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Transportation Construction Equipment

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Construction of the nation's transportation facilities necessitates a substantial investment in construction equipment. Earth moving requires machinery to loosen, load, haul, spread, and compact soil. Portland cement concrete and asphalt cement concrete for pavement construction are produced in plants, hauled in trucks, and shaped by pavers. Bridge construction requires heavy lifting equipment, such as cranes, while large tunnels require tunnel-boring machines, some of which are custom built for a particular project. In addition to the above equipment, a myriad of additional specialized pieces of equipment, including rail and marine equipment, is required to complete transportation construction projects.

Contractors, not transportation agencies, own the majority of transportation construction equipment. Equipment manufacturers and contractors will be responsible for most innovations in construction equipment at the beginning of the new millennium. By providing construction funding and specifications, however, transportation agencies will have a considerable influence on the amount and type of innovation that takes place.

CURRENT ENVIRONMENT

There is currently a high demand for construction of transportation facilities in the United States because of the expanding economy. In 1997, transportation infrastructure projects, including all modes, all levels of government, and private investment, amounted to $153 billion, or 1.89 percent of the U.S. gross domestic product. The transportation construction market has increased steadily since 1982 and is expected to approach $200 billion by 2003 (*1*). Recent federal legislation has increased funding for transportation construction, so the demand is expected to remain high.

Because the efficiency of construction machinery depends on the ability of operators, changes in the labor force also affect construction equipment. Changing demographics are causing the pool of traditional construction equipment operators to shrink. The baby boom generation is aging, leaving a smaller population from which to draw young construction workers. In many families, both spouses work, making travel and relocation more challenging.

Contractors have stepped up to these challenges by incorporating larger proportions of immigrants, women, and minorities in the labor force. To reduce the need for travel and relocation, they may hire local people to operate construction equipment for the duration of a single job. These people may be unfamiliar with the equipment. Moreover, many younger workers have higher expectations for comfort, safety, flexible work hours, and training than did construction workers of the past. In addition, the prestige of the construction industry has diminished; therefore, operating and managing construction equipment is often not the first choice for many potential workers.

On the other hand, younger workers may have greater computer literacy, which aids them in operating and maintaining complex, computerized equipment. At the same time, safety requirements demand that operators be provided minimum levels of training. Programs are currently under way to certify crane and fork lift operators. And once constructors have made the investment in such training, they will probably want to avoid losing these operators.

As the population increases and more facilities are built, less space is available for building new transportation facilities. As a consequence, there is a greater emphasis on rehabilitation of existing facilities, and when a new facility is built, it must often be placed on a crowded site. This means construction equipment is often being operated in areas with limited maneuvering room. Transportation constructors are also expected to take steps to provide safety for workers and the public, reduce disruptions to traffic and neighbors, and act responsibly with regard to the environment. Construction is often performed under traffic conditions and in areas where a minimum amount of noise, dust, exhaust emissions, and vibrations is demanded. To reduce traffic disruptions, construction may be performed at night; however, this practice creates the challenge of minimizing noise so neighbors are not disturbed.

Air quality concerns are having a special impact on construction equipment in urban areas, especially those areas that are having difficulty in meeting air quality guidelines. A report issued in 1997 by the Northeast States for Coordinated Air Use revealed that nonroad diesel equipment emitted more air pollutants than on-road trucks and buses in the region (*2*). On Boston's Central Artery and Tunnel project, an effort to fit 70 pieces of construction equipment with special air pollution control devices, is expected to reduce emissions by an amount equivalent to removing 1,300 diesel buses from the streets (*3*). California has recently been a leader in mitigating pollution from construction equipment (*4*).

Equipment manufacturers have an unprecedented amount of technology available to meet these challenges. Advanced computers and control systems assist operators and mechanics. Lighter, stronger materials are available for fabricating construction equipment. Wireless data links can transmit information between a base station and the equipment, and various types of positioning systems can be used to locate and guide the equipment.

The current environment has influenced construction machinery in several ways. Such machinery is becoming "simply complex." (The following discussion of "simply complex" construction equipment is adapted from a presentation given by Bill Morgan of Caterpillar, Inc., at the 74th Annual Meeting of the Transportation Research Board, January 22, 1995.) Modern point-and-shoot cameras provide a good example of a simply complex mechanism. These cameras focus, provide the correct light setting, and advance the film automatically. This makes them simple to operate. The electronic circuitry and computer chips that provide these capabilities are quite complex. Nevertheless, such cameras are much more affordable than their more difficult-to-operate ancestors.

Construction equipment has undergone a similar evolution. Pavers automatically maintain cross slope. Batch plants produce paving mixes from any one of a hundred recipes with the click of a mouse. Hydraulic pumps automatically match flow to requirements for hydraulic fluid, and many modern machines troubleshoot themselves with the aid of a notebook computer. Although some of these machines require less experience and judgment to operate, they may require more reading to learn how to operate and more computer knowledge to service. This makes them appropriate for a more mobile, computer-literate workforce. Greater comfort at ergonomically designed operator stations

increases productivity and enhances the likelihood of retaining more experienced operators.

Construction machines have also become more fuel-efficient. A construction company recently compared the fuel consumption in gallons per hour with the amount of horsepower available for lifting of a recently manufactured crane and two cranes that were commonly available 10 years ago (Thad Pirtle, Traylor Bros. Inc., Evansville, Indiana, personal communication). The recently manufactured crane had twice the fuel efficiency. Examples of similar advances are available elsewhere.

Because many of today's construction sites are smaller and more crowded, construction machines tend to be smaller and more maneuverable. There is a greater emphasis on mobility—on machines that can travel over the road from one job site to another or be loaded quickly onto another vehicle. As noted earlier, the machines must be quieter so neighbors will experience less disruption, and they must meet strict air quality standards. Because more projects today involve infrastructure rehabilitation instead of construction, equipment that is used for cutting and demolishing materials is becoming more common. Demolition attachments for excavators are an example. Other machines install facilities with minimum disruption; trenchless-technology machinery is an example.

The following are additional examples of current state-of-the-art construction equipment and methods:

- Paving
  - Automatic cross-slope control with profile grade control by string line or ski
  - Extraction of asphalt fumes from the work area
  - Dowel bar implantation for concrete paving
- Concrete and asphalt plants
  - Computer control on input and output
  - Addition of recycled materials to the mix
  - Recycled asphalt pavement
  - Fly ash for concrete
- Lift equipment
  - Load moment indicators that warn crane operators of overloads
  - High-capacity, self-erecting lattice boom cranes that can be set up without assistance from additional cranes
  - Hydraulic cranes that are maneuverable and versatile and do not require erection, now available in a wider variety of models and with greater load capacity
  - Personnel hoists that are replacing scaffolding when workers must have access to areas in which falling is a hazard
- Trenchless technology that allows installation of underground facilities with minimal disruption to the surface
- Excavators
  - A variety of attachments that make these machines more versatile for tasks such as cutting, demolition, and compaction
  - Long-reach configurations for utility work and work near wetlands
  - Short-reach, fast-loading excavators for loading haul units
  - Ultra-small units that increase productivity in tight areas

- Hauling equipment
  - Highway units in a variety of configurations that enhance load capacity and efficiency
  - Long-bed end-dump trailers
  - Truck-and-pup trucks (nonarticulated end dump with trailer)
  - Side-dump trucks
  - Bottom-dump trucks
  - Articulated dump trucks that provide greater maneuverability and can be used in more adverse soil and weather conditions

Many machines that exemplify the emerging state of the art are in operation today. They often take advantage of advanced positioning and sensing systems:

- Haul trucks are operated in mines without drivers. Sensors guide the vehicles along the road and stop them when obstacles are encountered.
- Earth-moving equipment makes cuts and fills to the proper grades without the use of survey stakes using differential Global Positioning System (GPS) technology, laser positioning, and other advanced surveying methods.
- Paving equipment operates without string lines using advanced surveying methods.
- Asphalt rollers sense the degree of compaction and record coverage during rolling.

FUTURE TRENDS

Demand for transportation construction should generally remain strong as people seek increased mobility and repairs to the transportation infrastructure are made. Periods of high demand can be expected to foster innovation as constructors strive to meet the demand for transportation construction. As in the past, however, there are likely to be periods of low demand that may lead to shakeouts in the construction equipment manufacturing industry.

Continued shortages of traditional, young construction workers can also be expected, and the industry will probably have to struggle to fill equipment operator positions with qualified people, except during downturns in construction. Equipment will have to be manufactured so workers can be trained quickly to operate it, even though they have limited familiarity with the construction industry. Constructors are likely to take advantage of easier operation by cross-training their operators to operate several different types of machinery. Doing so will mitigate the effects of the predicted labor shortage. Manufacturers must understand that an increasing proportion of operators will be women, minorities, and immigrants, and will have to make additional improvements in operator comfort and safety to help contractors retain qualified operators.

Future transportation facilities will have to fit into an increasingly crowded environment, and a larger proportion of transportation construction will involve the rehabilitation of existing facilities. Much rehabilitation work will be performed under traffic conditions. As the environment becomes more crowded, societal expectations will have more influence because those located near construction sites will be closer than ever before, and users of transportation facilities will be increasingly impacted by the construction process. Society will demand that equipment manufacturers do their part to minimize such impacts.

Transportation officials will want to lengthen the time between rehabilitation cycles to reduce interference with transportation users. Increased construction quality can contribute

to this goal, and construction equipment will be impacted by the need for better quality. Plants that produce materials will be challenged to do so in accordance with more stringent specifications, and construction machinery will be expected to produce smoother riding surfaces and more durable facilities.

Technology advances will help equipment manufacturers and transportation constructors meet these challenges. Computers will continue to become smaller, less expensive, and more capable. Control systems will become more responsive and robust. Positioning systems will become less expensive and more precise. These changes will result in more computer aids for operators and service technicians and reduced need for manual labor in surveying and layout. However, these same changes will necessitate more computer literacy among at least some of the operators and service technicians.

Compliance with air quality requirements is likely to be one of the biggest challenges for construction equipment in the future, particularly in urban areas that are having difficulty with achieving compliance. Since most construction equipment fleets are limited to a particular area (at least for the length of a construction project), they will be targeted for concentrated efforts to improve air quality. These efforts will include fitting the equipment with special noise reduction and air pollution control devices or converting them to use natural gas fuel.

Plants that produce materials (asphalt, concrete, and aggregate) will be especially challenged by air quality and neighborhood concerns because they are large facilities that attract considerable truck traffic. Efforts will be necessary to minimize noise, air pollution emissions, fugitive dust, and traffic impacts from these facilities.

MACHINES OF THE FUTURE

In general, the machines of the future will be smaller, more maneuverable, and easier to transport. Computers will assist operators in achieving increased safety and reduce the amount of time required to learn routine tasks. As a result, constructors will be able to cross-train operators, increasing their versatility. Wireless communications will allow experts to monitor several machines while they are operating and improve the effectiveness of servicing. The machines will be quieter and emit fewer air pollutants, making them better neighbors on the crowded construction sites likely to characterize future transportation facilities. Plants that produce construction materials will often be enclosed to reduce noise and improve their appearance.

The use of positioning systems on construction machinery will become common, reducing the time needed to prepare for construction, especially surveying. However, use of these systems will also increase the need for accurate plans because construction layout information will be transferred directly from computerized design files to the machines, and the opportunity to detect mistakes during the surveying process will be lost.

Assessment of quality *after* construction will be reduced as construction machinery becomes capable of assessing quality *during* construction so feedback can be given and problems corrected more quickly. For example, paving machines will assess the ride quality of pavements, and compaction equipment will assess the compaction of materials.

If construction labor is scarce, more items are likely to be prefabricated in a factory environment and assembled at the construction site. Prefabrication can also reduce construction time and the associated impact on transportation users. If prefabrication increases, the demand for versatile, transportable cranes will also increase.

As the trend toward infrastructure rehabilitation continues, equipment that is useful for this type of work will become more prevalent. More recycling trains will be constructed to

rehabilitate pavements, and trenchless-technology machinery will become more common and improved. Machines for cutting and demolition will also increase in number and effectiveness.

Many of the above improvements will reduce the training time for operators and the amount of servicing required for the machinery. At the same time, the computer technology in much of the machinery will require greater technical competence on the part of many transportation constructors.

In sum, high-technology construction equipment of the future will be comfortable, safe, and easy to operate, thus helping constructors deal with labor-force challenges. The equipment will be less disruptive to neighbors during the construction process because it will be smaller, quieter, more maneuverable, and less polluting. Instant quality assessment features will help provide more durable transportation facilities and lengthen rehabilitation cycles.

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