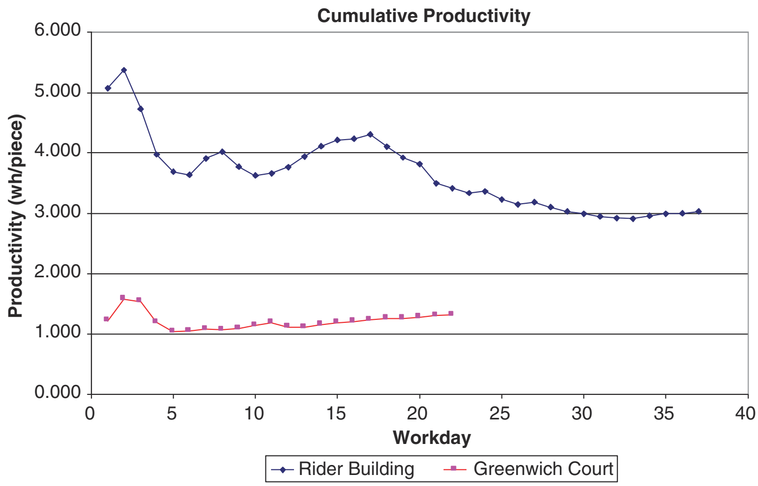

Fig. 6-30. Comparison of Cumulative Productivity, Rider Building and Greenwich Court

Overall, the work at Greenwich Court was well planned. Storage requirements were minimal. The crew knew their work assignments, and there were no difficulties in alignment. Alignment of the first two floors took only one workday (workday 7).

Material-Related Impacts—Calculating the loss of labor efficiency begins by defining the expected daily productivity as the estimated sustained productivity that could be attained on undisrupted days. This is shown in Fig. 6-29. Material-related inefficiencies were computed by comparing the actual daily productivity to the expected productivity values. The inefficiencies for running out of bolts on Greenwich Court were computed as 8.4 work hours. At a burdened payroll rate of $35/work hour, this equates to less than $300.

Benefit–Cost Analysis

Summary statistics for the two case study projects are given in Table 6-3. The two projects are generally comparable. The cost of ineffective material management is measured in terms of direct labor, equipment costs, and the indirect costs associated with the extended schedule on the Rider Building. Because the structural steel erection for both office buildings was on the critical path and the parking deck (for the Rider Building) was not, it is assumed that the inefficiencies in material management resulted in a 10-day delay in completing the Rider Building project. There was no schedule extension on the Greenwich Court project. The wage rates and equipment rental rates used to calculate the benefit–cost ratio were verified by a knowledgeable contractor. The jobsite and home office overhead rates and some other rates are assumed. The inefficient work hours caused by the material management on the Rider Building were calculated as 200.6. (This figure does not count any inefficient

Table 6-3. Project Summary Statistics

Project Attributes	Rider Building	Greenwich Court
Location	Downtown State College, PA	Downtown State College, PA
Type of structural frame	Structural Steel	Structural Steel
Number of stories	5	5
Building height (ft)	62	61
Footprint area (ft^2)	23,920	17,640
Site area (ft^2)	38,950	35,000
Building-to-site ratio	0.61	0.50
Number of pieces	414	399
Number of tons	171.7	179.7
Responsible entity	General Contractor	Specialty Contractor
Number of workdays required	37	33
Crew size	4	3–4
Labor force	Nonunion	Nonunion
Work hours required	1,256	526
Cumulative productivity (work hours/piece)	3.03	1.32
Construction time frame	Sept.–Feb.	Jan.–Feb.

work hours on the days immediately after the first and second steel deliveries when no pieces of steel were erected.) On Greenwich Court, the inefficient work hours were calculated to be 8.4. The following differential cost impact is calculated.

Contractor Cost	
Craft labor (ironworkers): (200 × (6 – 8.4) × \$35/h)	\$6,727
Operating engineer (10 days × 8 h/day × \$35/h)	\$2,800
Equipment rental (\$1,000/day × 10 days)	\$10,000
Total Direct Cost	\$19,527
Jobsite and home office overhead (10 days @ \$550/day)	\$5,500
Total direct and indirect cost for doing the work the Rider Building way	\$25,027

There are added expenses related to fabricator coordination. These include the additional staff hours needed to sequence steel deliveries and the extended wait time for delivery trucks as steel is off-loaded and erected directly in place. Using 25 truck trips to deliver all the steel on the Greenwich project, the following expenses are estimated.

Staff hours to sequence and expedite deliveries	\$200
Truck delivery charges (8 h of superintendent time @ \$75/h)	\$600
Demurrage: (25 trailers @ \$100/day for 25 days)	\$2,500
Total added expenses for the Greenwich Court way	\$3,300

Using these cost figures, the benefit–cost ratio is computed as 25,027/3,300 = 7.58. Thus, for every dollar spent in planning to erect directly from the delivery truck, the contractor can potentially save in excess of $7.58.

Clearly, when the invisible cost of labor and schedule delay times are considered, the Greenwich Court material management strategy is far more cost-effective compared with the Rider Building strategy.

6.9 Case Study 2—State College Municipal Building: Work Face Practices

This case study project is a three-story municipal office building in downtown State College, Pennsylvania (SCMB). The structural frame of the building is structural steel (aboveground stories) and the facade is masonry. The project also contains a basement with reinforced concrete basement walls. The site area is 70,000 ft^2 (200×350 ft), and the footprint area of the facility is approximately 18,750 ft^2 (75×250 ft). The project was estimated to cost about $5 million in 2001. The planned construction schedule was about 16 months.

Site Characteristics

The actual site plan for the project is shown in Fig. 3-3. It shows that the site had limited space for material storage and laydown areas and other facilities. Fig. 3-3 also shows how the contractor used the limited space. The use of storage and laydown areas was based on a "first come, first served" philosophy, so use of storage areas was largely unplanned. When the study began, steel reinforcement, structural steel, concrete block, and other materials were already stored on site. There was congestion and interference with trucks and deliveries entering and exiting the site. Drive-through deliveries were not applied. There was no evidence of a site plan.

Description of the Activity

The activity reported herein is the ductwork installation, and the operation covered four floors, from the basement to the third floor. The ductwork activity consisted of three subtasks, that is, hangers, duct erection, and connections. There were four major types of components involved in the work: small and large feeder duct, branch duct, and fire dampers.

Fundamental Principles

The following principles in Table 6-1 do not apply to this project or were not observed: 1.1, 1.2, 1.3, 1.5, 2.1, 2.2, 3.5, 4.3, 5.1, and 5.2. The contractor applied

Principle 1.7, and Principles 1.4, 1.6, 1.8, 3.1, 3.2, 3.3, 3.4, 3.6, 3.7, 4.1, 4.2, and 5.3 were not applied. The main focus of this case study is on work face storage practices and housekeeping.

Construction Methods

The duct crew included one supervisor and two sheet metal workers. During the first two weeks, there was enough clear work space for the crew to preassemble three or four pieces of duct together on the floor and use a lift to install the preassembly (Fig. 2-2). However, as the job progressed, the project became congested with framing, drywall, masonry partitions, and materials stored on each floor (Fig. 6-9). This meant that preassemblies could not be used and the duct was installed one piece at a time instead of as a preassembly. The duct was off-loaded and manually carried to where it was to be stored and then manually carried to the work face.

Fig. 6-24 shows the productivity for the first 33 working days of the ductwork activity (Han and Thomas 2002). After the first few weeks, the work was frequently disrupted. During the first two weeks, the productivity was frequently in the range of 0.30–0.35 work hours/ft when the crew made good use of subassemblies. Thereafter, the productivity on undisrupted days was more in the range of 0.50–0.60 work hours/ft. During this time, conditions at the work face prevented the use of subassemblies. The case study and data from this and other projects form the basis for Principle 3.2 (Table 6-1), that is, preassemble components into subassemblies to maximize productivity (Fig. 2-2). Not being able to use subassemblies on the case study project resulted in an estimated loss of productivity of almost 50%.

Material Management Practices

There was no material management plan for this project. Materials were stored on site in accordance with the layout shown in Fig. 3-3. The site was small, and material site access was at the one location shown. There were trailers, a tool storage shed, excavated spoil, and a parking lot located within the site boundary. Material was transported into the building in two places. Fig. 6-31 shows the material storage area on the north side of the building. This area was used to stockpile excavated soil, accumulate trash, and store miscellaneous materials. The temporary utility pole also impeded the free flow of materials. Because of the limited site storage, duct and other materials were stored inside the building. This aspect was shown in Fig. 6-9. The south side of the building was not available for storage because work on installing underground utilities was late.

Waste materials were removed periodically, but often the building interior was untidy. The plan for waste removal (Principle 3.5) was ad hoc.

The disorderly storage practices on the interior affected the duct installation in several ways (Principle 3.1). Duct could not be erected as a preassembly. Also, the framing, masonry partitions, and piping were done out of sequence. Several of these

Fig. 6-31. Storage Area on North Side, State College Municipal Building

aspects are shown in Fig. 6-9. As can be seen in Fig. 6-24, there were numerous disruptions from congestion, interferences, and out-of-sequence work, which negatively affected the work. Overall, the labor performance of the duct installation was poor.

6.10 Case Study 3—Beaver Avenue Parking Garage: Fabricator Relations

This case study project is the construction of a six-story parking structure in downtown State College, Pennsylvania. There is limited commercial space on the first two floors. The project was built in the spring of 2005 at an estimated cost of $11 million.

The entire structure was precast concrete. A specialty contractor using a Manitowoc 2250 and a 10-person crew of union ironworkers did the precast erection. The structure consisted of beams, columns, spandrels, slabs, panels, and stairs. The columns took approximately 45–60 min each to erect, and the other pieces took about 15–30 min each. A separate team of ironworkers did all the grouting. The erection was divided into five phases, but because of time constraints, only phases 1 and 2 were monitored.

Fundamental Principles

The following principles in Table 6-1 do not apply to this project or were not observed: 1.1, 1.2, 1.4, 1.5, 1.7, 2.1, 2.2, 3.1, 3.2, 3.3, 3.4, 3.5, 3.7, 5.1, and 5.2. The contractor applied Principles 1.3, 1.6, 1.8, 4.1, 4.2, and 4.3. Principles 3.6, 3.7, and 5.3 were not applied. The main focus of this case study is on effective vendor relations, use of a surge pile, development of site plans, and the principle of erection from the delivery truck.

Contractor Operations

Because the construction site was small and constrained, there was little or no room for storing precast pieces at the site. To counteract the small site, the contractor applied principles 4.1, 4.2, and 4.3 from Table 6-1.

There were two types of precast pieces: permit and nonpermit pieces. The distinction was the width. Nonpermit or narrow pieces could be delivered without a transport permit, and wide pieces required a permit. The specialty contractor used a vacant staging area about four miles away to maintain a surge pile (stockpile) of nonpermit pieces. As these nonpermit precast pieces were delivered from the fabricator, the loaded trailer was dropped at this remote staging area.

Permit pieces were delivered daily to the site on a prearranged time schedule (Principle 4.3). Because of permit limitations, permit pieces could not arrive at the site until about 10:30 a.m. The use of the remote surge pile of nonpermit pieces provided workers with work to do at the beginning and end of the shift because the superintendent could call for the nonpermit pieces to be delivered at any time (Principle 1.6). When pieces arrived at the site (of either type), they were erected directly from the delivery truck (Principle 4.1). A nonpermit element is shown being erected in Fig. 6-11 and also in Fig. 3-26. A hypothetical delivery schedule is shown in Fig. 6-32.

There was excellent coordination between the specialty contractor and the fabricator (Principle 4.2). The deliveries were timely, except for one day. The correct pieces were delivered per the erection sequence, and the pieces were oriented on the truck to facilitate erection directly from the truck. Thus, the specialty contractor applied good material management practices. The superintendent had a goal of 14 precast pieces per day (based on an estimated budget of 5.75 work hours/piece), but that goal was often exceeded. The remote surge pile was essential to exceeding this goal.

Time	Type	Mark Number
7:05	Nonpermit	W-SCPG-2204
7:20	Nonpermit	S-SCPG-2203
• • •		
10:30	Permit	T-SCPG-2218
11:00	Nonpermit	C-SCPG-2301

Fig. 6-32. Hypothetical Delivery Schedule, Precast Elements

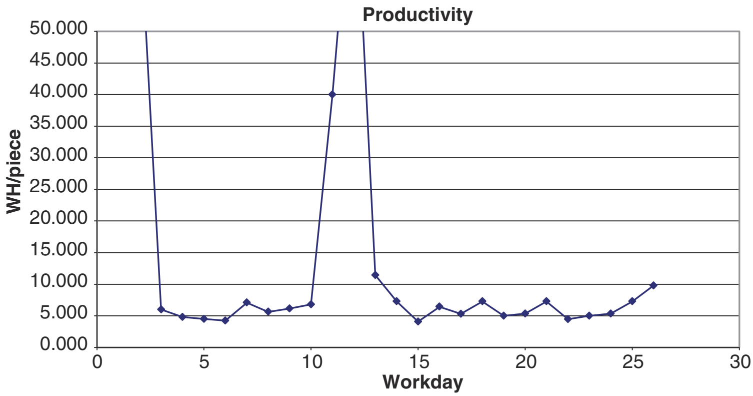

Fig. 6-33. Daily Productivity for Precast Elements, Beaver Avenue Parking Garage

The superintendent had an excellent opportunity to control the daily production because there was good communication and coordination with the fabricator. Most of the deliveries were made on time, and the off-site staging area meant that nonpermit pieces could be delivered as needed, so work for the crew was always available and there was little idle time. The productivity of the crew is shown in Fig. 6-33. Production variability was caused by the time differential needed for different components to be erected: columns took two to four times longer than other components to erect, the stairwells were complex and time consuming, there was an accident (workday 2), design errors affected the work (workdays 7–8), the crane needed to be moved as the work progressed from phase 1 to phase 2 (workdays 11–13), and precast permit pieces were delayed one day (workday 9). Output was low on another five or six workdays. But despite the unfavorable conditions, the goal of 14 pieces per day was exceeded most of the time.

6.11 Case Study 4—Food Science Building: Delivery Strategy

This case study was of the structural steel erection for the four-story Food Science Building classroom and research facility on the Penn State campus. The estimated cost of the facility was $45.1 million. The crew size ranged from seven to 10 ironworkers.

The work was planned in five phases. Two phases were monitored. The overall site was spacious, but to keep steel within the reach of the crane, the on-site storage area was limited. The specialty contractor chose to deliver steel to the site frequently from an off-site staging area, but steel was off-loaded from the trucks and stored on site instead of being erected directly from the truck (Fig. 6-2). Thus, the contractor used multiple staging areas and the final staging area was on site. Because of the U-shape nature of the building, only one crane setup for all five phases was required. Coordination with the fabricator was good, and deliveries to the off-site staging area from the fabricator were timely. The crew never ran out of steel.

Fundamental Principles

The following principles in Table 6-1 do not apply to this project or were not observed: 1.1, 1.2, 1.5, 2.1, 2.2, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 4.3, 5.1, and 5.2. The contractor applied Principles 1.3, 1.4, and 1.8. Principles 1.6, 1.7, 4.1, 4.2, and 5.3 were not applied. The main focus of this case study is on the use of the surge pile and the material delivery strategy.

Contractor Performance

The labor performance of the steel erection crew on the Food Science Building was not good. The site was spacious, but the storage area for structural steel was limited. The contractor staged the material at two locations: at a remote location about five miles away and at the site. Effective material management practices were not applied. Deliveries were made almost every day, and most crew members had nothing productive to do while steel was being off-loaded. There was much variability in production output. The productivity variability is visually observed in Fig. 6-34. In response to schedule delays, the contractor enlarged the crew, and performance suffered more. The crew performance was variable, especially after the crew size was increased (after workday 10).

It appears that by applying a strategy of staging the steel at the site and increasing the crew size, the contractor seriously affected the labor performance in a negative way.

Presumably, at the off-site staging area, material shakeout was done, as no fabrication errors were observed at the site. But, trailers were loaded randomly and driven to the site where the trailers were off-loaded. Some unused pieces of steel can be seen in Fig. 6-2.

The superintendent had the opportunity to control the production, but did little to do so. The reduction in daily output is largely associated with steel deliveries. Steel was delivered to the site regularly, stockpiled at the site, and then

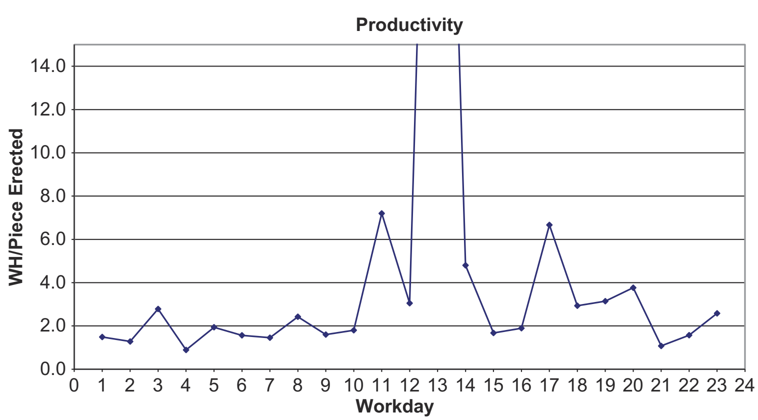

Fig. 6-34. Daily Productivity for Steel Erection, Food Science Building

erected from the stockpile. The problem with this approach is that off-loading and stockpiling took two to three members of the crew, leaving the other members of the crew with little or nothing productive to do. So daily output was greatly reduced on days when steel was delivered, which was done frequently. The superintendent failed to take advantage of the opportunity to erect steel directly from the delivery truck (Principle 4.1).

Based on 70 work hours/day and 1.20 work hours/piece, a daily goal of 58 pieces/day is calculated. The crew came close to this goal on only four workdays. The cumulative crew productivity was 2.06 work hours/piece compared with 1.32 work hours/piece on the Greenwich Court project described in Case Study 1. The cumulative steel erection productivity on the Food Science Building was about 60% worse than the Greenwich Court project.

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