Design of work facilities for transtibial people in sewing machine stations using TRIZ Method

H Mahardi[1], L Herdiman[1], S Susmartini[1]

[1] Department of Industrial Engineering, Universitas Sebelas Maret, Jalan Ir. Sutami No. 36A ,Surakarta, Indonesia

E-mail: mahardihafid@student.uns.ac.id

Abstract. A person with physical disability is someone who cannot carry out an activity caused by a physical condition or a biological system. Data from SAKERNAS states that the rate of disability in 2017 reached 16.81% with a total disabled workforce of 11,224,673. BBRSPDF Prof. Dr. Soeharso Surakarta is the implementing unit for empowering persons with physical disabilities, where empowerment developed is sewing skills. The empowerment of sewing machines in the garment industry is generally designed to be able to be run for physically normal workers, this is different if a person has a transtibial disability. The operation of a sewing machine that previously used the sole of the sewing machine was changed to the use of the knee. This problem can be overcome by making special work facilities. The design of work facilities for persons with transitional disabilities needs to be adjusted between needs and abilities through a participatory approach. The design of the sewing machine pedal motor also contradicts technical problems, due to differences in the use of limb functions. This problem can be solved using the TRIZ method to obtain a design that fits the user's needs.

1. Introduction

Persons with physical disabilities are someone who cannot carry out certain activities or activities caused by physical conditions or biological systems that are different from others in general [1]. A person with a physical disability has limbs that are different from normal people in general, limb paralysis or incomplete upper or lower limbs [2]. The number of persons with disabilities in Indonesia has increased significantly for each year. The average increase in the number of disabilities in Indonesia from 2012 to 2016 was 4.8% [3]. National Labour Force Survey Data (SAKERNAS (2017)) states that the disability rate in 2017 reached 16.81% with a total disabled workforce of 11,224,673.
Persons with disabilities are part of the Indonesian community who have the same position, rights, obligations and opportunities and roles, but some people still think differently about people with disabilities. Persons with disabilities are considered unproductive, not creative and not innovative. This presumption gives a limit for persons with disabilities to participate in various aspects of life, especially in employment. One government agency that empowers persons with physical disabilities is the Centre for Social Rehabilitation of Persons with Physical Disabilities (BBRSPDF) Prof. Dr. Soeharso Surakarta.

BBRSPDF Prof. Dr. Soeharso Surakarta is a technical implementation unit in the field of social rehabilitation of persons with physical disabilities. BBRSPDF Prof. Dr. Soeharso Surakarta has to carry out social services and rehabilitation, resocialization, distribution and advanced guidance for persons with physical disabilities to be able to play a role in community life, national referrals,

assessment and preparation of service standards. The most popular empowerment for persons with disabilities in 2018 is sewing empowerment with a total of 15 participants from a total of 77 participants. The number of interested people in the sewing field is due to quite open employment opportunities and many garment industries that employ disabled workers.

Sewing empowerment in persons with disabilities 3 facilities is consisting of sewing machines, overlock machines, and ironing machines. Sewing machines are widely used in the garment industry because sewing machines are the main process in making garment products. Sewing machines in the garment industry are generally designed to be run for workers who have normal physical conditions, to operate sewing machines using the soles of the feet by stepping on the pedals to be able to adjust the motorbike. This method is different if a person has a transtibial disability with physical limitations in the form of only knee-length legs. The operation of a sewing machine that previously used the sole of the sewing machine was changed to the use of the knee. This problem can be overcome by creating work facilities specifically for persons with transitional disabilities so that people can operate sewing machines as well as normal workers.

Work facilities are a facility and infrastructure needed to help workers to get things done more easily [4]. work facilities are created as a form of service to workers to support performance in meeting the needs of workers. The design of work facilities for persons with transitional disabilities needs to be adjusted between needs and abilities through a participatory approach. A participatory approach is an approach that involves the active participation of users and other stakeholders to improve performance starting from the design process to implementation [5,6,7]. Work facilities for people with transtibial disabilities are considered the size of anthropometry and user ergonomics.

The design of the sewing machine pedal motor also contradicts technical problems, due to differences in the use of limb functions. This problem can be solved using the TRIZ method to obtain a design that fits the user's needs. The TRIZ method gives space for designers to observe and design according to their ideas so that design considerations are not only from consumer demand but adapted to user needs [8]. Based on this problem, the proposal that will be given is to design the operation of the pedal motor at the sewing machine work station for people with transtibial disabilities to make it easier for users to operate sewing machines.

2. Methodology

2.1. Problem identification

The background of the problem is how to design work facilities specifically for persons with transtibial disabilities in order to operate sewing machines independently. It is known based on three identified constraints. Human constraints are caused by the physical limitations of the transtibial disability so that they cannot operate the sewing machine without working facilities, this causes productivity in the sewing process to decrease as shown in Figure 1.

Another obstacle is in terms of material used for work facilities, namely wood as supporting material for work facilities pedals causes instability in the operation of work facilities. The next obstacle in terms of the methods used in operating work facilities. Work facilities used today are operated using elbows, the use of elbows in operating work facilities can reduce the flexibility in carrying out the sewing process because the sewing process requires two hands in controlling the fabric to be sewn, in addition to the use of the elbows to press the work facility pedal can also reduce the comfort resulting in the occurrence of work fatigue in carrying out the sewing process.

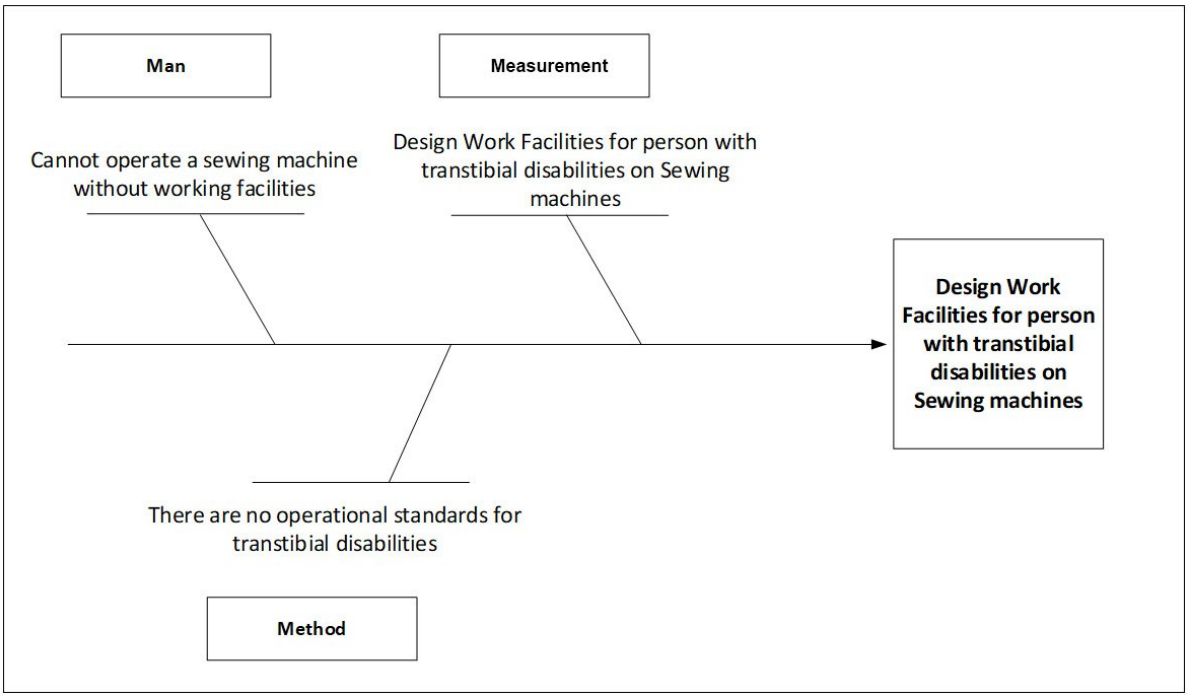

Figure 1. Cause effect diagram.

2.2. Identification dimensions of anthropometry

Anthropometric dimensions were used to determine the size of the body structure of persons with transtibial disabilities used as a basis for designing sewing machine work facilities. The anthropometric dimensions needed to design work facilities for persons with transtibial disabilities are knee height and knee length.

2.3. Participatory approach

The identification design requirement for a user is done using a participatory approach. Participatory is an approach by involving the active participation of users and stakeholders to improve performance starting from the design process to implementation. The participatory in this study was applied in the form of an open questionnaire given to stakeholders to identify user needs related to the design of work facilities. The results of this questionnaire are used as input to determine design criteria as shown in Table 1.

Table 1. Participatory questionnaire.

No	Criteria	Statement
1	Accessibility	Appropriate Function
2		Work facilities is not complicated
3		Work facilities can be assembled
4	Effectiveness	The length of time used to use the tool
5		Movements made by workers are not complicated
6	Easy to Handle	Easy to install work facilities
7		Can be applied to all types of sewing machines
8	Ergonomic	Minimize muscle fatigue
9		low physical effort
10		Good bodywork position
11	Tool Performance	Formation of formidable working facilities
12	Material	The material used is lightweight
13		Made from strong/tough material
14		Durable material
15	Design	Work facilities do not take place
16		Uncomplicated design
17		The attractive appearance of work facilities

2.4. Identification of user needs

Identification of user needs includes all information regarding the design requirements of a sewing machine work facility that will be used by persons with transtibial disabilities. Information about the design requirements of the tools obtained from the questionnaire given to stakeholders at BBRSPDF Prof. Dr. Soeharso sewing training section.

2.5. Determination of user needs

Determination of user needs is used to filter information in the form of user needs that are really needed by researchers to design a sewing machine work facility as stated in Table 2.

Table 2. Criteria design.

No	Criteria	Statement
1	Accessibility	Appropriate Function
2		Work facilities is not complicated
3	Effectiveness	Movements made by workers are not complicated
4	Ergonomic	Minimize muscle fatigue
5		Good bodywork position
6	Tool Performance	Formation of formidable working facilities
7	Material	The material used is lightweight
8		Made from strong/tough material
9		Durable material
10	Design	Work facilities do not take place
11		Uncomplicated design

2.6. Functional diagram

The functional diagram aims to identify the relationship between the functions of each element contained in the sewing machine operation process and the problem. The sewing machine operating element consists of electrical sockets, switches, Presser Foot Lifter, Foot Pedal, Dynamo, and Needle as shown in Figure 2.

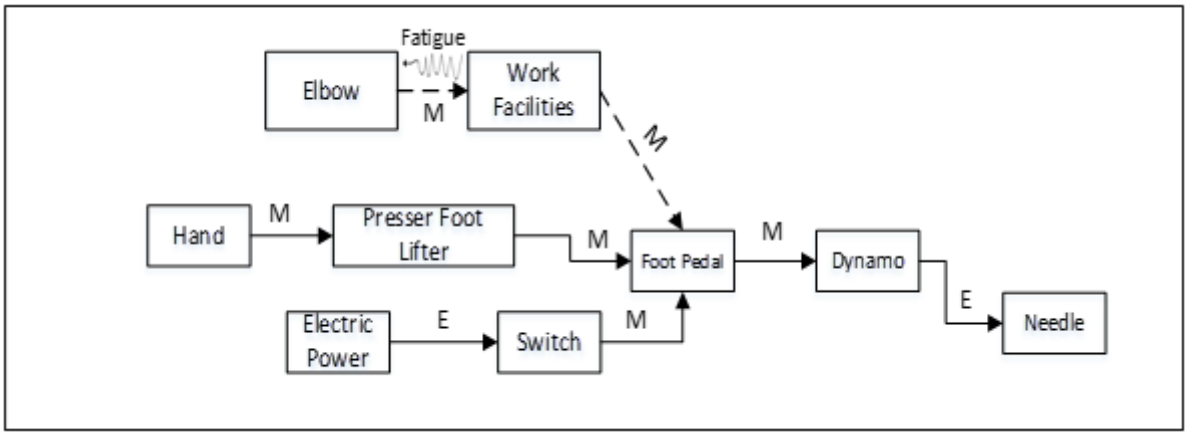

Figure 2. Functional analyse model of work facilities.

The relationship between the elements contained in the functional diagram above is used as a basis for determining technical requirements to determine the concept and design specifications. The diagram consists of 3 relationships, namely normal useful action, insufficient useful action, and dangerous action. The following is an explanation of each element in the process of operating a sewing machine.

1. The relationship between the elbow and the work facility is drawn by a dotted line. This indicates that the use of elbows to suppress work facilities does not function optimally. the use of the knee is not functioning optimally due to shock/lack of stability that occurs at work facilities.
2. The relationship between work facilities and pedals is drawn by a dotted line. This indicates that the work facilities do not function optimally at the time of operation. Work facilities do not work optimally due to lack of work facility functions so that obstacles occur when running the sewing process.
3. The relationship between the elbow and the work facility is drawn by a winding line. This shows that work facilities provide harmful action to the elbows. The harmful action on the elbows is caused by shocks/lack of stability that occurs at work facilities causing fatigue to workers.

2.7. Technical contradiction (TRIZ)

2.7.1. Technical requirement. Technical requirements are criteria for technical needs which are the needs of transtibial disability cases so that the design can operate sewing machine with knee. Technical requirements are obtained from participatory approach and functional analysis as stated in Table 3.

Table 3. Technical requirement.

No	Part	Technical Requirement	Statement
1	Main Frame	Strong Material	Participatory
2		Manually operated	Functional Analysis
3		Can Saving Space	Participatory
4	Lever	Uncomplicated Use	Participatory
5		Durable Material	Participatory
6		Strong Frame formation	Participatory
7		Low Physical Effort	Participatory
8		Appropriate Function	Participatory
9	Pad	Pad design according to knee conditions	Participatory
10		Pad height matches anthropometry	Functional Analysis

2.7.2. Improving feature. Improving feature is a classification stage based on technical requirements using 39 problem parameters used in development product based on TRIZ method as stated in Table 4.

Table 4. Improving feature.

No	Part	Technical Requirement	Improving Feature
1	Main Frame	Strong Material	Weight of stationary object (2)
2		Manually operated	Duration of action by a stationary object (16)
		Manually operated	Ease of operation (33)
3		Can Saving Space	Shape (12)
4	Lever	Uncomplicated Use	Ease of operation (33)
5		Durable Material	Duration of action by a moving object (15)
6		Strong Frame formation	Weight of moving object (1)
7		Low Physical Effort	Pressure (11)
8		Appropriate Function	Reliability (27)
9	Pad	Pad design according to knee conditions	Shape (12)
10		Pad height matches anthropometry	Measurement accuracy (28)

2.7.3. Worsening feature. The worsening feature is determined by considering the improving feature matrix. The determination of the worsening feature is taken based on 39 problem parameters in the TRIZ method and considers the impact that occurs as a result of improving the applied criteria as stated in Table 5.

Table 5. Worsening feature.

No	Part	Technical Requirement	Worsening Feature
1	Main Frame	Strong Material	Strength (14))
2		Manually operated	Ease of manufacture (32)
		Manually operated	Weight of stationary object (2)
3		Can Saving Space	Stability (13)
4	Lever	Uncomplicated Use	Productivity (39)
5		Durable Material	Strength (14)
6		Strong Frame formation	Speed (9)
7		Low Physical Effort	Loss of Energy (22)
8		Appropriate Function	Productivity (39)
9	Pad	Pad design according to knee conditions	Stability (13)
10		Pad height matches anthropometry	Weight of moving object (1)

2.7.4. Contradiction elimination

To resolve and eliminate the contradictions that occur in the design of a work facilities, the TRIZ method provides tools in the form of 40 inventive principles to help resolve existing contradictions as stated in Table 6.

Table 6. Inventive solution.

No	Part	Technical Requirement	Inventive Solution
1	Main Frame	Strong Material	Taking Out (2)
2		Manually operated	Universality (6)
		Manually operated	Merging(5)
3		Can Saving Space	Homogeneity(33)
4	Lever	Uncomplicated Use	Dynamics (15)
5		Durable Material	Local Quality(3)
6		Strong Frame formation	Mechanical Vibration (18)
7		Low Physical Effort	Parameter Changes (35)
8		Appropriate Function	Pneumatic and Hydraulics (29)
9	Pad	Pad design according to knee conditions	Asymmetry (4)
10		Pad height matches anthropometry	The other way Around (13)

2.8. Conceptual design

The next stage is conceptual design, which explains the design concept in detail, accompanied by illustrations of the design. The design concept is based on the solution interpretation produced at the technical contradiction stage.

3. Results and discussion

The results of the participatory questionnaire are used as a tool to find out the needs that need to be developed in the design work facilities. Design requirements are obtained through the average value of each criterion. Based on these calculations, it can be seen in Table 7.

Table 7. Criteria herarchy.

Criteria	Statement	Mean	∑ Mean
Accessibility	Q1	6.25	4.83
	Q2	6	
	Q3	2.25	
Effectiveness	Q4	3.5	4.75
	Q5	6	
Easy to Handle	Q6	2.75	2.75
	Q7	2.75	
Ergonomic	Q8	5.75	6.17
	Q9	6.5	
	Q10	6.25	
Tool Performance	Q11	5.75	
Material	Q12	6	5.75
	Q13	5.75	5.75
	Q14	5.5	
Design	Q15	6	4.9
	Q16	6	
	Q17	5.75	

There are 7 criteria processed in the participatory questionnaire. The average chart of criteria values shows that the easy to handle criteria has the lowest value 2.75, Effectiveness of 4.75, Accessibility criteria of 4.83, Design criteria of 4.9, Material of 5.75, Tool Performance of 4.75, and Ergonomic of 6.17. The Dimension of product is stated in Table 8.

Table 8. Dimension of product.

No	Size	Dimension of product (mm)
1	High work facilities from the base	470
2	Lever height	540
3	Length Lever	140
4	Length Main Frame	290
5	Length Pad	80
6	Width Pad	40
7	Length Frame Pad	120

The results of the evaluation will be the main development improvement. And the main criteria that form the basis of design are ergonomic, material, material, and accessibility. The following is a visualization design of the established criteria as shown in Figure 3 and 4.

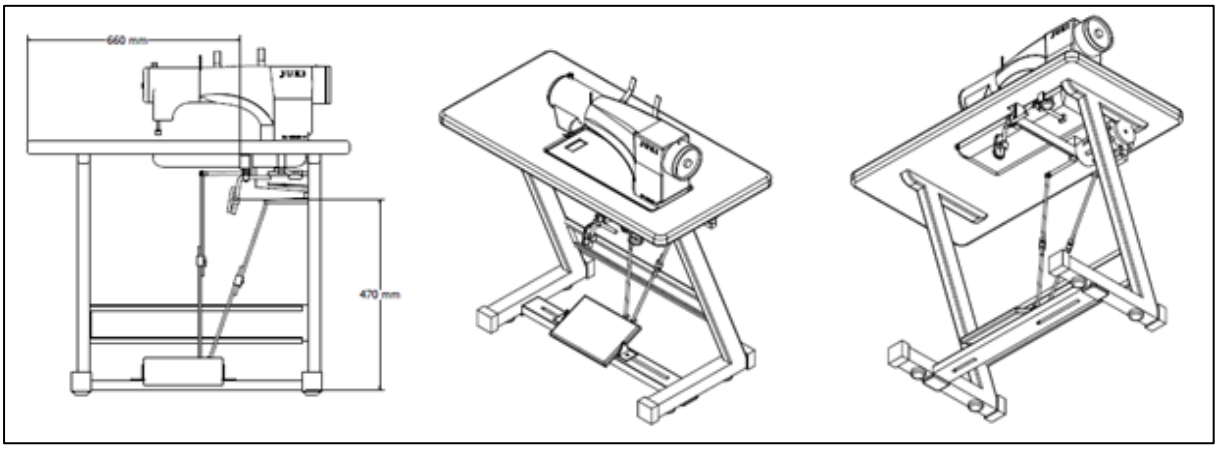

Figure 3. Work facilities with sewing machine.

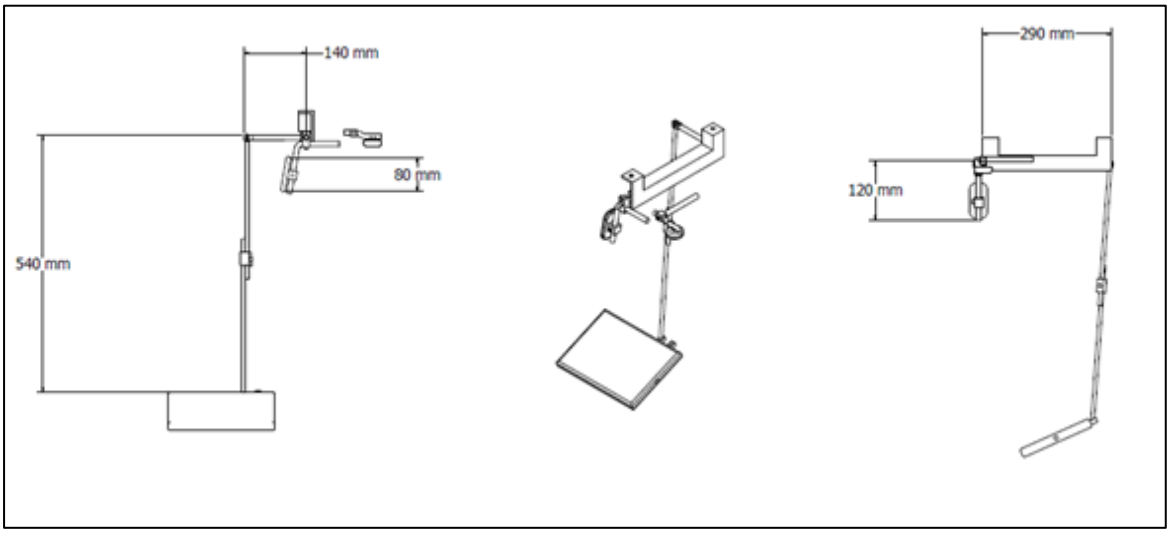

Figure 4. Work facilities.

4. Conclusions

Design of work facilities for people with transtibial disabilities is prioritized 5 criteria including Ergonomic, design, material, Tool Performance, and accessibility. The sewing machine working facility is moved by using the knee on the bearing so that it can move the sewing machine pedal. The cushion design is equipped with foam and upholstery that are adjusted to the shape of the user's knee. Work facility design is designed so that persons with disabilities can operate the sewing machine independently and minimize the occurrence of work fatigue.

5. References

[1] Anshar M 2017 *Electronic Theses and Dissertations* (Surakarta: Fakultas Psikologi Universitas Muhammadiyah Surakarta)
[2] Widjopranoto R and Sumarno S 2004 *Media Informasi Penelitian Kesejahteraan Sosial No 179* p 3-23
[3] Diana C L 2017 *Disability in Indonesia : What can we learn from the data ?*
[4] Husnan 2002 *Perilaku Organisasi Salemba Empat Jakarta International Labour Organization 2010 Inklusi Penyandang Disabilitas di Indonesia*
[5] Wilson J R Haines H M 1997 *Handbook of Human Factors and Ergonomics* (New York: Wiley) 490-513
[6] Manuaba A 2004 *Proceeding Seminar Nasional Ergonomi* **2** 160-165
[7] Nagamachi M 1995 *International Journal of Industrial Ergonomics* **15** 371-377
[8] Kai Y and Basem S E 2009 *Design for Six Sigma A Roadmap for Product Development Theory of Inventive Problem Solving (TRIZ)* (United States: The McGraw Hill Companies) 282