Proactive risk assessment and management tools for manual handling in manufacturing paving blocks

by Rika Taslim

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Abstract: This study was conducted on a business unit that manually manufactured paving blocks which led to injuries involving musculoskeletal disorders (MSDs). Data obtained from the Nordic body map of four workers, showed that 14.81% failed to fall sick, 40.74% were partly sick, 36.3% were sick, and 3.7 very sick. This study, therefore, proposed a RAMP (risk assessment and management tools) method to identify and analyse work activities. The result showed that the level of risk in paving block manufacturing activities was 7, 13, and 15 in categories of high, moderate, and low, respectively, with a total score of 80.40. After proper improvement, there was a reduction in moderate and high bending duration from 34.8 to 25 minutes and 131.55 to 95.8 minutes, respectively, with lifting frequency from 1000 to 500 times. The reduction made a total assessment score of 74.20, therefore, further study is required to conduct layout on the workspace.

Keywords: Nordic body map; manual material handling; MMH; musculoskeletal disorders; MSDs; risk assessment and management tools; RAMP.

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Biographical notes: Merry Siska is an Associate Professor at the Industrial Engineering of State University of Sultan Syarif Kasim Riau. She is an author of many research papers in different journals. She is also author of several text book, such as *Aplikasi Novel Ergonomic Postural Assessment Method (NERPA) pada Sentra Industri Sepatu dan Boneka di Bandung*, *Rancang Ulang Scissors Lift yang Ergonomis*, etc. Her main areas of her interests are ergonomic, plant layout and production system.

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1 Introduction

The role of humans as a source of labour remains dominant in the production processes of small and medium manufacturing companies. This is because humans have more advantages in terms of *flexibility* and cost effectiveness. These advantages are very useful in the manual transfer of material with tools or machines, where humans are more *flexible* (Restuputri and Primadi, 2017). Workers tend to opt for jobs with minimal energy to achieve maximum results. However, this is sometimes not achieved due to several inhibiting factors such as unhealthy and unsafe working environments, business skills, and employee's posture which leads to early fatigue and indirectly provides additional workload. When the application of ergonomics is unfulfilled, it causes discomfort or pain in certain parts of the body (Jalajuwita and Paskarini, 2015).

One of the ergonomic problems often encountered in the workplace, especially those related to the strength and endurance of humans are *musculoskeletal disorder* (MSDs). This is defined as the acceptance of load on the muscles statically and repeatedly for a long time, which causes pains to joints, ligaments, and tendons. *MSDs* occurs when workers carry heavy loads, and non-ergonomic tools resulting in excessive exertion and wrong postures (Suhadri, 2008). Materials are still manually handled in small and medium businesses, from the transporting process of sand to the machine *mixer*, printing *paving block*, and its transportation to the drying place, with dominant work carried out in a standing/bent positions.

Figure 1 (a) Workers groups sand in bent position (b) Workers filling moulds paving block in bent position (see online version for colours)

(a) (b)

Figure 1 show where a worker groups sand in a bent position and fill it into the mould *paving blocks*. When an employee stands for a long time, it potentially leads to MSDs. The assignment of duties on certain body parts is also risky for workers as they carry out these activities for 8 hours daily.

Figure 2 Workers transporting *paving blocks* ready for printing to drying places (see online version for colours)

Figure 2 shows the activities of workers transporting printed products to a drying place using a wheelbarrow. Although the transfer is carried out with the help of a wheelbarrow, it causes MSDs because they have to carry very heavy loads of +190 kg repeatedly over long durations.

Figure 3 (a) Workers lift products to wheelbarrow (b) Workers lowered products from wheelbarrow (see online version for colours)

(a) (b)

Figure 3 shows activities where:

a workers lift products that have been printed onto a wheelbarrow to be moved to the drying place

b the product is lowered.

Both activities are carried out repeatedly in bent positions for a long time with loads weighing 15 kg.

Work carried out by workers at CV. Riau Jaya tends to endanger their health due to a bent and rigid work posture that is carried out repeatedly over a prolonged duration. Such activities have the potential to cause *MSDs*, as seen from the results of the *Nordic body map* questionnaire on four workers. The percentages of complaints experienced are as follows (Table 1).

Based on Table 1, it is seen that work performed by workers indicated health problems to those unchecked. Many of them complained of pains on their neck, shoulders, upper arms, back, and waist.

A corrective step is, therefore, needed using an ergonomic approach, on the employees and tools used at work. To carry out these repairs, it is necessary to evaluate the activity or posture of workers. Many studies have been carried out to discuss and analyse these postures when carrying out their work such as *rapid upper limb assessment* (RULA), *rapid entry body assessment* (REBA), *Ovako working postures analysis system* (OWAS) and *quick exposure check* (QEC), *risk assessment and management tool for manual handling proactively* (RAMP) methods etc. In this study, the evaluation of body posture was conducted using the RAMP method, which is utilised for the physical risk management of ergonomics in the manual work production process in industries. The assessment is based on work posture, manual *handling*, as well as the influence of the environment, time, space, intensity, and speed of work.

Table 1 Recapitulation of questionnaires *Nordic body map*

No.	Type of complaints	Level of complaints							
		No pain		*Sufficiently painful*		*Pain*		*Very*	
		Number of	*%*	*Number of*	*%*	*Number of*	*%*	*Number of*	*%*
1	Pain/stiffness in upper neck	-	-	1	25	3	75	-	-
2	Pain/stiffness in neck section bottom	-	-	1	25	3	75	-	-
3	Pain in the left shoulder	-	-	-	-	3	75	1	25
4	Pain in the right shoulder	-	-	-	-	3	75	1	25
5	Pain in the left upper arm	-	-	-	-	4	100	-	-
6	Back pain	-	-	-	-	3	75	1	25
7	Pain in the right upper arm	-	-	1	25	3	75	-	-
8	Pain in the waist	-	-	-	-	2	50	2	50
9	Pain in the buttocks	-	-	3	75	1	25	-	-
10	Pain in the left elbow	-	-	4	100	-	-	-	-
11	Pain in the right elbow	-	-	4	100	-	-	-	-
12	Pain in the left forearm	-	-	3	75	1	25	-	-
13	Pain in the right forearm	-	-	3	75	1	25	-	-
14	Pain in the left wrist	-	-	3	75	1	25	-	-
15	Pain in the right wrist	-	-	3	75	1	25	-	-
16	Pain in the left hand	-	-	1	25	3	75	-	-
17	Pain in the right hand	-	-	1	25	3	75	-	-
18	Pain in the left thigh	1	25	2	50	1	25	-	-
19	Pain in the thighs n	1	25	2	50	1	25	-	-
20	Pain in the left knee	-	-	2	50	2	50	-	-
21	Pain in the right knee	-	-	2	50	2	50	-	-
22	Pain in the left calf	1	25	1	25	2	50	-	-
23	Pain on the right calf	1	25	1	25	2	50	-	-
24	Pain in the left ankle	2	50	2	50	-	-	-	-
25	Pain in the right ankle	2	50	2	50	-	-	-	-
26	Pain in the left leg	1	25	1	25	2	50	-	-
27	Pain in the right foot	1	25	1	25	2	50	-	-

The purposes of this research are as follows:

1 to determine the level of risk experienced by workers producing *paving blocks* using the RAMP method

2 to suggest improvement strategies in the form of design work tools to reduce the risk of *MSDs*

3 to determine the level of risk experienced by workers after repairs.

The RAMP tool was developed by researchers at the KTH Royal Institute of Technology in accordance with small, medium, and large-sized companies as well as logistics industries. This tool was developed using an iterative process, with feedback from managers, production personnel, and ergonomists (Lind et al., 2015). The lifting model utilised in this research was constructed using the RNLE as a base. Additional factors such as one-handed lifting, and hot ambient temperature included in the models, were mainly based on psychophysical and biomechanical studies, using European ergonomic standards (EN 1005-2: 2008) and judged from an expert group.

2 Ergonomic and *risk assessment and management tool for manual handling proactively* (RAMP)

2.1 Ergonomic

Ergonomics itself comes from the word Greek consists of two words namely 'ergon' means work and 'nomos' means rules or law and roughly translates to 'work science'. Ergonomics is the science, art and application of technology to harmonise or balance all the facilities used both in activities and breaks with the abilities and limitations of humans both physically and mentally so that the overall quality of life becomes better (Tarwaka et al., 2004).

2.2 Manual material handling (MMH)

This is an activity used to handle goods or materials that are carried out manually by one or more workers. It consists of the lifting, dropping, pushing, pulling and transportation processes. According to Suhadri (2008), it is the process of manually moving the load by the body, within a certain time frame.

2.3 Biomechanics

Biomechanics is a science that addresses aspects of mechanics movements of the human body. It is a combination between scientific mechanics, anthropometry and basic medical science (biology and physiology). Biomechanics is concerned with the working power of the muscles which is dependent on the position of the body, the direction of work and the difference in strength between the various parts of the body. This is in addition, to the speed and accuracy as well as the endurance of the body's tissues to the load (Mas'idah et al., 2009).

2.4 *Musculoskeletal disorders*

Musculoskeletal complaints are associated with the skeletal muscle due to prolonged static loads, which causes damage to joints, ligaments and tendons. This type of damage is usually termed complaints *MSDs* or injury to the system *musculoskeletal*.

There are various tools used to analyse risk factors or identify potentially hazardous jobs. These include observational, direct, self-declaration and psycho-physiological methods. However, these methods are time-consuming, despite being able to produce the best results, with the ability to evaluate large groups. Various methods are used to assess the load on employee body parts such as QEC, OWAS, SI, OCRA, HAMA, and PLIBEL. However, rapid entire body assessment (REBA) and RULA are two other common techniques used to assess postures at work in accordance with to economic reasons and ease of usage. The novel ergonomic postural assessment (NERPA) is one of the newest methods of postural assessment (Khandan, et al, 2018).

2.5 *Risk assessment and management tool for manual handling proactively (RAMP)*

RAMP is an observation-based method developed at KTH Royal Institute of Technology Sweden to analyse workplaces for MSDS risk. It is used for physical ergonomic risk management in manual work *handling* and the production process, which consists of two assessment methods namely RAMP I and RAMP II. These methods are used to determine corrective actions, and assess work environment. Identification and analysis of RAMP includes areas of posture, repetitive movements, lifting, pushing or pulling, influencing factors, physical tension and perceived discomfort.

The RAMP tool was developed by researchers at the KTH Royal Institute of Technology in accordance with small-medium, large-sized companies in the manufacturing and logistics industries. The tool was developed using an iterative process, with feedback from managers, production personnel and ergonomists (Lind et al., 2015). The analysed lifting model is constructed using the RNLE as a base. Additional factors (one-handed lifting, hot ambient temperature lifting and lifting teams), included in the models, are mainly based on psychophysical and biomechanical studies, European ergonomic standards (EN 1005-2: 2008) and judgment from an expert group with research and experience from ergonomists (Lind and Rose, 2016).

3 Research method

The directed and simplified analyses were used to determine a solution to the problem. Its preliminary studies were divided into literature and field survey by observing the state of workers in producing *paving blocks* on the CV. Riau Jaya Paving. Interviews were also conducted on workers with questionnaires from *Nordic body map*. This literature study aims to obtain references related to the RAMP method, to help solve existing problems.

Furthermore, supporting research sources were taken from books and journals that contain theories related to these problems. The researcher's results could then be evaluated within the context of the paradigm chosen. Quantitative methodologies would be the prerogative of the positivist paradigm and qualitative research situated on the side of constructivist or interpretative paradigm (Dana and Dumez, 2015).

This was preceded by the problem identification stage which aimed at identifying errors associated with the manufacturing activities of the *paving block*. This was carried out to identify the errors inherent a company, to obtain optimal solutions. Work postures not suitable for the manual production and transfer of goods were identification.

Problem formulation functions as a guideline in determining the direction or focus of study, which is based on how to improve work activities in the production process of *paving blocks* using the RAMP method.

Data were obtained using mail questionnaires, surveys or brief interviews, with traditional research conducted on small businesses to analyse entrepreneurs techniques (Dana and Dana, 2005). The purpose of this study is to determine and assess the level of ergonomic risk with suggestions for improvements in the form of design tools to lower the risk of *MSDs* using the RAMP method.

Furthermore, to produce scientific and accountable research, data was collected through the following sources:

1 Primary data

 This is obtained directly at the research site, through interviews, documentation, posture, weight load, duration of activities, and work environment.

2 Secondary data

 This is the number of workers, company profile, and organisation hierarchy, which is further processed in three stages, namely preliminary assessment, proposed improvement, and assessment after improvement.

3.1 Preliminary assessment

The assessment was carried out using the RAMP I and II to identify and assess in-depth risk factors that lead to *MSDs*, while the order of identification and assessment are as follows:

a posture

b assessment and repetition of work

c assessment of lifting work

d assessment of work with encouragement and attraction

e assessment of factors that influences it

f physical work report

g feeling of inconvenience

h result.

3.2 Proposed improvement

After determining the level of ergonomic risk based on the RAMP method, improvements are proposed to the posture activities and MMH, which have the greatest risk to avoid and reduce the risk of injury.

3.3 Assessment after improvement

After the proposed improvements process, a re-assessment of posture activity on MMH was carried out using the RAMP II method. This is conducted to determine the value of risk after the repairs.

4 Result and discussion

4.1 Early identification

This is the processing of initial identification data using RAMP I.

Table 2 Summary of identification results using RAMP I (see online version for colours)

Rate of risk	*Assessment*
Number of assessments in red (high risk)	1
Number of grey rating (investigating further)	25
Number of green rating (low risk)	25

4.2 Initial assessment of RAMP II

After identification with RAMP I, further analysis was carried out using the RAMP II method as shown in Table 3.

Table 3 Results of RAMP II analysis at levels detailed (see online version for colours)

Assessment		*Risk*
1	Posture	
1.1	Head posture (forward and sideways)	1
1.2	Head posture (backward)	6
1.3	Rear posture (moderate bending)	1
1.4	Rear posture (very bent and twisted)	5
1.5	Posture upper arm (hand equal to or above shoulder)	2
1.6	Upper arm posture (without inside or outside work area)	2
1.7	Wrist posture	0
1.8	Feet and leg and surface space	3
2	Repetitive work and work movement	
2.1	Arm movement (upper arm and bottom)	2
2.2	Wrist movements	0
2.3	Grip type	0
2.4	Recovery or shorter variations	4
2.5	Recovery or longer variations	10

Table 3 Results of RAMP II analysis at levels detailed (continued) (see online version for colours)

Assessment			*Risk*
3	Appointment		
	3.1	Appointment (average case)	8.7
	3.2	Appointment (worst case)	7.6
4	Encourage or attract		
	4.1	Encourage or withdraw (average case)	3.3
	4.2	Encourage or withdraw (worst case)	-
5	Factors affecting		
	5.1	Physical factors of the hand or arm	
	a + b	Hand or arm vibration	2
	c	Hot or cold objects handled manually	0
	d	Hand used as collision tool	0
	e	Hold hand tools weighing >2.3 kg, >30 minutes	2
	f	Hold precision tools weighing >0.4 kg, >30 minutes	0
	5.2	Other physical factors	
	a + b	Whole body vibration	2
	c	Inadequate visual conditions	0
	d	Hot, cold or windy environment	2
	e	Prolonged standing or walking on hard surfaces	2
	f	Prolonged sitting	0
	g	Prolonged standing	2
	h	Kneeling or squatting	0
	5.3	Factors organisation work and psychosocial	
	a	There is no possibility to affect the speed of work	0
	b	There is no possibility to influence work arrangements	0
	c	Difficulty in balancing work tasks	0
	d	Workers work faster to take longer rest	2
6	Reports on physically strenuous work		
	6.1	Documented labour reports on the job	0
7	Discomfort		
	7.1	Physical discomfort created	2
Summary of results:			
	Number of red assessments (high risk)		6
	Number of yellow rating (medium risk)		13
	Total green rating (low risk)		15
	Total score		71.60

Table 4 Results of RAMP II analysis at level of risk category (see online version for colours)

No.	*Assessment*	*Risk level*
1	Posture	3
2	Repetitive work and work movements	1
3	Appointment	2
4	Encourage or withdraw	1
5	Factors that affect	7
6	Reports on physically heavy work	0
7	Physical discomfort felt	1
Summary of results:		
	Number of red assessments (high risk)	6
	Amount of yellow rating (medium risk)	13
	Amount of green valuation (low risk)	15

Based on the tables, it is seen that the highest risk level is in the posture and lifting categories which tends to cause *muscular disorders* in workers with a total of 6, 13, and 15 high, medium, and low categories with a total score of 71.60.

The workers carried out various repair procedures by removing *paving blocks* from the printing site to the drying place. The design of this tool has a working principle such as a *forklift*, which is manually operated, thereby allowing workers to move products without any bending process and reducing the frequency of lifting. The manual design stages of *forklifts* are use anthropometric data as follows:

a Shoulder width (LSB)

This is used to determine the width of the tool and the distance between two handles.

b Elbow height (TS)

This is used to determine the height of the tool handle from the ground.

c Hand width (LT)

This is used to determine the size of the handle's width.

The tool used in designing the transfer *paving block* is the Indonesian anthropometric data.

4.3 Tool design

This design begins by determining the percentile used in ascertaining the size of the portions in accordance with the anthropometry. The percentiles used in the design of this tool *forklift* manual are in Table 5.

Table 5 Percentile and size of tool design

No.	*Tool specifications*	*Anthropometric data*	*Percentile*	*Size (cm)*
1	Height of tool	-	-	130
2	Length of tool	-	-	100
3	Tool width	-	-	80
4	Fork length	-	-	60
5	Distance between two forks	-	-	50
6	Width or distance between two handles	LSB	50th	38.75
7	Grip height	TS	5th	95.65
8	The width of the handle	LT	95th	15.17

This is followed by the *forklift* that has been designed.

Figure 4 Design of forklift (see online version for colours)

Figure 5 Forklift (see online version for colours)

The working system of the manually designed *forklift* is similar to the engine. However, it uses human power to increase and lower the load through an especially designed pulley to ensure it does not feel heavy when rotated by the worker. The designed *forklift* makes workers to easily carry out the activities of moving paving blocks from the printing site to the drying place without repetition. There is a reduction in the lifting frequency and work duration on certain postures. The design of this new work facility is expected to reduce the risk level of *MSDs*.

The manual pallet is needed as a base for placing *paving blocks* on a *forklift*. It is designed according to transportation requirements when moving *paving blocks* to the drying place and made of the iron plate with a load capacity of 12 piles of *block paving* or weighing up to 200 kg.

Figure 6 Pallet design *paving block* (see online version for colours)

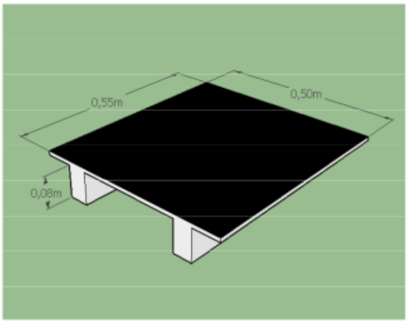

Figure 7 Pallet *block paving* (see online version for colours)

4.4 After evaluation

A forklift was used to replace the wheelbarrow, after conducting repairs, with several duration reductions, such as in the frequency of appointments, thereby, eliminating work activities. Therefore, it is necessary to conduct an assessment after improvement to determine the risk reduction that occurs.

Table 6 Results of RAMP II analysis at levels detailed after improvement (see online version for colours)

Assessment		*Risk*
1	Posture	
1.1	Head posture (forward and sideways)	1
1.2	Head posture (backward)	6
1.3	Rear posture (moderate bending)	0
1.4	Rear posture (very bent and twisted)	3
1.5	Posture upper arm (hand equal to or above shoulder)	2
1.6	Upper arm posture (without inside or outside work area)	2
1.7	Wrist posture	0
1.8	Feet and leg and surface space	3
2	Repetitive work and work movement	
2.1	Arm movement (upper arm and bottom)	2
2.2	Wrist movements	0
2.3	Grip type	0
2.4	Recovery or shorter variations	4
2.5	Recovery or longer variations	10
3	Appointment	
3.1	Appointment (average case)	5.5
3.2	Appointment (worst case)	7.6
4	Encourage or attract	
4.1	Encourage or withdraw (average case)	3.3
4.2	Encourage or withdraw (worst case)	-
5	Factors affecting	
5.1	Physical factors of the hand or arm	
a + b	Hand or arm vibration	2
c	Hot or cold objects handled manually	0
d	Hand used as collision tool	0
e	Hold hand tools weighing >2.3 kg, >30 minutes	2
f	Hold precision tools weighing >0.4 kg, >30 minutes	0
5.2	Other physical factors	
a + b	Whole body vibration	2
c	Inadequate visual conditions	0
d	Hot, cold or windy environment	2
e	Prolonged standing or walking on hard surfaces	2
f	Prolonged sitting	0
g	Prolonged standing	2
h	Kneeling or squatting	0

Table 6 Results of RAMP II analysis at levels detailed after improvement (continued) (see online version for colours)

Assessment				*Risk*
5	Factors affecting			
	5.3	Factors organisation work and psychosocial		
		a	There is no possibility to affect the speed of work	0
		b	There is no possibility to influence work arrangements	0
		c	Difficulty in balancing work tasks	0
		d	Workers work faster to take longer rest	2
6	Reports on physically strenuous work			
	6.1	Documented labour reports on the job		0
7	Discomfort			
	7.1	Physical discomfort created		2
Summary of results:				
	Number of red assessments (high risk)			6
	Number of yellow rating (medium risk)			13
	Total green rating (low risk)			15
	Total score			65.40

Based on the assessment result on Table 6, it is seen that the results of the analysis using RAMP II after repairs to the process of making *paving blocks* have 6, 13, and 15 risks at high, moderate and low levels, respectively with risk scores that decreased from 71.60 to 65.40. This shows that there has been a reduction in the level of risk in manufacturing activities *paving block*.

5 Conclusions

Based on the described objectives, the conclusions are as follows:

1 RAMP I, showed a high, moderate, and low-level risks values of 1, 25, and 25, respectively, while the RAMP II consisted of 6, 13, and 15 with a total score of 71.60.

2 The *forklift* manuals are improved in accordance with the proposed assessment, and work aid.

3 There was a reduction in duration on the moderate bending rear posture from 34.8 to 25 minutes, a very bent rear posture from 131.55 to 95.8 minutes, with a reduced frequency from 1,000 to 500 times, through the design of work tools *forklift* manual. The results of the assessment after improvement with RAMP II showed that there was no change in the risk levels that occurred in the initial assessment. However, there was a reduction in the total score of the assessment by 65.40.

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