DEVELOPMENT OF *COST-BENEFIT* CALCULATION MODEL IN HANDLING LOW BACK PAIN FROM THE ERGONOMIC PERSPECTIVE

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ABSTRACT

Variable determining and cost-benefit calculation method onergonomic intervention in handlinglow back pain (LBP), recently, have not had structured calculation model. Each researcher has his/her owm paradigm and calculation model which are different from other researchers. It causesthe cost-benefit calculation has no standard calculation so that the result obtained will be too easy to change if it is applied on other research cases. This research presents a conceptually, mathematically structured model which can be used as standard reference on calculatingcost-benefitin handling LBP on the workers. The implementation of the model is conducted in the material handling activity.
***Keywords**: ergonomic intervention, low back pain, cost-benefit, mathematic model, conceptual model*

1. INTRODUCTION

Work system which is not condusive and low back pain complaints are indicated to be be the factors that mostly work activities. (Tarwaka, et al. 2004; Goggins, et al. 2008; Liu, et al. 2009; Tompa, et al. 2009, Hsiang, et al. 1997; Burton, 2005; Hughes dan Nelson, 2009a, 2009b). It gives impacts on the performance of the workers and the company, in which if this condition continuously occurs without an entirely improvement on the system, the company will get disadvantages-both in materially and immaterial. Ergonomic intervention is used as a method to handle it because giving amount of benefits involves cost saving, increasement on productivity, and quality of the product-even though it needs to be put to amount of expense in doing it at first (Hendrick, 2002).

However, a settled calculation is needed in order to know the benefits achieved by a company based on ergonomic intervention conducted so that the result meets the needs and what the company wants. Basically, the calculation have much been done byother previous researchers. Each researcher has own paradigm and calculation model which is different from other researchers. As a result, *cost-benefit* calculation toward ergonomic intervention in handling of LBP does not have standard calculation so that the result obtained will be too easy to change if it is applied on other research cases (Hughes dan Nelson, 2009; Tompa, et al. 2013). Therefore, in this research, both conceptual and mathematic structured model designing will be conducted to be used as standard refenrence in calculating *cost-benefit* in order for handling of LBP on the workers.

2. RESEARCH METHODOLOGY

Flowchart of research methodology which is used in this research can be seen on Figure 1.

3. MODEL DEVELOPMENT AND IMPLEMENTATION

3.1 Model Development

Model developed is divided into 2 kinds of model, i.e. conceptual model and mathematic model.

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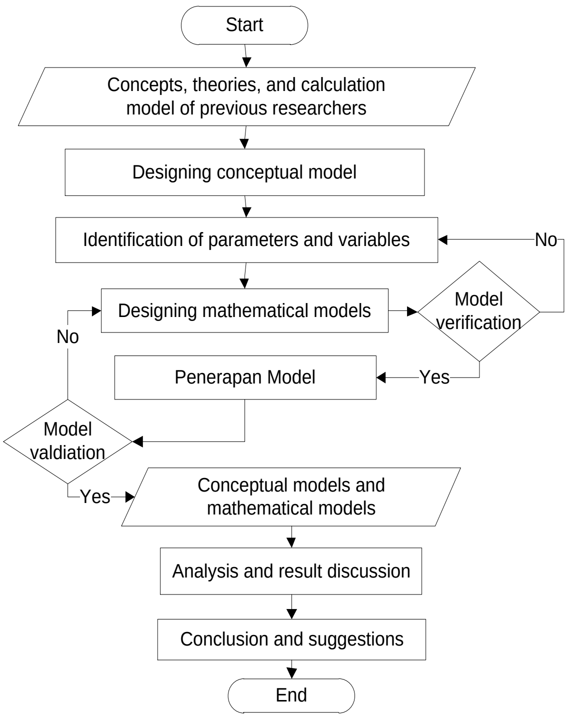

Figure 1. Research Methodology

3.1.1 Conceptual Model

The design of conceptual model is done by integrating the models proposed by other previous researchers. Those researchers are Hughes and Nelson (2009), Goggins, et al. (2008), Hendrick (2003), Guimaraes, et al. (2012), Tompa, et al. (2013), Helander and Burri (1995), Tompa, et al. (2009), Liu, et al. (2009), Muslimah, et al. (2009), Beevis (2003), Cagno, et al. (2013) and Bidassie, et al. (2010). Schematically, the conceptual model can be seen on Figure 2. Then, the conceptual model is developed into the framework aiming for standardizing the operation of ergonomic intervention in handling of LBP in a company. Figure 3 shows the framework of ergonomic intervention's operation for the management and prevention of LBP on the workers based on biomechanic evaluation, and Figure 4 refers to the operation conducted based on physiology of the workers evaluation.

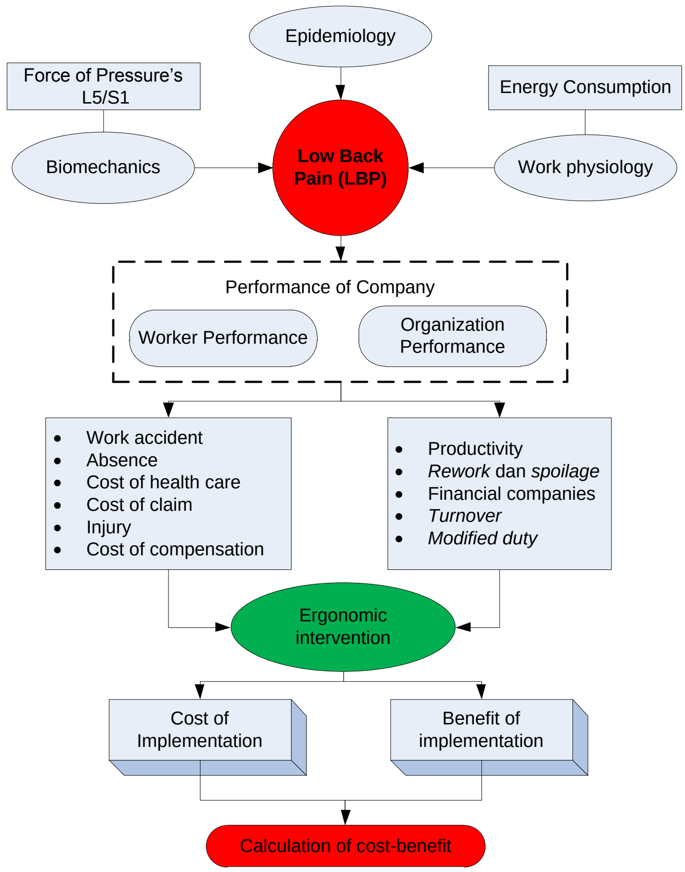

Figure 2. Conceptual Model of Ergonomic Intervention in Handling of LBP

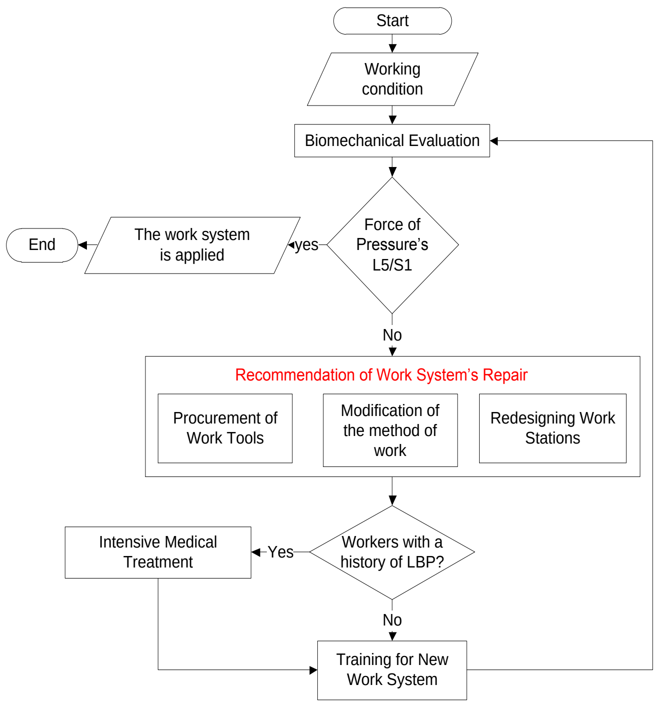

Figure 3. Flowchart of Biomechanical Evaluation on LBP to the Workers

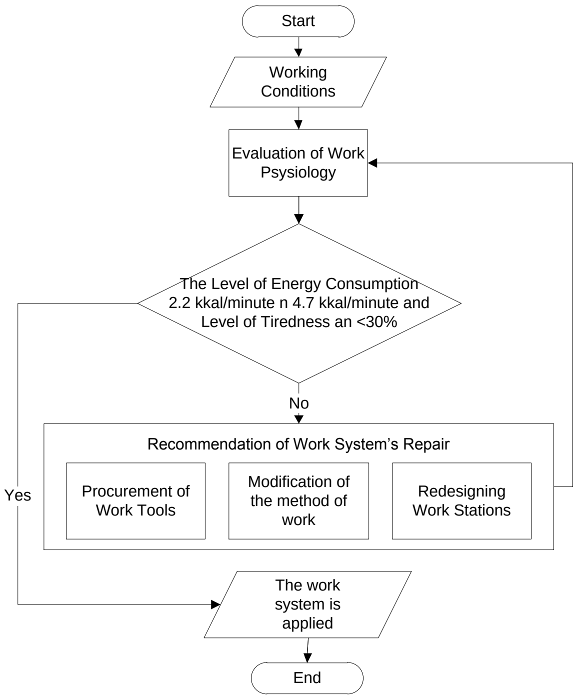

Figure 4. Flowchart of The wokers' Physiology Evaluation on LBP to the Workers

3.1.2 Mathematic Model

The first stage in designing this mathematic model is to decide the components determining the *cost-benefit* calculation in ergonomic intervention on the mangament of LBP on the workers. Schematically, the *cost-benefit* components can be seen on figure 5. Next, deciding the notation and parameter used in designing mathematic model.

1. Component of Conducting Ergonomic Intervention's Cost

Notation and parameter used in the cost component on ergonomic intervention can be seen on Table 1.

Table 1. Notation and Parameter of Conducting Ergonomic Intervention's Cost

No.	Parameter	Notation	Unit
Total cost		T_B	Rp
1.	Cost of change of physical environment and work station	B_{PS}	Rp
1.1	Cost of ergonomic intervention's consultation	B_{KE}	Rp
	a. Total of ergonomic consultants	n_a	Person
	b. Cost of payments for ergonomic consultants	b_{ke}	Rp/person
1.2	Cost of purchase on equipment	B_{PA}	Rp
	a. Total of the tools purchased	z_m	Unit
	b. Cost of purchasing tools	H_B	Rp/unit
	c. Cost of installation	b_i	Rp/unit
2.	Cost of conducting ergonomic intervention project	B_{IE}	Rp
2.1	Cost of the training	B_{PT}	Rp
	a. Total of the workers following the training	n_b	Person
	b. Operational cost of the training	b_{pt}	Rp/person
	c. Payment for trainer	b_t	Rp/person
2.2	Cost of employee downtime	B_{ED}	Rp
	a. Total of idle workers during process of work modification	n_c	person
	b. Cost of daily payment for the workers	U_H	Rp/person
2.3	The lost cost due to ergonomic intervention (*opportunity cost*)	B_{PH}	Rp
	a. Total of days of conducting ergonomic intervention	n	Day
	b. Daily target of the company	z_i	Unit/day
	c. Total of products that can be produced	z_d	Unit/day
	d. Price of the products produced	H_p	Rp/unit
3.	Operational cost	B_{OP}	Rp
3.1	Difference of maintenance cost	B_{ME}	Rp
	a. Payment for maintenance cost before intervention		Rp
	b. Percentage of maintenance cost	β	%
3.2	Difference of tool depreciation's cost	B_{DA}	Rp
	a. Payment for tool depreciation cost before intervention		Rp
	b. Month of purchasing prduct	d_b	1-12
	c. *Expected life*	EL	Year
	d. Residual rate at the end of the period	S	Rp/unit
3.3	Difference of *overhead*cost	B_{OH}	Rp
	a. Payment for *overhead*cost before intervention		RP
	b. Payment for *overhead* cost after intervention		Rp
3.4	Difference of the cost of the workforce	B_{TK}	Rp
	a. Total of workforce before intervention	n_d	Person
	b. Total of workforce after intervention	n_e	Person
	c. Payment for monthly workers	G_B	Rp/person

Formulation of mathematic model used for calculation of the cost is:

a. Cost of change of physical environment and work station

$$B_{PS} = B_{KE} + B_{PA}$$

- Cost of ergonomic intervention's consultation

$$B_{KE} = n_a \times b_{ke}$$

- Cost of purchase of tool and installation

$$B_{PA} = z_m \times (H_B + b_i)$$

b. Cost of conducting ergonomic intervention project

$$B_{IE} = B_{PT} + B_{ED} + B_{PH}$$

- Cost of training held

$$B_{PT} = b_{pt} \times (n_a + n_b) + (n_a \times b_T)$$

- Cost of*employee downtime*

$$B_{ED} = n_c \times U_H$$

- The lost cost due to ergonomic intervention (*opportunity cost*)

$$B_{PH} = n \times (z_i - z_d) \times H_P$$

c. Operational cost

$$B_{OP} = B_{ME} + B_{DA} + B_{OH} + B_{TK}$$

- Difference of *maintenance*cost

$$B_{ME} = B_{sebelum}^{ME} - (\beta \times H_B)$$

- Difference of tool depreciation's cost

$$B_{DA} = B_{sebelum}^{DA} - \left(\frac{d_b}{12} \times \frac{(H_B - S)}{EL}\right)$$

- Difference of *overhead*cost

$$B_{OH} = B_{sebelum}^{OH} - B_{setelah}^{OH}$$

- Difference of personnel's cost

$$B_{TK} = (n_d - n_e) \times G_B$$

2. Component of Ergonomic Intervention's Benefit

Notation and parameter used for component of benefit of ergonomic intervention operation can be seen on Table 2.

Table 2. Notation and Parameter of Ergonomic Intervention's Benefit

No.	Parameter	Notation	Unit
Total of Benefits		T_K	Rp
1.	Cost aving of the workers' health care	P_{MC}	Rp
1.1	Cost saving of the workers' compensation	P_{KP}	Rp
1.1.1	Payment of the workers' compensation 'scost before Intervention		Rp
	a. Total of workers being disabled before Intervention	n_f	Person
	b. Total of workers died before Intervention	n_g	Person
	c. Payment of compensation for those who become disabled	p_{kc}	Rp/person
	d. Payment of compensation for those who died	p_{km}	Rp/person
1.1.2	Payment of the workers' compensation 'scost after Intervention		Rp
	a. Total of workers being disabled after Intervention	n_h	Person
	b. Total of workers died after Intervention	n_i	Person
1.2	Cost saving of claim toward those who suffer from acute LBP	S_{PA}	Rp/claim
1.2.1	Payment of claim's cost toward those who suffer from acute LBP before Intervention		Rp
	a. Total of claim of acute LBP sufferers before Intervention	n_j	Claim
	b. Payment of claim of workers suffering from acute LBP	p_{pa}	Rp/claim
1.2.2	Payment of claim's cost toward those who suffer from acute LBP after Intervention		Rp
	a. Total of claim of acute LBP sufferers after Intervention	n_k	Claim
1.3	Cost saving of claim toward those who suffer from chronic LBP	S_{PK}	Rp
1.3.1	Payment of claim's cost toward those who suffer from chronic LBP before Intervention		Rp
	a. Total of claim ofchornic LBP sufferers before Intervention	n_l	Claim
	b. Payment of claim of workers suffeing from chronic LBP	p_{pk}	Rp/claim
1.3.2	Payment of claim's cost toward those who suffer from chronic LBP after Intervention		Rp
	a. Total of claim of chronic LBP sufferers after Intervention	n_m	Claim
2.	Cost saving of worker'sturnover and absence	P_{KK}	Rp
2.1	Cost saving of workers' *turnover*	P_{TP}	Rp
2.1.1	Payment of cost of worker's *turnover* before Intervention		Rp
	a. Total of the workers who get *turnover* before Intervention	n_n	Person
	b. Cost of separation	b_p	Rp/person
	c. Cost of the workers' development while working in a company	b_{pp}	Rp/person
	d. Cost of new workers' recruitment after *turnover*	b_r	Rp/person
	e. Indirect cost (lost of production during absence of replaced workers)	b_{tl}	Rp/person
	f. Cost separation pay of the workers	b_{po}	Rp/person
2.1.2	Payment of cost of workers' *turnover* after Intervention		Rp
	a. Total of the workers who get *turnover*after Intervention	n_o	Person
2.2	Cost saving of*modified duty*	P_{MD}	Rp
2.2.1	Payment of *modified duty's* cost before Intervention		Rp
	a. Total of workers getting involve in *modified duty* before Intervention	n_p	Person
	b. Total of days of conducting *modified duty* before Intervention	d_c	Day/person
	c. Daily payment of the workers	U_H	Rp/day
2.2.2	Payment of *modified duty's* cost after Intervention		Rp
	a. Total of workers getting involve in *modified duty* after Intervention	n_q	Person
	b. Total of days of conducting *modified duty* after Intervention	d_d	day/person
3.	Improvement of the whole productivity	P_{PN}	Rp
3.1	Productivity's Improvement	K_{PN}	Rp
	a. Percentage of productivity's Improvement	%pn	%
	b. Total of workday in 1 year	d_e	Hari
3.2	Cost saving toward total of *rework* and *spoilage*	P_{SR}	Rp
3.2.1	Payment of *rework* and *spoilage's* cost before Intervention		Rp
	a. Total of *rework* before Intervention	z_a	Unit
	b. Total of *rework* after Intervention	z_b	Unit
3.2.2	Payment of *rework* and *spoilage's* cost after Intervention		Rp
	a. Total of rework after Intervention	z_c	Unit
	b. Total of spoilage after Intervention	z_d	Unit

The formulation of the mathematic model of benefit calculation is as follow:

a. Cost aving of the workers' health care

$$P_{MC} = P_{KP} + P_{PA} + P_{PK}$$

- Cost saving of the workers' compensation

$$P_{KP} = P_{sebelum}^{KP} - P_{setelah}^{KP}$$
$$P_{sebelum}^{KP} = n_f \times p_{kc} + n_g \times p_{km}$$
$$P_{setelah}^{KP} = n_h \times p_{kc} + n_i \times p_{km}$$

- Cost saving of claim toward those who suffer from acute LBP

$$P_{PA} = P_{sebelum}^{PA} - P_{setelah}^{PA}$$
$$P_{sebelum}^{PA} = n_j \times p_{pa}$$
$$P_{setelah}^{PA} = n_k \times p_{pa}$$

- Cost saving of claim toward those who suffer from chronic LBP

$$P_{PK} = P_{sebelum}^{PK} - P_{setelah}^{PK}$$
$$P_{sebelum}^{PK} = n_l \times p_{pk}$$
$$P_{setelah}^{PK} = n_m \times p_{pk}$$

b. Cost saving of workers's*turnover* and absence

$$P_{KK} = P_{TP} + P_{MD}$$

- Cost saving of workers' *turnover*

$$P_{TP} = P_{sebelum}^{TP} - P_{setelah}^{TP}$$
$$P_{sebelum}^{TP} = n_n \times (b_P + b_{PP} + b_r + b_{tl} + b_{po})$$
$$P_{setelah}^{TP} = n_o \times (b_P + b_{PP} + b_r + b_{tl} + b_{po})$$

- Cost saving of*modified duty*

$$P_{MD} = P_{sebelum}^{MD} - P_{setelah}^{MD}$$
$$P_{sebelum}^{MD} = n_p \times U_H \times d_c$$
$$P_{setelah}^{MD} = n_q \times U_H \times d_d$$

c. Improvement of the entire productivity

$$P_{PN} = K_{PN} + P_{SR}$$

- Productivity's improvement

$$K_{PN} = \%_{pn} \times z_i \times H_p \times d_e$$

- Decrease of*rework* and*spoilage*

$$P_{SR} = P_{sebelum}^{SR} - P_{setelah}^{SR}$$
$$P_{sebelum}^{SR} = (z_a + z_c) \times H_P$$
$$P_{setelah}^{SR} = (z_b + z_d) \times H_P$$

3.1.3 Model Implementation

The implementation of the model in this research is done in *material handling*'s activity. In the current condition, a worker lifts the load manually (without using tool). This condition is indicated to be able to cause workers suffer from LBP so that it can slow down work activity. Proposal of improvement on work system used is to use two work methods, i.e. lifting by the use of *scissor lift* tool and modifying work method by hiring two people to lift for once. The comparison between the three conditions in general can be seen on Table 3.

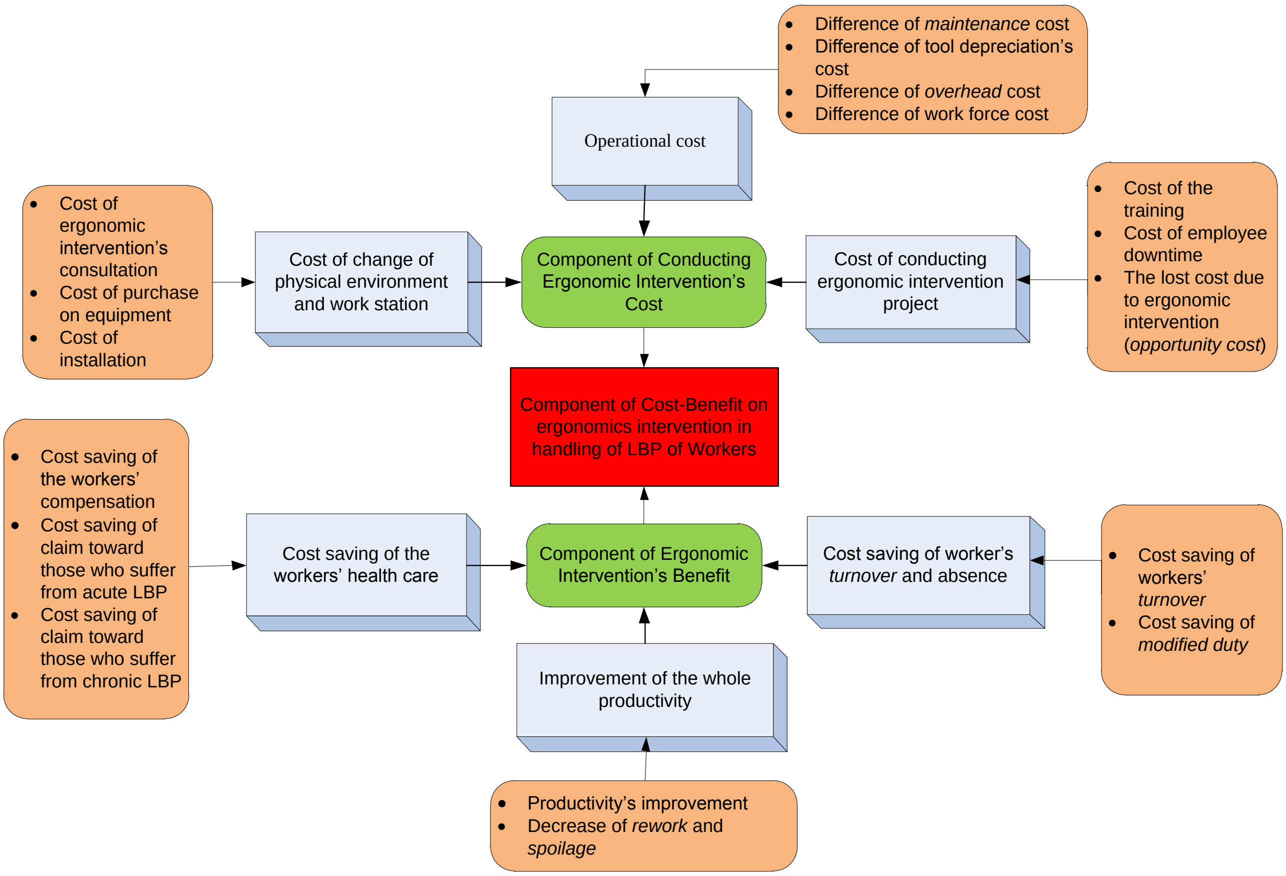

Figure 5.Components of Cost and Benefit of Ergonomic Intervention in Handling of LBP

Table 3. The comparison of Work System for the Three Conditions in the activity of Material Handling

No	Differing Variable	Condition 1	Proposal 1	Proposal 2
1	Total of workforce needed	30 people	34 people	30 people
2	Standard time of lifting 1 sack	4.2 minutes	2.4 minutes	4.15 minutes
3	Frequency of lifting	100 times	176 times	34 times (3 sacks in lifting for once)
4	Total of sacks that can be lifted by 1 worker in 1 day (target of the company is 3000 sacks)	100 sacks	176 sacks	102 sacks

The comparison of the result of L5/S1's force of pressure's calculation, consumption of energy and level of tiredness between the current condition and both proposals provided in the form of a chart that can be seen on Figure 6 for L5/S1's force of pressure, Figure 7 for the level of energy consumption and Figure 8 for the level of tiredness.

In consideration of amount of cost spent, work method by the use of tool gives more advantages than other two work methods in spite of the fact that this method, at first, spends more money. It is due to the need on the tool purchase investment and the conduct of ergonomic intervention. Graphically, the comparison of amount of cost between the three conditions can be seen on Figure 9.

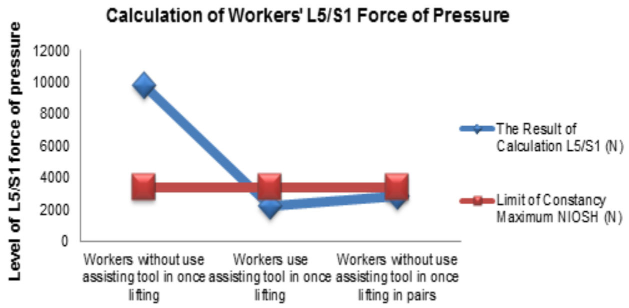

Figure 6.Comparisan of Workers' L5/S1 force of pressure for three conditions of work system

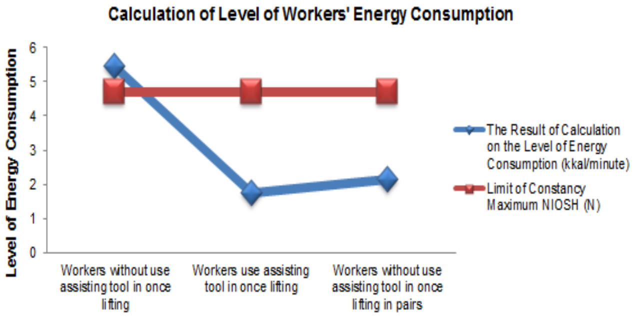

Figure 7.Comparison of Level of Workers' Energy Consumption for Three Conditions of Work System

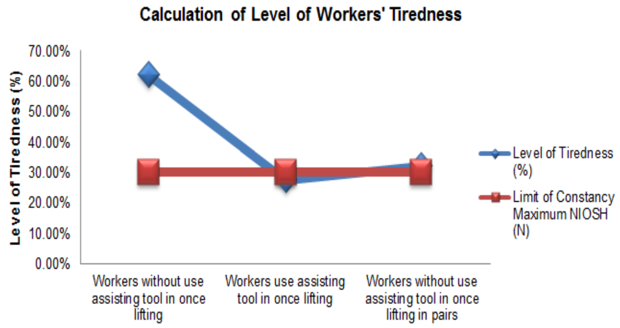

Figure 8.Comparison of Level of Workers' Tiredness for Three Conditions of Work System

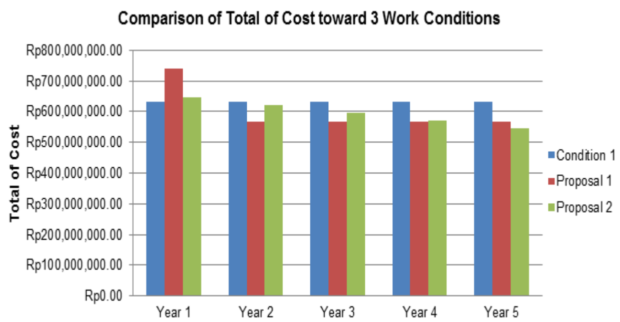

Figure 9.Comparison of Total of Cost toward 3 Work Conditions

If analysis of worthiness investment is done, the result of the comparison can be seen on Table 3.

Table 3. Analysis of Worthiness Investment on Method Proposal

Parameter	Workers use assisting tool in once lifting	Two workers in pair and without assiting tool in once lifting
NPV	Rp38,683,533.72	Rp16,147,703.83
IRR	24%	16%
PI	1.79	1.46
PP	2 years and 0.6 month	2 years and 0.04 month

4. RESULT DISCUSSION

The importance of the role of ergonomic intervention in handling of LBP case toward the workers is as mediator between side of company's management and workers of the whole. Influence brought by LBP toward company's whole performance causes financial condition and work system of the company becoming unstable. Ergonomic intervention in this case has role to make balance and improvement to the condition.

It can be proven by the research conducted by researchers in the entire field of ergonomics. The success of ergonomics in accomplishing the problems have been exposed in detail by Googins, et al (2008) toward 250 case studies on various research areas in many different countries of the world.

In Indonesia, the researches about *cost-benefit* calculation toward ergonomic intervention in handling of LBP's caseon the workers have been still in the stage of discourse's development. It can be recognizedby the fact that there still have been few scientific publishes about researches of this case. In general, the researchers done are studies which only focus on handling of LBP on the workers without studying further about cost calculation that must be spent and benefits received from doing the intervention. Model designed in this research is expected to be able to fill in the gap of the researches about this case and be capable of being the standard reference in handling of LBP's problem on the workers.

The model produced from this research is a comprehensive model to calculate *cost-benefit* inhandling ofLBP's on the workers. It is for the reason that in the process of ergonomic intervention conducted, this model involves study of theoretical biodinamics, physiology of work, and epidemiology where the standard used in the calculation is based on the decision of NIOSH. Mathematic model desiged is analytic, and the components formulating the model is objective and in the form of entity. It means that every component in the model has clear and definite values.

In general, the model has positive-causal relation with its input variables. It means that more money is spent for each parameter in the model, so total of the entire cost will be higher. And vice versa, if the cost is fewer, the total of the costs will be fewer.Nevetheless, there is a model that has negative-causal among the models, i.e. the cost related to cost saving of *turnover*, absence of work, and health care. In this case, it can be explaned that fewer the number of absence, acute and chronic LBP sufferers, *turnover* and *modified duty*, then the company's total of benefit will increase. Although in its calculation there is more in total of the parameter, the cost emerged will also be much more. The benefits achieved are the result of calculation on difference between conditions before and after the intervention conducted.

However, despite advantages having been exposed before, this model still has some limitations and weaknesses. This model does not consider the the condition where the workers get stress, environment of physic work, and various indicators of other physiology of work. However, the limitations in this model do not lessen the essence of the model. This model is still appropriate to be used for handling of LBP on the workers. It is because the model created entirely represents most of the factors needed to be considered in the model.

Based on the result of calculation done on the model implementation, it can be concluded that both proposals are predicted to be able to lower the number of LBP sufferers on the workers. It can be known by the result of calculation obtained which is in the position of where NIOSH still allow based on its standard limitations. By using *scissor lift*, number of LBP sufferers on the workers can be reduced 78% with the parameter of L5/S1 force of pressure. Meanwhile, by hiring 2 people for once lifting, number of LBP sufferers on the workers can be reduced 70% with the parameter of L5/S1 force of pressure.

It shows that work method by use of *scissor lift* is more able to reduce number of LBP sufferers on its work system. The high percentage which is shown by the use of the *scissor lift* is because energy used by the workers for activity of carrying sacks from the place they are stacked to the truck container has much been used for the activity of pushing. The actitvity is also assisted by the existence of wheel on the tool. In the activity of lifting the sacks, the process only occurs in 5 seconds so that Fl5/s1 force of pressure in the position becomes lesser. The workers lift with the position of standing upright and bending the knee to lift the sacks beneath; not with the position of bending over the body. In the activity of carrying the sacks to the truck container, the workers are assisted by the position of table that has almost the same height as the truck container, the entire level of tiredness of the workers become lower than the other work methods.

The work method by hiring 2 workers for once lifting needs good cooperation of this pair of workers. The aim is to be able to distribute the weight of work to be equal for both workers. In addition, it is also for the sacks lifted do not fall and becoming failed product. From biomechanical analysis, this method is better that the currently workers' condition. Level of worker's tiredness also becomes lower than the condition nowadays. However, if the pair of workers does not follow the work method decided before, this method can give more disadvantages than the condition now. It is due to the probability of more sacks falling and unequal distribution of work load.

Based on the *cost-benefit* calculation, it can be known that all calculation done to show that the cost spent by the company is reasonable to be done. It can be seen from the result obtained that meets the requirement of worthiness of an investment.

Based on the calculation, it can also be known that material handling by use of assisting tool, *scissor lift*, give more advantages than hiring 2 workers in every lifting. It is because in the second method the company will pay for quite much operational cost every year due to the additional workforce after intervention conducted. It gives ipact on total of benefits received by the company, where the calculation is done by calculating difference between operational cost and total of every year company's benefits. If the percentage influencing the level of the decreased number of LBP sufferers gets higher, the more benefits the company gets.

5. CONCLUSION

Based on the research result, the design of model and the discussion that have been done before, are concluded that:

1. LBP is one of the MSDs disorders which occurs in L5/S1 area and often followed by the spread to leg until foot which is caused by management of posture and working position that is not ergonomic, the weight of load lifted that is over the limit of the wokrers' capability, physiology ofwork with the use of energy overwhelmingly, and system of work that is not conducive.
2. The effect of workers suffering from LBP to the entire performance of a company impacts on the level of work accident, level of injury, absence, number of days missing, cost of workers' health care, productivity, *rework*, *spoilage*, cost of workers' claim, cost of compensation, level of *turnover*, and *modified duty*.
3. Handling of LBP on the workers can be done by ergonomic intervention toward biomechanical analysis in the calculation of L5/S1 force of pressure, level of energy consumption and tiredness, and epidemiology.
4. Components of *cost-benefit* calculated in conducting the ergonomic intervention on handling of LBP is the cost of change in physical environment and work station, operational cost, cost saving of workers' health care, cost saving of *turnover* and workers' absence, and productivity's improvement.
5. Material handling activity that occurs in fertilizer storage with condition nowadays causes L5/S1 force of pressure on the workers to reach 9809.28 N, level of energy consumption that is 5,45 kkal/menit and % CVL to reach 61.89%. Ergonomic intervention conducted by use of *scissor lift* and modification of work method shows 2226.83 N and 2863.90 N L5/S1 force of pressure for each, 1.77 kkal/menit and 2.15 kkal/menit level of energy consumption for each, and 27.59% and 32.06% level of tiredness for each.
6. Analysis of worthiness investment in conducting ergonomic intervention that is implicated by the result of NPV, IRR, PI dan PP calculation shows that work method by use of assisting tool, i.e. *scissor lift*, give more benefits that work method by hiring 2 workers in every once lifting.

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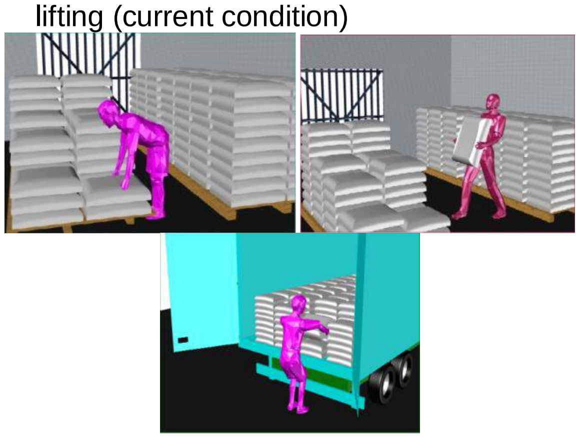
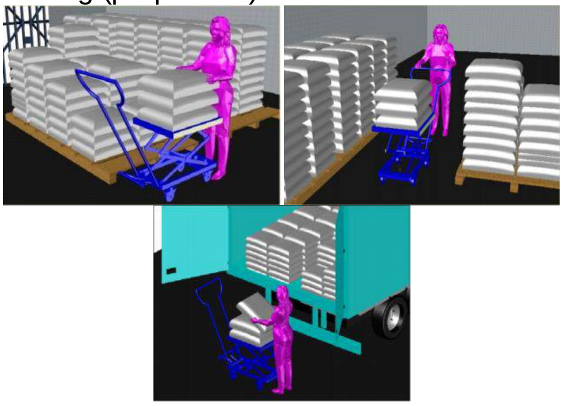
APPENDIX

a. A worker without assisting tool in once lifting (current condition)



b. A worker with use of assisting tool in once lifting (proposal 1)



c. A pair of workers lift the load without assisting tool (proposal 2)