Dewi Candraningrum
(Editor)

Narratives of Sustainable Development: Industry in the Global World Meeting Social Ecological Responsibility

Introduced by
Prof Bernard Adeney-Risakotta

Courtesy of painting by Vincent van Gogh, *Lady Arles*

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Redesign of Equipment and Work Methods in Tofu Industries

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Abstract: One This research was conducted on soybean seed processing industry into a product of Tofu. The problem that arises is a mismatch between humans and machines at work so often that causes pain in the body of artisans. Moreover, the working environment is too hot and has high humidity that causes the resulting output not optimal. Tofu-making process is divided into 5 work stations, namely station milling, cooking stations, filtration station, printing station and cutting station, and the fifth station must pass to produce a good product.

This study used an objective method to create the design of work equipment using Catia V.5, 0 and layout of the production floor using 3DMax, assessing the standard time by direct measurement using a stopwatch, and indirectly using the MTM-1. To determine the level of fatigue used questionnaires Nordic Body Map (NBM), while to study the response and health problems of workers against exposure to workplace conditions used questionnaire responses of working conditions.

Results obtained to resolve Tofu product is a human standard time 20.7211 minutes (0.30154 hours) and standard time machine 31.8186 minutes. Based on calculations using the indirect method of MTM-1 and based on the layout of the proposal obtained by the time the standard becomes 0.061289 hours. The proposed layout is based on data at 5 factories, obtained by rectilinear 23.74 meters / day to 21.74 meters / day occurred saving 0.06% / day, euclidean of 1539.45 square meters / day to 1341.36 meters / day occurred saving 0129% / day and euclidean 19.5712 meters / day to 18.18185 meters / day occurred saving 0071% / day. The research has been done to make a recommendation to the ergonomic conditions in manufacturing Tofu industries.

Keywords: redesign of equipment, work methods, ergonomic.

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I. Introduction

A Small Medium Industry making Tofu in Kartasura is one of the soybean seed processing industries to Tofu product. To be able to maintain its business with various competitors problem that arises is that the working equipment is not in accordance with the working capacity of workers—giving rise to a harmonious interaction between the equipment which does not work together with the worker. This incompatibility raises an impact in which work activities being performed is not optimal. The impact of the incompatibility of this interaction leads to a product in which the time finished between one worker with another worker has a different working capacity with equipment and working methods they use.

The problem here is that it should have a development of methods and tools which are reviewed from the aspect of ergonomics that allows workers to work safely and comfortably so that productivity can be effective and efficient.

II. Purpose

a. Analyzing methods of work (work attitude) and work equipment that is used in terms of ergonomics and layout aspects of the production floor.
b. Provide improvement recommendations for the development of working methods and work equipment in accordance with aspects of ergonomics.

III. Theory

Ergonomics is the science, art and technology practices to harmonize or balance between all the activities that are used both in activity and rest with the capabilities and limitations of human beings both physically and mentally so that the overall quality of life for the better (Tarwaka, et al, 2004: 6).

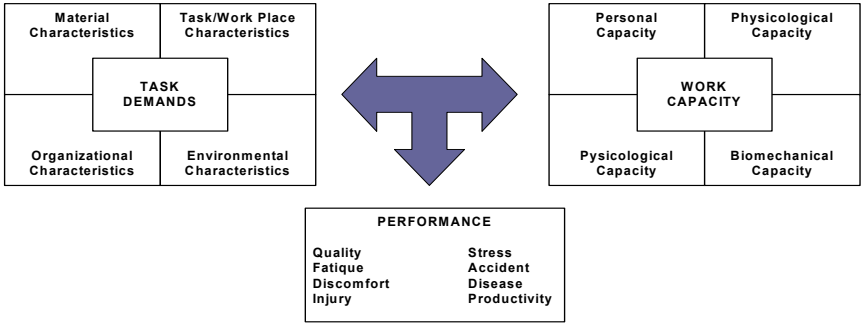

Figure 1 Basic Concept of Equilibrium in Ergonomics

Work load

Nordic Body Map is a tool of a body map that is used to determine the complaint on the muscle to the level of complaints ranging from discomfort to pain (Corlett, 1992 in Tarwaka, et al, 2004:129) The human body is designed to perform activities of daily work. The presence of muscle mass which weighs almost more than half of the weight, allow us to be able to move and do the job. Work on the one hand has significance for the advancement and improvement of performance, so as to achieve a productive life of a single purpose in life. On the other hand, work means the body will accept the load from the outside of his body. On other hand, every job is a burden for the concerned. These expenses may include physical and mental burden.

Raw Timing

Determination of standard of time to determine the production target is done by direct measurement using the clock stopping. Measurements were taken because of the work is influenced by several factors that cannot be avoided by both factors from within and from outside the company.

a. Time Average

$$\overline{X} = \sum \frac{Xi}{N} \quad (1)$$

In which:

$\overline{X}$ = time average
Xi = data measurement
N = sum of data measurement

b. Uniformity Test

$$UCL = \bar{x} + 2\,SD \quad (2)$$

$$LCL = \bar{x} - 2\,SD \quad (3)$$

$$SD = \sqrt{\frac{\left(Xi - \overline{X}\right)^2}{N-1}} \quad (4)$$

Where:
UCL = Upper Control Limit
LCL = Lower Control Limit
$\bar{x}$ = Average price of observational data
SD = Standard deviation of observation data

3. Sufficiency Test

$$N' = \left[\frac{k}{s}\sqrt{\frac{N\sum x_i^{\,2} - \left(\sum x_1^{\,2}\right)}{\sum x_i}}\right]^2 \quad (5)$$

Where:
N '= number of data needed
N = number of observations made.
xi = measurement data
i = 1,2,3 ... . n
s = level of precision
k = index
With 90% confidence level and degree of accuracy of 10% then the formula becomes:

$$N' = \left[\frac{10\sqrt{N\sum x_i^{\,2} - \left(\sum x_i^{\,2}\right)}}{\sum x_i}\right]^2 \quad (6)$$

4. Normal Timing

$$Wn = \overline{Xs}\ \text{x (p)} \quad (7)$$

5. Determination of Standard Time

$$W_B = W_n\,x\,\frac{100\%}{100\% - allowance} \quad (8)$$

6. Calculation of Standard Output

$$\text{Standard Output (OS)} = \frac{1}{\text{standard time}} \tag{9}$$

Anthropometry

Anthropometry is a collection of numerical data related to human physical characteristics, size, shape and strength as well as the application of these data for the handling of design issues (Wignjosoebroto, 1995).

Percentile is a value that states that a certain percentage of a group of people that its dimensions equal to or lower than this value (Nurmianto, 2003: 51).

IV. Research Methodology

1. Instruments of Data Collectors
   a. Video Tape (Video Camera) and Digital Images
   b. Questionnaires
      1) Nordic Body Map Questionnaire
      2) Questionnaire of Job Evaluation Tools
      3) Questionnaire of Response Working Environment Conditions
      4) Questionnaire for Occupational Health Disorders
   c. Meter body and Chair Anthropometry
   d. Stopwatch
   e. Pulse meter
2. Methods of Data Processing and Analysis
   a. Calculation of anthropometry: Test of Data Adequacy and Uniformity Test
   b. Study Time: Determination of Normal Time and Standard Time, Uniformity of Test Data, Test Data Adequacy, Normal Timing Analysis

V. Results And Discussion

1. Dimensions of Work Equipment

Table 1: Dimensions of Milling Station

Description	***cm***
Engine mountings long	*122*
Engine mountings width	*70*
Engine mountings high	*45*
The length of the engine	*70*
The width of the machine	*72*
The high of the machine	*77*
Distance milling to wash	*81*
The height of the hand when lifting soybean	*38*
The height of the hand when entering soybeans to milling	*155*

Table 2: Dimensions Cooking Station

Description	**cm**
High cooking station outside from the basin	76.5
Outer diameter	117
The diameter of the vessel	100
The depth of the tub	60
High water reservoir	72.5
Width water reservoir	48
Length water reservoir	72
Water storage Altitude of range hands down	40.5

2. Anthropometric data of Tofu workers

   Data anthropometry has: Name, Age (years), Weight (kg), Standing Shoulder Height (cm), Standing Elbow Height (cm), Reach fore Hand (cm), Thickness Chest (cm), Waist Standing Height (cm), Bottom Arm Length (cm)
3. Name area in Tofu Manufacture

Table 3: Size of Area of Each Area

NO	CODE	NAME AREA (DEPARTMENT)	SIZE (P x L)	AREA TOTAL (mm^2)
1	A	STATION OF WITHHOLDING	450 x 86	38700
2	C	MILLING STATION	122 x 70	8540
3	E	COOKING STATION	117 x 117	31329
4	F	FILTERING STATION	117 x 117	31329
5	G	MOULDING STATION	168 x 72	12096
6	I	IMMERSION STATION	225 x 85	19125
7	L	WAREHOUSE PRODUCTS	155 x 225	34875
8	H	COMBUSTION	253 x 108	27324
9	K	FUEL WAREHOUSE	450 x 80	36000
10	B	WAREHOUSE EQUIPMENT	203 x 236	47908
11	M	WELLS	120 x 236	28320
12	J	BATHROOM	253 x 80	20240
13	D	BASIN	72 x 48	3456
14	N	VINEGAR BOX	50 x 50	2500
Total				341742

4. Cycle Time Data

Table 4: Direct Measurement Data Standard Time

Description	Sampling (minutes)				
	1	**2**	**3**	**4**	**5**
Milling station	0.53	0.49	0.58	0.51	0.56
Cooking station	0.58	1.10	1.24	1.05	1.01
Filtering station	3.46	4.05	4.17	5.01	4.54
Molding station	2.45	2.34	2.16	2.57	2.21
Cutting station	6.43	6.52	6.38	6.47	6.13

4. Proposed Layout of Production Process Flow Chart, obtained from the processed BLOCPLAN layout proposal of production process flow chart to tofu as in Table 5

Table 5: Summary of Material Handling Distance

Factory	Distance Material Handling			Cook Result
	Rectilinear (m)	*Square Euclidean* (m)	*Euclidean* (m)	
I	23.125	1539.45	19.5712	40
II	17.2125	748.371875	13.4957272	24
III	13.825	733.675	13.42684205	24
IV	14.0375	658.609375	12.054833405	24
V	14.375	418.08125	12.06010658	24

Calculation of total material handling distance on the proposed layout with units of m within 1 work day.

Table 6: Distance of Material Handling on Proposed Layout

Factory	Distance of Material Handling			Cook result
	Rectilinear (m)	*Square Euclidean* (m)	*Euclidean* (m)	
Proposed	21.74	1341.36	18.18185	40

After doing the calculations regarding the size range of material handling at the beginning of the layout of the factory owned by Mr. Kasno with the proposed layout design conditions obtained results in Table 7:

Table 7: Comparison of Distance Material Handling initial layout with the Layout Proposed

Model Distance	Distance Material Handling		Reduction Distance Material Handling (meter/day)	Savings (% / day)	Description
	Initial layout (meter/day)	Proposed layout (meter/day)			
Rectilinear	23.125	21.74	1.385	0.06	Down
Square Euclidean	1539.45	1341.36	198.09	0.129	Down
Euclidean	19.5712	18.18185	1.38935	0.071	Down

In Table 7, there was savings; there will be additional income, Table 8

Table 8: Additional Income

Distance Model	Distance saving (meter/day)	Additional income (Rupiah/day)
Rectilinear	1.385	80.000
Square	198.09	200.000
Euclidean	1.38935	120.000
Euclidean		

Recapitulation comparison of actual conditions and conditions of the proposal can be seen in table 9:

Table 9: Comparison Now and Condition Proposed

Milling Station		
No	**Present condition**	**Proposed condition**
1	A height of 45 cm engine mountings	engine mountings height of 25 cm
2	Workers must lift a bucket of soy with forearm position when lifted upwards so that the burden includes soy to milling received by workers will be increased as well	Reduction of engine mounting height is expected to reduce the burden felt by workers when entering soybean to milling
3	The burden felt by workers when entering soybean to the milling. 3 Positions of soy marinade buckets on the floor with a height of 38 cm from the floor so that workers must be bent and lifting it up when going to milling.	The existence of a bucket seat with a height of 55 cm submersion length of 40 cm and 70 cm width allows workers lifted the bucket without having to bend and reduce the burden without having to lift from the top down
Cooking Station		
No	**Present Condition**	**Proposed Condition**
1	A vessel for cooking soy height 76.5 cm	A vessel for cooking soy height 96,5 cm
2	Workers must bend when taking soy extract in the primary vessel by using a paddle.	The position of the primary vessel to rise 20 cm with a fixed volume so that workers do not bend while taking soymilk in the primary vessel
Filtrating Station		
No	**Present condition**	**Proposed condition**
1	A vessel for cooking soy height is 76.5 cm.	A vessel for soy height is 96.5 cm
2	Length of the handle grip is extended to 27.5 cm.	Handle grip is extended 27.5 cm to make it easier to extract in the vessel.
3	Workers must bend when taking soy extract in the	The position of the primary vessel to rise 20 cm with a fixed

	primary vessel by using a scoop.	volume so that workers do not bend while taking soymilk in the primary vessel.
Molding Station		
No	**Present condition**	**Proposed condition**
1	Buffer height of 73 cm in	Buffer height of 80.5 cm
Cutting Station		
No	**Present condition**	**Proposed condition**
1	Position of the bucket where the results are too low-cut idea as high as 38 cm from the floor to make the workers have to stop when entering a piece out into a bucket so that makes it less comfortable of bucket seat	Additional table will help workers and inserting the soybeans into a bucket with a fixed stand upright without having to bow to the height 63 cm long and 40 cm wide.
2	Second ruler 95 cm of long piece out and know the width varies according to size.	Some rulers knew assembled into one piece with a tolerance 0:15 cm distance between the ruler as a hole cutter cuts that will accelerate and easy to make Tofu.

Table 10 is the cycle time measurement data directly by using a stopwatch, then by using actual data layout. standard time can be calculated by indirect measurement using the method of MTM-I, we got the result in Table 10:

Table 10: Comparison of two methods

Factory	Method	
	Stopwatch (hour)	MTM-1 (hour)
1	0.30154	0.0861289
2	0.32745	0.0847099
3	0.27325	0.0838766
4	0.33979	0.0835670
5	0.34535	0.0855679

By comparing the measurements of time directly and indirectly, the comparison method can be seen in Table 11:

Table 11: Comparison of direct and indirect methods

	Direct Method	Indirect Method
Advantages	1. It's easier, because the record only time without having to describe the work elements into his work. 2. More detail because the time is obtained based on the time	No need to place the work to be studied over and over note elements movement either record or videotape
Disadvantage	1. It takes longer to get a lot of time data to obtain measurements precisely and accurately. 2. Must go to a place where work measurement job lasted more than once	1. No data of movement time tables and thorough reply. So idle time is not counted 2. High accuracy required for an observer in classifying the elements of the job because it will affect the calculation results.

VI. Conclusions

1. Workers who experience problems/complaints in the last 6 months at 47.63% and 40.53% had problems/complaints in the last 7 days. This shows that the discrepancy between the dimensions of work stations with the capabilities and limitations of workers labor causes an unnatural attitude of the workers.
2. The dominant activity complained by workers at the station is to enter the soybean milling to milling (100%), raising soybeans is in the bucket (50%), the cooking station. Soybean extract from the vessel (75%), pour soymilk (25%), at the screening station is taking soya from the tub (100%), the

molding station turned out to mold the foundation board cuts (75%), raised ballast for pressing (25%), the cutting station is put out into the bucket (50%), cut out over and over again (25%).

3. Of the ten alternatives proposed layout of BLOCPLAN processed, then the chosen is an alternative to the proposed layout of the four because of the ten alternatives proposed layout has the highest proximity score.
4. Measurement of standard time between the two methods in plant I, which method of stopping at 0.30154 hours and time is obtained with MTM-1 method is 0.0861289 hours; there was a difference of 0.2154111 hours.
5. There is no reduction or increase in the time machine because motion elements have been carefully optimized in terms of standard time or from elements of the movement. Researchers can only suggest minimizing the time of the process of making out by changing the layout of equipment at each station and change the layout of the plant.

Suggestions:

Need to do repair work on equipment and labor method for workers to work comfortably and to be able to finish the product on time.

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