Part III

Systems Decision Making

Chapter **9**

Systems Decision Process Overview

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> Decisions are easy, it's only the rationale that is difficult.
>
> —Anonymous

9.1 INTRODUCTION

As we noted in Chapter 1, systems are becoming more complex, dynamic, interconnected, and automated and face significant security challenges. As a result of these trends and the increasing involvement of stakeholders, private and public leaders are faced with difficult systems decisions. Our definition of a decision is an irrevocable allocation of resources [1]. Decision makers can change their mind, but there is a resource penalty associated with the change. For example, consider the purchase of a new car. The decision occurs when we sign the contract. If we change our mind in one month, we now have a used car. The value of the used car may be significantly lower than that of the new car. Systems decisions are very similar. We make the acquisition decision when we award a contract. If we have to cancel the contract in 1 month, there are resource penalties.

A decision is an irrevocable allocation of resources.

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In this chapter, we introduce the systems decision process (SDP) that has been developed by faculty members of the Systems Engineering Department at the United States Military Academy. The process has been applied to many military problems in all stages of the system life cycle. It is the systems engineering decision process that our seniors are expected to use for their capstone research projects. While we follow the process, we should tailor the process to the system, the stage of the system life cycle, and the problem under consideration. Shortly after graduation, our graduates will apply the process to operations and logistics problems they encounter in their military careers. Later on in their careers, they may have the opportunity to apply the process to the early stages of the system life cycle for complex systems design and development.

> The systems decision process is a general problem solving process. We need to tailor the process to the system, the decision, and the stage of the system life cycle.

We believe the process is broadly applicable in many systems engineering and engineering management domains. The systems decision process and the techniques used in the process have been applied in many private and public problem domains.

9.2 VALUE-FOCUSED VERSUS ALTERNATIVE-FOCUSED THINKING

The lead systems engineer guides the team in how it approaches the systems decision process. Two main philosophies dominate the approach strategies: *alternative-focused thinking* (AFT) and *value-focused thinking* (VFT), although hybrid strategies have been proposed. The systems decision process uses a VFT approach.

“Values are what we care about,” Keeney notes in *Value-Focused Thinking* [2]. “As such, values should be the driving force for our decision-making.” Values, he notes, are principles used for the evaluation of actual or potential consequences of action and inaction, of proposed alternatives, and of decisions. The VFT process differs from traditional alternative-focused thinking (AFT) in that a clear understanding of values drives the creation of alternatives, rather than the traditional approach in which alternatives are identified first. This process can be applied not only to externally generated events, or decision *problems*, but also to internally generated events, or decision *opportunities*.

The sequence of actions in VFT and AFT is shown in Figure 9.1 [2]. Columns 1 and 2 show that the major difference in reactive approaches under VFT and AFT is in the timing of when values are specified. By understanding the decision maker’s values before identifying alternatives, alternatives tailored for the decision context can be generated. Keeney contrasts this with the alternative-focused approach that first identifies alternatives and then uses values to choose from what is available.

The sequences shown to create decision opportunities enable more aggressive control of a situation. Column 3 is similar to Column 2 except that rather than

React to decision problem		Identify or create decision opportunity	
Alternative-focused	**Value-focused**		
1. Recognize a decision problem	1. Recognize a decision problem	1. Identify a decision opportunity	1. Specify values
2. Identify alternatives	2. Specify values	2. Specify values	2. Create a decision opportunity
3. Specify values	3. Create alternatives	3. Create alternatives	3. Create alternatives
4. Evaluate alternatives	4. Evaluate alternatives	4. Evaluate alternatives	4. Evaluate alternatives
5. Select an alternative	5. Select an alternative	5. Select an alternative	5. Select an alternative
Column 1	**Column 2**	**Column 3**	**Column 4**

Figure 9.1 Value-focused versus alternative-focused thinking sequences. (Adapted from [2].)

reacting to a problem, the decision maker is alert to opportunities. Keeney cites a situation in which a clothing manufacturer who observes fabric scraps identifies a decision opportunity and, by working through Steps 2 through 4, decides to open a new product line built from scrap material [2]. Decision opportunities can be created once strategic objectives and values are specified.

A conceptual model of the multicriteria decision problem structure from both perspectives is shown in Figure 9.2. This figure, adapted from Buchanan [3], shows the opposing approaches. Alternatives are defined here as courses of action that can be pursued and will have outcomes measured in terms of the criteria. The criteria reflect the values of the decision maker. Attributes are defined as the objectively measurable features of an alternative. This model separates the subjective from the

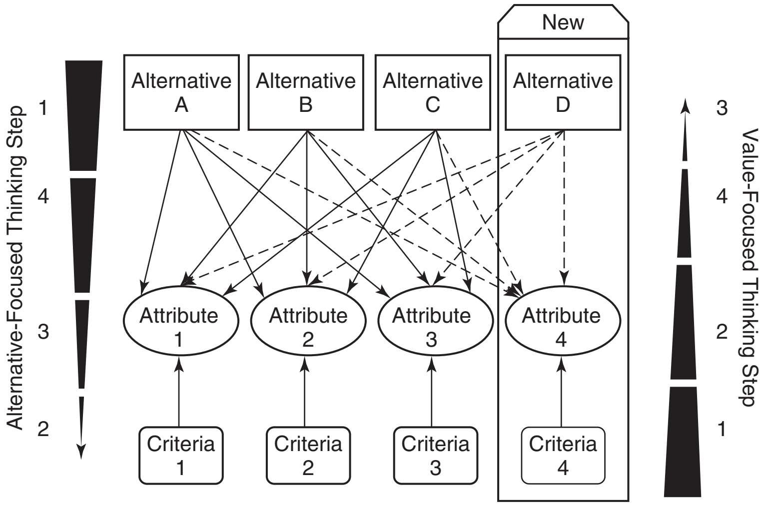

Figure 9.2 Flow of value-focused and alternative-focused thinking. (Adapted from [3].)

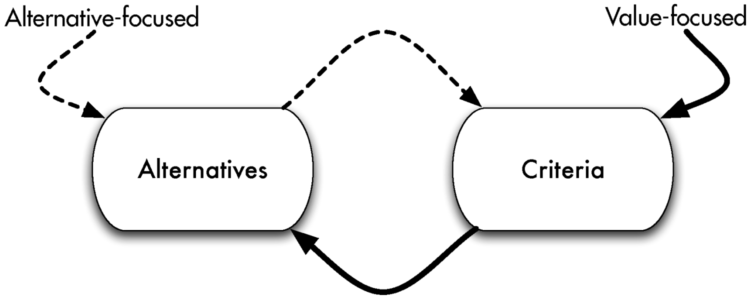

Figure 9.3 Dynamic approach to problem structuring [6].

objective components. The figure shows that the major difference of VFT is that is may result in additional criteria and new alternatives.

The greatest pitfall of a pure AFT approach is the danger of locking onto the list of alternatives and seeing only criteria that fit the alternatives while ignoring all others. Contrarily, a criticism of the VFT approach is that stakeholder values may not be sufficiently well formed in the early stages of the decision making process [4]. VFT is significantly different than AFT. First, the order is different. Second, VFT results in new criteria, new attributes, and new alternatives. Third, VFT changes the attribute ranges from local ranges to global ranges define by the existing alternatives defined by our values. Fourth, VFT takes additional effort to develop the value model, find new alternatives, and analyze the alternatives.

Finally, there is the chicken-or-egg dilemma that states that values are formed from experience with alternatives [5]. This leads some to argue that the starting point is not the issue. In their proposal for dynamic decision problem structuring, Corner, Buchanan, and Henig say, "What is important is that the decision maker learns about one (criteria or alternatives) from working with the other" [6]. Their concept is shown in Figure 9.3, where criteria and alternatives are shown as a causal loop, with entry through either an AFT (dashed line) or a VFT (solid line) approach. This suggests that by thinking about alternatives the solution designer helps identify criteria, and vice versa. This approach also recognizes the iterative nature of thinking about problems, so that both alternatives (or opportunities) and criteria can be refined during the problem definition and solution design phases.

9.3 DECISION QUALITY

Engineering managers and systems engineers need to make many decisions during the system life cycle. Since they face many complexities and significant uncertainties about the system and its environment, they should be concerned about the quality of their decisions. What makes a quality decision? Matheson and Matheson [7] used a chain illustration to identify the six elements of a quality decision for an R&D organization. Each link in the decision quality chain is important. Our systems decision process includes each of the six elements. In Figure 9.4, we identify

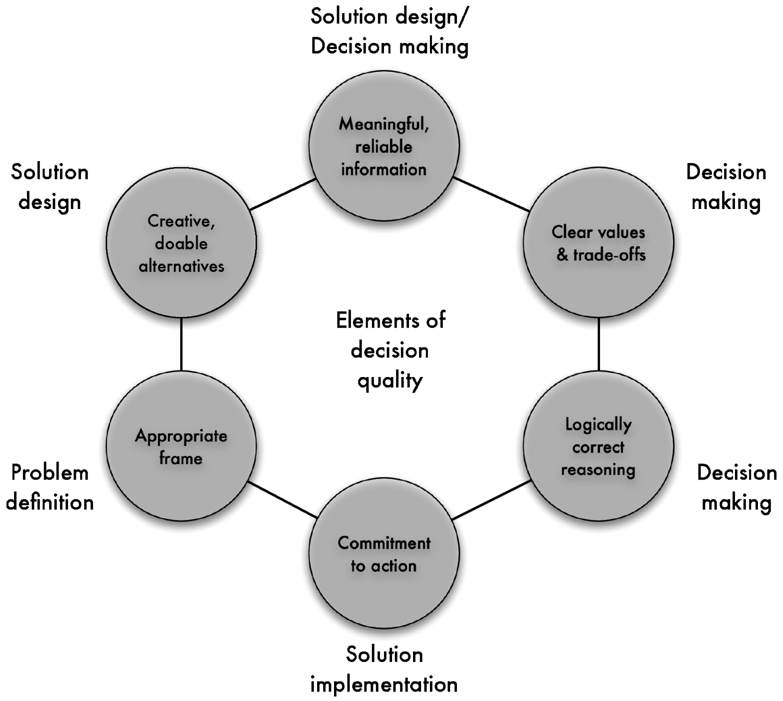

Figure 9.4 Elements of decision quality (the corresponding SDP phases are annotated in the diagram).

the systems decision process phases that address each element of decision quality. The following is a brief description of each link in the chain.

- *Appropriate Frame*. Our cognitive view of the problem must be appropriate to consider the full scope of the problem and all the needs of the stakeholders.
- *Creative, Doable Alternatives*. We want creative, feasible solutions that create value for the stakeholders and decision makers.
- *Meaningful, Realistic Data*. The data we use to generate and score candidate solutions must be understandable and credible.
- *Clear Values and Tradeoffs*. The values we use to generate and evaluate solutions must be defined and tradeoff analysis must be performed between system requirements, value measures, and resources.
- *Logically Correct Reasoning*. The mathematical techniques we use to evaluate alternatives must use a sound operations research technique. As stated in Chapter 1, the SDP uses multiple objective decision analysis (MODA) as its foundation for value tradeoffs.
- *Commitment to Action*. Finally, the decision maker(s) and stakeholders must be committed to solution implementation. Implementation barriers and risks must be identified and resolved.

9.4 SYSTEMS DECISION PROCESS

We first introduced our systems decision making process in Figure 1.7 of Chapter 1. We emphasized that the systems decision process can be applied in any stage of the system life cycle. We begin to describe further the systems decision process in this chapter. The SDP has four phases with three tasks in each phase. Chapters 10 through 13 describe many techniques to perform each task. The detailed explanation and illustration of each task will be described in the next four chapters.

The systems decision process can be tailored to any stage of the system life cycle.

The process has the following characteristics:

- Starts with efforts to understand the current system using systems thinking tools introduced in Chapter 2. The current system, or baseline, is the foundation for assessment of future needs and comparison with candidate solutions to meet those needs.
- Focuses on the decision maker and stakeholder value. Stakeholders and decision makers identify important functions, objectives, requirements (screening criteria that all potential solutions must meet), and constraints. The key stakeholders are the consumers of system products and services, the system owners, and the client responsible for the system acquisition.
- Focuses on creating value for decision makers and stakeholders and defines the desired end state that we are trying to achieve. The value modeling task of the problem definition phase plays an important role in defining the ideal solution for comparison with candidate solutions. The solution improvement task improves the alternative design solutions. Finally, we use value-focused thinking to improve the nondominated solutions.
- Has four phases (problem definition, solution design, decision making, and solution implementation) and is highly iterative based on information and feedback from stakeholders and decision makers.
- Explicitly considers the environment (historical, legal, social, cultural, technological, security, ecological, health & safety, and economic) that systems will operate within and the political, organizational, moral/ethical, and emotional issues that arise with stakeholders and decision makers in the environment.

Next, we discuss the symbolism of the SDP diagram. Although Figure 9.5 is not in color in the book here, we use colors to characterize each phase of the SDP. The colors selected have a symbolic meaning for system engineers and engineering managers.[1]

Problem Definition. Stop! Don't Just Do Something—Stand There! The most important task in any systems decision process is to identify and understand

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[1] The meanings of the colors were initially developed by one of our West Point colleagues, Daniel McCarthy.

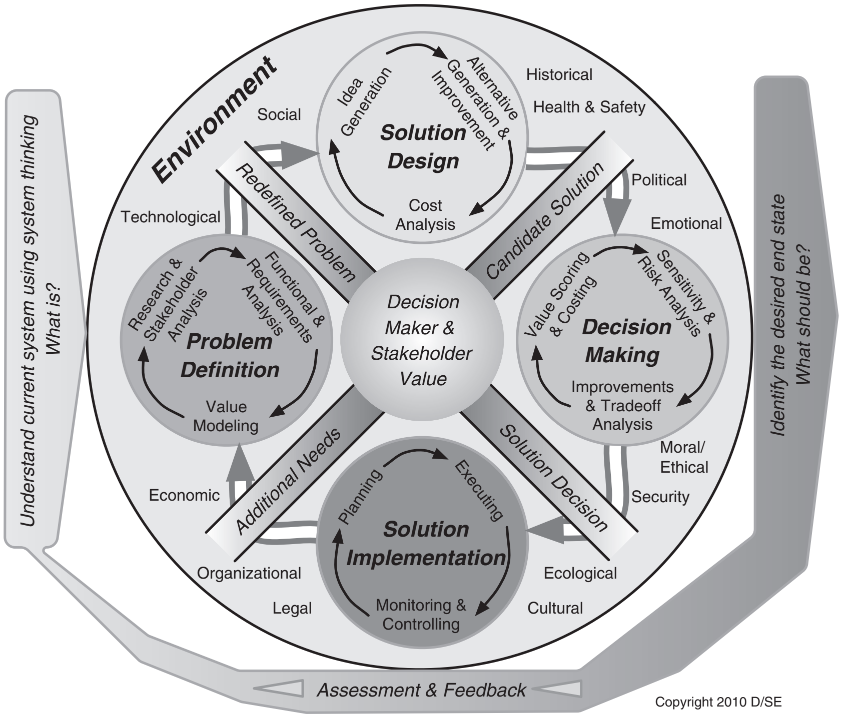

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Figure 9.5 Systems decision process.

the problem which is informed by understanding the concerns, objectives, and constraints of the decision makers and stakeholders. If we fail to identify and fully understand the right problem, we may end up expending a lot of time and energy creating a great system solution that solves the wrong problem. For this very reason, in the graphical depiction of the SDP we represent the Problem Definition phase with a **RED** circle to remind ourselves to **STOP!** and make sure we have a clear understanding of the problem before we try to design a solution.

Solution Design. Proceed with Caution! Having developed a clear understanding of the problem during the Problem Definition phase of the SDP, we can now go about the business of finding a system solution to the problem. However, we must avoid the temptation to select a solution too quickly. Perhaps we have "seen this problem before" and might "know the answer." Depicting the Solution Design phase with a **YELLOW** circle reminds us to **Proceed with Caution!** We should treat each problem with a fresh perspective and give due diligence by developing new ideas and generating and improving alternative solutions to the problem.

Decision Making. Green Light—Go! During the Decision-Making phase of the SDP, we take the information we have gathered in the previous phases of the SDP to prepare and make a recommendation to our clients seeking their approval of a system solution. We depict the Decision-Making phase with a **GREEN** circle to represent the **Green Light** we are hoping to get from our client to proceed with implementing the solution.

Solution Implementation. Once we have secured a decision from our client, we turn our attention to implementing the system solution. We represent the Solution Implementation phase of the SDP with a **BLUE** circle representing the **Blue Skies and Smooth Sailing** we hope to encounter while implementing our system solution. Unfortunately, as we will learn in Chapter 13, solution implementation is one of the most challenging phases of the SDP. In fact, since we can expect smooth sailing **once in a blue moon**, an alternative color choice might be **Black and Blue**!

Decision maker and stakeholder value are placed in the center of the SDP to remind us that we must continually focus on the value the system solution will provide them. The four spokes (defined problem, candidate solutions, solution decision, and additional needs) represent major outputs of each phase that are approved by the decision makers and stakeholders. The cradle and arrows in the SDP indicate the iterative nature of the process. Iteration takes place both between phases and within the tasks defining each phase.

9.5 ROLE OF STAKEHOLDERS

Stakeholder involvement is critical to the success of the systems decision process. Stakeholders ensure that we have the appropriate frame for our decision, and they help us obtain reliable and credible information; their early involvement is essential for their commitment to action necessary to implement the decision. Without stakeholder involvement, decisions will not be sustainable and stakeholders may force costly decision changes. Stakeholders have important roles in each phase of the systems decision process.

> Decision-maker and stakeholder involvement is critical to the success of the systems decision process.

Problem Definition. Conducting research is a key activity for identifying potential system stakeholders. Stakeholders provide information about the environment that helps frame the problem and accurately specify the problem statement. They help identify the system objectives and the requirements. They provide insights to help identify the constraints and functions. Finally, they validate the value model and the final problem statement.

Solution Design. Stakeholders participate in the solution design, assessment, and testing. They attend design reviews and provide comments on design solutions. They continue to identify constraints and requirements. They participate in spiral development processes by evaluating each prototype solution. Finally, they participate in test and evaluation programs. Stakeholders help identify the cost elements used in system cost analysis to ensure that the alternatives will be affordable.

Decision Making. Stakeholders are involved in the value scoring and costing of candidate solutions. They provide the operational data, test data, models, simulation, and experts to obtain the scoring data. They participate in interim reviews and final decision presentations.

Solution Implementation. Stakeholders are critical to solution implementation. They help identify the solution implementation plan, tasks, and controls. All tasks in this phase require stakeholder commitment to action.

9.6 ROLE OF DECISION MAKERS

The systems decision process exists to support systems decision makers. For technology based systems, the decision maker may be the project/program manager or the engineering manager of the organization. For complex systems decisions the decision maker may be an operational manager, a functional manager, the chief technology officer, the chief information officer, or even the chief executive officer. Interaction with the decision maker(s) occurs in each phase of the systems decision process. Decision makers approve the resources to perform the systems decision process. Decision makers should "inspect what they expect" [8]. The best practice is periodic interim progress reviews during each phase in the systems decision process.

> Systems engineers must communicate with decision makers and stakeholders. Decision makers should inspect what they expect.

Problem Definition. The SDP usually begins with a planned decision milestone in the system life cycle or a decision maker identifying a problem or opportunity requiring a decision. Not making a decision is also a decision. The decision maker should approve the list of stakeholders for stakeholder analysis, the functional and requirements analyses, the value model, and the final problem statement.

Solution Design. The decision maker should review the alternatives being considered and approve the candidate solutions that will be evaluated in the decision making phase. The decision maker should ensure that the alternative improvements have been considered and that cost analysis has been performed in the design process.

Decision Making. This is a major phase for decision-maker interaction. They participate in interim reviews and final decision presentations. Decision makers select the solution to implement. If required, they participate in decision reviews in their own or other organizations. Decision makers review the candidate solution value, cost, sensitivity analysis, and risk analysis. They also decide if more improvements are needed and make the difficult value versus cost tradeoff decision among the efficient solutions.

Solution Implementation. Decision makers must ensure stakeholder participation in the implementation phase, provide the implementation resources, and approve the implementation plan. They may also monitor the execution of the plan and take control actions as required to meet the performance, schedule, and cost goals.

9.7 ENVIRONMENT

During the systems decision process we must consider many factors that may affect the systems decision process and the environment that the system will operate in during its life cycle. We call all these factors the SDP environment. The factors we show on the SDP diagram and describe below are meant to be illustrative and not exhaustive. These factors are identified using the system thinking techniques described in Chapter 2. We briefly discuss some of the major environment issues that should be considered in the systems decision process.

Technological. System elements use technologies to perform functions for consumers and users. Some technologies are developed and available. New technologies may involve technical, cost, and schedule risks for the system. In addition, the consequences of technologies—for example, the health consequences of asbestos or the environmental impact of gasoline—are not always understood. A major system failure can delay a system for many years, as witnessed in the Challenger spacecraft failure.

Economic. Economic factors are almost always a major systems decision issue. Most program managers have a budget to manage. Stakeholders are concerned about the economic impact of the new system on their budgets. For example, design changes to the airline security system have dramatically impacted many government and commercial organizations.

Political. Political factors come into play for many systems decisions. Many stakeholder groups (e.g., lobby groups) exist to impact systems decisions by private or public organizations. Many public decisions require approval by U.S. government agencies and/or Congress. Press coverage can make any system a major political issue—for example, the space shuttle after the Challenger disaster.

Legal. Systems must comply with federal, state, and community legal requirements. For example, automobiles must meet federal safety and emissions standards and also state regulations.

Health & Safety. The impact of the system on the health and safety of system stakeholders are important considerations in all stages of the system life cycle. Health and safety issues can result in injury and death to system users, consumers, and affected stakeholders. Systems thinking and risk analysis are important tools to identify and mitigate potential health and safety issues.

Social. Systems can have social implications. For example, information technology (IT) systems have significantly changed how we work and how we interact with our family, friends, and associates.

Security. Systems must be secure. System owners, users, and consumers want to be sure that their system and their products and services are secure against potential threats. There are several security dimensions: Physical security and information security are very important issues for system designers.

Ecological. Systems can have significant consequences on all elements of the ecology. For example, the nuclear weapons and nuclear power industries have generated a significant amount of radioactive waste that must be properly processed and safeguarded to minimize the ecological impact.

Cultural. Many systems and products are designed for national cultural groups and international customers. System designers must consider cultural factors in their design and marketing, especially if they develop products and services for international markets with diverse customers. Cultural considerations also arise when an organization is faced with adapting to meet new challenges and desires to retain a set of cultural characteristics that define who they are or how they operate.

Historical. Some systems impact historical issues. Most states have historical preservation societies that are interested in changes that impact historical landmarks and facilities. These organizations can impact system designs and can delay solution implementation.

Moral/ethical. Many times moral or ethical issues arise in systems decisions. For example, there are privacy issues associated with information technology solutions. Also, the use of certain weapons systems (e.g., chemical, biological, or nuclear) is a moral issue to many stakeholders.

Organizational. Decisions are made within organizations. The key formal and informal organizational leaders can be important stakeholders in the decision process. Stakeholder analysis is the key to identifying and resolving organizational issues.

Emotional. Sometimes decision makers or key stakeholders have personal preferences or emotional issues about some systems or potential system solutions. For example, nuclear power is an emotional issue for some stakeholders. Systems engineers must identify and deal with these issues.

Our list of considerations in the system environment has several uses. Once we have defined the system boundary, the above list can be used as a system thinking tool to identify metasystems. It also provides a useful checklist when beginning the process of identifying research areas and stakeholders during the Problem Definition phase of the SDP.

9.8 COMPARISON WITH OTHER PROCESSES

There are other decision processes. Table 9.1 compares our systems decision process with two other problem solving processes. Both of these problem solving processes are similar to the SDP. Athey's systematic systems approach is more general. The

TABLE 9.1 Comparison of Problem-Solving Processes

Systems Decision Process	Athey's Systematic Systems Approach	Military Decision-Making Process
1. Problem definition (a) Research & stakeholder analysis (b) Functional & requirements analyses (c) Value modeling 2. Design solution (a) Idea generation (b) Alternative generation & improvement (c) Cost analysis 3. Decision making (a) Value scoring & costing (b) Sensitivity & risk analyses (c) Improvements & tradeoff analysis 4. Solution implementation (a) Planning (b) Executing (c) Monitoring and controlling	1. Formulate the problem 2. Gather and evaluate information 3. Develop potential solutions 4. Evaluate workable solutions 5. Decide the best solution 6. Communicate system solution 7. Implement solution 8. Establish performance standards	1. Receipt of mission 2. Mission analysis 3. Course of action (COA) development 4. COA analysis 5. COA comparison 6. COA approval 7. Orders production 8. Rehearsal 9. Execution and assessment

SDP provides more detail about the types of steps. The military decisions process focuses on a course of action instead of a system.

9.9 WHEN TO USE THE SYSTEMS DECISION PROCESS

The systems decision process we define in this book has broad applicability for systems engineers to many systems in all system life cycle stages. In addition, since the process is very general and grounded in sound principles, it may be useful for problem solving in domains when no one has been given the title "systems engineer." In some decision applications, only one or more of the tasks may be required. For example, the stakeholder analysis techniques can be used to help define the problem in any public or private decision setting. In this section, we provide some guidance on when to use the systems decision process and when it may not be appropriate.

When considering whether or not to use the systems decision process, the engineering manager and lead systems engineer should consider three criteria: need, resources, and consequences.

TABLE 9.2 Criteria for When to Use Each Task in the Systems Decision Process

Phase	Task	When Needed	When Not Needed
Problem definition	Research and stakeholder analysis	Many research areas and multiple decision makers and stakeholders with conflicting views about the system and system life cycle.	Single decision maker and known stakeholder views.
	Functional and requirements analyses	System functions and requirements not defined and are critical to system success.	System functions and requirements defined or not applicable.
	Value modeling	System objectives and value measures not defined.	Clear objectives and value measures are known.
Solution design	Idea generation	Concern about the quantity or quality of alternatives.	Several high value alternatives are known or an established model or process is available to develop high value alternatives.
	Alternative generation and improvement	Alternatives must be designed to ensure they perform system functions.	Solution design is complete or simple to complete.
		Alternatives need improvements to achieve the desired value.	Solution optimization techniques are already available.
	Cost analysis	Resources and costs are significant drivers for the decision	Costs and resources are not significant decision drivers.
Decision making	Solution scoring and costing	Solution performance and costs are unknown.	Solution performance and costs are known or not applicable.
	Sensitivity and risk analyses	Important to understand the most sensitive assumptions or parameters and to assess the key risks.	Impact of assumptions and risks are already known or not important.
	Improvements and tradeoff analysis	Opportunity to improve the solution. Tradeoffs must be made between efficient solutions.	Ideal solution is known or no opportunity to improve the solution.

(*continued*)

TABLE 9.2 (*Continued*)

Phase	Task	When Needed	When Not Needed
Solution implementation	Planning	Many complex tasks, significant resources, and many participants.	Simple tasks, few resources, and few participants.
	Executing	Critical to success of the decision.	Not required or not critical to decision success.
	Monitoring and controlling	Schedule and resource usage are important.	No management oversight is required.

TABLE 9.3 Systems Decision Process Example

Phase	Task	Army BRAC [9]
Problem definition	Research and stakeholder analysis	Many senior leader interviews and document reviews.
	Functional and requirements analyses	Requirements analysis used to develop installation portfolio constraints.
	Value modeling	Used for the ranking of installations and the evaluation of alternatives
Solution design	Idea generation	Performed by subject matter experts informed by modeling.
	Alternative generation and improvement	Developed by mission and functional experts
	Cost analysis	Used many cost models in the analysis process.
Decision making	Solution scoring and costing	Scoring data submitted and certified by each Army installation.
	Sensitivity and risk analyses	Significant sensitivity analysis at all parts of the process.
	Improvements and tradeoff analysis	The value was to transform Army installations and save operations and support funds. Solutions were improved after analysis.
Solution implementation	Planning	Performed by BRAC division on the Army staff.
	Executing	Will be performed by major commands and the Installation Management Command.
	Monitoring and controlling	Critical since execution is monitored by the U.S. Government Accountability Office and U.S. Congress.

9.9.1 Need

The systems decision process is needed if several of the tasks meet the criteria listed in Table 9.3 for each of the four phases.

9.9.2 Resources

If the systems decision process meets the criteria stated in Table 9.3, we next consider resources. The time any systems decision process takes to analyze systems engineering data and provide reports and presentations to senior decision makers can be significant for large, complex systems. The full process we describe in this book takes time and resources. The amount of time spent on systems decision making should be proportional to the type of system and the potential consequences of the decision to the decision makers and stakeholders. The decision to select the airplane design for the next Boeing commercial airliner should require more systems decision process resources than the design of the next Sunbeam coffee maker. The consequences of the next commercial airliner design may be much more significant to the future of Boeing (including its decision makers and stakeholders) and our national economy than the next coffee maker is to the future of Sunbeam. Our process requires access to senior leaders, decision makers, stakeholders, and subject matter experts. There may be costs for developing tools to enable the process—for example, functional analysis, systems models, simulations, and life cycle cost models. In addition, depending on the experience level of the systems engineering team, there may be costs for education and training.

9.9.3 Decision Maker and Stakeholder Support

Given that the systems decision process is needed and the potential resources are reasonable for the consequences of the systems decision, the final question is the support of decision makers and stakeholders. If the senior decision makers do not support the process, the resources (people and funds) will not be available to implement the process. If the decision makers and stakeholders do not participate in the process, the recommendations will not be accepted. The use of the SDP requires the support and participation of decision makers and stakeholders.

9.10 TAILORING THE SYSTEMS DECISION PROCESS

The systems decision process can be applied in any stage in the system life cycle for a system program or project.

> The systems decision process can be tailored to any stage of the system life cycle.

The process we have introduced in this chapter will be defined and described in detail in the next four chapters. For each phase, one or more techniques will be described to perform each task. For example, in Chapter 10, we describe three stakeholder analysis techniques: interviews, focus groups, and surveys. For large, complex systems engineering projects all phases and at least one technique for all tasks may be required. However, for many systems engineering projects, the process must be tailored to the systems engineering project and the stage of the system life cycle. Some phases or tasks may not be required.

As a first task in the tailoring process, we begin by considering when to use each task in each phase of the systems decision process. Table 9.2 lists criteria for the lead systems engineer to use to decide if a task is needed or not needed. Consider the first task, research and stakeholder analysis. The key criteria are the number of decision makers and our knowledge about the stakeholders' views. If there is a single decision maker and known stakeholder views, then the stakeholder analysis task may not be needed. However, if there are many decision makers and stakeholders with unknown or conflicting views of the system or the system life cycle, stakeholder analysis will be critical to the success of the systems engineering project. The engineering manager and lead systems engineer will clearly need to think about which techniques (i.e., interviews, focus groups, and surveys) are most appropriate for stakeholder analysis and may use multiple techniques. For intermediate situations when there are several decision makers and some stakeholders with conflicting views, the lead systems engineer will need to determine the appropriate stakeholder analysis technique. Chapters 10 through 13 provide additional information about how to tailor the process to the system life cycle including how to tailor techniques to the systems engineering project.

9.11 EXAMPLE USE OF THE SYSTEMS DECISION PROCESS

Table 9.3 lists an example of a systems engineering project that used a systems decision process similar to the process described in this book. For each task, we describe how the task was performed in the project. In some cases, the phases or tasks were not done or done after the systems engineering project by another group of people. For example, the Army Base Realignment and Closure (BRAC) study was done by the Army Basing Study team in 2002–2005. The solution implementation phase is being performed in 2005–2015 by the Army's Installation Management Command.

9.12 ILLUSTRATIVE EXAMPLE: SYSTEMS ENGINEERING CURRICULUM MANAGEMENT SYSTEM (CMS)—SUMMARY AND INTRODUCTION

This chapter introduced the four-phase systems decision process that we will develop in the next chapters of the book. Each phase includes a set of tasks to accomplish to successfully complete the phase, and several alternative techniques with which to perform each task.

- Chapter 10 describes the problem definition phase.

- Chapter 11 describes the solution design phase.
- Chapter 12 describes the decision-making phase.
- Chapter 13 describes the solution implementation phase.

Throughout this chapter, we have emphasized several themes. First, we have compared value-focused with alternative-focused alternative generation. Second, we have defined the characteristics of a good systems decision. Third, we have described the critical role of decision makers and stakeholders and the system environment. Fourth, we have discussed the criteria that can be used to assess if the systems decision process is appropriate for a systems decision. Fifth, we have emphasized that the systems decision process can be used for any stage of the system life cycle. Finally, we have emphasized that the process must be tailored to the systems engineering project and the system life cycle stage.

As we explore the systems decision process, we will use a rocket design problem to provide examples of the techniques. In addition, we have an illustrative example, the curriculum management system, which we will introduce next and then develop in the final section of each of the next four chapters. We hope that this illustrative example helps to explain the tasks in each phase and shows the relationships between each of the phases. We will usually illustrate the use of at least one technique for each task.

ILLUSTRATIVE EXAMPLE: PART I, THE OPPORTUNITY

Robert Kewley, Ph.D. U.S. Military Academy

Teaching undergraduate systems engineering disciplines to cadets is the core function of the United States Military Academy's Department of Systems Engineering. Teaching includes building and managing the curriculum, delivery of that curriculum to the cadets, and continuously assessing and adjusting that curriculum to maintain excellence. The department has processes in place for curriculum management, but they can be labor-intensive, slow, and disjointed. Given the proliferation of information technology into education, there may be an opportunity for the department to leverage information technology to improve its capability to manage the curriculum and to teach cadets.

The department has a complex, evolving curriculum that must be synchronized across four academic programs in accordance with Academy education goals and accreditation requirements. Advances in systems engineering, engineering management, systems management, and operations research require continuous curriculum changes at all levels. These include program goal updates, course additions or deletions, textbook changes, and lesson changes. Any one of these changes has the potential to disrupt the synchronization an academic program in a number of ways. They can jeopardize achievement of

Academy or program goals, force cadets to use multiple texts for the same material, present duplicate material, or present material out of order from the students' perspective.

Currently, the department and the Academy prevent some of these problems through centralization and committee work. However, these processes are slow and laborious, and they do not support frequent lesson-level changes that should be synchronized across one or two courses. These low-level changes often occur outside of the purview of academic committees, but, over time, they have just as much potential to disrupt synchronization. The department's curriculum development process stands to improve flexibility and synchronization through the application of information management and decision support.

Teaching, by its nature, is a collaborative process. Instructors must develop and deliver content by a combination of textbook reading and problem assignments, in-class instruction, electronic files, and graded events. Ideally, these are well organized and stored in a structured manner that supports easy access by cadets and instructors and consistency across courses.

In reality, the department employs a variety of methods to manage the curriculum. These include:

- Network drive storage for cadet access
- Network drive storage for faculty access
- Course Web sites maintained by faculty
- Academy-wide collaboration system to support teaching.

The Problem

Each faculty member selects the method or combination of methods to use based on his or her preferences. While this is not a problem within the context of a single course, it creates difficulties for cadets with multiple courses or for instructors who must collaborate across courses. People often cannot find needed information without directly contacting its originator. As a result, collaborative opportunities are lost, and the curriculum becomes disjointed. This also complicates archiving course information at the end of the semester.

Finally, the department faculty assesses and updates the curriculum at regular intervals. These assessments ensure responsiveness to a dynamic world, maintain accreditation, support educational goals, and improve teaching methods. Because they are so data-intensive, the assessments require many man-hours to compile the necessary information. The input data is scattered across many systems:

- Cadet surveys

- Instructor assessments
- Course administrative documents
- External assessment reports
- Meeting notes
- Various internal and external Web sites

The department has an opportunity to use a structured information system and well-synchronized processes to streamline and improve the assessment process. This will ensure the curriculum remains current and responsive to its stakeholders.

The Opportunity

In order to better build and manage the curriculum, deliver material to cadets, and continuously assess against dynamic demands, the Department of Systems Engineering proposes to build an integrated Curriculum Management System (CMS). This system will seek to synchronize advanced information technology with internal management processes in order to provide leap-ahead improvements.

Because this system is a new system, the decision we will illustrate in this book is the system concept decision from the second stage in the system life cycle (see Figure 3.1). That decision requires commitment of resources. The department will choose to buy (or not buy) system development software and hire (or not hire) people to do system design and development. Illustrative sections at the end of each of the succeeding four chapters will illustrate how the department employed techniques in each phase of the systems decision process to arrive at a system concept that best supports the department's stakeholders and their values.

9.13 EXERCISES

9.1. What is the definition of a decision? Using this definition, explain how the purchase of an automobile fits this definition.

9.2. What are the six links in the decision quality chain? Which is the most important link from a systems engineering perspective? Why is the analogy of a chain used?

9.3. Describe the four phases of the SDP. What are the tasks performed in each phase? What is the role of the systems engineer in each phase?

9.4. What is the relationship between the SDP and the system life cycle?

9.5. Describe the roles of stakeholders during each phase of the SDP. Are these roles the same for active and passive stakeholders? Explain.

9.6. Describe the roles of decision makers in each phase of the SDP. Give an example of a system in which the decision maker is simultaneously the owner, a user, and consumer.

9.7. Describe the impact of each SDP environmental factor on each of the following systems decision problems.

- **(a)** A decision by an automobile company to build a car an electric car. Would the the life cycle cost profile of an electric car be the same as a gasoline powered car? Explain.
- **(b)** A coastal U.S. state deciding to allow off-shore oil drilling. Would the impact you propose change if the supply of oil in the United States reached a critically low level? Explain.
- **(c)** The decision to adopt a law requiring all U.S. citizens to possess private health insurance. Define the system boundary you are working with. What type of stakeholder would you classify a lobbyist as? What is their relationship to the system?
- **(d)** The decision by a school board to remove carbonated soft drinks with sugar from the cafeteria menu. Draw a concept map that illustrates the relationship between the following objects: school board, students, soft drink companies, local schools, parents of students, local stores.
- **(e)** The decision by a young person to engage in a dangerous lifestyle (pick one). Describe how this person can be defined as a system. Identify an appropriate metasystem and at least one lateral system for this decision problem.

9.8. Compare the SDP to one of the other decision making processes in Table 9.3. What are the similarities and differences?

9.9. What types of systems decision problems require the full SDP? Explain and give three examples.

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The SDP is a refinement of the Systems Engineering and Management Process developed by Dr. Daniel McCarthy of the United States Military Academy faculty.

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