as avoiding projects that might overly congest a high-traffic area (see figure) or properly sequencing subprojects such as grading, surfacing, and finishing.

The PMSS system gives management a "big picture" perspective of what is happening in terms of workflow over time and geography. It has also enhanced the department's ability to answer questions about activities, funding, labor, and equipment, and to present reports in a variety of configurations to satisfy the needs of many different parties.

Source: R. Pearson, "Project Management in the Minnesota Department of Transportation," *PM Network,* November 1988.

6.2 SYSTEMS INTEGRATION

Systems integration (sometimes called *systems engineering* or *concurrent engineering*) is one part of *integration management*, discussed further in Section 6.5, and plays a crucial role in the performance aspect of the project. We are using this phrase to include any technical specialist in the science or art of the project who is capable of integrating the technical disciplines to achieve the customer's objectives, and/or integrating the project into the customer's system. As such, systems integration is concerned with three major objectives.

1. *Performance* Performance is what a system does. It includes system design, reliability, quality, maintainability, and repairability. Obviously, these are not separate, independent elements of the system, but are highly interrelated qualities. Any of these system performance characteristics are subject to overdesign as well as underdesign but must fall within the design parameters established by the client. If the client approves, we may give the client more than the specifications require simply because we have already designed to some capability, and giving the client an overdesigned system is faster and less expensive than delivering precisely to specification. At times, the aesthetic qualities of a system may be specified, typically through a requirement that the appearance of the system must be acceptable to the client.
2. *Effectiveness* The objective is to design the individual components of a system to achieve the desired performance. This is accomplished through the following guidelines:
   - Require no component performance specifications unless necessary to meet one or more systems requirements.
   - Every component requirement should be traceable to one or more systems requirements.
   - Design components for effective system performance, not the performance of subsystems.

   It is not unusual for clients or project teams to violate any or all of these seemingly logical dicta. Tolerances specified to far closer limits than any possible system requirement, superfluous "bells and whistles," and "off the shelf" components that do not work well with the rest of the system are so common they seem to be taken for granted by both client and vendor. The causes of these strange occurrences are probably associated with some combination of inherent distrust between buyer and seller, the desire to overspecify in order "to be sure," and the feeling that "this part will do just as well." As we saw in Chapter 4, these attitudes can be softened and replaced with others that are more helpful to the process of systems integration.

3. *Cost* Systems integration considers cost to be a design parameter, and costs can be accumulated in several areas. Added design cost may lead to decreased component cost, leaving performance and effectiveness otherwise unchanged. Added design cost may yield decreased production costs, and production cost may be traded off against unit cost for materials. Value engineering (or value analysis) examines all these cost trade-offs and is an important aspect of systems integration (Morris, 1979). It can be used in any project where the relevant cost trade-offs can be estimated. It is simply the consistent and thorough use of cost/effectiveness analysis.

Multifunctional teaming (see Section 6.5) is a way of achieving systems integration and, as such, may play a major role in the success or failure of any complex project. If a risky approach is taken by systems integration, it may delay the project. If the approach is too conservative, we forego opportunities for enhanced project capabilities or advantageous project economics. A good design will take all these trade-offs into account in the initial stages of the technical approach. A good design will also avoid locking the project into a rigid solution with little flexibility or adaptability in case problems occur later or changes in the environment demand changes in project performance or effectiveness. Multifunctional teams are also valuable for assessing and mitigating risk in the project, particularly in anticipating crises during the execution of the project (refer to the Directed Reading: "Planning for Crises in Project Management" at the end of this chapter).

The details of systems integration are beyond the scope of this book. The interested reader is referred to Blanchard et al. (2006). In any case, the ability to do systems integration/engineering depends on at least a minimal level of technical knowledge about most parts of the project. It is one of the reasons project managers are expected to have some understanding of the technology of the projects they head.

6.3 THE ACTION PLAN

In this and the following sections of this chapter, and in Chapters 7 and 8 on budgeting and scheduling, we move into a consideration of the details of the project. We need to know exactly what is to be done, by whom, and when. All activities required to complete the project must be precisely delineated and coordinated. The necessary resources must be available when and where they are needed, and in the correct amounts. Some activities must be done sequentially, but some may be done simultaneously. If a large project is to come in on time and within cost, a great many things must happen when and how they are supposed to happen. Yet each of these details is uncertain and thus each must be subjected to risk management. In this section, we propose a conceptually simple method to assist in sorting out and planning all this detail. It is a *hierarchical planning system*—a method of constructing an action plan and, as we will see shortly, a WBS. We have also named it the "*level planning process*."

To accomplish any specific project, a number of major activities must be undertaken and completed. Make a list of these activities in the general order in which they would occur. This is Level 1. A reasonable number of activities at this level might be anywhere between 2 and 20. (There is nothing sacred about these limits. Two is the minimum possible breakdown, and 20 is about the largest number of interrelated items that can be comfortably sorted and scheduled at a given level of aggregation.) Now break each of these Level l items into 2 to 20 tasks. This is Level 2. In the same way, break each Level 2 task into 2 to 20 subtasks. This is Level 3. Proceed in this way until the detailed tasks at a level are so well understood that there is no reason to continue with the work breakdown.