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INTRODUCTION AND OVERVIEW

Higher education has become the "poster child" for out-of-control costs, replacing healthcare, which now seems more or less under control. Tuition increases have far outpaced increases of the overall cost of living. This is due to the relative decline of public support for higher education, while administrative costs have been steadily growing much faster than the costs of teaching and research. A primary enabler and consequence of this cost growth has been student debt levels that exceed the total credit card debt in the United States.

We need to get a grip on the economics of higher education, with a goal of transforming the system to improve the overall value proposition. Academia provides a wide variety of offerings that serve a diverse mix of constituencies. Delivery processes for these offerings can be quite creative but are often burdened with inefficiencies. This is complicated by academic governance processes, which can be overwhelming, more so when the university is also a public sector agency. Yet, universities are basically well-intentioned, creative, and committed. There is much to build on but nevertheless much to overcome.

Figure 1.1 depicts a multilevel architecture of academic enterprises (Rouse, 2015). The practices of education, research, and service occur in the context of processes, structure, and ecosystem. Understanding the relationships among practices, processes, structure, and ecosystem provides the basis for transforming academia, leveraging its strengths, and overcoming its limitations. In this book, I explicitly address these relationships in terms of both conceptual and computational models of academic enterprises.

Universities as Complex Enterprises: How Academia Works, Why It Works These Ways, and Where the University Enterprise Is Headed, First Edition. William B. Rouse.

The architecture in Figure 1.1 helps us to understand how various elements of the enterprise system either enable or hinder other elements of the system, all of which are embedded in a complex behavioral and social ecosystem. Practices are much more efficient and effective when enabled by well-articulated and supported processes for delivering capabilities and associated information, as well as capturing and disseminating outcomes.

Processes exist to the extent that organizations (i.e., campuses, colleges, schools, and departments) invest in them. These investments are influenced by economic models and incentive structures and are made in pursuit of competitive positions and economic returns. These forces hopefully coalesce to create an educated and productive population, at an acceptable cost.

When we employ Figure 1.1 to understand relationships among universities, the interesting phenomenon in Figure 1.2 emerges. The hierarchical structure of Figure 1.1 dovetails with the heterarchical nature of academic disciplines. The dotted rectangle in Figure 1.2 represents how faculty disciplines both compete and define standards across universities.

The disciplines define the agenda for "normal" science and technology, including valued sponsors of this agenda and valued outlets for research results. Members of faculty disciplines at other universities have an enormous impact on promotion and tenure processes at any particular university. Such professional affiliations also affect

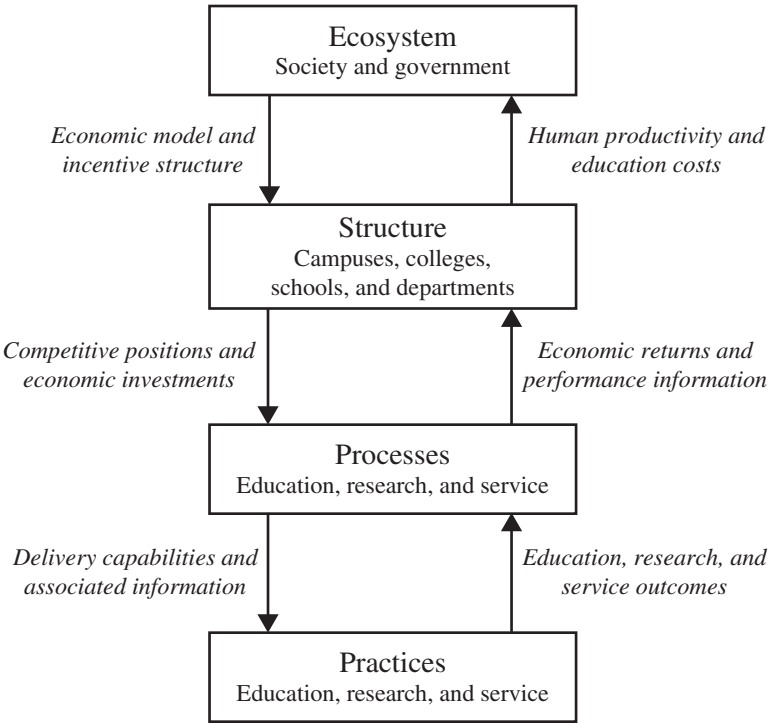

FIGURE 1.1 Multilevel architecture of academic enterprises.

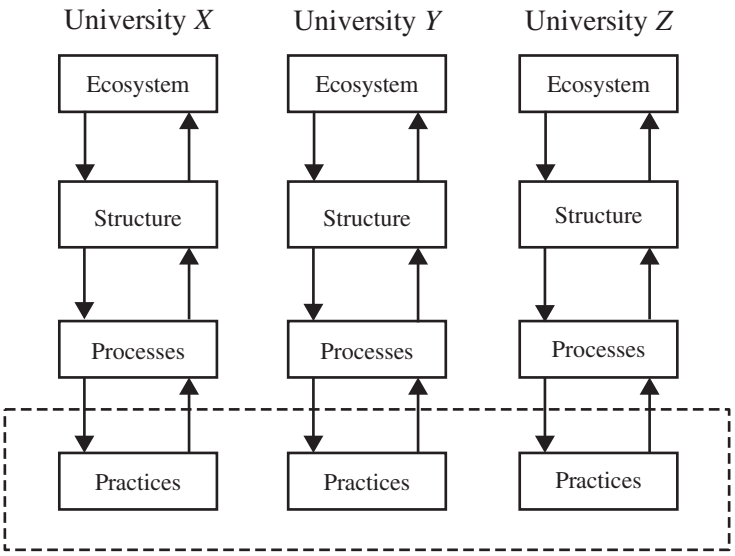

FIGURE 1.2 Hybrid multilevel architecture of academia.

other types of enterprises (e.g., healthcare). However, universities seem to be the only enterprise that allows external parties to largely determine who gets promoted and tenured internally. This has substantial impacts on understanding and modeling the performance of any particular university.

More specifically, the standards set at the discipline level determine:

- Agenda for "normal" science and technology
- Valued sponsors of this agenda
- Valued outlets for research results

Consequently, almost everyone chases the same sponsors and journals, leading to decreasing probabilities of success with either. In addition, each faculty member produces another faculty member every year or so, swelling the ranks of the competitors. Recently, retirements are being delayed to refill individuals' retirement coffers, which decrease numbers of open faculty slots.

As probabilities of success decrease, faculty members write an increasing number of proposals and submit an increasing number of journal articles, resulting in constantly increasing costs of success and congested pipelines, which foster constantly increasing times until success. Bottom line is less success, greater costs, and longer delays. The models discussed in this book enable exploration of these phenomena.

Universities can hold off these consequences by hiring fewer tenure-track faculty members, that is, using teaching faculty and adjuncts. But this will retard their march up the rankings and hence slow the acquisition of talented students, who will succeed in life and later reward the institution with gifts and endowments. The trade-off between controlling cost and enhancing brand value is explored in this book.

Alternatively, universities can pursue "niche dominance" and only hire tenure-track faculty in areas where they can leapfrog to excellence. This will, unfortunately, result in two classes of faculty—those on the fast track to excellence and those destined to teach a lot. The first class will be paid a lot more because of the great risks of their being attracted away to enhance other universities' brands.

OVERALL APPROACH

Many contemporary commentators have made similar observations to those offered in this introduction, although with less emphasis on the structure and processes of the enterprise. For example, Lombardi (2013) provides an exposition of the basic blocking and tackling of academia, primarily from a more general perspective than science and technology. This is relevant in terms of the nature of academic guilds portrayed and the multilevel nature of governance. He also provides a useful discussion of performance and quality management. However, his book does not articulate an overall enterprise perspective.

Christenson and Eyring (2011) explore how universities can find innovative, less costly ways of performing their uniquely valuable functions and thereby save themselves from decline. The authors outline the history of Harvard University and how various aspects of academia were defined by Harvard leadership in response to issues and opportunities of the times. They explore the strategic choices and alternative ways in which traditional universities can change to ensure their ongoing economic vitality. They emphasize the need for universities to address key trade-offs and make essential choices as they decide how to compete.

DeMillo (2011) addresses the challenges faced by "the middle," the 2000 universities that are not part of the "elite"—those with $1 billion plus endowments—and also face stiff competition from for-profit online universities. Computer-based and online technologies, such as MOOCs, and new student-centric business models are discussed. The book culminates in 10 rules for twenty-first-century universities, expressed in terms of defining value and becoming an architect of how this value is delivered. Some of the ideas presented are very relevant to the issues addressed in this book.

These three books are representative of a vast literature on higher education. Many other sources are referenced throughout this book as specific issues are discussed. This book leverages and integrates this material in the following ways:

- The university is viewed as an enterprise system competing in a complex economic, political, and social environment where both competition and collaboration are prevalent
- Examples are drawn from a broad range of experiences with over 50 university enterprises in the United States, Europe, Asia, Africa, and Latin America
- A multilevel architectural view of universities as enterprises enables identifying interactions and opportunities across levels of this architecture, including both avenues and barriers to fundamental change

I address university enterprises both qualitatively and quantitatively. Qualitative expositions draw from history, public policy, economics, etc. Many, but not all, of these expositions set the stage for quantitative models of the phenomena of interest. The quantitative models are valuable for addressing various "what-if" questions discussed in this book.

Examples of such models include use of the enterprise architecture in Figures 1.1 and 1.2 for computational modeling of enterprise performance and economic models of key trade-offs such as the mix of tenure-track versus nontenure-track faculty members. Discounted cash flow models are employed to reflect the time value of money involved in such decades-long investments.

Another example is statistical models of the dynamics of the *US News & World Report* ranking system, in particular time series models of the lags in ranking changes following university investments in faculty, facilities, and other strategic investments. There is a frequently expanding range of university ranking systems, for example, *Financial Times* World University Rankings and Shanghai Jiao Tong University Academic Ranking of World Universities. The various ranking schemes are contrasted in terms of purpose and attributes.

UNIVERSITIES AS COMPLEX SYSTEMS

Universities certainly seem complex—so many stakeholders, agendas, and often conflicting priorities. What type of complex system is a university or, more broadly, universities collectively? They certainly are not similar to airplanes, factories, and process plants, all of which were engineered to achieve specified objectives. They are a subset of the society in general, but they do not seem as complex as the overall society.

Snowden and Boone's (2007) Cynefin Framework includes simple, complicated, complex, and chaotic systems. Simple systems can be addressed with best practices. Complicated systems are the realm of experts. Complex systems represent the domain of emergence, as discussed in the following text. Finally, chaotic systems require rapid responses to stabilize potential negative consequences.

The key distinction with regard to the discussions in this book is complex versus complicated systems—simple certainly is not warranted and we hope to avoid chaotic. There is a tendency, Snowden and Boone contend, for experts in complicated systems to perceive that their expertise, methods, and tools are much more applicable to complex systems than is generally reasonable.

Poli (2013) also elaborates the distinctions between complicated and complex systems. Complicated systems can be structurally decomposed. Relationships can be identified, either by decomposition or in some cases via blueprints. "Complicated systems can be, at least in principle, fully understood and modeled." Complex systems, in contrast, cannot be completely understood or definitively modeled. He argues that biology and all the human and social sciences address complex systems.

Poli also notes that problems in complicated systems can, in principle, be solved. The blueprints, or equivalent, allow one to troubleshoot problems in complicated

systems. In contrast, problems in complex systems cannot be solved in the same way. Instead, problems can be influenced so that unacceptable situations are at least partially ameliorated.

These distinctions are well taken. Complicated systems have often been designed or engineered. There are plans and blueprints. There may be many humans in these systems, but they are typically playing prescribed roles. In contrast, complex systems, as they define them, typically emerge from years of practice and precedent. There are no plans and blueprints. Indeed, much research is often focused on figuring out how such systems work. Good examples are human biology and large cities.

COMPLEX ADAPTIVE SYSTEMS

The nature of human and social phenomena within complex systems is a central consideration. Systems where such phenomena play substantial roles are often considered to belong to a class of systems termed complex adaptive systems. This class of systems includes healthcare delivery (Rouse, 2000, 2008), urban systems (Rouse, 2015), and, as discussed in the following text, universities

Complex adaptive systems have the following characteristics:

- They tend to be **nonlinear, dynamic** and do not inherently reach fixed equilibrium points. The resulting system behaviors may appear to be random or chaotic
- They are composed of **independent agents** whose behaviors can be described as based on physical, psychological, or social rules rather than being completely dictated by the physical dynamics of the system
- Agents' needs or desires, reflected in their rules, are not homogeneous and, therefore, their **goals and behaviors are likely to differ or even conflict**—these conflicts or competitions tend to lead agents to adapt to each other's behaviors
- Agents are **intelligent and learn** as they experiment and gain experience, perhaps via "meta" rules, and consequently change behaviors. Thus, overall system properties inherently change over time
- Adaptation and learning tend to result in **self-organization** and patterns of behavior that emerge rather than having been designed into the system. The nature of such emergent behaviors may range from valuable innovations to unfortunate accidents
- There is **no single point(s) of control**—system behaviors are often unpredictable and uncontrollable, and no one is "in charge." Consequently, the behaviors of complex adaptive systems usually can be influenced more than they can be controlled

As summarized in Table 1.1, understanding and influencing systems having these characteristics creates significant complications. In general, leaders, who have more

TABLE 1.1 Implications of Complex Adaptive Systems

	Traditional System	Complex Adaptive System
Roles	Management	Leadership
Methods	Command and control	Incentives and inhibitions
Measurement	Activities	Outcomes
Focus	Efficiency	Agility
Relationships	Contractual	Personal commitments
Network	Hierarchy	Heterarchy
Design	Organizational design	Self-organization

influence than power, replace managers. These leaders craft incentives and inhibitions to influence behaviors—they cannot employ command and control. The goal is to influence outcomes because activities cannot be controlled and are often unobservable.

The focus is on organizational agility rather than efficiency. Highly efficient systems are usually very rigid and cannot effectively respond to changing incentives and inhibitions. Personal commitments from independent agents underlie relationships rather than contractual obligations due to the agents' independence. Heterarchical networks among agents provide the dominant social mechanism despite the typical existence of a nominal hierarchy.

Hierarchical organizations are usually designed in terms of roles, reporting structures, etc. Heterarchical systems are much more likely to self-organize. This is particularly true for organizations of professionals who also have strong affiliations with professional associations. A good example is physicians, whose professional affiliations have strongly driven the evolution of the healthcare system (Rouse & Cortese, 2010).

The characteristics summarized in Table 1.1 have significant impacts on how such organizational systems address fundamental change or transformation. The leaders cannot simply command change. Instead, change has to emerge organically in terms of agents' responses to new incentives and inhibitions. Transformation will emerge from agents' collective self-organization.

A useful construct in this regard is the notion of "tipping points," popularized by Gladwell (2000). Within the context of organizational transformation, the idea is that a small change can propagate and gain momentum across the heterarchical organizational network and lead to bottom-up discussions and desires for fundamental change. In other words, top-down "push" for change is replaced by bottom-up "pull" for change.

In healthcare, for example, there is a pending change from fee for service to payment for health outcomes (Rouse & Serban, 2014). While this is far from fully implemented, it has caused healthcare provider organizations to study carefully how they will need to adapt to such a fundamental change. More specifically, it has caused serious study of what does and does not affect health outcomes.

One approach to understanding possible tipping points involves mathematical and computational modeling of the enterprise (Rouse, 2015). These models can be useful

in the exploration of leading indicators of the different tipping points and in assessing potential ways to accelerate desirable outcomes as well as mitigations for undesirable outcomes. Such models can be embodied in interactive visualizations called "policy flight simulators" that enable stakeholders to computationally experiment with alternative futures (Rouse, 2014).

UNIVERSITIES AS COMPLEX ADAPTIVE SYSTEMS

The construct of complex adaptive systems can help to understand and enable fundamental change both within and across universities. As a first step in this direction, it is useful to discuss how the organizational phenomena discussed earlier are manifested in university environments.

Nonlinear, Dynamic Behavior

Linear behavior means a system responds proportionately to stimuli. Nonlinear behavior means disproportionate responses. University communities typically underrespond in the sense that, for the most part, they ignore stimuli. Faculty members tend to be oblivious to most things external to their specialty. Occasionally, they overrespond, for instance, to offhand comments by the administration that can be interpreted as being less than fully committed to some faculty initiative. A typical result is a barrage of emails from all corners of the community.

Independent Agents

Faculty members embrace academic freedom in a broad sense. This includes freedom in what they research and how they research it. Some faculty members simply go in their office, close the door, and immerse themselves in their scholarly pursuits. More broadly, faculty members feel free to openly oppose organizational endeavors. I have experienced many instances of faculty members investing significant energy to undermine initiatives of senior administrators. Occasionally cabals of faculty members emerge to support or oppose a cause.

Goals and Behaviors That Differ or Conflict

Faculty disagreements are common and occasionally heated. Disrespect across disciplines is a good example. A portion of the faculty will assert that the only fundamental research is that which involves axioms and theorems. A different portion of the faculty will assert that theory and experimentation are the essence of science. If these two groups are in the same academic department, there can be much conflict, for example, about requirements for the Ph.D. degree. I have occasionally defused such conflicts, at least temporarily, by noting that we not only need Newtons and Einsteins; we also need Darwins.

Intelligent and Learning Agents

Most faculty members were good students. They were bright, did their homework, and got top grades. Thus, they are intellectually intelligent, although not always emotionally intelligent. They learn how their university system works and they learn how to work the system to achieve their desired ends. Of course, as indicated earlier, there is seldom universal agreement on the ends. The result is a lot of smart, usually well-intended, people working at odds with each other. University administrators call this situation "herding cats." It often results in creative but hopefully not destructive chaos and substantially impedes progress.

Self-Organization

There are two types of organization of interest. As shown in Figure 1.1, there are colleges, schools, and departments that invest in processes to support practices. There are also self-organized interest groups within and sometimes across departments. In addition, as depicted in Figure 1.2, there are discipline-specific organizations across universities that, as discussed earlier, define research agendas and vet sources of funding and publication outlets. These groups self-organize independent of the hierarchies of the universities shown in Figure 1.1.

No Single Point(s) of Control

The president and board of trustees (or board of regents) are nominally in control of a university. They approve hiring, promoting, and tenuring of faculty members. They are the authority that grants degrees. They decide about operating and capital budgets. However, they have little control over the daily activities of the many independent agents in the university community. In this sense, the president has much more influence than power. If, for instance, a subset of the faculty disagrees with the president's vision for the university, they can drag their heels and wait until he or she leaves office.

Implications

Referring to Table 1.1, universities are better led than managed. The leadership needs to articulate and gain support for a vision of the university's future. They also need to create and sustain a set of incentives and inhibitions that motivate the independent agents to personally commit to pursuit of the vision. There need to be agreed-upon outcomes that successful pursuit of the vision will yield.

The organization needs to be sufficiently agile to pursue the vision and create the desired outcomes. Both the hierarchy and heterarchy need to be agile in the sense of having the orientation and resources needed to make the changes necessary to successfully pursue the vision. To some extent, the requisite agility can be designed into the organization. However, inclinations to self-organize can yield creative and highly effective modifications to any initial design.

OVERVIEW OF CHAPTERS

Chapter 1: Introduction and Overview

This chapter begins by providing a characterization of the overall architecture of a university enterprise and its relationship to other university enterprises. These diagrams provide a framework for discussing the overall approach of this book as contrasted with the enormous body of literature on higher education. The nature of complex enterprises is then considered, with emphasis on complex adaptive systems. The specific attributes of universities that reflect the characteristics of complex adaptive systems are elaborated. Finally, an overview of the book is provided.

Chapter 2: Evolution of the Research University

This chapter begins in Europe where universities as independent institutions first emerged almost 1000 years ago, followed by consideration of early universities in America. In the early nineteenth century, Wilhelm von Humboldt transformed German higher education by integrating teaching and research. This leads to discussion of the Morrill Land-Grant Acts in the United States that provided resources that enabled adoption of a version of the Humboldt model, with less hierarchy and more participation.

The central role of World War II in advancing science and engineering is next discussed. The war also prompted the recognition that engineering education needed stronger roots in science and mathematics. Pursuit of engineering science led to great advances but also sometimes led to overemphasis on mathematics and intense specialization. These tendencies have served as both strengths and weaknesses. The many challenges faced by today's research universities are discussed—they stem in part from these forces.

Chapter 3: Mission and Structure

This chapter begins by reviewing several university mission statements. They typically have much in common with regard to education, research, and service. A substantial problem in recent decades has been mission creep, whereby universities attempt to provide value in varying ways to different constituencies. This inevitably leads to greater costs, which are mostly recouped via tuition increases despite the fact that many of the new activities do not directly benefit those paying tuition.

This chapter next addresses the multilevel structure of universities. Education, research, and service practices occur in the context of processes that provide capabilities that enable practices. These capabilities are created via investments by departments, schools, colleges, and campuses. These investments are motivated by the "rules of the game" created and sustained by the overall ecosystem.

Finally, this chapter discusses how the traditional structure of universities does not align well with the mission and needs of interdisciplinary research centers. There are inherent conflicts between traditional discipline-oriented departments, schools, and colleges and the crosscutting nature of interdisciplinary research centers. This poses

challenges for faculty members who are attracted to larger problems but also want to be successful in securing tenure and promotions.

Chapter 4: Leadership and Governance

This chapter considers the role of leadership as enterprises seek to change, including the importance of how leaders spend their time. The negative impacts of stewards of the status quo are elaborated. Experiences of leading research centers are considered. Examples of good and bad leadership are discussed.

Governance is considered in terms of governing boards, administration and faculty, and other players. Numerous vignettes of governance are discussed. Decision making in universities clearly exhibits the characteristics of complex adaptive systems. Many independent agents influence the process and much time is typically consumed getting to a decision.

Chapter 5: Administration

This chapter addresses the nature of administration in terms of managing and sustaining a university. The corporatization of academia has resulted in enormous growth of the number of administrators and administrative staff and costs of these personnel. A relatively simple model is proposed for projecting these costs.

This chapter also considers several core administrative functions, including performance evaluation, conflict management, compliance and abuse, and marketing and communications. The costs of conforming to various administrative practices are discussed.

Chapter 6: Money and Space

This chapter addresses the economics of higher education, including the value of education, the impacts of government subsidies, and the possibilities of a higher education bubble. The costs of higher education are discussed in terms of cost analyses, indirect costs, staffing patterns, and student and institutional debt. Consideration of revenue sources includes discussion of tuition, government dependencies, and philanthropic fundraising. An overall economic model of a university is presented. Finally, the challenging issue of space is addressed.

Chapter 7: Promotion and Tenure

This chapter addresses the nature and process of promoting and tenuring university faculty members. The nature and roles of faculty are discussed in terms of academic disciplines, faculty impact, tenure-track versus nontenure-track positions, availability of positions, and faculty turnover. The nature of tenure decisions is explored. I relate my experiences serving on several promotion and tenure committees. Finally, a model of tenure decision making is introduced that is integrated into an overall model in Chapter 12.

Chapter 8: Education Programs

This chapter addresses the current and future student populations that higher education will serve. Both science, technology, engineering, and mathematics (STEM) challenges and evolving student inclinations and preferences are discussed. Challenges to higher education's value proposition are reviewed. Types of degree programs and the design and delivery of curricula and courses are considered, including alternative approaches to delivery. I relate a variety of my teaching experiences. Finally, a workforce model is introduced and a range of staffing trade-offs is discussed.

Chapter 9: Research and Intellectual Property

This chapter addresses the challenges of research in terms of the role of peer review of publications and proposals, bibliometrics associated with citations, and difficulties securing funding. A variety of research experiences are related. A model of research is presented that predicts probabilities of articles being accepted, expected citations after publication, and probabilities of research proposals being funded. This model is a central element of the integrated model discussed in Chapter 12.

The last major section of this chapter addresses intellectual property, which is often one of the outcomes of research. In some cases, this takes the form of patents, but more often it is embodied in the know-how of the researchers. Either form of intellectual property may result in spin-off businesses that create jobs, revenue, profit, and perhaps public stock offerings. I relate several of my experiences in launching and growing spin-offs.

Chapter 10: Rankings and Brand Value

This chapter addresses several ranking schemes that emphasize different attributes of a university. Georgia Tech is used as an example to illustrate the types of initiatives needed to improve rankings. Statistical analyses of rankings of one program—industrial/manufacturing/systems engineering—are reported. The best predictors of a program's ranking are last year's ranking plus the number of faculty.

The brand value of a university is discussed as a proxy for rankings. An index of brand value is presented that is a weighted sum of number of articles published, number of citations received, and *h*-index, totaled across all faculty members of an institution. An example is used to illustrate the nuances of the brand value index as affected by research sponsors and publication outlets chosen by faculty members.

Chapter 11: Transformation Scenarios

In this chapter, forces for change are discussed in terms of costs and benefits, globalization, and technology. Organizational change in higher education is then addressed, including concepts and principles drawn from domains other than higher education. Four alternative scenarios for the future of higher education are next elaborated. These

scenarios provide the basis for considering transformation of academia. The chapter concludes with a discussion of historical perspectives on how change happens. This sets the stage for exploring the future.

Chapter 12: Exploring the Future

This chapter brings together all the pieces of the puzzle elaborated in this book. The elements of the education and research enterprise are integrated to enable projecting the likely consequences of several rather disparate scenarios of the future of the academic enterprise. We cannot predict what mix of these scenarios will actually emerge. However, we can argue that universities need strategies and investments that enable robust responses to whatever mix emerges.

Fundamental change is in the offing. Higher education cannot remain the poster child for runaway costs. We need a healthy, educated, and productive population that is competitive in the global marketplace. If the population is not educated, it will not be healthy. If the population is not productive, it will not be competitive. The pieces all fit together. We have to make it happen.

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