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levels of complexities than the 7 MP tools. In addition to solutions facilitated by EC, we will also illustrate two known approximations to AHP solutions using manual calculations. Manual calculations can be used to solve relatively less-intricate problems. We therefore emphasize EC as an important companion to AHP.

Our interest in AHP goes beyond prioritization. AHP has a wide range of applications as a multiobjective decision technique in which qualitative factors are present along with quantitative factors or are dominant. AHP has an important application in Quality Function Deployment (QFD), as discussed in the short cut “Understanding Customer Needs: Software QFD and the Voice of the Customer,” also available at <http://www.prenhallprofessional.com/title/013235134X>. AHP lets you structure complexity and measure and synthesize it. It uses ratio scale measures that can be meaningfully synthesized to arrive at not only a ranking of alternatives, but assign true proportions that can be used to optimally allocate resources. AHP has a variety of applications in economics, business, agriculture, engineering, social sciences, politics, and numerous other fields. In software development it can be used for decision-making in various phases of the software development process, from

requirements development to design to review, test, and evaluation to maintenance and decommissioning, involving situations with multiple objectives.

AHP is essentially a theory of measurement and decision making developed by Thomas L. Saaty when he was at the Wharton School of the University of Pennsylvania. The real value of AHP lies in its ability to combine, or synthesize, quantitative as well as qualitative considerations in an overall evaluation of alternatives. As such, it can be especially applicable when you evaluate complex system designs involving software, hardware, and humanware that can easily include hundreds of system quality indicators.<sup>2</sup> AHP has emerged as a powerful technique for determining relative worth and ranking among a set of elements. You can use it to make design, evaluation, and benefit/cost or optimal resource allocation decisions throughout the software development process.

## **Multiobjective Decision-Making and AHP**

Software development includes numerous situations involving multiple factors, criteria/objective, and

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metrics. Depending on size, complexity, and level of analysis, there could be dozens of quality characteristics. Our definition of trustworthy software contains five major customer requirements: reliability, safety, security, maintainability, and customer responsiveness. Each of these comprises several quality characteristics at various levels of analysis. Add to this the cost and schedule requirements, and we have a high degree of problem intricacy from decision and design perspectives. Figure 1 illustrates this point: Just two customer-demanded quality characteristics, maintainability and usability, result in 15 characteristics from the developer's perspective. Furthermore, quality metrics based on these characteristics would result in dozens of characteristics. The Walter and McCall Model identifies (at a minimum) a three-level hierarchy in quality characteristics:<sup>3</sup>

- ▶ The first level includes quality characteristics from the perspective of users. These are called *factors*.
- ▶ The second level comprises quality characteristics from the perspective of developers. These are called *criteria*.
- ▶ The third level includes quality characteristics that are further deployments of criteria to a level

where qualities can be measured. These are called *metrics*.

Figure 1 illustrates just the simplest hierarchy of software quality characteristics. It is not uncommon to have subcriteria and sub-subcriteria in large and complex software. Given the complexity caused by a large number of variables, intuitive decision making is insufficient to make the best design choices. Littlewood and Strigini articulate the challenges of software complexity:<sup>4</sup>

Great complexity brings many dangers. One of the greatest is difficulty of understanding: it is common to have systems that no single person can claim to understand completely, even at a fairly high level of abstraction. This produces uncertainty about the properties of the program—particularly its reliability and safety.

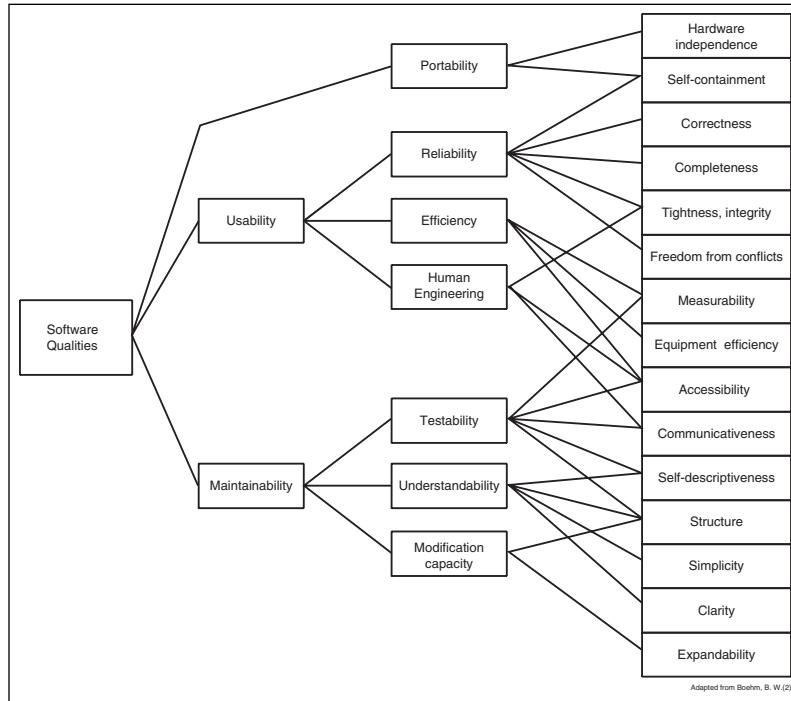
Managing complexity remains a critical design challenge, especially in a large software development process. This can be addressed by a two-pronged strategy:

- ▶ Deploy a strategy for minimizing complexity.
- ▶ Use AHP as a decision tool in a complex multiple-objective decision environment. This can be done throughout a software development process that involves both quantitative data and qualitative

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judgments, beginning with the requirements development phase through decommissioning, wherever software complexity is an issue.



**FIGURE 1** Hierarchical Structure of Software Product Quality Characteristics

The Gartner Group offers a line of Decision Engine Products,<sup>5</sup> as well as a best practice for technology selection called Refined Hierarchical Analysis. They are based on AHP and Expert Choice (EC), a computerized implementation of AHP and extensions to AHP.

This short cut uses a relatively simple decision situation (Case Study 1) to describe the application of AHP as a practical decision theory and then illustrates the use of Expert Choice.

## Terminology

The terminology used in decision-making can be confusing, as evidenced by terms such as *factors*, *characteristics*, *attributes*, *criteria*, *objectives*, *requirements*, *pros*, *cons*, *metrics*, *musts*, and *wants*. The formal decision making literature includes three different descriptions of what some might consider the same endeavor:

- ▶ Multiattribute decision making
- ▶ Multicriteria decision making
- ▶ Multiobjective decision making

Although some subtle differences exist, they are mostly historical and academic in nature and serve to confuse