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Conceptual design of semi-automatic wheelbarrow to overcome ergonomics problems among palm oil plantation workers

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Abstract. An ergonomics problem is one of the main issues faced by palm oil plantation workers especially during harvesting and collecting of fresh fruit bunches (FFB). Intensive manual handling and labor activities involved have been associated with high prevalence of musculoskeletal disorders (MSDs) among palm oil plantation workers. New and safe technology on machines and equipment in palm oil plantation are very important in order to help workers reduce risks and injuries while working. The aim of this research is to improve the design of a wheelbarrow, which is suitable for workers and a small size oil palm plantation. The wheelbarrow design was drawn using CATIA ergonomic features. The characteristic of ergonomics assessment is performed by comparing the existing design of wheelbarrow. Conceptual design was developed based on the problems that have been reported by workers. From the analysis of the problem, finally have resulting concept design the ergonomic quality of semi-automatic wheelbarrow with safe and suitable used for palm oil plantation workers.

1. Introduction

Malaysia has a rapid economic growth and able to meet global demand of palm oil products [1-3]. This is an important industry and has emerged as a major agricultural activity in Malaysia [3, 4]. However, since 2006 palm oil production in Malaysia had showed a decline compared to previous years, which has brought down Malaysia to become world second top producer of palm oil after Indonesia [1]. There were many problems that need to be resolved immediately in order to increase the productivity and profit. Among the influential factors are majority of plantation workers are still using manual tools, workplace environment, and worker's abilities in using high technological equipment, interrelation human-machine problems and management programs [5, 6]. This is because, traditional methods to collect palm oil fruits are still been widely practiced in palm oil plantations. This approach



is no longer efficient, wasting time and the source of work related musculoskeletal disorders (WMSDs) problems to the workers. Therefore, to stay competitive in global market, the palm oil industry needs to improve the productivity of fresh fruit bunches (FFB) through technological improvement and innovation of harvesting and handling equipment [6, 7]. For example, uses of mechanized harvesting equipment and material handling device that can help workers work safely, efficiently and smoothly.

Up till now, there are various harvesting and collecting machines have been developed either by researchers, industrial or agriculture machine manufacturers such as; tractor-mounted grabber, CantasTM, pruner and harvester machinery [6, 8, 9]. However, not all these new technologies were implemented successfully. Presently, the new technology and machineries are still facing low level acceptance and limited application of harvesting technology in palm oil industry [5, 10]. The low acceptance or rejection was due to several factors such as; machine tool vibration effects on the body, the machine is too large, difficult to use, unskilled workers due to lack of training [11]. Thus, the workers still preferred to use manual handling compared to new existing harvesting technologies. This finding is in line with the study result by Abdullah & Samah [12] which focused on factors impinging farmers' to use new agriculture technology.

2. Manual tools in palm oil plantation

In the long run, the continued use of manual tools will negatively affect the health of workers. Manual plantation workers need to perform many movements and lifting heavy loads every day. Table 1 shows the daily work activities by a palm oil plantation worker. Starting with harvesting, workers will cut FFB by using a chisel for shorter and a sickle for taller palm oils trees. Having done that, FFB collector will pick up the detached FFBs on the ground by using either a hook or metal pole to pierce and load them onto a wheelbarrow. When the wheelbarrow is full, the FFB collector will push it to the roadside along the main truck route and unload it at a collection point. Later, trucks will stop at each collection point along the main route to load all the FFBs to be sent to the palm oil mill.

Table 1. Daily activity of palm oil workers.

Activities in palm oil plantation	Description of the activities
Harvesting	Harvesters performed the FFB harvesting activity using a chisel or sickle; cutting the ripe palm oil fruit.
Collecting and Loading	Collector and loader using a skewer of sharp metal to load the FFB in a wheelbarrow. The loader then pushes the fully loaded cart with FFB to the nearest collection station.
Time of pruning jobs (every evening or weekend)	Pruning (cutting the palm oil frond at the base of the trunk), Gather, wedding and spraying using herbicides.

From the table 1, the manual plantation workers are exposed to ergonomics problems during performing job tasks in the palm oil plantation that include manual handling of FFBs, repetitive upper extremity motions and awkward postures. The palm oil industry shows many employees are reported to be at risk for work-related musculoskeletal disorders (WMSDs) [7]. Among the workers in palm oil plantations, collectors and loaders have a high risk of experiencing MSD pain. This is because, palm oil workers had to bend their body to pick the FFBs on the ground and put them in the wheelbarrow. Workers need to use a lot of energy to lift heavy FFBs and push fully loaded wheelbarrow from one tree to another tree. This finding is supported previous study by Nawi et al. [13] which had identified risks of working postures in the palm oil plantation based on REBA (Rapid Entire Body Assessment) developed by Hignett and McAtamney [14]. From the results, it is clear that the risk of experiencing MSDs is high for FFB collectors and loaders. The purpose of this study is to design an ergonomically

wheelbarrow, which is intended to be used by palm oil workers. Therefore, this study is focused on palm oil collectors and loaders, which discussed on development of the semi-automated wheelbarrow specially dedicated for palm oil workers.

3. Issues of manual wheelbarrow

Wheelbarrow or wheel loaders are working machines used to lighten the load to carry in many different fields and situations. The use of manual wheelbarrow gives advantages, in terms of the cheap price and low maintenance costs. However, it results in many shortcomings, particularly to the palm oil plantation workers. Based on analysis of the observations and the results of preliminary study by [13], several key issues have been identified. Among the issues that arise from the use of manual wheelbarrow is:

Among the issues that arise from the use of manual wheelbarrow are as follows:

- a) Its size is too small and cannot be used to carry FFBs in large quantities. It can only carry for 5 to 6 bunches of FFBs weighing 10-20 kg each at a time, which is not efficient to be used especially for large plantations. Workers had to work repeatedly. It takes a long time and may reduce the number of FFBs daily collections.
- b) As shown in figure 1, workers have to manually push the fully load wheelbarrow with FFBs through the hilly and bushy undergrowth by using a lot of effort. The workers had to do it repeatedly for many times every day, from collected area to its deposition area.

This situation shows that the collectors and loaders are exposed to the risk of having musculoskeletal injury due to their high work demands. Due to the small size of wheelbarrow, large-sized FFBs always fall off the wheelbarrow. Workers had to repeat the work of collecting the fallen fruit and push it back the on the cart. This practice will increase the risk of accidents in the workplace. Therefore, the safety of the collectors and loaders is also an important issue here. A lot of time is wasted in collecting back the fallen FFBs and eventually decreasing the overall productivity.



Figure 1. Palm oil workers pushing manually of fully loaded wheelbarrow.

4. Methodology

Challenges faced by collectors and loaders in these situations have been identified and new approaches to solve the problems need to be considered. To overcome these problems, mechanize equipment has been suggested as solutions to improve productivity and make it easier during performing the work tasks compared to being performed manually [6, 15]. It could be achieved through the introduction of efficient and economical mechanical technology with an ergonomic interface. There are many existing machineries and tools, which have been developed, but they are too expensive to buy and high maintenance costs. It is not efficient to small-scale palm oil plantation owner. Besides, large and heavy machines have not suitable for use at palm oil plantations which have hilly landscape.

Several steps are carried out to create improvement designs on existing wheelbarrow. The steps were; analysing current problems, identify product attributes and impact of the equipment to be designed on workers performance. It was performed by conducting observation at palm oil plantation,

interviewing palm oil workers and analyses on the existing design. Several aspects need to be taken in account to ensure the newly designed machine or tool can be easily utilized and commercialized to market. Therefore, the required innovation should have the ergonomics characteristics, such as: good human and machine interface with work environment as shown in figure 2. The main features of semi-automatic wheelbarrow to be developed for the improvement of traditional wheelbarrow are: lower cost that can be afforded not only for large plantation owner but also for small holders, easy to use without the need for a lot of training, can be used even without requiring a lot of energy, easy to access into the hillside, no or low vibration to avoid the long term health effects, easy to take care and maintenance.

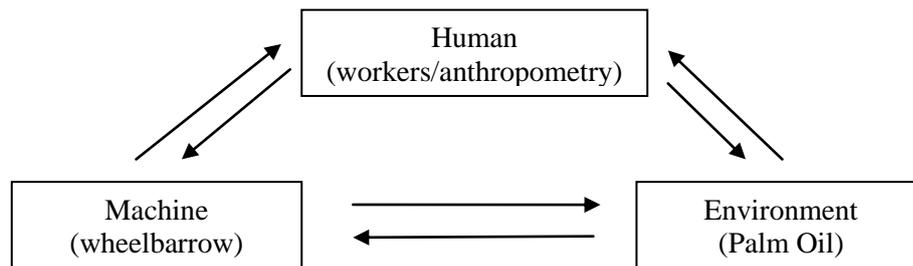


Figure 2. Interrelation of ergonomics relationship.

Finally, the product criteria specification were determined. There are multiple criteria which need to consider in designing new model of wheelbarrow. These criteria cover technical, ergonomic, environment and economical consideration. Table 2 shows the evaluation criteria and parameter of product design.

Table 2. Evaluation criteria and parameter of product design.

Evaluation Criteria	Parameter
Function	Overall geometry, capacity
Safety	Operational, human, environmental
Quality	Quality assurance, quality control, reliability
Manufacturing	Production and purchase of components
Timing	Schedule in designing, development and production
Economic	Cost in resources, designing and manufacturing
Ergonomic	User needs, ergonomic design
Ecological	Environment impact, sustainability, material selection
Aesthetic	Customer (workers) appeal, future expectation
Life-Cycle	Operation, Maintenance, Disposal
Legal/Ethical	Regulation, ethics, intellectual property

5. Result and discussion

New design and innovation of the semi-automatic wheelbarrow is very important to overcome the inadequacy of the traditional manual wheelbarrow. From the data collected and previous researches, the authors have proposed a conceptual design of a semi-automatic wheelbarrow as shown in figure 3. Critical analyses were done to satisfy palm oil plantation owners, small holders and workers. This semi-automatic wheelbarrow was chosen based on the following factors: lower costs, affordable by small holder of palm oil plantation; it require little training for workers; low maintenance cost to the owners; and easy to control in the hilly plantation environment.

In designing a product, ergonomic aspects such as working posture, energy, conditions of environment, safety and usability need to be taken into account. These features were emphasized in the design of this semi-automatic wheelbarrow. A few improvements have been made on the design of semi-automatic wheelbarrow. Among new design innovations that have been done are: using a power motor to reduce the burden of manual worker pushing the wheelbarrow; increase the number of wheels from two to three to get a better balance; increase the size or storage capacity to avoid the collected FFBs fall to the ground and cart that can be opened at the front to facilitate palm oil plantation workers placing and lifting the FFBs.

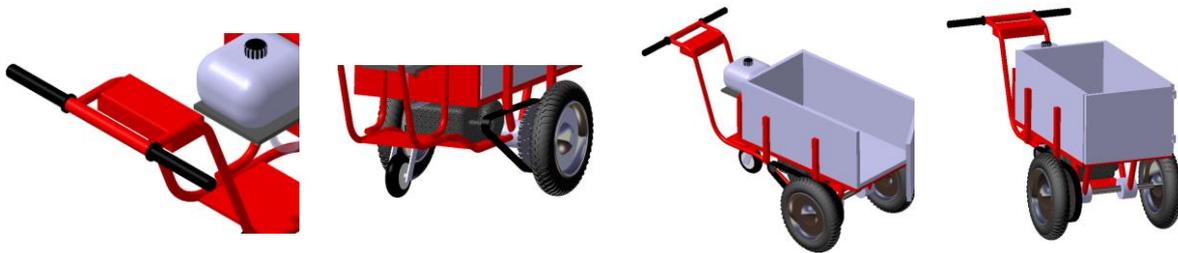


Figure 3. Conceptual design of a semi-automatic wheelbarrow.

There were several significant differences between the traditional manual wheelbarrow and the new design of a semi-automatic wheelbarrow, such as: wheelbarrow wheels, power motor, hand grip, cart size, maintainability, improve safety and lower cost. A comparison between manual and semi-automatic wheelbarrow is shown in table 3.

Table 3. Comparison between manual and semi-automatic wheelbarrow.

Characteristics	Manual Wheelbarrow	Semi-automatic wheelbarrow	Differences
Cart size	Small	Medium	The cart size or load area of semi-automatic wheelbarrow is larger than the traditional wheelbarrow. Therefore, workers will have no problems of loading the FFBs and it would not fall off to the ground.
Hand grip	Normal hand grip	Rubbery elastic hand grip	Semi-automatic wheelbarrow also has a firmer, longer and rubbery elastic hand grip, which can reduce hand pain.
Maintainability	Low maintenance cost	Low maintenance cost	Semi-automatic wheelbarrow using low cost materials and spare parts are easily available.
Safety	High risk of injury	Low risk injury	Semi-automatic wheelbarrow will eliminate the need to lift and push which is present in manual wheelbarrow.
Cost	Cheap	Affordable cost	Semi-automatic wheelbarrow is still considered at affordable costs to palm oil small holders.

Power motor	No power motor	Small power motor	Addition of small power motors on handcarts of semi-automatic wheelbarrow. The power motors will help workers to reduce burden from using a lot of energy while pushing a fully loaded wheelbarrow.
Wheels	1 medium size wheel	2 medium size and 1 small size of wheels	Semi-automatic wheelbarrow adding more wheels from one commonly used to three wheels. Additional wheels will strengthen the equilibrium of the carts and can be handled more easily even to accommodate heavy loads of FFBS.
Environment	Not suitable for hilly landscape	Suitable for hilly landscape	Semi-automatic wheelbarrow is easy to use in the hilly plantation because does not require a lot of energy to push a fully loaded of wheelbarrow.

The innovation of semi-automatic wheelbarrow for palm oil collectors was designed to solve their current problems. The palm oil collectors and loaders can get many benefits such as lighten the load and reduce the risk of injury to workers from the use of this semi-automatic wheelbarrow. The two most significant improvements are in the use of power motor and two extra wheels to stabilize the semi-automatic wheelbarrow as shown in figure 4. The heavy manual task is taken over by the power motor, which powers the semi-automatic wheelbarrow. Palm oil collectors and loaders only need to hold and steer the semi-automatic wheelbarrow. This situation will help the palm oil collectors and loaders to reduce energy consumption by eliminating the need to push heavy load and thus shall reduce work related muscular skeletal disorders (WMSDs) risks and injuries. Furthermore, this new semi-automatic wheelbarrow could help collectors and loaders to collect more FFBS from one tree to the next tree more efficiently and subsequently it will increase work productivity. The manufacturing process is also very practical because it does not require expensive machines or materials that are difficult to obtain.



(a)



(b)

Figure 4. Design of semi-automatic wheelbarrow (a) before and (b) after.

6. Conclusion

Technology and innovation appears to provide more benefits to users. Improved technology and operation will exhibit higher productivity for Malaysian palm oil production. However, technology alone will not succeed without the support of other factors such as financial and knowledge capability, human-technology relationship, training and others. Thus, the innovation of the proposed design semi-

automatic wheelbarrow considers ergonomic relationship between the human, machines and the environment. Compared with manual wheelbarrow, this new design is much better and provides many benefits to palm oil plantation workers. Application of ergonomic relationship in the design of semi-automatic wheelbarrow will help collectors and loaders in palm oil industry in providing the following positive impacts, such as: increasing productivity, reducing energy and workload, low maintenance cost and reducing risk of collectors and loaders' injury. Palm oil industry should pay more attention to the principles and application of ergonomics rules on occupational safety and health of manual workers.

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