated workers' compensation statutes. Under these laws, requirements to demonstrate employer's negligence were waived for most occupational injuries and an employee was entitled to compensation based on a percentage of lost wages.

Within 20 years, similar laws were passed in England and a number of States in the US.

3.4 Societal Risk Management – Private Sector Self-Regulation

In most societies there have been strong incentives for the private sector to refrain from actions that would recklessly endanger the health of the public based on:

- moral and altruistic norms and values,
- self-interest based on fear of monetary loss, possible civil or criminal litigation, or punitive or restrictive government action.

3.4.1. Industrial Self-Regulation

Most important mechanism of Industrial Self- Regulations = Standard Setting

Two conditions need to be met for this risk management strategy to work:

1. the involved risk and technologies must be well understood.
2. The potential liability must be significant enough to force a responsible industrial approach to risk reduction

- **1880:** the American Society of Mechanical Engineers;
- **1894:** the underwriters laboratory;
- **1896:** National Fire Protection Association;
- **1898:** American Society for Testing and Materials;
- **1918:** the American National Standards Institute.

3.4.2. Licensure and Certification

Currently: 550 occupations are licensed in the US
Pre 20-th Century: Little of no use of licensing and certification .

This was even true for the **clearly risky** and **currently heavily regulated** areas as medicine. 1st Licensure in medicine began early 1800's, was abandoned from 1820 to 1850 and reinstated in the late 1800's.

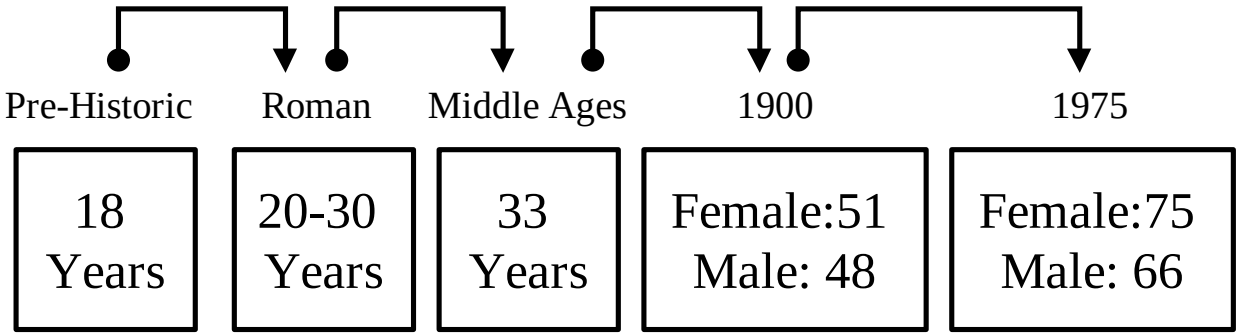
SECTION 5.
NINE IMPORTANT CHANGES BETWEEN PAST AND THE PRESENT.

1. Shifts in the Nature of Risks:

1900: Leading cause of death: infectious diseases - pneumonia, influenza, and tuberculosis.
1940: Infectious diseases replaced by adulthood- hart disease and cancer.

No change in the rank of accidents as leading cause of death, but there has been a shift in the types of accidents. For example: occupational fatalities , fatalities due to natural disasters, the number of automobile accidents .

2. Increase in Average Life Expectancies



3. Increase in New Risks

Nuclear war, nuclear power plant accidents, exposure to synthetic pesticides and chemicals, supertanker oil spills, chemical plant and storage accidents, ozone depletion, and acid rain.

Risks not easily estimated:

- historical data does not exist.
- cause-effect relationships not well understood.

More importantly:

- long term,
- involuntary,
- irreversible.

4. Increase in Ability of Scientists to Identify and Measure Risk

Major advances in:

- Laboratory tests (e.g. animal bioassays),
- Epidemiological methods,
- Environmental modeling,
- Computer simulations, and
- Engineering risk assessment (e.g., fault trees and event trees).

5. Increase in the Number of Scientist and Analysts whose work is Focused on Health, Safety, and Environmental Risks

6. Increase in Number of Formal Quantitative Risk Analysis that are produced and used.

Past: Risk management decisions were based primarily on common sense, ordinary knowledge, trial and error, etc.
Present: Risk management decisions have been increasingly based on highly technical **quantitative risk analysis**.

7. Increase in Role of Federal Government in Assessing and Managing Risks

Dramatic increases in:

- the number of health, safety, and environmental laws;
- the number of federal agencies charged with managing health, safety, and environmental risk
- the number of health, safety, and environmental cases adjudicated by the courts.

8. Increase in Participation of Special Interest Groups in Societal and Risk Management.

Risk Analysis and Risk Management activities have become **increasingly politicized**, with virtually every major health, safety and environmental decision subject to **intense lobbying by interest groups**.

Number of groups ↑ & Scientific Sophistication ↑.

These changes have contributed to at least two others:

- It has become increasingly necessary for government decisions to consult representatives from these groups and to make risk analysis information publicly available.
- The adversarial nature of most contemporary risk debates appears to be causing increasing confusion amongst the public.

9. Increase in Public Interest, Concern, and Demands for Protection.

Despite that average life expectancies increased most **Americans believe that life is getting riskier**.

Research has suggested that the primary correlates of public concern are **not** mortality or morbidity rates, but characteristics such as:

- potentially catastrophic effects,
- lack of understanding,
- involuntariness,
- scientific uncertainty,
- lack of personal control,
- risk to future generations,
- irreversible effects.

IMPLICATIONS FOR THE FUTURE?

- Public Concern will continue to rise due to an increased awareness that injuries, deaths, and diseases are not acts of God to be fatalistically accepted, but are avoidable events subject to some degree of human control i.e. **that something can be done**.
- Increase in the belief that Individuals should be allowed to live their lives free of risk imposed on them by others i.e. **that something should be done.**

"Hydra effect" – for every risk problem resolved, two new one are raised in its place.