Macroergonomics Conceptual Assessment of a Local SME in Banda Aceh using Causal Loop Diagram (CLD) and System Archetype: a Case Study in Banda Aceh

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Abstract. Macroergonomics is a sociotechnical approach that sees the relationship between one element and another in optimizing a work system. MP is one of Small Medium Enterprise (SME) that produces perfume in Banda Aceh, it often experiences work system problems such as uncomfortable physical environment, small workstation, tentative work schedule and a work demand, broken machine and lack of skilled human. In order to reduce the problems found in this SME, macroergonomics approach is implemented to improve the work system by selecting important elements based on macroergonomics factor and elements. The result consists of 15 elements are the most influential element and analyzed to find the relationship of one variable to another by using system thinking or the Causal Loop Diagram (CLD). The result are success to the successful and fix that fail system archetype were obtained from the final CLD and interview. The result shows that, SME must spent macroergonomics investment by giving a training to the employees therefore they can understand and capable in manufacturing technology and tools, and decrease the number of evaluation, from twice a day becomes once a day and once a week for meeting.

Keywords: SME, CLD, Macroergonomics, Systems thinking, System archetype

1. Introduction

The limitation of technology and skilled human resources is the main problem facing SMEs when it comes to the production process. MP is one of SME produced Aceh's fragrance product which is expected to become the locomotive of national perfume. MP has been distributed throughout Indonesia, now it can be enjoyed by residents from Sabang to Marauke. This perfume is also often being a souvenir for foreign tourists who visit Aceh. MP is located in Lam Ara, Banda Raya, Banda Aceh. It hires many local manpower especially in Banda Aceh.

MP often faced production problems such as the work system. This SME has broken machine, and it makes the production system must be postponed, the physical environment of this SME is not comfortable for example a small workstation, tentative workschedule and such as the poor production processes such the number of production target never be reached by this SME, and the physical environment of this SME is not comfortable for example a small workstation, tentative workschedule, work demand, lack of skilled human. Macroergonomics is the appropriate approach to solve the MPs'
problem by considering its five factors; person, organisation, technology and tools, task and environment.

The problems also caused by the design of the system that is less effective, therefore there is an absence of a harmonious system. According to Kleiner [1] macroergonomics is a work system design that focuses on the interaction of organizations and systems, and it is a sociotechnical approach from the top down to create harmonious work system design through five factors and its 25 elements [2]. By using macroergonomics approach, there has been a emphasis on ergonomics in terms of achieving large scale organizational improvement. Macroergonomics can change an organization's culture and can achieve 60% to 90% performance improvements [1,3].

Macroergonomics is often used in a health sector to identify about work system design in a hospital [4-7] it also decreases the risk by involving managerial staff, workers or organization to attain a new system design which will be more effective [3,8-9]. The goal of macroergonomics is achieved through a general approach to design which consider interrelated subsystem [1,10].

The problem that is interconnected with other variables that can be said as a systemic problem. Therefore this problem is necessary to be solved by using system thinking. The system thinking is a tool to enhance a complex problem from various perspectives, to understand connectedness and interactions [11].

System thinking is used to see the behaviour of the variable in a complex system, shows the link one to another variables, understand the system and its structure [12]. This study integrates macroergonomics and system thinking to find and predict a future trend of variables. Based on the explanation of the problems that occurred in MP, using macroergonomics approach and Causal Loop Diagram (CLD) and System Archetype is the appropriate to solve the problem.

2. Research Methodology
The process of selecting primary data is done using in-depth interview (IDI) to collect the main variables and Focus Group Discussion (FGD) to verified the conceptual model, the interview result will eliminate unimportant element. The table 1 will show macroergonomics factor and its elements. All of these elements will be asked to the respondent in the interview process. The secondary data will be number of production from April 2015 to April 2018, then the CLD is developed through three steps, namely preliminary CLD, Working CLD and Final CLD.

The final CLD will be analyzed and based on the field observation and also based on the information obtained from the interview. in FGD the researcher also gives the respondents several graph about behaviour over time for each system archetype, the respondents are asked to choose one the element performance through the graph for the elements which do not have any data, but for the elements which have the data, the researcher find the behaviour over time through its data that will show particular system archetype pattern. Then, the prescriptive action is made by stakeholders, based on the future trends that has been explained.

3. Macroergonomics Factor and Element
The interview with seven people in MP was completed. The System Engineering Initiative for Patient Safety (SEIPS) model helps to capture themes indicated the important factors in the work system. The interview is able to show how the problem can be solved through barriers, physical work design and personnel issues. These next five factors describes its elements in detail then the relationship were identified in each factor with verbatim employee comments example and research interpretation.

3.1 Person
There are four elements in person factor and employees mention. Three among them are important, and they believe motivation and need is not important element that affect work system performance.
3.2 Organisations
There are eight elements in organisation factor, employees consider three among them are not important such as coordination, collaboration and communication, social relationship and supervisor and management style.

3.3 Technology and Tool
Among three elements in technology and tools factor based on the interview, the employees claims information and technology is not important.

3.4 Task
Based on the interview with employees among six elements in task factor, they consider the only two elements are important. There are task variety and work demand.

3.5 Physical Environment
The employees believe among five elements in physical, distribution only an element that considered as not important element.

The finding in table 1 shows that the organisational culture was the most statements during the interview. The employees believe that the organisational culture is the most important element in manufacturing process to complete their work.

Table 1: Macroergonomics Element Selection.

| No | Factor                  | Element                              | Total Statement |
|----|-------------------------|--------------------------------------|-----------------|
| 1  | Person                  | Education, Knowledge and Skill       | 7               |
|    |                         | Physical Characteristics             | 4               |
|    |                         | Psychological Characteristics        | 7               |
|    |                         | Motivation and Need                  | 0               |
|    |                         | Teamwork                             | 16              |
|    |                         | Coordination, Collaboration, Communication | 0       |
|    |                         | Organisational culture               | 17              |
|    |                         | Culture                              | 0               |
|    |                         | Work Schedule                        | 6               |
|    |                         | Social Relationship                  | 0               |
|    |                         | Supervisor and Management Style      | 0               |
|    |                         | Evaluation and Rules                 | 11              |
|    |                         | Information and Technology           | 0               |
| 2  | Organisation            | Manufacturing technology and Tools    | 14              |
|    |                         | Human Resource Characteristics in Technology and Tools | 5       |
| 3  | Technologies and Tools  | Task Variety                         | 3               |
Job Content 0
Challenge and use of skills 0
Autonomy, Job Control and Participation 0
Work Demand 4
Distribution 0
Noise 10
Lighting 7
Temperature, Humidity and Air Quality 5
Workstation and Layout 10

This results are consistent with the studies that found the organisational culture is the key of the system running well, and this is in line with the studies that show the significant relationship between organizational culture and employees’ innovation. In this SMEs, the employees stated that they felt comfort because their organizational culture, namely Trust Care Love (TCL) and they felt home when they are working in the office. This SME is quite different; they implement the culture of the Islamic too. All of employees are obliged to go to mosque performing Jemaah. The teamwork element is the second highest rank in the interview. The employees acknowledge the teamwork makes them feel respected thereby increasing the job satisfaction. The manufacturing technology and tool element is the third highest rank in the macrorergonomics elements. The employees realize that the manufacturing technology is really matter for the manufacturing system now due to make their activity easier, but the advance technology will spend so much cost and need a serious investment, and if the demand remain stable the employee will need the advanced manufacturing technology to help them in manufacturing process because there are several machines that often broken and it makes the employee works semi manually. The lowest rank in the 25 elements is the task variety elements because they believe that they still can cover all of the manufacturing system even one person hold two responsibilities. It does not really matter for them as long as they can manage their time as well as possible. To sum up this discussion, every factor do not have difference significantly employees agree that all of these five factors are affected the manufacturing system, therefore these 15 elemets chosen become the main key variables to build an preliminary CLD.

Table 2 shows the main key variables of the Causal Loop Diagram, this variables are obtained from through the interview based on table 1. The variables which is considered as unimportant element has been eliminated. The main key variables consists of 15 macroergonomics elements and two additional elements.
Table 2. The Main Key Variables.

| No | Key Variables                                         | CLD variable         |
|----|-------------------------------------------------------|----------------------|
| 1  | Education, Knowledge and Skill                        | EKK                  |
| 2  | Physical Characteristics                              | Physical Characteristics |
| 3  | Psychological Characteristics                         | Psychological Characteristics |
| 4  | Teamwork                                              | Teamwork             |
| 5  | Organisational Culture                               | Organisational Culture |
| 6  | Work Schedule                                         | Work Schedule        |
| 7  | Evaluation and Rules                                  | Evaluation and Rules |
| 8  | Manufacturing Technology and Tools                    | Manufacturing technology and tool |
| 9  | Human Resource Characteristics in Technology and Tools | HRCT                 |
| 10 | Task Variety                                          | Task Variety         |
| 11 | Work Demand                                           | Work Demand          |
| 12 | Noise                                                 | Noise                |
| 13 | Lighting                                              | Lighting             |
| 14 | Temperature, Humidity and Air Quality                 | THAQ                 |
| 15 | Workstation and Layout                                | WL                   |
| 16 | Sales                                                  | Sales                |
| 17 | Production                                            | Production           |

4. Result and Discussion

4.1 Causal Loop Diagram (CLD)

The preliminary CLD based on the SEIPS model without the intervention of researcher’s logic and FGD. The preliminary CLD shown in figure 1 has been used for examining different component of work system. It has five key components or five variables, namely macroergonomic factor. This preliminary CLD was adopted from pharmacy work system. All of variables has been connected each other. It contains nine reinforcing loop (R) and there is no balancing loop in this preliminary CLD or no loop that encounter the system. The model is also used to see the how the interrelationship between structural variables to influence the work system process as the outcomes of the work system. The preliminary CLD will be a basic information to build an working CLD. This working CLD is built based on MP case, researchers’ logic and field observation without any intervention by stakeholders.
Figure 1. Preliminary CLD

Figure 2 is the working CLD which is built based on MP case, researchers’ logic and field observation without any intervention by stakeholders. Many variables are added in the CLD such as task, teamwork, HRCT, production, sales and evaluation and rules. This working CLD contains two feedback loops, namely two reinforcing loops, both of these loops is affecting the work system.

Figure 2. Working CLD

Figure 3 shows the final CLD which is built from Focus Group Discussion (FGD) with the manager of SME as an expert is shown in figure. There are three feedback loops, they are R1, R2, and R3.
4.2 System Archetype

The most obvious system archetype seen in the conceptual model is success to the success to the successful and fix that fail. These system archetypes are obtained from final CLD by seeing the dominant loop generally and based on the historical data that construct the graph. Figure 4 is an archetype which presents the improvements in R1 group is given more resources than another group namely manufacturing technology and tools loop or R2, that can make teamwork performance continues to improve and manufacturing technology and tools loop will erode. In the case of SME MP, to increase the number of production there are two ways, namely improving the teamwork or improving manufacturing technology and tools or do this both with the same effort. Below is the explanation about both of loops:

R1. When the production is getting higher, the variety of task will increase too, and the work demand of employees also increase, it needs a good teamwork which require a good psychological characteristics of the employees and can increase the production again.

R2. When the production is getting increase, this SME keep buying the manufacturing technology, but do not have any kind of human resource in technology and tool (HRCT), therefore the production is going to erode.
In this case, the teamwork loop is given more effort to spent the personal bonding between employees are getting higher day by day. Meanwhile, the manufacturing technology and tools need more effort to support production. In the field study, there are five machines in the SME but, the operator is not there and the machine does not work anymore. Therefore, it can decrease the number of production too. Hence, the success to the successful archetype can be represented by behaviour over time.

Figure 5 is the Behaviour Over Time (BOT) of Success to The Successful archetype. This archetype can be identified through its trended data, by looking for diverging variables are examined. As a group that has been given more effort, the success improves even more. In the other hand, other partys’ performance will continued to erode. The second archetype appears in the CLD is fix that fail.
Figure 6 shows the second archetype, namely fix that fail. This archetype consists of two loops which is balancing loop and reinforcing loop. Below is an explanation about each loop:

R1. This archetype shows the condition where the SME is very busy to improve the organisational culture performance by improving the teamwork of the employees as the short term solution that SME expected will increase the organisational culture performance.

R2. Teamwork is the short time solution and also can be a cause toward the unintended consequences. However, the teamwork will increase the number of rules and evaluation. The meeting will be often than usual and it spends more employees’ time to attend the meeting and absolutely it increase the work schedule which can make employees feel bored. Meanwhile the meeting keep facing the same problems every day and it will reduce the employees’ satisfaction to work which can cause the uncomfortable feeling toward the employees and at the end can decrease the organisational culture performance.

The organisational performance data obtained through the FGD by giving behaviour over time of 10 system archetype and the employees choose the fix that fail archetype which similar to their organisational culture performance can be seen in figure 6. The unintended consequence is a work schedule that makes employees do not satisfied with their job and can impact the production due to many evaluations that has been made by the SME. The employees will feel tired and their performance in work will be decreased. The trend of organization as the quick fix solution, at the first place it can increase the performance, but over time it continue to decrease and almost reach the unintended consequences.

![Figure 6. Fix that Fail Archetype](image)

4.3 Prescriptive Action

4.3.1 Success to the Successful. First, the measurement or the result of this study shows that the improvement in organisational culture continually do not set up to favor the SME’s performance or work system. The SME need to stop taking a look about the organizational culture, because it has been being a custom of the SME and the members will apply it unconsciously.

The SMEs’ goal is to improve their work system through the production. This can be achieved if this SME spent macroergonomics investment to the manufacturing technology and tool. This SME should give a training toward their employee and at the end can be able to fix and understand the manufacturing
machine, to prevent the same problems recur over time such as after the machine is brought to the SME, the SME cannot use it to support their production.

Then, investigate the initial condition of the manufacturing technology and tool. Later, evaluate the current measurement of manufacturing technology whether or not the technology or organizational cultures really support the work system. After that, ask the outsiders or the expert for the alternative strategy. The next step is assess the effects of the new alternatives after hiring the human resource characteristics in technology and tool. Last but not least, keep scanning the gaps and areas for the continuous improvement.

4.3.2 Fix that Fail. The second archetype is about the management of this system archetype is must focusing on the fundamental cause and identifying a problem symptom. Here is the explanation about the prescriptive action of the fix that fail archetype.

This SME aims to improve their organizational culture through the teamwork as the quick-fix solution that results so many evaluations and rules to prevent the employees becoming bored. This SME should decrease their meeting for evaluation. Second, the evaluation of this SME is in every morning and also, when the work had been finished, this SME have a special meeting for every week to talk about their problems and it tends to discuss the same problems. Last, SME should decrease the number of evaluation or remove the evaluation after they work everyday and the problems faced today by employees can be evaluated in the every morning.

In this study, we have applied the system thinking to have an understanding about feedback structures influencing the production system in one of local SME in Banda Aceh. This is can be an alternative to production management that attempts to find a weaknesses of traditional forecasting methods, that assume tomorrow’s world will be much like today.

5. Conclusion
There are 15 macroergonomics elements from 25 elements that has been chosen in this research, the most important macroergonomics element that has been assessed through the SEIPS model are the organisational culture, teamwork and manufacturing technology and tools element. The CLD is developed based on the SEIPS model as preliminary CLD obtained 10 reinforcing loop and the working CLD obtained two reinforcing loop and in the final CLD there are three loops namely manufacturing technology and tools, organisational culture and sales, all of loops are reinforcing loop.

The system archetype has highlighted success to the successful archetype and fix that fail. The archetype presents the situation which can decrease the performance of work system. The action step is the manager need to spent macroergonomics investment, to give a graining toward the employees. Therefore, the SME can have an employee who has capability in manufacturing technology and tool, and also the SME should decrease the number of evaluation from twice a day to once a day and once a week for meeting. Research is needed to have better understanding about the prescriptive action as the solution. Hence, develop a dynamic model and scenarios simulation will obtain a better result.

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