# Risk Level for Manual Material Handling Activities Using Key Indicator Method in the Simulation of TPS Laboratory at Industrial Engineering, Diponegoro University

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## Abstract

The activities that are often carried out by the Indonesian people is manual material handling. Based on a preliminary study distributed to 31 simulation participants at Toyota Production System in Industrial Engineering Laboratory, Diponegoro University, the top three of complaints about body parts after simulation were 93.5% on the upper neck, 87.1% on the left shoulder, right shoulder, back, and 83.9% on the lower neck. It is necessary to identify work attitude factors to reduce these complaints. The study used the first, second, third, fourth, packaging and shipping, warehouse, and logistics workstation. The results of the risk factor rating points of four simulators in all areas in a row are 34-36, 34-36, 34-36, 23, 16, 21, and 25. These risk rating points do need to be improved because it got slightly increased category level based on the KIM-MHO assessment. To overcome risks, it is necessary to improve work by changing the work attitude of hand/arm position also body posture/movement indicator. After proposed improvements were implemented, the results of the risk factor rating points in all areas in a row are 17, 17, 17, 17, 16, 15, and 15. These risk rating points do not need to be improved because it got low category level.

## Keywords
Manual Material Handling, Key Indicator Method, Movement.

## 1. Introduction

One of the activities that is often carried out and tends to be repeated by the Indonesian people is manual material handling (MMH). Manual transfer of goods can pose a risk in doing the job if it is not done correctly, for example an accident. Based on data, manual material handling activities, such as handling, lifting or carrying, have a fairly large percentage of work that causes injuries in 2019 in the UK, reached 20%, which ranks second after activities such as tripping or falls (slips, trips or falls on the same level) which ranks first by 29% (Health and Safety at Work, 2019). Meanwhile, work accidents related to the spine reached 88% in 2017-2018 with a bad body condition (body stressing) having a large enough percentage of occupations that cause injuries in Australia, reached 45% (Safe Work Australia, 2017). Meanwhile, back injuries had 142,230 work-related injuries in 2018 in the United States (U.S. Bureau of Labor Statistics, 2018). Manual material handling was defined as the transportation of loads by one or two workers, like lifting, holding, lowering, pushing, pulling, carrying, or moving loads. Improving manual material handling activities is still needed because it still has advantages when compared to improving by using tools, that manual material handling can be done in a limited space and is carried out when doing activities that rely heavily on human physicality to lift goods, more flexible, cheaper, and easier to do, also actually we can still improve our physicality with better strategies to working in some physical job.

The Toyota Production System Laboratory is a laboratory that approaches lean principles, especially on process optimization, so that it has a focus on results in an efficient way, both in terms of costs, resource use and process speed. The goal of this laboratory is similar to that of lean principles, which is to increase process efficiency, increase productivity, and reduce waste. Laboratory simulations can be adjusted as needed. These simulations can be related to the ergonomics of manual material handling activities which allow excessive muscle stretching if carried out continuously, so that it is very likely to cause the risk of injury to workers. Preliminary studies are used to determine body complaints obtained through questionnaires. The questionnaire has been adjusted to the simulation conditions. Based on a preliminary study distributed to simulation participants, the top three complaints that occurred during

simulation activities were as many as 93.5% of simulation participants experienced complaints on the upper neck, as many as 87.1% of simulation participants experienced complaints on their left shoulder, right shoulder, and back, and as many as 83.9% of simulation participants experienced complaints in the lower neck. Due to the high percentage of complaints, it is very important to evaluate these activities, so that efforts are made to identify or find out the work attitude factors that affect the risk when carrying out manual material handling activities by considering factors related to the work movement of workers rather than proposing additional new tools.

Recommendations for manual material handling are needed to achieve the goal of eliminating or reducing risks. To identify this risk, an ergonomic approach can be used in manual material handling. Several methods have been developed in the evaluation of work risks in manual material handling activities, including observation, measurement or checklists such as NIOSH, RULA, REBA, and KIM. We know that there are so many research projects using ergonomic approach. For examples of some research projects about KIM, from Steinberg (2012), we know that he focused on explained the KIM LHC and PP in version of 2007, from Yarmohammadi, et al. (2016), we know that they focused on relationship between KIM-MHO and the WMSDs on auto mechanics, from Klussmann, et al. (2017), we know that the focused-on KIM-MHO criterion validity regarding the prevalence of WMSDs, from Feldmann, et al. (2019), we know that they focused on evaluation in order picking systems.

In conducting research on manual material handling, many research projects still do not have used the KIM, especially KIM-MHO as an assessment tool, even though according to Chao et al. (2018), the use of KIM-MHO can examine both in terms of task characteristics, body posture, and environment. KIM-MHO also has high simplicity and suitability scores so that it can be applied as a risk assessment tool for physical work. The results of risk assessment can provide a tool to determine risk priorities and actions to reduce the risks, so the new work attitudes will be designed, especially in manual material handling work. In addition, KIM-MHO is used to assess work that need of high accuracy or activities related to small objects. The objects in this study categorized as assembly activities that need of accuracy, so that KIM-MHO will appropriate to use as an assessment tool. It hoped that beside to enrich the research using KIM, the using of this appropriate assessment tools also will be able to reduce work risks in this activity. This study will focus on assembling system in the workstation, delivery system in the logistics, and packaging-delivery system with new version of the KIM assessment. Based on the background, the objectives that to be achieved from this research are:

1. Compare the results of the work attitude assessment from each activity of the simulation
2. Provide proposed improvement of work attitudes of the simulation
3. Compare the before and after results of the work attitude assessment from each activity of the simulation

## 2. Literature Review

The literature review contains an understanding of the sciences related to research, that consist of manual material handling, risks, risk factors, risk management, and risk assessment.

### 2.1 Manual Material Handling

The dominant form of manual activity in the industry is commonly referred to as Manual Material Handling (MMH). MMH is defined as the transportation of loads by one or two workers whose activities include lifting, holding, lowering, pushing, pulling, carrying, or moving loads, both living and inanimate. MMH is a physical activity that is most often done while on the job every day. It is very necessary to have a lifting limit to create a safe and healthy work atmosphere so that workers have little or no injury (Karlheinz et al., 2012). In order to create a safe and healthy working atmosphere, it is necessary to have a lift limit for the operator. According to (Suhadri, 2008), international lifting limits are men under the age of 16 (maximum 14 kg), men aged 16-18 years (maximum 18 kg), men aged over 18 years (no restrictions), women aged 16. -18 years (maximum 11 kg), and women over 18 years (maximum 16 kg). This lifting limit can help to reduce pain, pain in the spine and reduce discomfort at work.

### 2.2 Risk

According to Srinivas (2019), risk is defined in terms of uncertain events that may be positive or negative that affect the objectives of activities. However, the actual risk is more about a situation, an existence or event that makes sense and results in losses and has an impact on aspects of the implementation of activities.

### 2.3 Risk Factor

Risk factors that influence manual material transfer are divided into four characteristics (Suhadri, 2008), including worker characteristics (physical, motoric, psychomotor, sensory, personal, health), material characteristics (load, dimensions, load distribution, coupling, stability), job characteristics (geometry, frequency, complexity, environment), and work attitudes (individual, organizational, administrative). But apart from that, the risk factors that are interrelated with the occurrence of injuries due to manual handling include unnatural work attitudes, forced work attitudes, awkward body postures, repetitive movements, use of excess capacity, and static work attitudes (Klussmann et al., 2017). Examples of work attitudes include standing work attitude, sitting work attitude, bending work attitude, lifting weights, carrying loads, pushing loads, and pulling loads. The work attitude is carried out depending on the conditions of the existing work system. Wrong work attitude will increase the risk of injury at work. Hazardous conditions caused by working attitudes when manual material handling is not appropriate, of course, must be prevented and handled properly. Handling and prevention will be easier to do after knowing the risk factors for these activities.

### 2.4 Risk Management

According to Srinivas (2019), The stages in carrying out risk management in general start from risk identification, risk classification, risk assessment, proposed improvement, risk control, and assessment of risk control results. Meanwhile, the stages in carrying out a manual risk assessment of object handling work consist of four stages starting from manual identification of object handling jobs that require assessment, developing an assessment plan, carrying out the stages of risk assessment, to reviewing controls. Whereas in selecting the method of assessing the risk of material handling work manually, it must be based on the purpose of using the method, the characteristics of the work being assessed, the person who will use the assessment method, and the availability of data sources for collection and processing. The benefits of implementing risk management include:

1. The risk management process must be carried out in a sustainable manner to obtain a maximum process efficiency
2. Related to the stakeholders involved. A clear understanding and awareness of the potential risks in the project contribute to better risk management with appropriate mitigation techniques.
3. More efficient troubleshooting process which can be better supported
4. Careful preparation regarding risk management will bring many benefits.

### 2.5 Risk Assessment

Methods or tools that can be used in risk assessment in the scope of ergonomics include through RULA, REBA, NIOSH, and KIM. Here's the explanation.

1. RULA. RULA (Rapid Upper Limb Assessment) is an ergonomic assessment tool in the workplace, where spinal diseases are a major problem (Jagadish et al., 2018). RULA conducted an assessment of upper body posture. RULA assesses the movement of posture and energy spent related to the activities carried out. RULA has 4 levels from negligible, low, medium, and high.
2. REBA. REBA (Rapid Entire Body Assessment) is an ergonomic assessment tool in the workplace where it assesses all parts of the body (Jagadish et al., 2018). REBA assesses activities caused by posture static, dynamic, rapid change, and posture imbalance. REBA has 5 levels from negligible, low, medium, high, and very high.
3. NIOSH. NIOSH (National Institute for Occupational Safety and Health) is used to identify any complaints in the spine by knowing the forces that occur in the back (Kamat et al., 2017). It has two methods, the MPL (Maximum Permissible Limit) and RWL (Recommended Weight Limit) methods.
4. KIM. KIM is the best assessment tool for assessing working conditions that have work characteristics, load descriptions, and others (Chao et al., 2018). The indicators possessed by KIM, especially KIM-MHO, are the duration of work, hand-arm posture, type of work, work frequency, work organization and working environment conditions. KIM has 4 levels from green, green-yellow, yellow, and red along with measures for prevention.

## 3. Methods

The method contains the stages in conducting research, which consists of a conceptual framework, research procedures, research design, research methods, and simulation flow.

### 3.1 Conceptual Framework

The framework used in the research refers to the stages in carrying out risk management for manual material handling work according to Srinivas (2019) in the previous chapter.

1. Identification of risks, by identifying possible risks during simulation

2. Risk classification, by defining the type of risk during the simulation and determining the risk assessment method
3. Risk assessment, by conducting evaluation based on the real conditions according to the assessment criteria
4. Proposed improvement, by providing recommendations of working conditions that exceed the standard
5. Risk control, by implementing the proposed improvement
6. Assessment of risk control results, by evaluating implementation of the proposed improvement

### 3.2 Research Procedures

The research was started through field observations to find out real conditions in the field, especially related to the simulation process flow in the laboratory for more detail. In addition, to strengthen the background, we will use questionnaires distributed to students who have done simulations in the TPS laboratory to find out the complaints when conducting simulations. The next step is formulating the problem being faced by the object of research. The formulation of the problem from this research is regarding the description of work risks and the implementation of improvements. The next step is formulating the objectives of the research, there are determine the results of the risk evaluation of the simulation activity, provide suggestions for improvement, and compare the results of the evaluation before and after implementing suggestions for improvement of the simulation activity. The next step is literature study. Literature study was conducted to obtain information in solving the problems being faced by the object of research. Literature study is carried out by formulating theories based on scientific publications that have been published previously so that a method will be obtained to solve problems using an appropriate approach. The next step is data collection by collecting information and data directly from the field. Data collected directly in the form of work attitudes, worker data, and supporting data. In addition to interviews, data collection uses cameras and direct observations while the simulation is in progress. Then data processing step is done by processing the collected data as input to calculate the risk factor score, then categorizing the risk factors, sorting the activities with the highest risk factors. The risk assessment using the KIM-MHO assessment sheet. Then the analysis step is carried out on the score of risk factors that have a bad category, so the proposal for improving work attitudes will be given based on the indicators from assessment sheet. After implementing the proposed improvement, the latest risk factor value will be calculated. The last step of research is making conclusions that are able to answer the research objectives. In addition, suggestions are also given to future research in order to develop research that has been carried out.

### 3.3 Research Design

In the research design, this research is a quantitative study with the research location in the Toyota Production System Laboratory at the Industrial Engineering Department, Diponegoro University, Semarang. This research was conducted in July 2020 with the object are all material handling activities in the simulation at the first workstation, the second workstation, the third workstation, the fourth workstation (quality control), the product packaging and delivery workstation, the warehouse, and the logistics workstation. This study used four samples as a simulator with the characteristics of being healthy, having no history of spinal diseases and having simulated at least 4 times.

### 3.4 Research Method

The method or tool used in the risk assessment is the Key Indicator Method in Manual Handling Operation. KIM is a manual screening method to rapidly assess work activities by identifying risks (Feldmann et al., 2019). The KIM-MHO checklist, which was developed by Federal Institute for Occupational Safety and Health (BAuA) in Germany around 2007 and now they have the new version one, is a kind of assessment that suitable for assessing the working conditions for physical work and contains an objective requirement, load description, and job characteristics and their interaction. The key indicators considered in KIM-MHO have 3 steps, first we collecting time rating point from activities, then we collecting time rating point from indicators, like type of force exertion in the finger/hand area, gripping condition, hand/arm position, unfavorable working conditions, body posture, work organization, then the last steps are evaluated and assess by calculating all of the key rating point, then multiply with activity rating point so we got the result. After we know the result, then we have to categorizing the result in risk range and level, also we know how to making the proposed improvement. KIM-MHO has the typical activities like assembly activities, soldering, sewing, sorting, cutting, cashiering, manually controlling, pipetting, work at a microscope, making music, joining, turning, shifting, pressing, lifting, holding, relocating, wrapping. The simulation doing assembling or joining activities, so it will appropriate for this simulation. The choice of tools be used to assess the risk should depend on (Chao, et al., 2018), i) the problem being investigated, ii) the characteristic of the work, iii) the preference of the analysts, and iv) the conditions of the workplace. KIM-MHO has high simplicity and suitability scores so that it can be applied as a risk assessment tool for physical work than the other one. KIM-MHO can examine both in terms of task characteristics, body posture, and environment. The risk rating point level category of this assessment consists of 4, that is, it will be low/green if the work indicates <20 points, it will be slightly increased/green-yellow if the work

indicates 20 - <50 points, it will be substantially increased/yellow if the work indicates 50 - <100 points, and it will be high/red if the work indicates >100 points.

### 3.5 Simulation Flow

The flow of the simulation in the study will be shown in Figure 1 and will be explained afterwards.

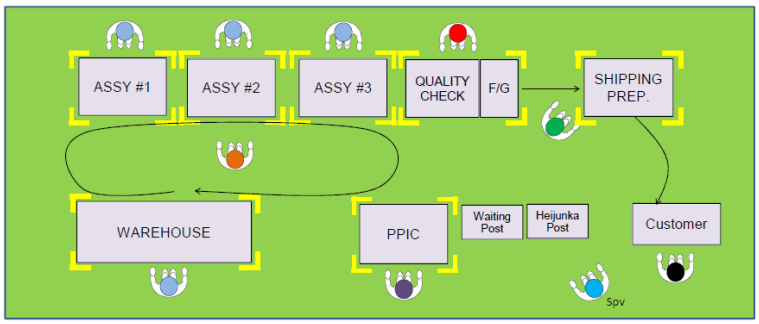


Figure 1. Simulation flow

1. The consumer sets the time for 10 minutes. The bell will sound to signal the start of the scenario. The bell will ring every 1 minute. Consumers place orders to the company every 1 minute.
2. PPIC performs scheduling according to consumer demand. Scheduling is done by paying attention to the variety of products arranged in the Heijunka post.
3. Operator of the 1st, 2nd, and 3rd workstation will assemble the products according to the kanban provided in the kanban box.
4. Operator of the 4th workstation will repair products with minor defects using assistive devices. The goods that defect will not immediately put into the defect container (non-good product), but they can still be repaired. In this simulation, it is required to complete the product according to the demand from the consumer.
5. Packaging and delivery operators will deliver the product to the consumer when the product reaches 10 products in 10 minutes.
6. Consumers will check the product (good or not)
7. Simulation over.

When the simulation takes place, the logistics person is obliged to check the availability of components and kanban at each workstation and the warehouse is obliged to adjust the number of components in each box.

## 4. Data Collection

Data collection contains the data used in conducting research, which consists of simulator data, workstation, and risk assessment methods.

### 4.1 Simulator Data

The four-simulator data will be shown in Table 1. The simulator consists of two men and two women.

Table 1. Simulator data

| Num. | Operator | Gender | Age (year) | Weight (kg) | Height (cm) |
|---|---|---|---|---|---|
| 1. | 1 | Female | 22 | 90 | 160 |
| 2. | 2 | Male | 22 | 80 | 165 |
| 3. | 3 | Female | 22 | 69 | 162 |
| 4. | 4 | Male | 22 | 65 | 165 |

### 4.2 Workstation

The flow of workstations will be explained in this section.

1. The First Workstation with the workflow takes the chassis, takes the axle, inserts the axle at each end of the chassis, takes the axis holder, puts the axle holder at each end of the axle, takes the bolt, and hooks the axle to the chassis by tightening the bolt.

2. The Second Workstation with the workflow takes the chassis assy, picks up the tire, puts the tire at each end of the axle, takes the nut, and hooks the nut to the chassis by tightening the nut.
3. The Third Workstation with the workflow of takes the assy, takes the cabin 1, puts the cabin 1 on the assy, takes the bolt, hooks the assy and cabin 1 with the bolt, takes the box, puts the box on the assy, takes the bolt, and attach the assy and box by screwing the bolt.
4. Fourth Workstation (Quality Control) with the workflow to check the quality of the final product with tools.
5. Packaging and Shipping Workstations with workflow to package and ship products to the consumer section.
6. Warehouse section with workflow to manage the material inventory and serving logistics.
7. Logistics section with the workflow to ensure the components and kanban at each workstation are always available.

### 4.3 Risk Assessment

Risk assessment is carried out for each activity and in each simulator. During the simulation, the first operator's left hand grasps the component while the average right hand of the first operator performs the component assembling activity. The average activity lasted 53 seconds and 17 seconds. The activity of assembling by combining several components is included in the activity of using moderate energy. To determine the holding time, the activity gets a rating point of 9 and to determine the moving time, the activity gets a rating point of 4. For force exertion in the finger/hand area uses the highest rating point between the holding time and moving time so that the activity gets a rating point of 9. Then for the grip condition (gripping condition), because the components have different shapes and a caution is needed in handling the components, this condition is included in the restricted force transfer and the activity gets a rating point of 2. Regarding the condition of the position and movement of the hand (hand/arm position and movement), the operator holding the component with the hand facing upward and clasped hands in static conditions and continuously, so that the condition of the operator's hand included in the category of bad (poor) and activity gets a rating point of 3. Regarding working conditions, including better because when the simulation progresses, the condition of noise, lighting in the room is in a normal condition and there are no significant obstacles, then the activity gets a rating point of 0. Regarding body posture/movement, the operator's position is in a standing position, the upper body is bent slightly, the position of the hands is floating above the work area and the position of the right leg is bent, then the activity gets a rating point of 2. Regarding work organization (work organization/temporal distribution), the physical workload condition that is felt is not too heavy (medium), so it is included in the rare variation of the physical workload situation, then the activity gets a rating point of 2. An example of the simulator work posture at the first workstation will be shown in Figure 2.

Figure 2. Simulator’s body postures

## 5. Results and Discussion

Results and discussion contain the results of data processing and discussion used in conducting research, which consists of results, discussion, proposed improvement, and evaluation of proposed improvement.

### 5.1 Results

Data processing is obtained by adding up the rating points of all indicators, then multiplying that rating point by the time rating point. An example of a recapitulation of risk rating points at the first workstation will be shown in Table 2.

Table 2. First workstation's risk rating point

| Workstation | Indicator | Op. 1 | Op. 2 | Op. 3 | Op. 4 |
|---|---|---|---|---|---|
| First WS | Holding Time (sec) | 53 | 51 | 55 | 54 |
| | Moving Time (sec) | 17 | 19 | 16 | 19 |
| | Time Rating Point | 2 | 2 | 2 | 2 |
| | Force Excertion | 9 | 9 | 9 | 9 |
| | Gripping Condition | 2 | 2 | 2 | 2 |
| | Hand Positions | 3 | 2 | 2 | 3 |
| | Work Conditions | 0 | 0 | 0 | 0 |
| | Body Posture | 2 | 2 | 2 | 2 |
| | Work Organisation | 2 | 2 | 2 | 2 |
| | Total Indicator Points | 18 | 17 | 17 | 18 |
| | **Results** | 36 | 34 | 34 | 36 |

For the results of the risk rating point for the first workstation is 34-36 (average 35), the second workstation is 34-46 (average 35), the third workstation is 34 -36 (average 35), the fourth workstation is 23, the packaging and shipping workstation is 16, the warehouse section is 21, and the logistics section is 25.

## 5.2 Discussion

To explain the level of risk for manual activity in research, a summary of risk rating points classified in the risk level category will be shown in Table 3.

Table 3. Workstation's risk category before improvement

| Workstation | Op. 1 | Op. 2 | Op. 3 | Op. 4 | Category |
|---|---|---|---|---|---|
| First WS | 36 | 34 | 34 | 36 | Slightly Increased |
| Second WS | 36 | 34 | 36 | 36 | Slightly Increased |
| Third WS | 36 | 34 | 36 | 34 | Slightly Increased |
| Fourth WS | 23 | 23 | 23 | 23 | Slightly Increased |
| Packaging and Delivery WS | 16 | 16 | 16 | 16 | Low |
| Warehouse | 21 | 21 | 21 | 21 | Slightly Increased |
| Logistics | 25 | 25 | 25 | 25 | Slightly Increased |

It appears that the majority of workstations need improvement because they have slightly increased levels, except the packaging and shipping workstation do not need improvement. We can list several statements related to the simulator posture when doing the simulation, including:

1. Hands take longer to lift weights than they are placed on the worktable
   According to Faber, et al. (2017), they showed that estimating hand forces using an ambulatory measurement system that still have errors, this error is regarded acceptable for the assessment of spinal loading during manual lifting. So, for this study also focused on hand forces and hand position to reduce the risk.
2. Bending and bowing position
   According to Kim and Yoo (2015), they showed that the manual material working with high activations of the shoulder muscles or forward head and shoulder postures causes an increased risk of neck and shoulder musculoskeletal disorders. The forward head and shoulder angles while performing manual work need to be considered in selection of the forward distance of a worktable form the body. The forward distance of a worktable can be an important factor in preventing neck and shoulder pain in manual material handling workers. So, for this study also focused on body posture/movement to reduce the risk like bending and bowing position.
3. Different hand / arm position
   According to Faber, et al. (2017) again, that hand force related to arm position acceptable for the assessment of spinal loading during manual lifting to reduce the risk.
4. The position of the legs varies
   Even though Kim and Yoo (2015) just showing of upper body posture, it is necessary to focused on the lower body posture, too.

### 5.3 Proposed Improvement

To reduce the risk rating point, things that need to be changed at the workstation are:

1. Reducing time of force exertion in the finger/hand area
   By placing objects on the work table, it can reduce the holding time longer and can combine the two hands to work. This is related to the economic concept of movement. The principle of movement economics is to analyse and evaluate work methods in order to obtain more efficient work methods. The principles that are applied include: (1) movement of only the parts of the body that are needed, (2) the work should be designed as easily as possible, (3) it is made to ensure that materials and equipment have a fixed place, (4) place the materials and equipment in a place that is easy, fast, and convenient to reach and (5) balance the load of the left hand and right hand based on Dewi et al. (2015). The design evaluation stage can be carried out by analysing the processing time based on the map of the left hand and right hand before and after improving the work method. So that we get a summary of time, which are idle time, working time, and total time in a row on the left hand are 0 seconds, 59 seconds, and 59 seconds, and on the right hand are 3 seconds, 56 seconds, and 59 seconds. One of the ways to fix the imbalance of working time with both hands is by placing the work object on the workplace. So, we get a summary of time, which are idle time, working time, and total time in a row on the left hand are 0 seconds, 31 seconds, and 31 seconds, and on the right hand are 3 seconds, 28 seconds, and 31 seconds, respectively. The imbalance in the working time of the two hands becomes more balanced after being improved and combining the two hands is quite effective when working.
2. Changing the position of the hand in the hand/arm position and movement
   Changing the position of the hand that originally held the component with the hand facing upward or tilted sideways in making one component of the raft become face down or straight sideways. Changing the posture of the body posture/movement
   Changing the posture which was originally with the body bent, the head bowed, and the legs bent in making one component of the raft upright, the head is kept down to a minimum, and the legs are straight with a distance of 2 feet about 20-30 cm. This refers to a study according to Miftahudin (2016) which shows that there is a relationship between a bending work attitude and a change in the position of the spine. The results of this study provide information about changes in the vertebral curve of construction workers as a result of non-ergonomic work positions such as bending done every day and causing low back pain.

### 5.4 Evaluation of Proposed Improvements

Data processing after improvement is the same as before, which is obtained from adding up the rating points of all indicators then multiplying that number by the time rating point. Example of the risk rating point recapitulation before (a) and after (b) improvement at the first workstation will be shown in Table 4.

Table 4. First workstation's risk rating point before (a) and after (b) improvement

| Indicator | Op. 1 | | Op. 2 | | Op. 3 | | Op. 4 | |
|---|---|---|---|---|---|---|---|---|
| | a | b | a | b | a | b | a | b |
| Holding Tim | 53 | 28 | 51 | 28 | 55 | 28 | 54 | 28 |
| Moving Time | 17 | 17 | 19 | 19 | 16 | 16 | 19 | 19 |
| Time Rating | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Force Excertion | 9 | 4,5 | 9 | 4,5 | 9 | 4,5 | 9 | 4,5 |
| Gripping Cond. | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 2 |
| Hand Positions | 3 | 0 | 2 | 0 | 2 | 0 | 3 | 0 |
| Work Conditions | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Body Posture | 2 | 0 | 2 | 0 | 2 | 0 | 2 | 0 |
| Work Org. | 2 | 0 | 2 | 0 | 2 | 0 | 2 | 0 |
| Total Indicator | 18 | 8,5 | 17 | 8,5 | 17 | 8,5 | 18 | 8,5 |
| **Results** | 36 | 17 | 34 | 17 | 34 | 17 | 36 | 17 |

The results of the risk assessment when applied for improvement at the first workstation is 17, the second station is 17, the third workstation is 17, the workstation The fourth is 17, the packaging and shipping workstation is 16, the warehouse section is 15, and the logistics section is 15. To explain the risk level category for manual activity after improvement, a summary of the results of the risk category will be shown in Table 5.

Table 5. Workstation's risk category after improvement

| Workstation | Op. 1 | Op. 2 | Op. 3 | Op. 4 | Category |
|---|---|---|---|---|---|
| First WS | 17 | 17 | 17 | 17 | Low |
| Second WS | 17 | 17 | 17 | 17 | Low |
| Third WS | 17 | 17 | 17 | 17 | Low |
| Fourth WS | 17 | 17 | 17 | 17 | Low |
| Packaging and Delivery WS | 16 | 16 | 16 | 16 | Low |
| Warehouse | 15 | 15 | 15 | 15 | Low |
| Logistics | 15 | 15 | 15 | 15 | Low |

It appears that the entire workstation does not need improvement again because they have low risk category. In addition, according to Steinberg (2012), KIM has proven its feasibility in assessing risks to physical workloads in manual handling activities for the screening level. When KIM is applied to industrial cases, KIM has the ability to produce significant results in a structured and transparent way (Götze et al., 2020).

## 6. Conclusion

Manual object handling activities in the simulation at the TPS Laboratory consist of activities at the first workstation, second workstation, third workstation, fourth workstation (quality control), product packaging and delivery workstation, warehouse station, and logistics station. The results of the risk assessment for each workstation in a row with the KIM-MHO assessment are 34-36, 34-36, 34-36, 23, 16, 21, and 25. The highest risk rating point was found at the first workstation to the third workstation with the rating point reaching 36 and the lowest risk rating point was found at the packaging and delivery workstation with a rating point reaching 16. The packaging and shipping workstation does not need improvement because it has a low risk category, while other workstations still need improvement because they have a slightly increased risk category.

Recommendations for improvements that can be made include reducing the time on force exertion in the finger / hand area which originally held the component in a floating state for 31-60 seconds in making one component of the raft to putting the component right on top of the work area so that the holding time is reduced and becomes less than 31 seconds, change the position of the hand in the hand / arm position and movement which originally held the component with the hand facing upwards or tilted sideways to facing downward or straight sideways, and changing the body posture in the body posture / movement which was originally with the body bent, the head is bowed, and the legs bend to become straight, the head is kept down to a minimum, and the legs are straight with a width of about 20-30 cm.

After the applied improvement, the risk rating point at the first workstation which was originally 34-36 become to 17, the risk rating point at the second workstation which was originally 34-36 became 17, the risk rating point at the third workstation which was originally 34-36 became 17, the risk rating point at the fourth workstation which was originally 23 became 17, the risk rating point at the warehouse section which was originally 21 became 15, and the risk rating point at the logistics section which was originally 25 became 15. All of the workstations get a risk rating point below 20. All of the workstations do not need improvement because their have a low risk category.

In addition, other researcher knows that there are many developing ergonomics tools and KIM is the new tools one. In the KIM's new version, it has 6 assessment that have the different purpose based on our specification, so that researcher can enrich the studies about KIM, it will give the better proposed improvement especially in manual handling activities that affect to workers and company. Maybe in the future research, the KIM tools can be combined with other tools to get the better improvement or focused on work area design.

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# Appendix

**Key Indicator Method for assessing and designing physical workloads during Manual Handling Operations**
**KIM-MHO**

**Overview of Key Indicator Methods:**

Key Indicator Method for assessing and designing physical workloads ...

- with respect to manual Lifting, Holding and Carrying of loads (KIM-LHC)
- with respect to manual Pushing and Pulling of loads (KIM-PP)
- **during Manual Handling Operations (KIM-MHO)**
- with respect to Whole-Body Forces (KIM-BF)
- with respect to Awkward Body Postures (KIM-ABP)
- with respect to Body Movement (KIM-BM)

as well as the respective Extended versions in a spreadsheet program (e.g. KIM-MHO-E)


**Scope of the Key Indicator Method (KIM-MHO)**

- This type of physical workload concerns uniform, repetitive motion and force exerted by the upper extremities using instruments, small tools or hand-guided machines if necessary, usually in a stationary sitting or standing position. The work task is to process (modify) the working object or move (handle) small objects with a weight of up to approx. 3 kg in most cases.
- **Typical activities**: Assembly activities (e.g. assembly of electrical appliances), soldering, sewing, sorting, cutting, cashiering, manually controlling, pipetting, work at a microscope, making music (e.g. playing the piano, violin), joining, turning, shifting, pressing, lifting, holding, relocating, wrapping

**Distinction from other Key Indicator Methods**

- If the sub-activity includes moving loads ≥ 3 kg, the types of physical workload "Lifting, Holding and Carrying" and/or "Pushing and Pulling" must also be considered.
- If the sub-activity includes exerting high forces frequently, e.g. when using tools, fittings and devices, the type of physical workload "Whole-Body Forces" must also be taken into consideration.
- If there are several different sub-activities per working day, they must be recorded and assessed separately (e.g. using KIM-MHO-E). The probability of physical overload can only be assessed if all physical workloads occurring during a working day are assessed.

Figure 3. KIM-MHO Assessment Sheet (1)
(Source: www.baua.de)

**KIM for assessing and designing physical workloads during Manual Handling Operations (KIM-MHO)**

| | | | |
|---|---|---|---|
| Workplace/sub-activity: | | | |
| Duration of the working day: | | Evaluator: | |
| Duration of the sub-activity: | | Date: | |

**1st step: Determination of time rating points**

| Total duration of this sub-activity per working day [up to … hours] | up to 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Time rating points:** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |

**2nd step: Determination of the rating points for other indicators**

**Type of force exertion in the finger/hand area within a "standard minute"**

| Level | Description, typical examples | Holding[1] average holding time [sec. per minute] 31-60 | 16-30 | ≤ 15 | Moving average movement frequencies [number per minute] < 5 | 5-15 | 16-30 | 31-60 | 61-90[3] |
|---|---|---|---|---|---|---|---|---|---|
| | | Rating points | | | Rating points | | | | |
| low | **Very low / low forces** (up to 15% $F_{max}$M) e.g. button actuation / shifting / ordering / material guidance / insertion of small parts | **5.5** | **3** | **1.5** | **0.5** | **1** | **2.5** | **5** | **7** |
| | **Moderate forces** (up to 30% $F_{max}$M) e.g. gripping / joining small work pieces by hand or with small tools | **9** | **4.5** | **2.5** | **0.5** | **2** | **4** | **7.5** | **11** |
| | **High forces** (up to 50% $F_{max}$M) e.g. turning / winding / packaging / grasping / holding or joining parts / pressing in / cutting / working with small powered hand tools | **14** | **7** | **3.5** | **1** | **3** | **6** | **12** | **18** |
| | **Very high forces** (up to 80% $F_{max}$M) e.g. cutting involving major element of force / working with small staple guns / moving or holding parts or tools | **22** | **11** | **5.5** | **1.5** | **5** | **10** | **19** | |
| | **Peak forces**[2] (more than 80% $F_{max}$M) e.g. tightening, loosening bolts / separating / pressing in | **100** | | **35** | **8** | **30** | **100** | | |
| high | **Powerful hitting**[2] with ball of the thumb, palm of the hand or fist | | | | **8** | **30** | | | |

*The work cycle must be observed and the rating points for the force categories marked. Added (left and right hands separately), these produce the force rating point. To calculate the total score (step 3), the higher value must be used.*

| Rating points of force exertion: | Left hand | Right hand |
|---|---|---|
| | | |

[1] *The amount of time of holding work is only considered as such in the assessment if one arm is held continuously statically for at least 4 seconds!*

Figure 4. KIM-MHO Assessment Sheet (2)
(Source: www.baua.de)

| Force transfer / gripping conditions | Rating |
|---|---|
| **Optimum force transfer/application** / working objects are easy to grip (e.g. bar-shaped, gripping grooves) / good ergonomic gripping design (grips, buttons, tools) | 0 |
| **Restricted force transfer/application** / greater holding forces required / no shaped grips | 2 |
| **Force transfer/application considerably hindered** / working objects hardly possible to grip (slippery, soft, sharp edges) / no or only unsuitable grips | 4 |

| Hand/arm position and movement[4] | | Rating points |
|---|---|---|
|  | **Good**: position or movements of joints in the middle (relaxed) range, only rare deviations / no continuous static arm posture / hand-arm rest possible as required | 0 |
|  | **Restricted**: occasional positions or movements of the joints at the limit of the movement ranges / occasional long continuous static arm posture | 1 |
| | **Unfavourable**: frequent positions or movements of the joints at the limit of the movement ranges / frequent long continuous static arm posture | 2 |
| | **Poor**: constant positions or movements of the joints at the limit of the movement ranges / constant long continuous static arm posture | 3 |

[4] *Typical positions are to be considered. Rare deviations can be ignored.*

| Unfavourable working conditions (specify only where applicable) | Rating points |
|---|---|
| **Good**: there are no unfavourable working conditions, i.e. reliable recognition of detail / no dazzle / good climatic conditions | 0 |
| **Restricted**: occasionally impaired detail recognition due to dazzle or excessively small details difficult conditions such as draught, cold, moisture and/or disturbed concentration due to noise | 1 |
| **Unfavourable**: frequently impaired detail recognition due to dazzle or excessively small details frequently difficult conditions such as draught, cold, moisture and/or disturbed concentration due to noise | 2 |

*Indicators not mentioned in the table are to be taken into account accordingly.*

Figure 5. KIM-MHO Assessment Sheet (3)
(Source: www.baua.de)

| Body posture/movement[5] [6] | | Rating points |
|---|---|---|
|  | - Alternation between sitting and standing, alternation between standing and walking, dynamic sitting possible<br>- Trunk inclined forward only very slightly<br>- No twisting and/or lateral inclination of the trunk identifiable<br>- Head posture: variable, head not inclined backward and/or severely inclined forward or constantly moving<br>- No gripping above shoulder height / no gripping at a distance from the body | 0 |
|  | - Predominantly sitting or standing with occasional walking<br>- Trunk with slight inclination of the body towards the work area<br>- Occasional twisting and/or lateral inclination of the trunk identifiable<br>- Occasional deviations from good "neutral" head posture/movement<br>- Occasional gripping above shoulder height / occasional gripping at a distance from the body | 2 |
|  | - Exclusively standing or sitting without walking<br>- Trunk clearly inclined forward and/or frequent twisting and/or lateral inclination of the trunk identifiable<br>- Frequent deviations from good "neutral" head posture/movement<br>- Head posture hunched forward for detail recognition / restricted freedom of movement<br>- Frequent gripping above shoulder height / frequent gripping at a distance from the body | 4 |
|  | - Trunk severely inclined forward / frequent or long-lasting bending<br>- Work being carried out in a kneeling, squatting, lying position<br>- Constant twisting and/or lateral inclination of the trunk identifiable<br>- Body posture strictly fixed / visual check of action through magnifying glasses or microscopes<br>- Constant deviations from good "neutral" head posture/movement<br>- Constant gripping above shoulder height / constant gripping at a distance from the body | 6[7] |

[5] *Typical body postures are to be taken into account. Rare deviations can be ignored.*
[6] *If the manual handling operations are not carried out in a stationary sitting, standing, kneeling, squatting, lying position, but in motion (walking, crawling), it is recommended to evaluate the sub-activity also using the KIM-BM.*
[7] *Please note: If this category was chosen, it is recommended to evaluate this sub-activity also using the KIM-ABP!*

| Work organisation / temporal distribution | Rating points |
|---|---|
| **Good:** frequent variation of the physical workload situation due to other activities (including other types of physical workload) / without a tight sequence of higher physical workloads within one type of physical workload during a single working day. | 0 |
| **Restricted**: rare variation of the physical workload situation due to other activities (including other types of physical workload) / occasional tight sequence of higher physical workloads within one type of physical workload during a single working day. | 2 |
| **Unfavourable**: no/hardly any variation of the physical workload situation due to other activities (including other types of physical workload) / frequent tight sequence of higher physical workloads within one type of physical workload during a single working day with concurrent high load peaks. | 4 |

Figure 6. KIM-MHO Assessment Sheet (4)
(Source: www.baua.de)

**3rd step: Evaluation and assessment**

| | | |
|---|---|---|
| **Type of force exertion in the finger/hand area** | | |
| **Force transfer / gripping conditions** | + | |
| **Hand/arm position and movement** | + | |
| **Unfavourable working conditions** | + | |
| **Body posture** | + | |
| **Work organisation / temporal distribution** | + | |
| **Time rating points** | x **Total of indicator rating points:** | = **Result** |

**The risk score calculated and the table below can be used as the basis for a rough evaluation:**

| Risk | | Risk range | Intensity of load[*] | | Probability of physical overload / Possible health consequences | Measures |
|---|---|---|---|---|---|---|
| | 1 | < 20 points | low | a)<br>b) | Physical overload is unlikely.<br>No health risk is to be expected. | None |
| | 2 | 20 - < 50 points | slightly increased | a)<br>b) | Physical overload is possible for less resilient persons.<br>Fatigue, low-grade adaptation problems which can be compensated for during leisure time | For less resilient persons, workplace redesign and other prevention measures may be helpful. |
| | 3 | 50 - < 100 points | substantially increased | a)<br>b) | Physical overload is also possible for normally resilient persons.<br>Disorders (pain), possibly including dysfunctions, reversible in most cases, without morphological manifestation | Workplace redesign and other prevention measures should be considered. |
| | 4 | ≥ 100 points | high | a)<br>b) | Physical overload is likely.<br>More pronounced disorders and/or dysfunctions, structural damage with pathological significance | Workplace redesign measures are necessary. Other prevention measures should be considered. |

[*] *The boundaries between the risk ranges are fluid because of the individual working techniques and performance conditions. The classification may therefore only be regarded as an orientation aid. Basically, it must be assumed that the probability of physical overload will increase as the risk scores rise.*

Figure 7. KIM-MHO Assessment Sheet (5)
(Source: www.baua.de)