FIELD STUDY 3: Productivity, Ergonomic and Safety Risk Analysis

- Tejaswini Hegade

Project Background:

Project Name	College View Apartments
Project Type	Student Housing
Number of Unit	90 (1,2,3 and 4 BHK with in-unit laundry, Pool, 41 Parking spaces, 10 Motorcycle spaces, Locker Storage, Fitness facility with yoga and tanning rooms)
Project Size	170,503 gross square feet
Location	5420 55th St, San Diego, CA 92115
Project Start	Dec'21
Expected completion	Aug'24
Construction company	Morley Builders (Benchmark Contractors, Inc.)
Project Manager	Allen McKinley
Senior Engineer	Joshua
Engineer	Abigail
Operation Analysis	Kitchen Faucet Installation

1. Operation Analysis

1.1Work Scope

The work scope involves the installation of kitchen faucets, including all necessary bottom parts, in student housing units. The faucets and associated components are provided by the manufacturer, Pfister, in pre-packaged kits for each sink. This ensures that all the required parts and materials are readily available for the installation process.

1.2Crew Composition and Production Rate

The crew assigned to this task consists of 4 workers, with 2 workers working together on each faucet installation. The production rate is 6 units completed per day, with each 2-person crew installing 3 units per day. This division of labor and teamwork approach allows for efficient and coordinated installation across multiple units.

1.3Installation Process

1.3.1Material Retrieval and Preparation:

Material is directly delivered from Pfister manufacturer to the construction site for all units, lead time was 3-4 weeks. And then stored at temporary storage room at construction site only.
The workers bring the faucet kit boxes from the storage area located in the garage at the ground floor of the site at the start of day, for the one day's work. This centralized storage location ensures easy access to the necessary materials.

Fig: Before Facute Installation

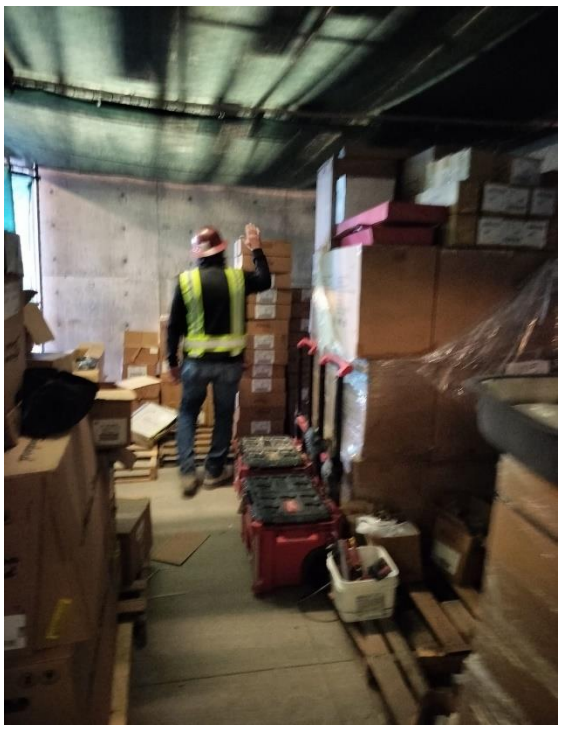

Fig: Storage Garage in parking

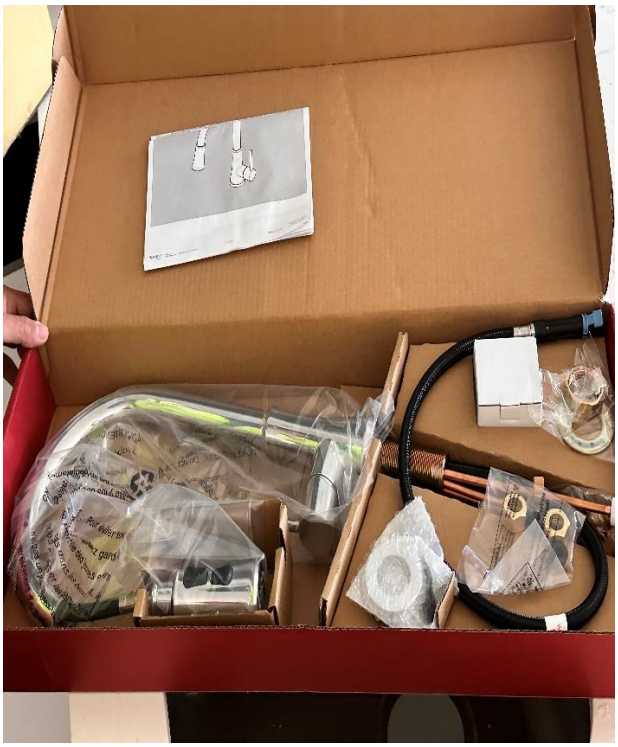

Fig: Box of Material

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They bring the boxes containing the faucet and associated components, such as the sink strainer, garbage disposal cup, water supply lines, and drainpipes, to the floor where the installation is to be performed and stored in one of the units where installation is going to happen.
As needed, they shift boxes and tools from stored units to required units. Upon reaching the unit, first he removes protective plastic covering that was on the countertop to prevent damage during the installation process.

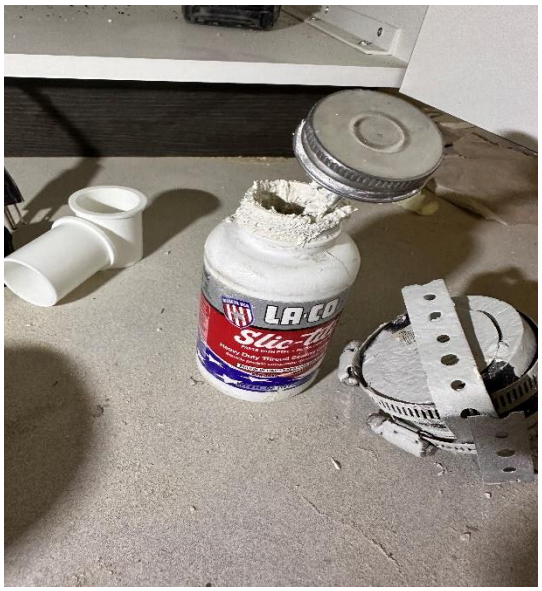
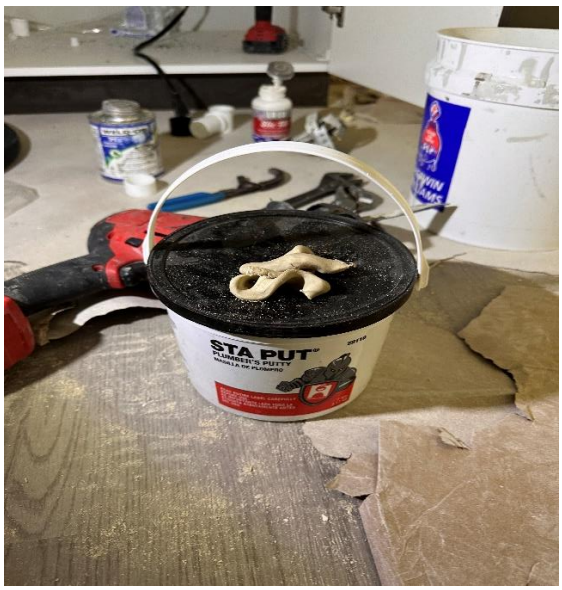


Fig: Glue



1.3.2 Faucet Installation:

At that time One of the workers opens the faucet kit and prepares the components for installation. They carefully review the manufacturer's instructions to ensure a proper and secure installation.

They place the faucet in the designated hole in the sink and secure it using the provided screws. This step ensures a tight and stable fit of the faucet.
The worker then installs the sink strainer and secures it from underneath the sink using a nailing gun. This step helps to prevent debris and food particles from entering the drain system.
Next, they connect the garbage disposal cup below the sink. This component is essential for efficient waste management in the kitchen.
The worker proceeds to connect water supply lines to the faucet.
They then assemble and install the drainpipes, including the U-shaped trap and the discharge tube. This step ensures the proper drainage of water from the sink.
As needed, the worker trims and cuts the pipes to fit the specific configuration of the installation.
Finally, they tighten all the connections and check for any leaks. This final inspection step helps to identify and address any potential issues before the installation is complete.

1.4 Assistance and Task Distribution:

The second worker assists the primary installer throughout the process, providing support as needed.
The tasks are distributed between the two workers, with the primary installer responsible for most of the hands-on work, and the second worker providing additional support and coordination.

1.5 Transition to the Next Unit:

Once the installation is complete, the workers move to the next unit and repeat the process. This systematic approach ensures that the installation is carried out consistently across multiple residential units.

1.6 Cycle Time, Crew Balance Chart and Process Chart:

The average installation cycle time for a single kitchen faucet, including all the associated bottom parts, is 20-21 minutes. This cycle time reflects the efficiency of the installation process and the coordination between the two workers.
The Crew Balance Chart would show the tasks and durations for the two workers, with the primary installer responsible for most of the hands-on work and the second worker providing support as needed.

Fig: Crew Balance Chart; Cycle length – 23 mins.

	A	B	D	E	F	G	H	I	J	K
1			Operation	Inspection	Movement	Delay	Storage	Handle	Labor	Time
2	Sr. No.	Activity								
3	1	Material Load on truck							-	-
4	2	Material Transportation							1	2 hour
5	3	Material unload from truck							3	-
6	4	Store onsite							1	45 min
7	5	Material Inspection							1	5 min
8	6	Material taken each unit							1	20 sec
9	7	Counter Top removal							1	40 sec
10	8	Open Box and Unwrap material							1	1 min
11	9	Insert Facuet on sink							1	1 min
12	10	Drilling screws and placing pipes							1	11 min
13	11	Install garbage disposal							1	2 min
14	12	Stick Glue on pipe and Install it by pressure							1	3 min
15	13	Install Soap Dispenser							1	2 min
16	14	Clean sink and inspect							1	1 min

Fig: Process chart.

1.7 Analyze productivity.

1.7.1Production Rate:
According to observation, the production rate of the crew is 6 units per day with 2 crew members. There are 2 crews working on the same operation in different units.

1.7.2 Time Utilization:
The time required for sink faucet installation is specified as 22 minutes per unit. However, the time required for other installations, such as restroom sinks and shower taps, is not known.

1.7.3 The significant idle time can be attributed to several factors:

Several factors can contribute to idle time, leading to inefficiencies in the production process. Firstly, the coupling and grouping of different installation tasks (sink faucets, restroom sinks, shower taps) to be performed by the same crew can result in idle time if these tasks have varying durations or material requirements. Secondly, the material supply system, where materials are delivered and stored on the ground floor, may introduce delays if the material handling and distribution processes are not streamlined and efficient. Additionally, workers may take breaks or rest periods during their shifts, contributing to idle time.

While it is observed that all required material components come in one box, which can help reduce idle time spent searching for components, other factors such as tool availability and the crew's experience and training can still impact time utilization.

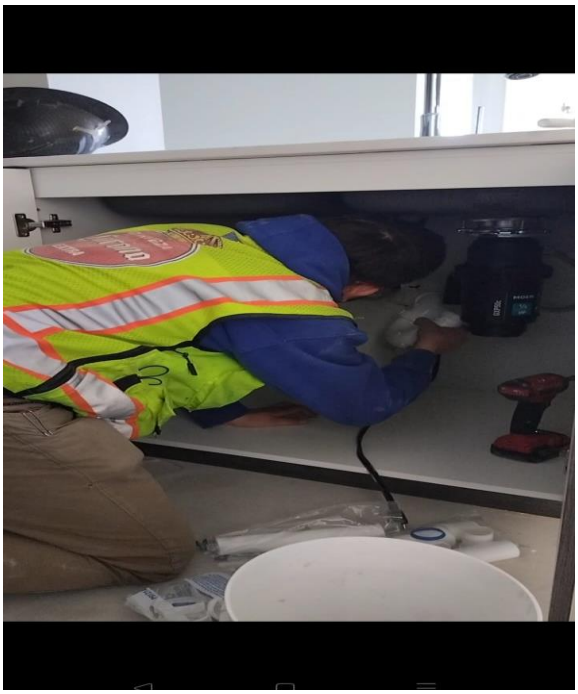
1.7.4 The productive time per unit may seem excessive for a sink faucet installation. Possible reasons could include:

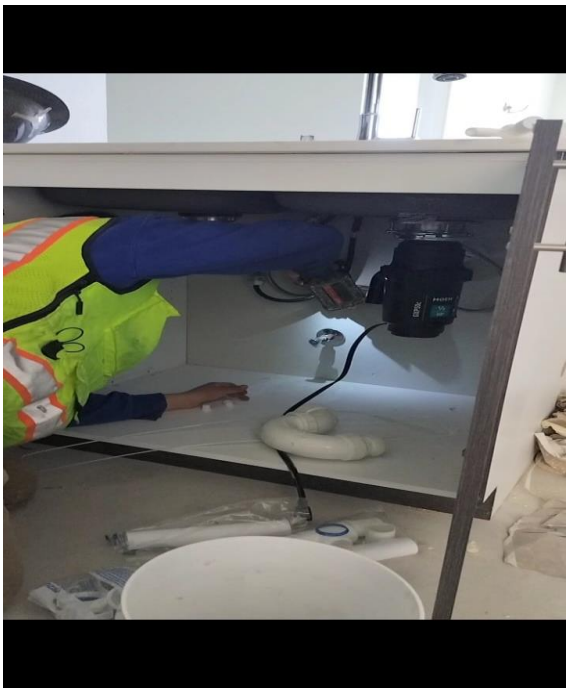
- Difficulties in accessing the installation locations such as tight space below sink and working in confined spaces to installation makes it more challenging.
- Complexity of the installation process or the need for precise workmanship, requiring multiple steps and specialized tools.
- Time required for material handling, setup, and cleanup.
- Coordination with other trades or dependencies on preceding work.
- Potential rework or quality checks.
- Quality control measures, ensuring proper installation and leak testing, adding to the productive time.

2. Analyze Ergonomic risks

Each task was completed in series, one right after the other. The tasks could not be completed in parallel because only one worker is doing most of the work, and each subsequent task could not begin until the last task had been completed.

Fig: Ergonomic Positions





kitchen faucet installation is a moderately intense operation because working under countertop is comparatively hard, because of limited work area. The main ergonomic stressor is the consistent time spent kneeling on both knees and looking upward. Another main ergonomic stressor is the repeatedly switching of positions from kneeling to standing. And worker needs to sleep on his back. Figure 3 below analyzes cycle in depth and lists each time the laborer switched ergonomic positions. Ergonomic positions and loads were assigned a score based on the OWAS (Ovako Working Posture Analysis System) standards and are graphed in Figure.

A	B	C	D	E	F	G	H	I	J	K	L
Task	Task Description	Time start	Ergonomic position Description					OWAS Score	Ergonomic position score	Forces	Force score
				Back	Arm	Leg	Head & Neck				
1	Removing Countertop protection	0	standing	1	2	2	1	1221	6	low	1
2	Opening package	0.45	standing	1	1	2	1	1121	5	low	1
3	Arranging facuet (Tap)	1.05	standing	3	1	2	2	3122	8	low	1
4	Placing tap at location	1.39	standing	1	1	1	2	1112	5	moderate	2
5	Fixing screw underneath	2.1	Seating down on knee	2	2	6	3	1163	13	moderate	2
	Fixing screw underneath	2.45	One hand above sink & other below	3	3	6	5	3365	17	moderate	2
6	Fixing tap	3.05	seating on knee , both hand on tap	4	3	6	4	4364	17	low	1
7	opening screw box	3.4	standing	2	1	1	1	2111	5	low	1
8	Drilling	3.53	seating	2	1	6	2	2162	11	moderate	2
9	fixing pipe	4.19	kneeling & bending	4	3	6	4	4364	17	low	1
	fixing pipe	4.32	standing	1	1	2	1	1121	5	low	1
	fixing pipe	4.44	seating	1	1	6	2	1162	10	low	1
10	removing wrapper from water pipe	5.04	standing	2	1	1	1	2111	5	low	1
	removing wrapper from garbage	6.05	standing	1	1	2	4	1124	8	low	1
11	attaching sink filter	6.22	standing & putting pressure by hand	2	1	2	2	2122	7	high	3
12	attching filetr, clips & screw underneath	7.12	sleeping on the back	4	3	6	5	4365	18	high	3
13	Installing garbage disposal cup	8.12	seating	1	1	6	2	1162	10	low	1
14	making ready water pipe	8.5	standing	1	1	6	1	1161	9	low	1
15	fixing screw	9.05	seating	2	1	1	1	2111	5	low	1
16	attaching water pipe	9.49	seatig underneath sink & looking upward	4	3	2	4	4324	13	low	1
17	attching another sink filter	10.29	standing	1	1	1	1	1111	4	high	3
	attching another sink filter	10.39	bending & putting pressure by hand	4	2	6	2	4262	14	high	3
	attching another sink filter	10.57	kneeling & looking upward	4	3	1	5	4315	13	high	3
18	Installiing trap	11.51	standing	2	1	1	1	2111	5	low	1
	Installiing trap	11.59	seating	2	1	6	1	2161	10	low	1
19	putting down, dishwasher drain, discharge tube	12.15	bending down	4	1	6	2	4162	13	low	1
	putting down, dishwasher drain, discharge tube	12.31	seating on knee , both hand on tap	4	3	6	3	4363	16	low	1
20	Removing pipe cap	12.41	kneeling & bending	4	3	6	2	4362	15	moderate	2
21	Fixing trap	13.03	kneeling & bending	4	3	6	2	4362	15	moderate	2
22	fixing discharge tube	12.36	kneeling & bending	4	3	6	1	4361	14	moderate	2
23	looking for glue	15.13	stadning & walking	1	1	7	2	1172	11	low	1
	looking for glue	15.45	kneeling & bending	1	1	6	3	1163	11	low	1
24	Applying glue	15.59	seating	2	2	6	1	2261	11	low	1
25	fixing pipe	16.17	kneeling & bending	4	3	6	2	4362	15	low	1
26	applying glue	15.49	seating	2	1	6	1	2161	10	low	1
27	fixing pipe	17.01	kneeling & bending	4	3	6	2	4362	15	low	1
28	drilling	18.08	kneeling & bending	4	3	6	2	4362	15	low	1
29	Attaching all glued pipe parts	18.18	kneeling & bending	4	3	6	2	4362	15	low	1
30	cutting pipe	19.09	seating	3	1	6	1	3161	11	moderate	2
31	attaching pipe	19.39	kneeling & bending	4	3	6	3	4363	16	moderate	2
32	drilling	19.41	kneeling & bending	4	3	6	3	4363	16	moderate	2
33	attaching pipe	20.05	seating	1	1	6	1	1161	9	low	1
34	Tighting everthing	20.25	kneeling & bending	4	3	6	3	4363	16	moderate	2
35	installing soap dispenser	20.59	kneeling	4	3	6	4	4364	17	low	1
36	applying glue on dispenser	21.14	seating	2	1	6	1	2161	10	low	1
35	tightning soap dispenser	21.51	seating one hand below & one above	4	2	6	5	4265	17	low	1

Figure above shows that the worker experienced a moderately intense load for about maximum of the cycle. The maximum ergonomic score is 18, which may not seem like much, but the number of times the worker switches from kneeling to standing is captured here, as the score goes from high to low repeatedly throughout the operation.

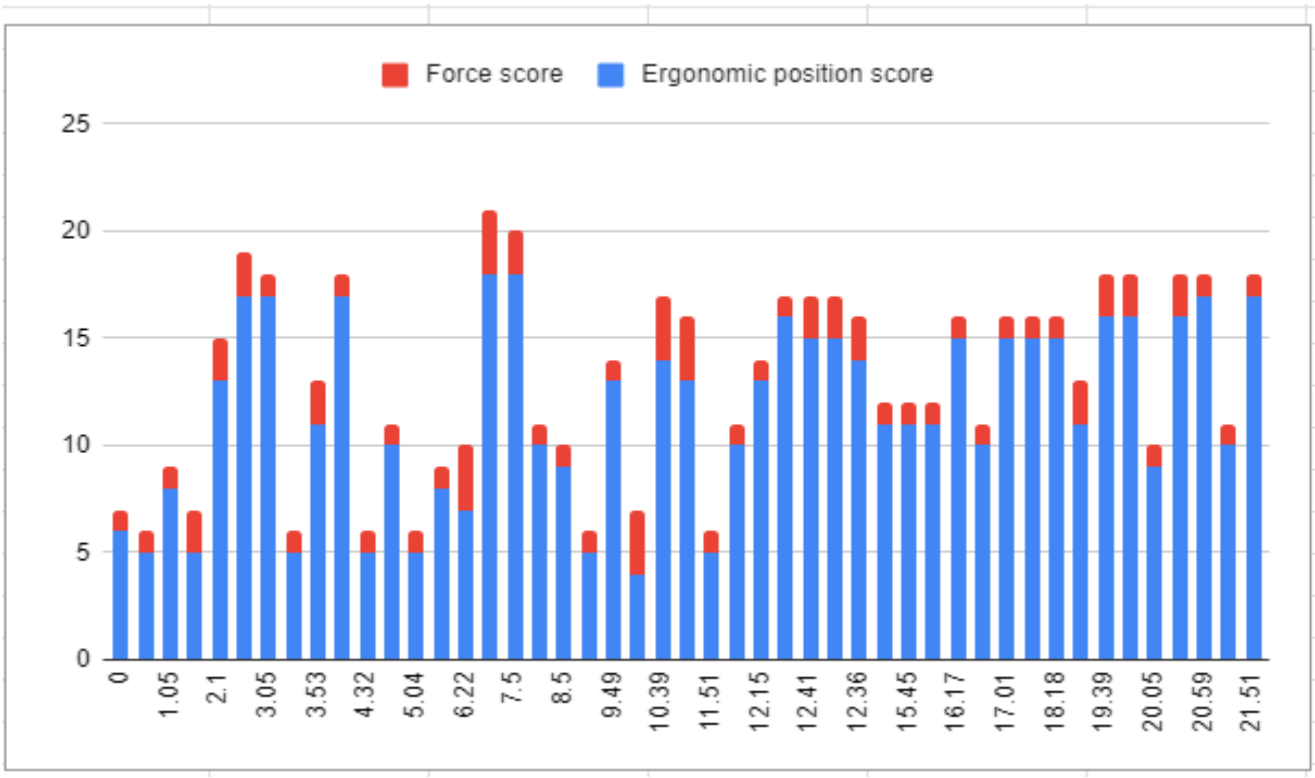


Fig: X axis – Time Scale & Y axis – Ergonomic position score & Ergonomic Force Score

The highest ergonomic loads are experienced during the drilling task and installing sink strainer part as he needs to put pressure by his hands to fit it properly. The drilling tasks are when the worker was required to exert the most force as he drilled looking upward.

The extreme posture and load during this task unfortunately cannot be reduced because there is no easier way to install strainer and drill.

3. Analyze Safety Risk:

In the construction industry, safety risks are a significant concern, and it is crucial to identify and quantify these risks to implement appropriate control measures. In this case, several potential safety risks should be assessed.

3.1 Quantity the Safety Risk

3.1.1. Select Safety Risks to Assess:

- Manual material handling such as lifting, carrying, moving materials from ground floor to each floor without damaging product.
- Ergonomic hazards (e.g., repetitive motions, awkward postures, manual material handling)
- Slip or fall hazards for example cluttered work areas or wet surfaces after inspection of sink faucet installation.
- Struck-by hazards (e.g., falling objects, moving equipment)
- Confined space hazards for e.g. Working in tight spaces or crawl spaces.

3.1.2. Identify Workers to Assess:

- Plumbing crew members performing sink faucet and tap installations.
- Material handlers transporting materials from the storage area to units.
- Supervisor or foreman overseeing the operation.

3.1.3. Define Exposure:

- Manual material handling: The process of lifting, carrying, and moving materials from the ground floor storage area to each floor can pose a risk of musculoskeletal injuries or damage to the product. The weight, size, and distance of material handling should be considered to quantify this risk.
- Ergonomic hazards: Repetitive motions (such as bending, laying on back, kneeling etc.), awkward postures, and manually installment of pipe by hard pressure and handling tasks can lead to ergonomic issues such as fatigue, and discomfort. The frequency, duration, and severity of these tasks should be evaluated to quantify the ergonomic risks.
- Slip or fall hazards: cluttered work areas, poor housekeeping practices, and wet surfaces after inspections or leak testing can increase the risk of slips, trips, and falls. The condition of the work areas, lighting, and potential for wet or slippery surfaces should be assessed to quantify this risk.
- Struck-by hazards: Falling objects, such as tools or small screws on head or around the eye while lying on the back can pose a struck-by hazard. The proximity of workers to these hazards and the likelihood of such incidents should be evaluated.
- Tight Space hazards: Working in tight spaces or crawl spaces during installations can expose workers to confined space hazards, such as limited access and potential hazardous atmospheres. The frequency, duration, and conditions of confined space work should be assessed.

Time	0	0.44	1.06	1.41	2	3.13	3.55	5	5.53	6.27	7.11	7.51	8.15	9	10.3	11.59	12.4	13.1	16	18.08	18.4	19.1	20	21	22
Worker 1	Remove plastic from coutertop	Open boxes & unwrapping	Prepare Facuet	Insert Facuet at location	Tight screws underneat h of facuet	Unbox another screw box	Drilling & placing	Preparing 2 adaptor	Unwrapping garbage disposal cup	Install ring pad & rubber ring	Install cardbord ring, screw ring	Drilling screws	Install garbage disposal cup	Install 2 adaptors	Install Rubber gasket, steel filter & steel bowl	Unwrap Garbage disposal pipe, U trap & drain pipe	Drilling	Install Garbage disposal cup & all	Applying glue inside pipe	Drilling	Install Utrap	Cutting pipe	Install Drain pipe	Installing soap dispenser	Cut black pipe & fixes soap dispenser
Worker 2	Brings boxes	Standing				Brings drilling tool	Standing	Went outside	Standing	Bring another drilling tool	Standing					Giving few screws	Went outside to bring glue	giving glue	Giving drilling matchine	standi ng	Went outside for cuttter	Giving cutter	standing	Bring black pipe	standing
Exposed to Hazard	Worker 2 Exposed to Hazard while manually handling box				Worker 1 Exposed to hazad of falling Object							Worker 1 hazad of falling Object on eye						Worker 1 Exposed to ergonomi c hazard							Worker 1 Exposed to hazad For not wearing any safety gloves

3.1.4. Quantify Safety Risk:

While workers are exposed to hazards following accidents might happen:
Risk factors for Material Handling

- Weight and distance of manual material handling affects the back of the worker. According to observation this type of risk factor is low as Weight of material is less than 25 lbs.

Risk factors for ergonomic hazards:

- Frequency and duration of repetitive motions such as bending, kneeling repeatedly etc. This is one of the main factors affecting operation highly as repetition of motion affects workers' bodies.

Risk factors for slip, trip, and fall hazards:

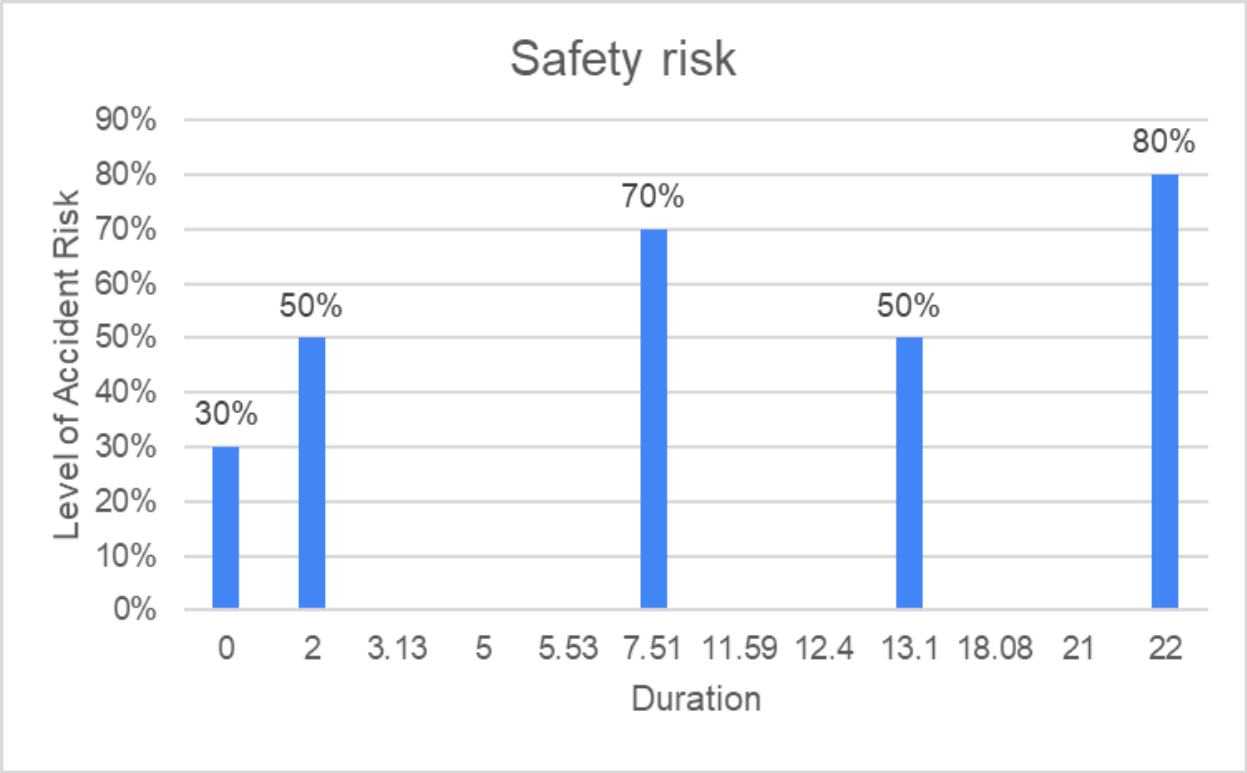
- Clutter and housekeeping in the work area, Wet or slippery surfaces. As seen on site all this factor affect to risk is very low as the site was neat and clean.

Risk factors for struck-by hazards:

- Overhead work or falling objects on eyes as workers not wearing safety glasses. Worker not wearing safety gloves while cutting black pipe of dispenser. Workers need to use PPE all the time. Still, it can affect Moderately to operation. Worker not wearing Safety Cap during operation which can lead to head injury due to falling object and limited head space under sink.

3.1.5. Graph Safety Risk:

According to the above observation and Quantify task risk factor. We can derive the graph of safety risk for workers.



3.1.6. Calculate Percentage of Time in High/Moderate Risk:

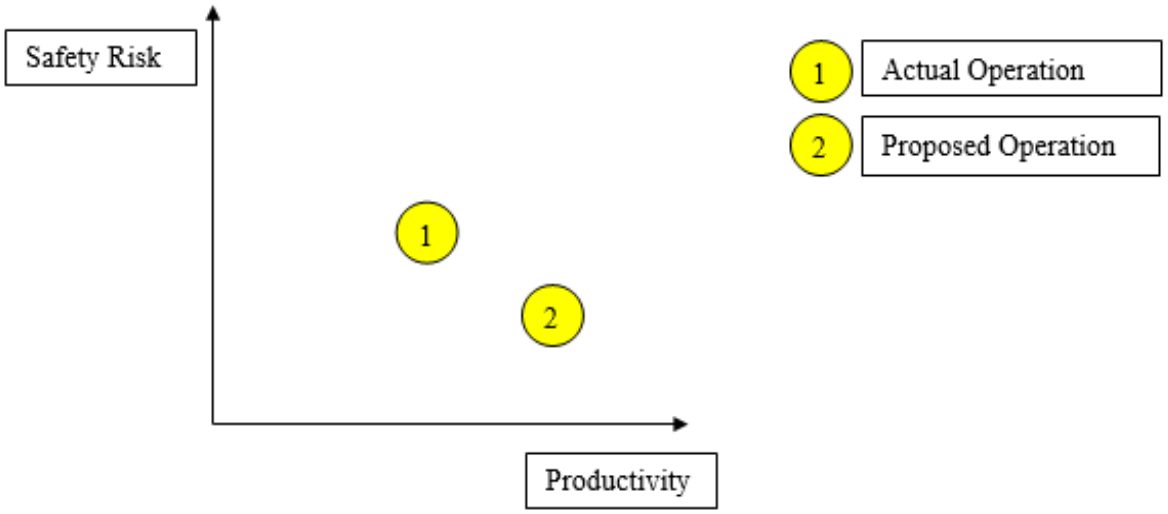
Based on the risk assessment and exposure conditions 50% of time each worker 1 is at high or moderate risk during the operation.

3.2 Perform Productivity Safety Analysis
Examine potential changes to improve productivity:

- Optimize task sequencing and crew coordination: Assign workers to install multiple units in a row, reducing idle time and material handling.
- Material supply system: Establish designated material staging areas on each floor or near work areas to minimize transport distances.
- Ergonomic interventions: Provide adjustable workstations, tools with improved ergonomic design, or material handling aids to reduce awkward postures and repetitive motions.
- Implement ergonomic interventions (e.g., lifting aids, adjustable workstations)

Examine potential changes to reduce safety risk:

- Housekeeping measures: Implement regular cleaning and organizing of work areas to minimize clutter and wet surfaces.
- Implement job rotation or rest breaks: Provide training on proper installation techniques and ergonomics, and rotate workers between tasks to reduce exposure to repetitive motions.



3.3. Trade-offs to Increasing Productivity and Reducing Safety Risk:

1. To increase productivity, measures such as optimizing task sequencing, improving material handling, and providing proper tools and equipment could be implemented.
2. Conducting a thorough risk assessment and implementing targeted risk mitigation measures without compromising productivity.
3. Implementing stricter safety protocols, such as mandatory rest breaks or job rotations, could reduce safety risks but may also decrease productivity.
4. Investing in ergonomic tools, equipment, and workstation designs that improve both productivity and safety.
5. Implementing lean processes and optimizing material handling to reduce non-value-added activities and minimize exposure to hazards.