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# Design of Material Handling for Gallon Mineral Water Loading and Unloading Activities

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***Abstract.*** *The main activity in the distribution of gallon mineral water is loading and unloading gallons from built-up trucks to medium trucks and pick-up trucks. In the loading process, the operator's posture is not netral, such as bending and lifting heavy weights, that can risk on worker experiencing spinal injury. At a distributor where research conducted, the lifting of 19 kg gallons of mineral water was carried out repeatedly with a total of 1440 gallons per-day. The process of loading gallons onto trucks is the initial activity before mineral water is distributed to stores. This study assesses manual material handling gallon activities and designs equipment to reduce the risk of workers experiencing musculoskeletal disorders. The measurement of the potential for musculoskeletal disorders refers to the Lifting Index (LI) of the lifting process. The assessment of the loading and unloading from built-up trucks to medium trucks and to pick-up cars got a LI value of more than point 3 which means that the lifting process is not recommended because it can cause musculoskeletal disorders. To reduce musculoskeletal risk, material handling was designed. The material handling is in the form of a slide that can be folded so that it is easy to carry around. The sliding size is according to the anthropometry of adult males to reduce the physical load of the loading and unloading process and gallons dimensions*

***Keywords:*** *lifting; lifting index; material handling; recommended weight limit; loading unloading*

## I. INTRODUCTION

Manual lifting activities can cause musculoskeletal disorders. Lifting mineral water gallon and carried it from first floor to second floor got a Lifting Index (LI) value above 3.0 (Ilmi, Muqimuddin, et al., 2021), the lifting activity could cause a high chance of Musculo Skeletal Disorders (MSDs), where the Recommended Weight Limit (RWL) for the lifting more than 3.0. Research conducted by Novariyanto and Suparti (Novariyanto, et al, 2016) at a grocery store found gallon distribution workers complained of muscle skeletal disorders, they feel disorder at the left shoulder, right shoulder, left upper arm, wrist, left hand, right hand, waist, and back. The research on the physical workload in loading and unloading sacks of rice in Bulog Surakarta got LI value above 4.0 (Muslimah et al., 2006) which the activity could cause Musculo Skeletal Disorders (MSDs) to the operators. Lifting activities have the potential to be medium to high causing MSDs in various activities in the industry (Andianingsari et al., 2022; Dewantari et al., 2022; Lady & Nuraeni, 2024; Mayangsari et al., 2020).

Musculo Skeletal Disorders (MSDs) caused by MMH in the motor vehicle parts manufacturing researched by (Yang, et al, 2020). This study conducted a risk assessment for predicting the possibility and severity of the injuries and MSDs. Of 236 injured persons registered for occupational incidents and MSDs caused by MMH tasks, 124 (52.5%) were caused by lifting/lowering, followed by 92 (39.0%) pushing/pulling and 20 (8.5%) carrying. The biomechanical loads and kinematics of workers during multiple-task Manual Material Handling (MMH) have been investigated by (Harari, et al, 2020). The origin/destination height was the most influencing predictor of the spinal and shoulder moments and the peak trunk, shoulder

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and knee angles. The relationship between the origin/destination heights and the above parameters was nonlinear. The mass of the box, and the subject's height and mass, also influenced the spinal and shoulder moments. Miswari (2021) assessed the safety of lifting gallons of mineral water for offices by calculating the compressive force at L5/S1. The L5/S1 compressive force on the MMH activity were 1644 N for the lifting position and 2475N when carrying (Miswari et al., 2021). An improvement suggests the operator keep their body position upright, keep the angle of trunk to reduce the moment of force, and use mechanical and electrical material handling tools.

Raichaanah and Susanto (2024) research activity in the procurement of pallet wood materials and analyze manual handling workload on wood lifting by calculating RWL. Operators are potentially exposed to MSDs because the LI value of lifting wood pallets is more than 1, operators also work with high fatigue levels (Raichaanah & Susanto, 2024). Manual material handling research, in gallon and sack lifting activities, has been carried out. Mas'idah (2009) researched lifting rice sacks and got a LI value above 4, they provide a pushcart for carrying rice so the activity is safer with a LI value can be dropped below 3 (Mas'idah, et al, 2009). Iryani (2023) researched lifting rice sacks and improving lifting posture to avoid MSDs (Iryani Inayah et al., 2023). A Welding workbench have designed by Abryandoko (...) for

Application in Laboratory, these findings include enhancing safety and efficiency in welding learning processes.

This research observes the gallon mineral water loading and unloading process that is carried out at the second distributor of gallon mineral water. These distributors receive gallons of mineral water from the first distributors and distribute them to retailers. The activities carried out by workers are unloaded from the built-up truck then loaded directly into the delivery truck and the unloading from the built-up truck to be loaded into the storage warehouse. Loading and unloading activities include lifting, carrying, and arranging products. During the loading process, workers work in a bent posture, thus causing a risk of spinal injury. The gallon loading and unloading workers were all men. Every day workers load and carry 1440 gallons. Weight of one gallon of mineral water is 19 kg. The total load transported by a worker every day was too weight, unloading and loading 19 kg gallons repeatedly with a total weight of around 27,360 kg/day. The process of loading gallons is done manually without tools. Ilmi et al. (2021) said that the use of trolleys in the process of unloading and transporting gallons can slow down work because trolleys should push and control (Ilmi, Okta Dwiyanti, et al., 2021). The repeated manual loading process can drain excess energy and cause pain in the shoulders, upper arms and calves. The physical workload of the gallon loading process in the category of heavy physical workload and it can cause muscle fatigue and increase the risk of spinal injuries. Therefore, it is necessary to analyze the material handling process in this work.

This research aims to analyze the potential of gallon mineral water distributor operators exposed to Musculo skeletal disorders (MSDs) and reduce the risk by designing material handling of gallon unloading and carrying equipment. The lifting indicators are Recommended Weight Limit (RWL) and Lifting Index (LI). RWL and LI are used to assess whether the load weight lifted and lifting position are safe for the operator.

## II. RESEARCH METHOD

Observation on the process of loading and unloading gallon mineral water from the built-up truck and loaded directly into the delivery truck. Interviews were conducted with the workers to find out paint complaints about their experience during work. The lifting variables measure to get recommend weight limit (RWL) and Lifting Index (LI).

**Material Handling Operator**

All workers are male, age range from 25 to 51 years, and work experience more than 1 years. There are 3 workers on unloading and loading activity, all gallons unloaded from the built-up truck and then loading them to medium trucks, pick-ups, or warehouses. The position of the worker when they perform unloading and loading activities are measured.

The process of unloading from large vehicles and loading gallon to medium vehicles was assessed based on lifting variables to obtain the Recommended Weight Limit (RWL) dan Lifting Index (LI) value. The position of the operator when lifting and carrying also was recorded by taking photos of the workers from the side that is perpendicular to the operator.

**Lifting Variables**

Recommendation to limit the load that could be lifted by workers without causing injury known as Recommended Weight Limit (RWL) (NIOSH, 1991). Lifting variables are measured based on the position and working conditions of the lifting, including the calculation of the horizontal multiplier (HM), the vertical multiplier (VM), the distance multiplier (DM), the Asymmetric Multiplier (AM), the determination of the frequency multiplier (FM), and the Coupling multiplier (CM). Measures of lifting variables were carried out in several activities including unloading from Built-up and loading to medium truck, loading to pick up, and transport to warehouse. The loading process is divided into several stack levels of gallons where every level has specific heights. In every unloading and loading activity just two levels of stack were measured, at the first stack or bottom stack, and the last stack or top stack. In collecting data, a roll meter been used to measure. The Recommended Weight Limit (RWL) was calculated, and the Lifting Index (LI) value was calculated by dividing the lifting load by the RWL value to identify whether the lifting process poses a risk of spinal injury or not.

**Design of material handling**

The design of the material handling follows several stages: 1). Analysis of activities during loading and unloading includes the sequence of activities, how teamwork works, size and shape of the gallons, 2). Sketching the material handling, 3). Determine the dimensions of the material handling, 4). Determine the anthropometric data used for the dimensions and the percentile for the anthropometric data used. 5) Make technical drawings of the equipment.

## III. RESULT AND DISCUSSION

In distributing mineral water gallons, the second distributor has 3 types of transportation vehicle with different capacities. Three vehicles used in unloading and loading process are built-up (Hino FG 235), medium truck, and pick-up with capacities of 1440, 200, and 200 gallons, respectively.

There are several types of activities in the process of gallons loading and unloading, including:

1. Unloading from the Built-up truck, loaded them into the medium truck. Lifting from the built-up truck, then carry the gallons and arrange them into the delivery truck.
2. Unload from the Built-up truck, load them into the pick-up. Lifting from the built-up truck, then carrying and arranging them into a delivery pickup.
3. Unload from the built-up car, load them into the warehouse. Lifting from the built-up truck, then bring and arrange them in the warehouse.

**Measures Manual Material Handling (MMH) Variables**

The lifting activity variables collected and measured included the type of activity, the number of gallon stack, the weight of the load, the horizontal distance of gallon, the vertical distance, the angle of asymmetry, the average frequency of lifting per-minutes, the duration of loading and unloading, and type of coupling of gallons. Measurements were carried out on three types of activities on the first and last stack, where each stack was measured 2 times at the initial lifting position (origin) and the destination position (destination). Table 1. consist of the lifting conditions at the initial lifting position (origin) and destination positions of the gallon unloading on the three types of activity.

The calculation of RWL and LI uses the following formula from NIOSH (1991).

$$RWL = LC \ x \ HM \ x \ VM \ x \ DM \ x \ AM \ x \ FM \ x \ CM \quad (1)$$

$$LI = \frac{W}{\min(RWL_{origin}, RWL_{destination})} \qquad (2)$$

where HM = Horizontal multiplier
VM = Vertical Multiplier
DM = Distance Multiplier
AM = Asymmetry Multiplier
FM = Frequency Multiplier
CM = Coupling Multiplier

A lifting is safe if the Lifting Index (LI) in both the original and the destination position has a value of less than 1. The LI value of 1<LI<3 can be said to be safe if it is done by a person who is used to the job. However, if the LI value is > 3, then the activity is at risk of causing Musculo Skeletal Disorders (MSDs) and should not be carried out. Next Table 2 and 3 content of lifting

**Table 1.** Worker position on Manual Material Handling activity

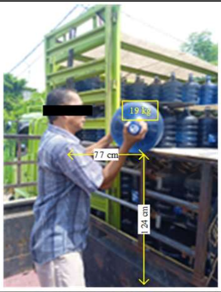
| No | Type of activity | Stack | Position | Figure | Simulation |
|---|---|---|---|---|---|
| 1. | Unloading from *Built up*, loading to *Truck* | First | *Origin* |  |  |
| | | | *Destination* |  |  |
| | | Last | *Origin* |  |  |
| | | | *Destination* |  |  |

**Table 1.** Worker position on Manual Material Handling activity (continued)

| No | Type of activity | Pile | Position | Figure | Simulation |
|---|---|---|---|---|---|
| 2. | Unloading from *Built up, loading to Pick up* | First | *Origin* |  |  |
| | | | *Destination* |  |  |
| | | Last | *Origin* |  |  |
| | | | *Destination* |  |  |

variables and its RWL dan LI.

On origin position there are two lifting activities that can cause MSDs and should be improved because they have a LI value of > 3, while four other activities have a LI > 1 that potentially can cause MSDs. On destination position there are four lifting activities that can cause MSDs and should be improved because they have a LI value of > 3, while two other activities have a LI > 1 that potentially can cause MSDs. In helping workers carry out the loading and unloading process safely, material handling

**Table 1.** Worker position on Manual Material Handling activity (continued)

| *No* | *Activity type* | *Pile* | *Position* | *Figure* | *Simulation* |
|---|---|---|---|---|---|
| *3.* | *Unloading from Built up, arrange into Warehouse* | *First* | *Origin* | 60 cm 128 cm |  |
| | | | *Destination* | 54 cm 24 cm |  |
| | | *Last* | *Origin* | 46 cm 128 cm |  |
| | | | *Destination* | 58 cm 120 cm |  |

for unloading and loading in the form of a manual conveyor is designed. Table 2 and 3 outlines the lifting variables and RWL and LI values for each activity.

**Tabel 2.** Variables of lifting, RWL, dan LI on origin

| No | Type of actifity | Stack | LC | HM | VM | DM | AM | CM | FM | RWL | LI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Uloading from *Built up, loading to medium Truck* | First layer | 23 | 0.32 | 0.89 | 0.87 | 1 | 1 | 0.92 | 5.28 | 3.60 |
| | | Last layer | 23 | 0.38 | 0.89 | 1.32 | 1 | 1 | 0.92 | 9.41 | 2.02 |
| 2. | Unloading from *Built up loading to Pick up* | First layer | 23 | 0.32 | 0.96 | 0.87 | 1 | 1 | 0.92 | 5.70 | 3.33 |
| | | Last layer | 23 | 0.36 | 0.96 | 1.03 | 1 | 1 | 0.92 | 7.51 | 2.53 |
| 3. | Unloading *from Built up* arrange into *Warehouse* | First layer | 23 | 0.42 | 0.88 | 0.86 | 1 | 1 | 0.92 | 6.67 | 2.85 |
| | | Last layer | 23 | 0.54 | 0.88 | 1.38 | 1 | 1 | 0.92 | 13.94 | 1.36 |

**Tabel 3.** Variables of lifting, RWL, dan LI on destination

| No | Type of actifity | Stack | LC | HM | VM | DM | AM | CM | FM | RWL | LI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Uloading from *Built up, loading to medium Truck* | First layer | 23 | 0.45 | 0.82 | 0.87 | 0.86 | 1 | 0.92 | 5.84 | 3.25 |
| | | Last layer | 23 | 0.42 | 0.93 | 1.32 | 0.81 | 0.95 | 0.92 | 8.26 | 2.30 |
| 2. | Unloading from *Built up loading to Pick up* | First layer | 23 | 0.31 | 0.82 | 0.87 | 0.86 | 1 | 0.92 | 4.06 | 4.68 |
| | | Last layer | 23 | 0.38 | 0.96 | 1.03 | 0.71 | 0.95 | 0.92 | 5.45 | 3.48 |
| 3. | Unloading *from Built up* arrange into *Warehouse* | First layer | 23 | 0.46 | 0.82 | 0.86 | 0.81 | 1 | 0.92 | 5.60 | 3.39 |
| | | Last layer | 23 | 0.43 | 0.90 | 1.38 | 0.90 | 0.95 | 0.92 | 9.76 | 1.95 |

**Table 4.** Data source for determining material handling dimensions

| No | Data source | Dimension name | Initial Dimensions (cm) | Dimensions refer to percentile (cm) | Allowance (cm) | Final Dimension (cm) |
|---|---|---|---|---|---|---|
| 1 | Gallon diameter | Conveyor width | 26 | 26 | 15 | 41 |
| 2 | Standing elbow height | Conveyor front leg height | 121.63 | 143 | 2 | 145 |
| 3 | Distance between truck | Conveyor length | 200 | 200 | 30 | 230 |
| 4 | Knee height | Conveyor rear leg height | 62.5 | 74 | 2 | 76 |

**Design of Manual Conveyor**

The unloading material handling have desained is a slide that can be folded so that it is easy to carry around. The material handling can reduce the physical load of workers and the risk of injury during gallon unloading activities. The size of the equipment uses anthropometric data that taken from Indonesian anthropometric data and considers the size of the workpiece. Determination of the percentile of any anthropometric data consider that the equipment can be used comfortably by a large portion of the unloading operator population. The data sources, selection of percentiles, and material handling dimensions are described in Table 4.

The diameter of the gallon is used as reference to determine the width of the conveyor. Meanwhile, the distance between trucks is used as reference to determine the length of the conveyor. The height of the standing elbow is used as reference data to determine the height of the highest leg of the conveyor (front leg), percentile 95%tile is used or as high as 143 cm. Knee height is used as the conveyor's shortest leg (rear leg), percentile 95%tile is used or as high as 74 cm. The 95%tile is used with consideration that tall people can use the equipment comfortably and not bend over, as well as short people can also use them comfortably. The final dimensions of the device also add allowances for the operator and the workpiece. The calculation of the final dimensions of the device is as follows.

Conveyor width
= width of gallon + allowance
= 26 + 15 = 41 cm

Height of the highest legs of the conveyor
= $\bar{x}$+1,64 SD + allowance
= 121.63 + 1,64 (13.13) + 2 = 145 cm

Conveyor length
= Distance between Truck + allowance
= 200 + 30 = 230 cm

Height of the lowest legs of the conveyor
= $\bar{x}$+1,64 SD+ allowance
= 62.5 + 1,64 (7.14) + 2 = 76 cm

Width of conveyor refers to diameter of the gallon plus an allowance of 15 cm. Allowance is an additional space to prevent gallons from getting stuck when unloaded and to prevent the accumulation of gallons during the transfer process. Height of the conveyor leg is the 95th percentile of standing elbow height, this leg height is assumed to be the maximum height and can be adjusted to be shorter. Length of the conveyor is the distance between the built-up car and the delivery car plus an allowance of 30 cm. This allowance ensures that both ends of the conveyor position inside of the two vehicles so that in the process of transferring the gallons fall in the destination vehicle. The rear leg height of conveyor is the 95th percentile of knee height, this height is the minimum height of the conveyor leg and can still be adjusted to be higher.

The recommended material for the manufacture of the Manual Conveyor uses aluminum for all parts including the frame, base (anvil board), and the legs. Aluminium was chosen because it has lightweight so it can be moved just by one or two people. Aluminum material has a strong structure to withstand a dynamic load of 55 kg (Uji et al., 2019) Wibawa. The Aluminum material used is an alloy 3003-H12, with the standard frame used is DIN EN 10056-1 (Equal angles). This material is also resistant to corrosion, so it has durability and a long lifespan. The design of the manual conveyor is portable and adjustable so that it is easy to move and adjust in height.

Figure 1 is a drawing of the material handling design of manual conveyor for gallon loading activities.

**RWL and LI Improvement**

The simulation was carried out with Catia software. The simulation assesses the RWL and LI as workers load gallons from the manual

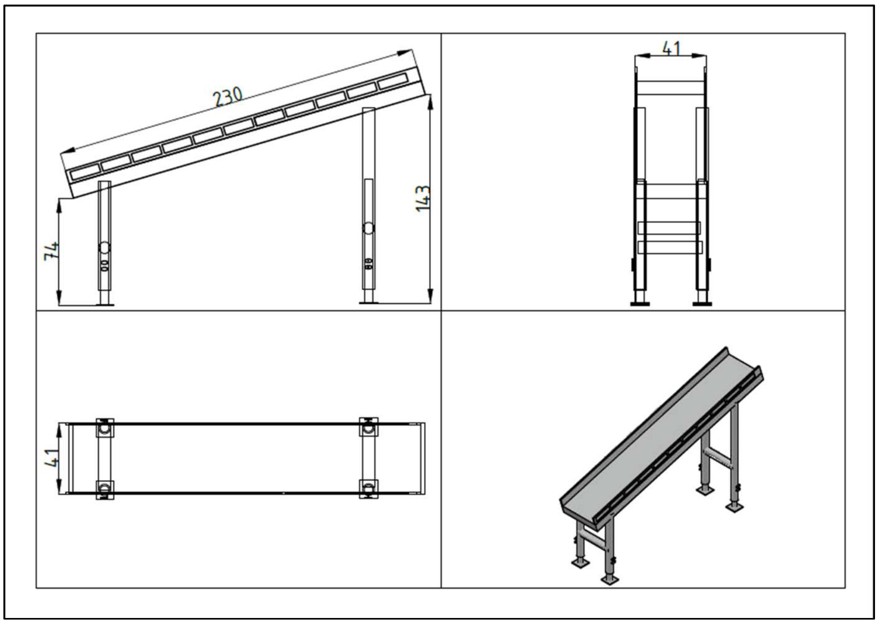



**Figure 1.** Design of Manual Conveyor

conveyor and carrying the gallons from the manual conveyor to the gallon stuck on the second vehicle. Figure 2 is the posture of workers when lifting the gallon from manual conveyor.

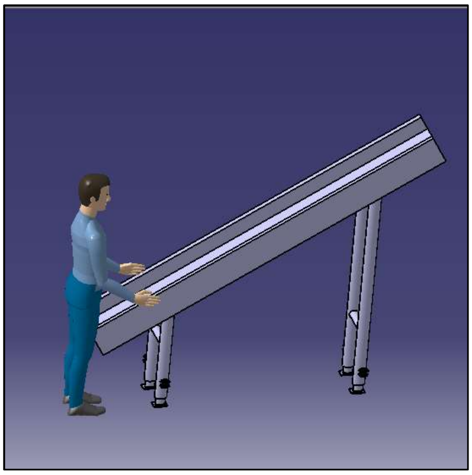


**Figure 2.** Operator position at the end of the manual conveyor

The calculation of the RWL and LI of the simulation using Catia software, where the variables used correspond to the initial data. The results of the calculation got the RWL and LI values on the Origin position is 13.85 and a LI value 1.37. There is a significant decrease in RWL and LI from the first condition which is not using the manual conveyor, according to Table 1 LI before using manual conveyor is more than 3. There is a reduction in physical load when using manual conveyors because they minimize the lifting and carrying activities. With the implementation of this manual conveyor, all gallon loading activities will have a LI<3, safe for workers who have been trained for the job.

## IV. Conclusion

The loading and unloading Lifting Index in transfering gallon mineral water from built-up trucks to medium trucks and to pick-up cars at the first layer got a LI value of more than point 3 which means that the lifting process is not recommended because it can cause musculoskeletal disorders. The last layer at the loading and unloading process got a LI above point 2 which means that caution is needed in lifting because it is at risk of causing injury. To reduce musculoskeletal disorders, gallon material handling was designed. The material handling is in the form of a slide that can be folded so that it is easy to carry around. The diameter of the gallon is used as reference to determine the width of the conveyor plus an allowance of 15 cm. The height of the rear leg of the conveyor is the 95th percentile of standing elbow height, this foot height is assumed to be the maximum height and can be adjusted to be shorter. The length of the conveyor is the distance between the built-up car and the delivery car plus an allowance of 30 cm. The height of conveyor's front leg refers to the 95th percentile of knee height, this height is the minimum height of the conveyor foot and can still be adjusted to be higher.

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