CONE 650: CONSTRUCTION LABOR PRODUCTIVITY

FIELD STUDY 4: Complexity/Difficulty Analysis

Tejaswini Hegade

1. Operation Analysis

1.1 Work Scope: The scope involves the installation of linear suspended LED lights throughout the fitness area on the ground floor of College View Apartments. This includes ensuring proper placement, wiring, and connection of the light fixtures according to the electrical and lighting plans.

1.2 Crew Composition: The crew consists of two electrical contractors who are experienced in installing commercial lighting fixtures. One crew member takes the lead role, while the other assists with tasks such as material handling, preparation, and supporting the installation process.

1.3 Estimated Production Rate: The production rate will depend on the type of light fixtures they are going to install that day, there are a total 40 different types of light fixtures for the whole project. That day's crew aims to complete the installation of all lighting fixtures in the fitness room, install four A4 Suspended light fixtures and six A10 light fixtures.

1.4 Layout and Conditions:
The fitness area where the lighting fixtures are being installed is located on the ground floor of the apartment complex. The electrical temporary storage area, where the lighting materials are stored, is situated approximately 60 meters away from the fitness area, but still on the same floor.
All the lighting materials are stored in boxes placed on wooden pallets within the storage area. This layout allows for easy access and efficient transportation of the required materials to the work area. When needed, the material for a few installations (1 or 2 installation) is moved on a forklift from the storage room to the specific installation unit. The installation unit is equipped with the necessary tools and equipment, including a scissor lift, two ladders, one table with all the required tools and equipment. This well-organized layout and the availability of essential tools and equipment in the installation units contribute to the smooth and efficient execution of the lighting fixture installation process.

1.5 Materials:
The materials for this project were purchased in bulk by Wesco, the electrical material distributor, from multiple manufacturers including Juno Lighting, Pinnacle Architectural Lighting, L.H. Dottie, and others . Some of these manufacturers are based overseas in countries like China, Europe, and Vietnam
The materials were ordered one year before the design phase. and delivered to the warehouse a year and a half ago before electrical work starts. Warehouse is located in Los Angeles which is 2 hrs away from the project.

The primary lighting fixtures to be installed are linear suspended LED lights, which are long, linear LED lights designed to provide uniform and energy-efficient illumination for the fitness area. There are a total of 40 different light fixtures.
Other materials include electrical components such as wires, cables, junction boxes, conduits, driller, stinger clips, and aircraft cable, which are necessary for proper wiring and connection of the light fixtures
Ceiling blocks and covers are also used to secure the light fixtures to the ceiling and cover any exposed wiring or electrical components

1.6 Method and Steps:
The installation process began by referring to the MEP (Mechanical, Electrical, and Plumbing) plans to identify the designated area for the podium deck. The podium deck structure was then assembled according to the manufacturer's instructions or project specifications, ensuring it was level and secured in place. Next, the MEP plans were consulted to determine the layout and routing of the piping. The piping was laid out on the floor, following the planned path, and secured to the floor using appropriate supports or fasteners. Proper alignment and leveling of the piping were ensured.
For the ceiling preparation, the locations for the light fixtures were identified on the ceiling, following the MEP plans. The electrical component installation involved referring to the electrical plans and specifications for the required components, such as junction boxes, conduits, and wiring. These electrical components were installed at the designated locations on the ceiling or within the piping system. Proper routing and termination of the electrical wiring were ensured according to local electrical codes and regulations.
When it came to the light fixture installation, the fixtures were carefully unpacked and inspected for any damage or missing components. The manufacturer's instructions were followed for assembling and mounting the light fixtures. Firstly, workers install aircraft cable with the help of a screwdriver using scissor lift to reach a certain height up to ceiling and add cover around it. After one aircraft cable is attached to the ceiling he attached another aircraft cable with a similar method. After installation the worker moves the scissor lift forward so he can easily put 2 ladders next to aircraft cable and linear led light on ground surface as aircraft cables are 4 ft away and cannot easily be accessible by scissor lift. Next step is attaching Linear light with aircraft cable and pull cable to place light on a certain height. Both workers measure the height of light from ground and cut aircraft cable. Once the fixtures were secured to a certain height from ceiling according to plan support structures by another crew member appropriate hardware and connected to the electrical wiring, ensuring proper connections and grounding.
Finally, the testing and inspection phase involved energizing the electrical system and testing the light fixtures for proper operation. The installation was inspected for any loose connections, misalignments, or potential safety issues. Any necessary adjustments or corrections were made, and the required inspections and approvals from local authorities were obtained, if applicable.

1.7 Task Distribution:
- One crew member takes the lead in positioning and securing the light fixtures, while the other assists with material handling, wiring connections, and any necessary ladder or lift operations.

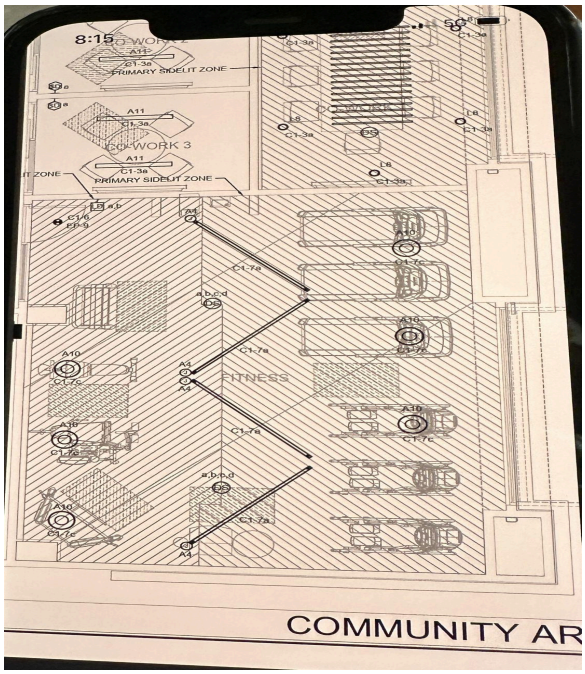
- Tasks such as layout, piping/conduit installation, and wiring connections may be divided between the crew members for efficient workflow.

1.8 Tools:

- Standard electrical tools: Wire strippers, pliers, screwdrivers, voltage testers, and other hand tools necessary for electrical work.
- Power tools: Drills, saws for cutting screws
- Ladders or lifts: To safely access the ceiling and perform the installation at the required heights.
- Scissor Lift: This equipment is used to attach cover and aircraft cable to ceiling before installation of light.
- Personal protective equipment (PPE): Hard hats, safety glasses, gloves, and PPE for the crew's safety.

1.9 Difficulties:

1. Installed Wrong box cover:



Round white color box covers, which have two holes, one for aircraft cable support and second for power line delivered 6 similar types in one pack. Which is going to be installed 4 at the fitness room and remaining two at another unit. The same day when installing box covers workers installed all 6 of them in the fitness room, because he thought all came in one box so it was supposed to be installed in one unit. But later when he was going to install the light fixture he got to know that he installed 2 wrong covers, he was supposed to install steel one’s which are smaller in size. So he needed to remove them and detach the aircraft cable from cover. and again he needs to make a steel box cover ready and attach aircraft cable to that cover, which causes a time and effort to the process.

2. Wire attachment part/ Stinger clip size issue: During the final stages of installation, when attempting to tight the wires to the light box, the crew encountered an issue where the provided stinger clips were smaller than the size of the wires themselves. making it challenging to securely fasten the wires to the box. Because there were two different sizes of wires or cables and only one size of stringer clip was provided, which was a smaller size, which didn't fit properly. That caused a lot of time and struggle. So now work stops, and they need to order a bigger size of stringer clip which takes a few days of time.

3. Fixtures broke while transporting: During the transportation of the lighting fixtures from the workshop, located 2hrs away from the construction site, to the site for a week's worth of work, some fixtures fell and broke while being transported by truck. This incident caused significant damage to many of the fixtures. As a result, the contractor was required to order new materials to replace the damaged fixtures. However, the delivery of the new materials took an additional 6 weeks to arrive at the site. This delay in receiving the replacement fixtures caused a substantial setback in the project timeline. To prevent such incidents in the future, it is crucial to ensure that the lighting fixtures are properly secured and protected during transportation.This may involve using sturdy packaging materials, such as foam or bubble wrap, to cushion the fixtures and prevent them from shifting or colliding during transit.

Additionally, the contractor should consider implementing a more frequent delivery schedule to minimize the impact of any potential delays in receiving replacement materials

2. Process chart and CBC chart

2.1 Process chart

Sr. No.	Activity	Operation	Inspection	Movement	Delay	Storage	Handle	Labor	Time
1	Material Load on truck							-	-
2	Material Transportation							1	2 hour
3	Material unload from truck							3	-
4	Store onsite							4	-
5	Material Inspection							1	-
6	Material taken Fitness area							2	2.00
7	Attach aircraft cable with plate							1	3.51
8	Operating scissor lift							1	1.21
9	Attach square plate with ceiling							1	0.31
10	Install cover around plate							1	0.55
11	Move scissor lift forward							1	1.55
12	Move 2 Ladder near aircraft cable							1	1.43
13	Placing light on ground surface according to MEP							2	1.31
14	Attach cable with light and pull cable							1	0.59
15	Measure light placement from ground							2	1.41
16	Cut extra Cable							2	1.10
17	Attach light with Power supply							2	5.04
18	Align Power cable with Aircraft cable							1	2.07
19	Inspection of light after connection							1	0.45
20	Attach stringer clip							1	8.00

2.2 Crew Balance Chart

Time	0	3.51	6.21	11.58	14.51	17.42	19.01	20.01	20.16	22.01	26.25	32.28	38.03	40
Worker 1	Start	Making blank cover ready	Removed old cover plate and aircraft cable	Install New cover & aircraft cable	Unobxing & brining light	Measures height of light from bottom	Removed old cover plate and aircraft cable	Install New cover & aircraft cable	Attaching aircraft cable to light	Inserting power cable	Making wire connections	Aglin power cable to aircraft cable	Clipping stringer clip	Down from ladder
Worker 2	Not Present		Arrived	Standing	Unobxing & brining light	Measures height of light from bottom	Holding light			Down from ladder	Standing			

Calculations :

1.Total time of cycle length is 40 mins.

2. Removing and Installing Box Covers
Time taken to remove old/wrong box covers and install aircraft cables: 1.81 minutes
Time taken to install new box covers and aircraft cables: 5.17 minutes

Total time for this activity: 7.38 minutes
If the worker had installed the correct box covers at the desired location, this time could have been saved, reducing the overall cycle time.

3. Stringer Clip Installation
Time taken to try installing the smaller-sized stringer clips: 6.15 minutes
Time that would have been taken with the right-sized stringer clips: 1 minute
Time saved if the right-sized stringer clips were available: 5.15 minutes
Total Time Saved
If the worker had installed the correct box covers and used the right-sized stringer clips, a total of 13 minutes could have been saved from the 40-minute cycle.
This would have resulted in a cycle length of 27 minutes, a significant reduction in the overall task duration.

4. Crew Utilization
Worker 1 was doing most of the work, while Worker 2 was standing by for a significant portion of the time.

If the tasks were divided more equally between the two workers, the overall productivity and efficiency of the work could have been improved, further reducing the cycle length.

Unequal distribution of tasks between the two workers, resulting in one worker being underutilized.

3. Difficulty factors and evaluate the level of difficulty factor of the task

Difficulty level 1 = low 4 = high

- End-to-end alignment: If the task requires precise end-to-end alignment, it would be considered a difficulty factor.
- Orientation about insertion axis: If the part is not pre-oriented, requiring the worker to orient it correctly, it increases the difficulty.
- Part size: Parts that are difficult to handle due to their size or shape would be considered a difficulty factor.
- Insertion clearance: Tight clearances for insertion would increase the difficulty.
- Insertion direction: Awkward insertion directions, such as horizontal or upwards, would be considered a difficulty factor.
- Insertion condition: The presence of fasteners, tight fits, or other factors that complicate the insertion process would increase the difficulty.
- Handling condition: Factors that make handling the parts or tools more challenging, such as slippery surfaces, heat, or vibrations, would be considered difficult factors.

		Difficulty Factor							
		A	B	C	D	E	F	G	H
No.	Task	End to End Orientation	Orientation about Insertion axis	Part Size	Insertion Clearance	Insertion Direction	Insertion Condition	Fastening	Handling Condition
1	Attach aircraft cable with square plate	3	2			2		2	
2	Attach square plate with ceiling	4	1		2	4	2		
3	Install cover	1	1			3			
4	Attach lights with cable	1	1		2		2	2	3
5	Pull strings and cut extra cable	1							
6	connect wire with electrical supply	2		2					
7	Align power cable to aircraft cable	2							
8	Clipping stringer clip	4	3	4		2	2		

4. Summarize the task info

Task	Difficulty score	Difficulty factors	Task duration	Defects freq	Comments
Ordering Correct size of stringer clip	4	Mismatch between wire/cable size and stinger clip size provided	Work stopped to order correct size clips, took a few days	1	Careful observation of different types of cables required
Installing box covers to the right location	5	- Similar-looking box covers provided in one pac - Lack of clear communication and verification on cover type required for each location	Extra time and effort required to remove an replace incorrect cove	3	Carefully reading MEP plans
Transporting Lighting Fixtures	4	Inadequate packaging and securing of fixtures during transportation - Infrequent delivery schedule	6-week delay in receiving replacement fixtures	2	Improved packaging and more frequent deliveries needed
Installing Electrical Components	3	Interpreting electrical plans and specifications - Proper routing and termination of wiring	Coordination required between electrical and lighting crews	2	Clear communication between workers crucial

5. Analyze impact of task difficulty factors on task durations and defects

Impact of Task Difficulty Factors

Impact on Non-Productive (Idle) Time

The mismatch between the wire/cable size and the provided stinger clip size caused a significant delay, as the work had to be stopped to order the correct size clips. This idle time could have been avoided if the appropriate stinger clip size had been procured and available on-site.

The installation of the wrong box covers also led to non-productive time, as the crew had to remove the incorrect covers and replace them with the right ones. This idle time was a direct result of the difficulty in correctly identifying and installing the appropriate box cover type.

The 6-week delay in receiving replacement fixtures due to the transportation damage caused substantial non-productive time, as the project timeline was significantly impacted.

Impact on Productive Time

The careful observation and identification of the different cable and box cover types, as well as the assembly of the podium deck structure and the layout and securing of the piping, required additional time and effort from the crew, increasing the overall productive time needed to complete these tasks.

The need to carefully read and interpret the MEP and electrical plans to ensure the correct installation of components also contributed to the increased productive time, as this attention to detail was essential to avoid mistakes.

Impact on Defect Frequency

The mismatch between the wire/cable size and stinger clip size led to one defect, as the crew struggled to securely fasten the wires to the light boxes.

The installation of the wrong box covers resulted in three defects, as the incorrect covers had to be removed and replaced with the right ones.

The transportation damage to the lighting fixtures caused two defects, as replacement fixtures had to be ordered and installed.

Relation between Difficulty Scores and Outcomes

The higher difficulty scores (4 and 5) for the more complex tasks correspond to the observed issues with non-productive time, productive time, and defect frequency.

The tasks with higher difficulty scores required more careful attention to detail, clear communication, and adherence to plans, which were not consistently achieved, leading to the observed problems.

In general, the higher the difficulty score, the more likely the task is to experience delays, increased production time, and a higher frequency of defects, unless the crew is well-trained and has the necessary resources and procedures in place to effectively manage the complexity of the task.

The tasks with lower difficulty scores (3) still had some impact on non-productive and productive time, as well as defects, but to a lesser extent than the higher-difficulty tasks.

6. Propose improvements

1.Carefully reading MEP plan - Before

2. Installed Wrong Box Cover
To reduce the difficulty and prevent the installation of the wrong box covers, the following changes can be implemented:

- Improved Material Organization: Clearly label and segregate the different types of box covers (steel vs. round white) to avoid confusion during the installation process. This can be done by using color-coded labels or storing them in separate designated areas.
- Enhanced Communication: Ensure clear communication between the crew members about the specific box cover requirements for each installation location. This can be achieved through detailed work instructions, checklists, or regular team meetings to discuss the installation plan.
- Verification Checks: Implement a quality control step where the crew members cross-check the box cover type against the installation plan before proceeding with the installation. This will help identify any discrepancies and prevent the installation of the wrong covers.
- Training and Supervision: Provide thorough training to the crew members on the proper identification and installation of the different box cover types. Additionally, have a more experienced crew member closely supervise the installation process to catch any mistakes early on.

3. Wire Attachment Part/Stinger Clip Size Issue
To address the stinger clip size issue and ensure a secure wire attachment, the following changes can be implemented:

- Material Procurement: Ensure that the correct size of stinger clips is ordered and available on-site before the installation begins. This may require better coordination with the material supplier or a review of the material specifications.
- Material Inspection: Implement a quality check process where the crew members inspect the stinger clips upon delivery to verify that they match the size of the wires being used. This will help identify any discrepancies before the installation starts.
- Inventory Management: Maintain a well-organized inventory of various stinger clip sizes to have the appropriate ones readily available on-site. This will prevent delays in obtaining the correct parts during the installation process.
- Standardization: Consider standardizing the wire and cable sizes used throughout the project to minimize the need for different stinger clip sizes. This can simplify the material procurement and installation process.

4. Fixtures Broke During Transportation
To prevent the breakage of lighting fixtures during transportation, the following changes can be implemented:

- Improved Packaging: Invest in sturdy and well-designed packaging materials, such as custom-made foam or cardboard inserts, to securely hold the lighting fixtures in

place during transit. This will help cushion the fixtures and prevent them from shifting or colliding.

- Transportation Procedures: Develop and implement detailed transportation procedures, including specific loading and unloading instructions, to ensure the fixtures are handled with care. Train the transportation crew on these procedures to ensure consistent and safe handling of the materials.
- Frequent Deliveries: Consider implementing a more frequent delivery schedule, where smaller batches of fixtures are transported from warehouse to the site instead of a single large shipment. This will reduce the overall exposure to transportation risks and minimize the impact of any potential delays or damages.
- Supplier Collaboration: Work closely with the fixture suppliers to explore alternative transportation methods or packaging solutions that can better protect the materials during transit. This collaborative approach may lead to more effective solutions.

By implementing these changes, the contractor can address the identified difficulties, reduce the duration and quality problems, and ensure a more efficient and successful installation process for the linear suspended LED lights in the College View Apartments project.