Corporate Finance and Enterprise Risk Management (CFE)
Course Study Note: How Business Dynamics Applies to Actuaries
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This note is intended to aid candidates in reading *Business Dynamics* by John D. Sterman. While it can be a valuable aid in preparation, the material in this note will not be tested.

Since candidates do not have classroom interactions with a professor, this study note acts as a "Missing Professor" guide or an informal chat akin to what a professor might say on the first day of class. This note attempts to answer,

- Q#1: "how does *Business Dynamics* apply to actuaries – what should a student know and be able to do?"

Note the question to be answered is not,

- Q#2: "what will be on the exam?"

However, the two questions are related. By answering the first question, the candidate might be guided as to the second. A point to be made is that unlike the class professor, I am not creating SDM exam questions, although that is role I previously held. Thus, throughout the note, when I say, a candidate may be asked *abc*, I really mean a candidate might infer that it is likely they might be asked *abc*, and by omitting *xyz*, I do not mean to imply that candidates will not be asked *xyz*.

Business Dynamics does not delve into insurance, makes no mention of actuarial science, and/or many of the topics actuarial candidates study. So how do business dynamics and the book's coverage of models apply to actuaries? Obviously, a candidate will not be expected on the exam to construct or run models by literally coding programs and building or running software models. Such tasks take many resources – teams of specialists with broad and deep knowledge, expertise, and skill sets as well as lots of time from weeks to many months. However, candidates can be expected to sketch diagrams such as causal-loops and stock and flows as well as evaluate, interpret, and apply diagrams that are provided.

First, consider how *Business Dynamics* fits into the continuum of your actuarial education. If you reflect upon each actuarial exam from Probability, Financial Mathematics, and progressing to Predictive Analytics and other exams, models are either implicitly or explicitly omnipresent. Cash flow models underlie everything from calculating the price of non-callable bonds to life reserves, economic capital, financial options, and risk metrics for assets and insurance products. There are also models within models within models. For example, assumptions related to insurance

- economic scenarios including interest rates, equity returns, and inflation
- mortality, morbidity, casualty, and liability
- policyholder behavior such as lapses, benefit utilization, premium payments, and exercising embedded optionality such as conversions, guaranteed purchase options
- assets/debt assumptions such as defaults and mortgage prepayments

- company actions such as sales, products, credited interest rates, and dividends
- third party actions such as reinsurers, distributors

are all models, and typically are a model within a model. The ubiquity of models is such that you might forget they are models.

Models

In constructing a financial or cash flow model, the real world is represented by key risk factors which are modeled as assumptions and assumed relationships between variables. A **model** is a simplified representation of relationships among real world variables, entities, or events using statistical, financial, economic, mathematical, or scientific concepts and equations. A **financial model** or **cash flow model** forecasts or projects some or all items associated with financial statements including income statements and balance sheets such as revenues, expenses, income, asset and liability values, and equity.

An **actuarial model** or **statistical model** is a model reflecting some degree of uncertainty. However, actuarial models often make simplifications and treat inputs as deterministic, i.e., certain. A range of outcomes to reflect uncertainty are captured through simulations. There are nuances that differentiate statistical models and predictive models. However, since uncertainty always exists in the real world, I make no distinction between a model, an actuarial model, a financial model and so forth and simply use the word “model”. **Output** is the result of a model including point estimates, likely or possible ranges, parameters (as input for other models), or qualitative criteria on which decisions could be made. Model output, often made suitably presentable in content and display, is often called a **projection** or a **forecast**.

Introductory Models and Systems

Early SOA exam content and associated models are often introduced in simplified contexts. The number of variables considered might be limited. Variables might be deterministic versus stochastic. Typically, variables have a one-way dependency: X is dependent on Y which is dependent on Z. That Z might affect Y and that Y and Z might affect X, namely, that there could be scores of variables which are interdependent, might be discussed in a general sense but seldom tackled head-on.

Introductory textbooks appropriately often simplify assumptions, or models within a model, and make complex systems less complex perhaps by limiting the scope of the system or limiting the number and nature of the system or variables that are considered. The treatment in some introductory models is often at a micro-level versus a macro-level.

For example, introductory physic books might consider a single object, assume wind resistance is constant, and forces are linear and predictable. Advanced studies might consider how shapes and design behave in non-constant, non-linear, shifting winds. We know that automobile and aeronautic companies employ large teams of engineers and other specialists because reality is much more complex and accordingly so are models and the underlying science. Similarly, assuming a variable in an insurance or financial context is constant over time is a model, albeit a simple model.

Applying *Business Dynamics* and Models To Strategic Decision Making
Business Dynamics continues the progression of models as an important element of the actuarial toolkit. *Business Dynamics* expands the scope beyond insurance and finance, and expands the system in complexity, and in particular, variable interdependencies. The focus is at the macro-level. With the expanded scope, terminology is generalized rather than the specialized terminology used in actuarial and financial worlds. Although the terminology is different, many of the concepts are the same or similar to what you previously know from actuarial, statistical, financial, and predictive models. This is similar to economics using words such as marginal price and cost, physics using words such as speed and acceleration, and math using words such as first and second derivative.

Decision makers and actuaries use models in conjunction with other tools in the actuarial and SDM toolkit. The modeling processes, tools, and diagrams in *Business Dynamics* are applicable whether the context is a complex system or a simple system or whether the model reflects a macro perspective or micro perspective. In other words, both complex and simple models can be used to determine financial values and risk metrics to make decisions. As such, all of the ways risk managers, actuaries, and decision makers use models apply including:

- Simulations
- Scenario testing (deterministic and/or stochastic)
- Stress testing
- Sensitivity analysis
- What ifs
- Performance measures
- Risk metrics and risk management
- Strategy formulation
- Other aspects of modeling such as validation, controls, and governance

Models can pertain to various levels of complex systems within complex systems zooming in and out – for example,

- Nations, regions, cities, neighborhoods
- National economies, industries, companies, products
- Risk management frameworks
- Manufacturing processes

***Business Dynamics* Content**
Chapter 1 establishes the expanded scope and perspective. How do decisions, change, outcomes, experience, and learning affect the system and future states of the system? Figure 1.4 illustrates that actions alter the environment, i.e., interdependencies. The feedback structure in a system is a key driver in the real world and hence in a model. Feedback is perhaps the most challenging part of a system to understand and predict and the most challenging aspect to model.

***Business Dynamics* Figure 1.4**

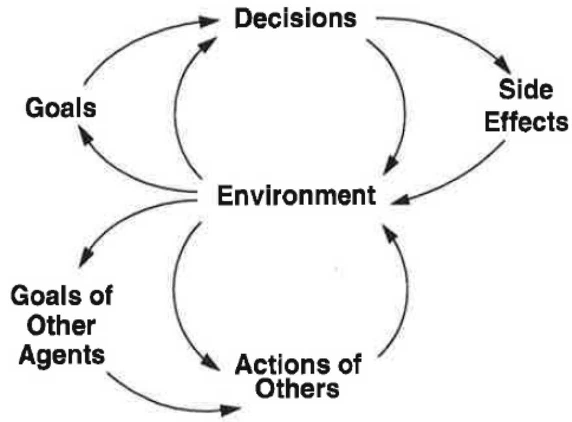
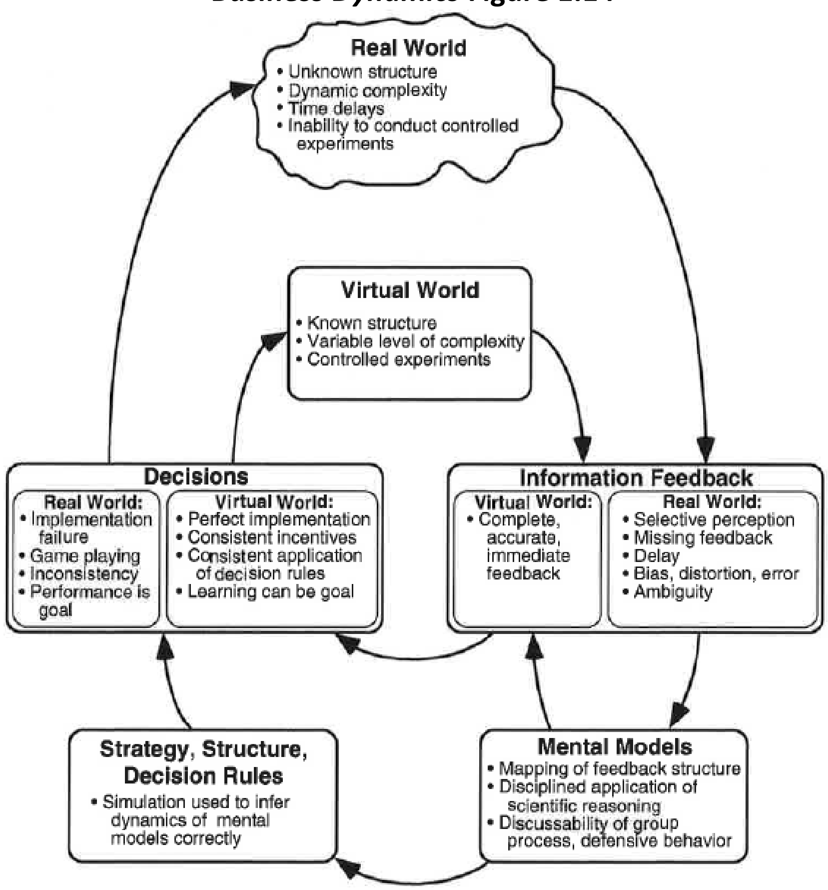


Figure 1.14 illustrates relationships of complex system models to their representations of the real world and *<u>the use and application of models as tools to formulate strategy and make decisions</u>*. The candidate should see the point of emphasis in the last sentence as a clue to answering the opening question Q#1: how does *Business Dynamics* apply to actuaries?

***Business Dynamics* Figure 1.14**



The eight chapters covered in the SDM syllabus present various themes and numerous variations and extensions on Figures 1.4 and 1.14. I make a brief comment or two on each chapter and include some questions to indicate answers to the first opening question allowing the candidates to form their views as to the second question: the kind of things candidates might be asked. My commentary is not comprehensive or exhaustive. Also, comments and question made for one chapter are likely applicable to other chapters as well.

Chapter 3 describes modeling as a continuous iterative process and not a one-and-done exercise. The world changes, so too should models. Candidates should expect to be asked more than to simply list the steps in Table 3-1' s modeling process. As with other SDM decision tools, a model is a means to an end. Candidates should expect to be asked to illustrate models and maps via visual pictures. Candidates can be expected to recommend, evaluate, and assess models in each of these steps in light of the business or socio-economic context. What are the key variables? What mappings should the model use?

For example, Table 3-1 Step 2, Formulation of Dynamic Hypothesis, lists many of the mapping tools to be covered in later chapters including model boundary diagrams, casual loop diagrams, stock and flow maps, and policy structure diagrams. How should the simulation be formulated? Is the model's policy design appropriate? What are the important "what ifs" and sensitivity analyses? Corporate and government policy decision makers and risk managers must use the right metrics, right models, and right formulas. As with other SDM contexts, what is "right" depends on context and judgment.

Chapter 4 considers behavior and structure. For example, Figure 4-1 illustrates common modes of behavior such as exponential growth, goal seeking, S-shaped growth, oscillation, and overshoot and collapse. Given the behavior, loops, and delays in a model, what are the implications? What is the right behavior to use in a model? What are the negative and positive loops and time delays in a model? What are the implications of a model that uses inappropriate or flawed model behaviors, loops, and delays on model outcomes and hence decisions?

Chapter 5 presents casual loop diagrams as an important tool for representing the feedback structure of systems. Chapter 5's examples and figures range from simple to complex to very complex (Figure 5-36). Beyond notation, can you interpret and explain a diagram or parts of a diagram - for example, causation vs. correlation, polarities, and delays? How do the limitations of casual loop diagrams apply in a context? Does the diagram accurately portray the system or the intended model? Given information about a system such as key variables, relationships, and behavior, can you sketch a diagram? Due to constraints inherent in an exam, I wouldn't ask you to sketch something like Figure 5-36.

Chapter 6 presents stocks, flows, and accumulations. Table 6-1 presents some examples of stocks and flows. An additional example pertinent to insurance actuaries is risk capital and reserves as stocks and premiums and claims as flows. *Business Dynamics* bridges the gap from introductory textbook models considering simplified contexts to an insurance company or insurance holding company as a complex system. Enterprise risk capital, income, revenue, and liquidity entail many dynamic feedbacks such as:

- optionalities in both assets and liabilities
- behaviors by policyholders, companies, third-parties, and competitors
- interdependencies between assets and liabilities, e.g., market returns, interest rates, and policy credited rates
- economic drivers and cycles – asset prices and rates, market returns, volatilities, inflation, available credit, credit spreads, contagions, and bubbles
- regulations.

Candidates can expect to be asked to identify, illustrate, and apply stock and flows in general as well as specifically to the case study companies. Are stocks and flows continuous or discrete? What are implications of model simplifications or limitations (e.g., continuous as discrete or vice versa). How are stocks and flows linked with feedback? How does feedback affect stocks and flows?

Chapter 9 considers S-shaped growth and numerous examples. Some models are linear or continuous in nature for some period of time. However, Chapter 9 introduces nonlinear interactions and discontinuities and incorporates tipping points. Examples include:
What causes an epidemic? What is the impact of new products, innovation and diffusion, obsolescence, abandonment, or eradication, new technologies, and other small or large disruptors?

Chapter 12 extends Chapter 6's stocks and flows to coflows and aging chains. Chapter 12 consider more granular models by adding underlying details to the model, in other words, a micro-level underneath the macro-level: components of the stocks, flows, delays, etc. These details reflect a system's population and other key variables may depend on many factors, i.e., behavior is heterogeneous and not homogeneous. In addition to Chapter 6 questions, a candidate can expect to evaluate and/or recommend the appropriate level of granularity for a model.

Chapter 15 considers human behavior. Many elements of Chapter 15 relate to other topics such as organizational behavior in the SDM syllabus including rational vs. irrational behavior and biases. To be useful, models need to reflect reality, and actual human behavior does not always make sense. People do not always make optimal choices and sometimes make bad decisions. Candidates can expect to be asked to evaluate a model's formulation of human behavior and how models can be tested for consistency with the real world.

Chapter 17 considers supply chains and oscillations. Previous chapters considered other patterns such as exponential and S-shaped growth. Chapter 17 consider cycles – the ups and downs of business cycles. Cycles apply to supply, demand, economies and their many components such as employment, inflation, and GDP. Chapter 17 extends previous content illustrating managing stocks through cycles or oscillations. How do actions amplify or dampen stocks, flows, and delays? Another book example considers real estate and available capital.

How does stock of each impact prices? What are impacts of steady growth versus boom and bust cycles? Candidates can expect to be asked how system feedbacks and actions can impact the stability and other characteristics of a system. How do companies in general, and case study companies in particular, manage through short-term and long-term business and economic cycles?

SDM Exam and Conclusion

Candidates should expect exam contexts to be found in the case study and/or to be provided within the question and that context should inform and shape their responses. Candidates should also expect exam questions will reflect the limits and time constraints of an exam versus a class project or work project.

Returning to the opening questions of what should a candidate know and be able to do and what can be expected on the exam: I can't say it any better than the learning objectives and outcomes which articulate what is expected of candidates.

4. **Topic: Modeling Complex Systems**
Learning Objectives
The candidate will be able to analyze and model dynamic systems and evaluate the risks and sustainability of these complex systems.
Learning Outcomes
The Candidate will be able to: a) Identify and model the dynamic processes within a complex system: i. Develop and apply causal loop diagrams that model the feedback structure of complex systems ii. Apply stocks and flows to dynamic modeling iii. Apply dynamic modeling to business decisions b) Explain the underlying factors that drive the sustainability and stability of a dynamic system: i. Evaluate the structure and behavior of dynamic systems ii. Identify the factors that contribute to risk and instability in dynamic systems c) Evaluate complex systems and describe how actuarial principles can mitigate risks and improve sustainability