

COMPARATIVE ANALYSIS OF OIL PALM IN-FIELD COLLECTION SYSTEMS

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ABSTRACT

The purpose of this study is to determine the most efficient system for the evacuation of oil palm fresh fruit bunches (FFB) from the oil palm tree to the mill. The study employed a quantitative method by utilising primary data, gathered by randomly selecting 500 oil palm estates in Malaysia. A descriptive analysis was conducted to identify the most used system for the in-field collections. The efficiency of each system was then measured by dividing the total output of each system by its respective operating costs involved. The study found that most oil palm plantations in Malaysia are using the conventional way of evacuating oil palms to the mill (termed as System 1). However, System 1 was found to be inefficient because it requires a higher cost of operation to produce the same amount of FFB. The study found that System 2, in which the FFB was immediately transferred to the collection bin after being removed from the oil palm tree and sent directly to the palm oil mill, is the most effective. System 2 has the highest ratio of production compared to the other systems under consideration, producing 0.0213 t of FFB on average per month for every Malaysian Ringgit (MYR) spent.

Keywords: bin system, efficiency, evacuation, productivity, oil palm.

Received: 1 August 2022; **Accepted:** 28 August 2023; **Published online:** 11 September 2023.

INTRODUCTION

The palm oil industry has contributed significantly to the Malaysian economy total export revenue for palm products in 2022 amounted to RM137.89 billion (Parveez *et al.*, 2023). This had positioned the palm oil sector as the largest contributor to Malaysia's export earnings besides electrical and electronic, petroleum and chemical products. The significant role of the palm oil industry is not limited to the country, but also to the global vegetable oils market. In 2022, Malaysia was the world's second-largest palm oil producer after Indonesia, representing 23.3% of the total global palm oil production of 79.2 million tonnes (MPOB, 2023). Being the world's second-largest producer of palm oil, continuous production of palm oil is crucial in ensuring adequate supply of palm oil to the world. Hence the country needs to ensure that factors affecting production are well-observed and

managed. In economic theory, factors of production are divided into four categories namely land, labour, capital and entrepreneurship. This study focuses on labour and capital as the main factors of production for Malaysian palm oil. As the palm oil industry continues to expand, there is a corresponding rise in the demand for labour within this sector. However, as oil palm plantation sector requires high physical labour, the demand for labour is hardly able to be covered by local sources which ultimately forced employers to hire foreign labour to fill this gap. In 2022, a total of 381 713 people were reported to be involved in the oil palm plantation sector in Malaysia (MPOB, 2023) in which more than 70% of the total workers were foreigners (MPOB, 2021). The high percentage of foreign workers causes the industry to be vulnerable. Any changes in policies related to foreign worker recruitment would significantly affect the labour supply in the oil palm plantation sector and disrupt the production of fresh fruit bunches (FFB), hence reducing crude palm oil (CPO) production.

The main country from which foreign workers are recruited for Malaysian oil palm plantations is Indonesia. As the oil palm plantation sector in

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Indonesia grows rapidly, the demand for labour in that sector becomes higher. This prompted Indonesia to offer a better wage rate to retain its people inside the country. Therefore, the potential for Indonesian workers to migrate to Malaysia to fulfil a career in the oil palm plantation sector is declining, hence affecting the production of Malaysian palm oil. The scarcity of labour, especially in agricultural settings, has detrimental effects on the process of harvesting and collecting FFB, resulting in millions of dollars in losses for the oil palm plantation business (Reuters, 2021). Thus, plantation owners are urged to invest in mechanisation and automation to minimise losses and improve the profitability of the companies.

In aiming to reduce the reliance on manual labour, especially foreign workers and ensure optimal levels of production, mechanisation and automation are crucial factors. However, unlike other agricultural areas, the oil palm estates' terrain has become one of the reasons hindering mechanisation and automation. Due to the topography reason, particularly on the hilly and undulating terrain, manual labour is almost preferable to machines. A good work system equipped with machines needs to be adopted to assure the best possible production of FFB, as the problem of a workforce shortage is becoming more acute. Besides reducing the dependency on manual labour, the adoption of mechanisation also helps to retain a good quality of crude palm oil as the FFB should be transported to the mill within 24 hr after harvesting (Sharif *et al.*, 2017). Conventionally, after being harvested, FFB and the loose fruit were loaded into the wheelbarrow and were transported either to the roadside or to the platform for collection. From the platform, FFB were loaded manually into a lorry and ready to be sent to the mill. These conventional methods of manual handling require huge manpower and consequently increase the cost of wages (Awaludin *et al.*, 2015). The conventional loading process also causes damage to the fruits and lowers their quality. Apart from that, the chances of having more uncollected loose fruits are also higher by using this conventional work system. The lack of efficiency within the work process may result in the company's failure to attain maximum profit. Putranti *et al.* (2013) explained that the work of picking loose fruit is the most tiring activity as it takes the longest time in the FFB harvesting process. It was empirically reported that scattered fruit bunches account for up to 14% of the total fruit harvested in Papua New Guinea and about 60%-70% of scattered fruit bunches are left to rot on the ground contributing to huge losses for the palm oil industry (Adetan *et al.*, 2007)

Along with technological advancement, several machines were introduced to ease the fruit collection process. Over the years these machines and the technologies have been upgraded and enhanced to handle the challenges encountered during the

process. These machineries help to smooth the work process of collecting FFB from the oil palm tree to the collection point.

In maximising the performance of the work system, the process of transferring FFB to the mainline transportation has also been enhanced. Instead of leaving FFBs by the roadside or on the platform, the FFBs are directly transferred into the collection bin. Once the collection bin reaches its maximum capacity, a lorry equipped with a hook-on mechanism will attach to the bin and transport it directly to the mill (Shuib *et al.*, 2010). Despite the effectiveness of this integrated system in collecting and evacuating FFB in the estates, the costs of purchasing and maintaining the machines will always be the major cause that limits the uptake of such technologies. The cost issue may not be a major problem for established plantations, but it plays a very important role for small and mid-size plantation companies in considering the best system that can maximise their productivity. Productivity can be measured simply as the ratio of outputs to the inputs used in production. It could be measured either as land productivity, labour productivity or total factor productivity. The interest of this study was to examine the productivity of the system which focuses on how much the system can generate the output for every Malaysian Ringgit (MYR) spent to operate the system.

Various systems have been applied by the plantation for the evacuation of FFB from the oil palm trees to the palm oil mill. The three most common systems utilised for this purpose are; (1) the platform, (2) the collection bin, or (3) the combination of platform and the collection bin. Hence, a comparative analysis of the various in-field FFB collection systems, which also include the usage of the bin was conducted to determine the most efficient system that would maximise the productivity and profitability of the plantations. This study aims to identify the most extensively utilised in-field collection systems in Malaysian oil palm plantations and assess their efficiency to improve the overall process in terms of effectiveness, efficiency and sustainability in the production of Malaysian palm oil. The study's findings were expected to offer parameters for selecting the most appropriate in-field collection.

Mechanisation in Oil Palm Plantation

In discussing the work system for in-field FFB collection, it is essential to address the advancements in mechanisation and automation that have been implemented in the harvesting and evacuation process of FFB. The advancements in oil palm plantation mechanisation and automation have improved over the years to overcome the issue brought up due to the labour-intensive collection

process. However, mechanisation and automation should not be seen as a substitute but as a method of increasing productivity in the same number of workers (Shuib *et al.*, 2010). The advancement in mechanisation includes developing machinery and equipment suited to local topographical conditions. The appropriate option of machines depends on various factors such as the area, the topography, management preferences and economic returns. Shuib *et al.* (2010) discussed the development of machines used in the harvesting and FFB evacuation process to the mills. The study explored various mechanisation tools such as motorised cutters for short palms, mechanical harvesters for tall palms, mechanical grabbers, compact transporters, battery-powered wheelbarrows, three-four-eight-wheeler power carts and loose fruit collectors. The functionality and productivity of each machine were discussed as new inventions were introduced throughout the times. Additionally, a new six-wheel drive with a four-wheel steering transporter was designed to increase FFB evacuation accessibility, efficiency and cost (Shuib *et al.*, 2020). Compared to the mini-tractor trailer, the usage of this machine led to cost savings of RM1.03/t. The usage of FFB collector-transporter designed by the Department of Biological and Agricultural Engineering, University Putra Malaysia was also found to reduce the cost of collection and transportation by 16.6%/t FFB collected against that of mini tractor trailer with grabber (Ali and Yahya, 2001).

Aside cost factor, the type of terrain also influences the usage of machinery in the in-field FFB collection process by the plantation players (Awaludin *et al.*, 2015). Despite being well-received, the usage of the mini-tractor-trailer system for example limited to flat to slight undulating terrain. On top of that, the soil conditions also affect the effectiveness of the machines. Most of the prototypes recorded poor traction on the soft ground such as coastal and peat areas (Shuib and Hitam, 2003). These limitations combined with the cost factors need to be considered for the decision making. Apart from these abovementioned factors, the element of sustainability also plays an important role in determining the types of machines or mechanisation systems for the plantation. The integration between clean solar energy and electric vehicles in farm mechanisation operations was advantageous to the people, planet, and profit. It was found that this integration could reduce carbon dioxide emissions by up to 8 kg/ha/yr from the total diesel consumption (Azwan *et al.*, 2017). Apart from the automation, Lim *et al.* (2021) proposed a harvesting and evacuation route optimisation model that minimises travelling routes while maximising output collection for different plantation sites. The model is also beneficial for small and medium enterprise farmers

as the model can propose multiple trip solutions for the transporter with low loading capacity. Overall, the proposed model improved the efficiency of harvesting and evacuation of the FFB with the potentiality of better time and human resource management. On the other hand, another study developed a modified towable backhoe for the FFB collection process with the aim of time-saving (Sarip *et al.*, 2020). The innovative hydraulic grabber with its technical specifications of agriculture towable backhoes was designed to assist the smallholders of oil palm in speeding up the collection process.

All the above-mentioned technologies help in improving the productivity of the plantation. The Organisation for Economic Co-operation and Development (OECD) in its manual on measuring productivity interpreted productivity as a ratio of a volume measure of output to a volume measure of input use (OECD, 2001). In this study, the indicators for the inputs were the combination of labour and capital. All inputs were converted into monetary units, which, in turn, allowed for the aggregation of a variety of them into a common measure. The conversion of input into common measure is important to prove that inputs can be combined optimally to allocate scarce resources and allow firms to maximise profits subject to a cost constraint resulting in an optimal input allocation (FAO, 2017). In estimating the productivity of the system, the study considered all relevant inputs in operating the system and defined it as operational productivity. This definition is in line with the concept of productivity discussed by the Food and Agriculture Organization (FAO) of the United Nations which measures the amount produced by a target group given a set of resources and inputs (FAO, 2017).

MATERIALS AND METHOD

The study used primary data collected through mail survey which was conducted in 2021 to randomly selected estates all over Malaysia. Before the survey, a series of virtual interviews were conducted with 10 selected estate managers via various online meeting platforms. The interviews were conducted mainly to explore the work process in oil palm plantations and to have a better understanding of the existing work system applied by the plantations and the costs involved within the systems. The interview was conducted within a predetermined thematic framework related to the estates' operational activities and was recorded and transcribed to extract the relevant information such as the workflow, cost structure and challenges. The information was then used to design a set of questionnaires for distribution to the estates under the scope of study. To enhance the validity of the study by limiting the influence

of other variables, the study focused only on estates with the topography of the planted area of more than 50% flat and undulating. The screening of the estates' topography was made based on the data from internal Malaysian Palm Oil Board (MPOB) database namely the eCOST system. In 2020, there were 1494 estates in Malaysia which reported that more than 50% of their area is on flat and undulating terrain. With a margin error of 5%, following the formula from Cochran (1977), the minimum sample size needed for this study is 306 plantations.

The questionnaires were divided into three parts whereby the first part of the questionnaires consisted of the estate profile such as licence number, estate's name, reporting officer's name and position as well as their contact details. These details were important in assisting the researcher to clarify the information given when it was needed. Meanwhile, the second part of the questionnaire was about the current harvesting and in-field collection system in the plantation. Among the questions under this section included the size of the planted and harvested area, the method used for harvesting and FFB collection as well as the number of labourers involved in harvesting and in-field collection works. The third part of the questionnaires was the main highlight of this study. In this part, plantations were presented with three systems of in-field FFB collection, which were identified during the interview conducted before the survey and they were asked to choose which system had been applied in their operation. Plantation owners were required to fill up the relevant information such as the number of harvesting rounds/month, the FFB production/month and the monthly cost involved for the chosen system. This also included the cost of machinery involved in their operation.

The construction of cost-related questions was made based on the virtual interviews with 10 estates for the exploratory study as mentioned earlier. All cost-related data were based on MYR/t of FFB. The questionnaires included the operational cost of harvesting and evacuating FFB from the oil palm tree manually as well as mechanized processes, cost of loading FFB to the collection bin and the cost of transporting FFB to the mill.

The survey was first started with a pilot study with 30 randomly selected plantations nationwide. The questionnaires were enhanced according to the comments received during the pilot study. Then it was sent to 500 plantations nationwide with a topography of their planted area of more than 50% on flat and undulating terrains. The sampling for 500 estates from the 1494 plantations was made randomly regardless of plantation size using the randomiser function provided in Microsoft Excel and the pilot study's respondents were excluded

from the list. The simple random sampling method allows each member of the population to have an equal chance to be chosen as part of the sample. This sampling method helps to remove bias from the selection procedure and should result in representative samples (Gravetter and Forzano, 2011).

For this study, the data obtained were analysed using Statistical Package for Social Science (SPSS) version 20. Descriptive, statistical methods were used to analyse the data as it simplifies the interpretation of the data. Descriptive analysis involves nominal scales such as percentage and frequency used to describe the profile of respondents as well as the estates that were questioned in the first and second parts of the survey. To eliminate outliers, inconsistencies and odd patterns in the data received, a data cleaning process was carried out before the analysis. Results from the study will be more accurate if the data has been standardised validated, and checked for errors and duplicates. The parameters such as mean (the average), median and mode measure the dispersion of the data were ensured to be normally distributed.

Data from the questionnaire was examined in accordance with the three methods for in-field FFB collection to determine how effective the system was.

Figure 1 shows the three systems that were established based on the interviews conducted prior to the development of questionnaires. The primary distinctions between these methods were how the plantation handled its FFB collection from the oil palm trees before it was transferred to the mill. In System 1, FFBs were gathered from beneath each palm and taken to the platform before being sent directly to the mill by mainline transportation. Multiple FFB handling and a significant amount of labour are required by this approach (Awaludin *et al.*, 2015).

For System 2, the FFBs were transferred directly to the collection bin after being evacuated from the oil palm tree and then directly sent to the palm oil mill. Except for the harvesting processes, this system is entirely automated and requires less labour interaction. Meanwhile, System 3 is a combination of System 1 and System 2. The use of this system was necessitated by poor road conditions and prevented the use of machinery for direct FFB evacuation to the bin. With the use of a wheelbarrow, the FFBs were moved from the oil palm tree to a platform, where then moved a bin using machinery with scissor-lift technology.

Based on the workflow, this study predicts that System 2 will be the most effective since it involves less labour participation and eliminates multiple handling of FFB, both of which contribute to an increase in productivity and FFB quality. Most importantly it helps to partly address the low

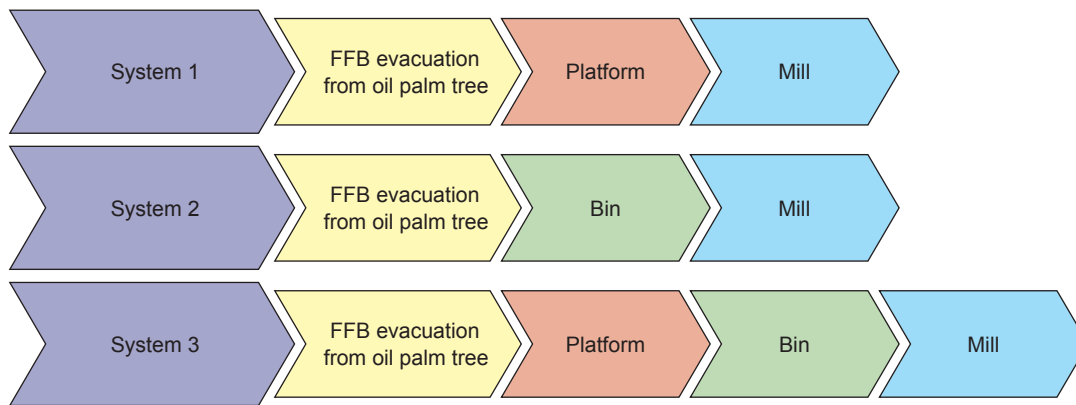


Figure 1. The in-field FFB collection systems in Malaysia.

productivity issue which is caused by the shortage in labour.

The efficiency of the system was inferred based on the productivity of each system. The term efficiency which is measured by productivity, often refers to the distribution of resources, where resources are defined as the cost of transporting FFB to the mill. When a system can produce the same amount of output with fewer inputs, it is said to be efficient (Sumanth, 1994; Tangen, 2005). Efficiency is also described as how much money is spent in relation to the minimum amount that is necessary, in theory, to produce the intended results in a system (Jackson, 2000). For this study, it was assumed that each system has similar working hours. Therefore, the time element was not considered in the computation of the system's productivity. The productivity was calculated based on a formula derived by Al-Darrab (2000) in his study on the relationships between productivity, efficiency, utilisation and quality.

The productivity [Equation (1)] is as follows:

$$\text{Productivity} = \text{Output} / \text{Input} \quad (1)$$

where, output is the number of FFB produced/month (t) and Input is the total costs involved in evacuating FFB/month (MYR).

The costs associated with FFB evacuation include wages paid to harvesters and FFB collectors; costs of fuel and maintenance costs for the machinery used; wages paid to the FFB loaders; and lastly the transportation cost to the mill/km.

In addition to the productivity analysis, the study also considers the financial decision relating to bin ownership. The estimated costs of both buying and leasing the bins were assessed using the net present value (NPV) method (Berlin and Lexa, 2006; Gordon, 1974; Ruegg and Marshall, 1990). NPV is a financial model that calculates the

current value of predicted cash flows in the future. It helps determine the potential profitability of a buy *vs.* lease decision by discounting predicted future cash flows by a certain percentage rate. The analysis allows businesses to make a comparison between the cash flows of an operating lease and buying, thus, helping to make a financially informed decision. The decision either to buy or to lease the bin, cash flow with lower NPV value is advantageous as it reflects the lower cost alternative (Hah and Lee, 1993).

The Equation (2) for NPV calculation is as follows:

$$\text{NPV} = \text{Initial Investment} + \sum \text{CF}_t / (1 + i)^t \quad (2)$$

where, CF is the net cash flow at time, i is the discount rate and t is the time of the cash flow.

RESULTS AND DISCUSSION

Respondent's Profile

The sample size of 500 respondents was calculated from the population of 1494 plantations in Malaysia which have more than 50% flat and undulating terrains. The study is unable to draw a precise conclusion about the system utilised at a state level as a result of the sampling technique used. Considering this, the outcome would merely depict the overall situation of in-field FFB collection in Malaysian oil palm plantations without any further analysis on a state or regional basis. The profile of the respondents by job position is as *Table 1*. It should be highlighted that the estate managers themselves accounted for the majority of responses (60.8%), followed by the administrative officers and the account executives at 21.7%, the company's director at 8.3% and other positions at 9.2%. "Others" refers to the positions such as sustainability officers, cadet planters, mandores and supervisors.

Apart from the job position, it is also crucial for the study to capture the size of the planted area as well as the harvested area of the plantations. Table 2 shows the breakdown of the estates according to their size. According to the table, the respondents' planted area and harvested area distributions do not differ significantly from one another. The survey was dominated by plantations with size of under 500 ha with a percentage of 54.8% for the planted area and 59.6% for the harvested area. Plantations with sizes of between 500-999 ha represented 13.1% and 12.3% of the planted and harvested area respectively. About 26.0% and 25.0% of the plantations were reported with planted and harvested areas of 1000-3000 ha each. Only 6.2% and 3.1% of the plantation were with more than 3000 ha for planted and harvested areas respectively. The total planted area reported by survey participants was around 0.50 million hectares, which represents 8.5% of the 5.87 million hectares of the total planted area reported by MPOB in 2020 (Parveez *et al.*, 2021).

A question on the harvesting method was also included in the survey. Table 3 lists the three harvesting methods that were established in advance for the survey, either manual, a combination of manual and mechanised, or, exclusively mechanised. According to Jelani *et al.* (2008), the terms "manual method" and "mechanised method" relate to the use of chisels and sickles, and machines such as motorised cutters, respectively.

It was found that most of the plantations were using manual methods for the harvesting works with a percentage of 96.9% and another 2.7% were using a combination of manual and machine. Only one plantation was fully mechanised in its harvesting process. It is conceivable that the vibration issue caused by the powered cutter is the cause of the tardy adoption of motorised cutter in the plantations. Despite the shortcomings, the productivity increases from using the powered cutter cannot be disputed. According to the field-testing findings, the motorised cutter was able to harvest between 9.5 and 12.6 t/day, compared to the manual method's productivity of between 4.2 and 6.0 t/day (Jelani *et al.*, 2008). This benefit led to the development of a more suitable motorised cutter design, which addresses the vibration issue and promotes increased use of the device.

Similar to the harvesting process, the respondents were questioned about whether the evacuation process is totally manual, semi-mechanised or fully mechanised (Table 4). The term manual system refers to the use of a mini tractor with or without a grabber, a three or four-wheeler power cart.

It was found that more than 60% of the respondents were using machinery in evacuating FFB from the trees to the collection centre. About 16.0% of the respondents were found to be fully mechanised in the FFB evacuation process, while 53.5% were integrating machinery into the

TABLE 1. NUMBER AND PERCENTAGE OF RESPONDENTS BY JOB POSITION

Job position	Estate manager	Administrative officer/Account executive	Director of the company	Others
Number of Respondents (Percentage)	304 (60.8%)	109 (21.7%)	41 (8.3%)	46 (9.2%)

TABLE 2. RESPONSES BY SIZE OF PLANTED AND HARVESTED AREAS

	Area (ha)			
	< 500	500-999	1000-3000	>3000
Planted (Percentage)	274 (54.8%)	65 (13.1%)	130 (26.0%)	31 (6.2%)
Harvested (Percentage)	298 (59.6%)	62 (12.3%)	125 (25.0%)	15 (3.1%)

TABLE 3. HARVESTING METHOD ADOPTED BY THE RESPONDENTS

Harvesting method	Manual	Semi manual	Fully mechanised
Number of the respondents (Percentage)	485 (96.9%)	14 (2.7%)	1 (0.2%)

TABLE 4. FFB EVACUATION METHOD FROM OIL PALM TREE TO COLLECTION CENTRE APPLIED BY THE RESPONDENTS

Evacuation method	Manual	Semi manual	Fully mechanised
Frequency (Percentage)	153 (30.6%)	267 (53.5%)	80 (16.0%)

conventional work system. Only 30.6% of the respondents were still using the conventional way of evacuating FFB. The controlled variable of only flat and undulating terrain might influence the pattern of the results. According to interviews that were performed as part of exploratory research in the early stages of drafting a questionnaire, the use of machinery in carrying FFB from the oil palm is dependent on the kind of terrain and the readiness of the harvesting path. Proper terracing and detailed preparation of the harvesting path is important to ensure the accessibility of the machines used (Khalid and Shuib, 2014).

The work process of FFB evacuation is not completed without detailing the collection systems used by the estates. The discrepancies between the collection centre for FFB before it was transferred to the mill were the subject of this study's in-field collection systems. Three separate collection mechanisms were used. System 1 refers to the use of a platform only. System 2 to the use of a bin system only, and System 3 is the combination of platform and bin systems.

Table 5 shows that 79.1% of the respondents were using System 1 whereby after the FFB were evacuated from the trees, the FFB was collected at the platform and sent to the mill. This system requires more labour participation and poses a higher risk of damage to the FFB due to the multiple handlings. Only 8.7% of the respondents are using only bin systems in their operation. The bin system which is originally designed for industrial bins and waste helps to facilitate the collection of FFB. The full integration of machinery in the FFB evacuation process from the palm to the collection bin and the mill eliminates multiple handling issues (Radzi *et al.*, 2020) and directly maximises the profit of the plantations. Most importantly, this system helps to reduce the participation of

labour (Nadzar and Sapry, 2020; Radzi *et al.*, 2020) and consequently assist in reducing the loss due to labour shortage. Apart from these two options, 12.2% of the respondents reported that their plantations were using a combination of platform and bin systems. Most of the plantations that opted for this system indicated that they are in the process of implementing full integration system for FFB in-field collection. It is also noted that the use of bin system requires proper planning in terms of the placement to facilitate and minimise the movement of the tractor transporting the FFB. Sufficient space for the tractor is needed to facilitate the work of unloading FFB into the bin. Users of System 3 indicated that they are currently meeting the aforementioned conditions. To temporarily streamline their operations, they are integrating the use of platform and bin systems.

Comparison of the In-Field FFB Collection Systems

In terms of the FFB yield/ha/month, System 1 recorded the highest yield of 1.36 t FFB as against that of 1.22 t and 1.24 t of FFB/ha for System 2 and System 3 respectively. However, comparing over these three systems, the output generated by the system needs to be analysed together with the cost element. The cost factor plays a pivotal role in determining the most efficient system. The questionnaire included questions about many cost factors, including the wage for the labour involved, the operational costs of the machinery employed, the loading cost and the transportation cost. According to the survey, the average harvester's salary was roughly RM35/t of FFB. The cost of the harvesters within the three systems under consideration does not require further examination because the majority of the respondents harvested their FFB manually.

TABLE 5. COLLECTION SYSTEMS APPLIED BY THE RESPONDENTS

Collection system	System 1 (Use of platform only)	System 2 (Use of a bin system only)	System 3 (Combination of a platform and bin system)
Number of respondents (Percentage)	396 (79.1%)	44 (8.7%)	60 (12.2%)

TABLE 6. COST COMPARISON OF THE IN-FIELD FFB COLLECTION SYSTEMS

Cost element	Average cost		
	System 1	System 2	System 3
Operational cost for manual process (RM/t)	50.78	38.50	47.18
Operational cost for machinery used (RM/t)	31.15	42.23	39.46
Loading cost (RM/t)	8.50	5.80	6.70
Transportation cost (RM/t/km)	1.80	0.76	0.77
Overall cost (RM/t)	92.23	87.29	94.11

The operational cost, whether for a manual process or a mechanised process, is another crucial cost component that would significantly alter the situation. The three system's manual processes had an average monthly cost of RM45/t of FFB. On the other hand, the average monthly operational costs for the three systems' mechanised processes were RM37/t of FFB. These expenses cover fuel as well as maintenance and repair charges. The comparison of the operational cost for manual and machinery for each system is summarised in *Table 6* together with other cost elements namely loading costs and transportation costs. The operational cost of machinery was found to be higher in System 2. This is in line with the level of usage of machinery within the respective systems. The use of the collection bin exclusively in System 2 necessitates the automation of all other job operations aside from harvesting, which helps to explain why its operating costs are higher. System 1 recorded the lowest operational cost for equipment. This system refers to the traditional method of evacuating FFB, where the majority of the work was done manually. As a result, the system does not require many machineries at a high cost.

The next important cost that needs to be examined is the loading cost. On the assumption that manual loading operations will decrease, it is known that the FFB evacuation procedure as described in System 2 helps to resolve the multiple handling problem. Given these circumstances, System 2 must have the lowest loading cost when compared to the other two systems. For these three methods, the loading cost on average was about RM7.00/t. Based on the survey, it was found that the loading cost for System 2 was at RM5.80/t FFB, 31.8% and 13.4% lower as compared to the loading cost for System 1 and System 3 respectively. The significant reduction in the cost of loading the FFB throughout the evacuation process in System 2 supports the argument of less labour participation within the said system and consequently helps to maximise the profitability of the plantations.

The other cost element is the transportation cost. This cost refers to the expenses paid for sending the FFB to the mill. The average transportation cost for these three systems was RM1.10/t of FFB/km. There was a significant difference between the transportation cost in System 1 and that of System 2 and System 3. The average transportation cost for System 1 was RM1.80/t, which was two-fold higher than the transportation cost in System 2 and System 3. This might probably due to the differences in the type of transportation used between the systems. Systems 2 and System 3 used bins, which are attached to the lorry using a hook-on device. Meanwhile, System 1 requires the plantation to use a trailer to transport the FFB to the mill. As a result, the rate varies depending on the type of vehicles used. Overall, System 2 was the most affordable system

for evacuating and transporting FFB from the palm to the mill, with System 1 and System 3 coming in second and third. Compared to the operational cost of System 3, System 1 was marginally more affordable (2.0% less expensive).

On the labour involvement, *Table 7* suggests that the land-labour ratio for System 1 was 1:23, which translates into one worker can cover about 23 ha of the planted area. For System 2, the land-labour ratio was 1:30, where one worker can cover about 30 ha of the area and lastly for System 3, the land-labour ratio is 1:29, which means that one worker can cover 29 ha of the area. This finding confirmed that System 2 requires less workers than System 1 and System 3. System 2 was found to reduce labour participation by 23% as against the conventional system (System 1) which has been used by most of the plantations in Malaysia.

Efficiency of the Systems

In examining the efficiency of the pre-specified in-field FFB collection systems, the productivity of each system was calculated based on the formula described in the methodology section whereby the monthly FFB production is divided by the total cost involved in evacuating FFB from the trees to the mill per month. Based on the formula, the highest productivity was recorded by System 2 with the productivity FFB of 0.0213 t/RM which is equivalent to 21.32 kg/RM. The second most efficient system was awarded to System 1 with FFB productivity of 0.0179 t/RM (17.89 kg/RM) and the least efficient system was System 3 with FFB productivity of 0.0163 t/RM (16.32 kg/RM).

Based on the findings summarised in *Table 8*, it is also possible to conclude that System 2 could produce an average of 0.0213 t of FFB/month for every MYR used to remove FFB from the oil palm, System 3 was found to be the least efficient due to the multiple handling element which could also harm the FFB, preventing plantations from selling it for the highest possible price. Additionally, repeated handling could hinder plantations from maximising their revenue by preventing the collection of loose fruits from being maximised. Meanwhile, System 1 can generate 0.0719 t of FFB and it is lower compared to the productivity of System 2. The multiple handling element in System 1 makes the system less efficient compared to that of System 2.

Buying vs. Leasing Decision for the Bin

Based on the results tabulated in *Table 6-8*, the study revealed that System 2 was found to be the most efficient system for the in-field FFB collection system in terms of the utilisation of inputs to evacuate oil palm to the oil palm mill. However, it should be noted that the element of capital

TABLE 7. LAND-LABOUR RATIO BY SYSTEMS

	System 1	System 2	System 3
Land-Labour ratio (Planted area to one worker)	23:1	30:1	29:1

TABLE 8. AVERAGE PRODUCTIVITY OF THE SYSTEMS

	System 1	System 2	System 3
Average productivity (t/RM)	0.0179	0.0213	0.0163

expenditure is not included in the determination of the most efficient system. In the survey, the respondents were also asked about the details of the collection bin which include the number of bins, the capacity, the price per unit and the ownership of the bin. Out of the 44 respondents who opted for System 2, 47.6% of them bought the bins and 52.4% contracted (leased) it out with the mainline transporter. The differences in the ownership of the bin have financial implications for the plantation as it requires huge capital investment. The results of the survey suggested that the average price for a bin with 10 t capacity was about RM16 500/unit and typically the respondents owned an average of 10 units of bins to accommodate their needs. In determining this so-called finance decision, a capital budgeting technique needs to be employed in comparing either buy or lease the bin and the best approach for evaluating this decision is to calculate the NPV of each options.

Leasing is a contractual arrangement whereby the owner (lessor) grants the lessee the right to use the asset in return for a periodic payment. Under the lease contract, the ownership of the asset remains with the lessor, but the use of the assets is available to the lessee. The lessee has to pay the agreed rental amount to the lessor periodically according to the agreement made between both parties. In the case of System 2, the bins were leased from the mainline transporter and the rental amount was included in the transportation cost to the mill. This can be seen from the differences in the transportation costs reported by the respondents in the survey. The average transportation cost of FFB (t/km) of the plantations that owned the bin was about RM0.65, lower by 27.8% as compared to that of RM0.90 for the plantations that leased the bin with the transporter.

From the above discussion, it was noted that under System 2, most of the plantations had on average 10 bins for their operation and the average price per unit of bins was RM16 500. Hence, the total cost to acquire 10 units of bins was RM165 000. To ease the calculation of the NPV, the lifespan of the bin was assumed to be 5 yr and the maintenance cost of the bin was estimated at RM100/month on average. Meanwhile, if the

plantation leased the bin, the lease rental was assumed to be RM0.25/t. This was derived from the differences in the transportation cost between the plantations who owned the bin and leased the bin (RM0.90-RM0.65). *Table 9* further explains the details of the costs involved in the calculation of the NPV. In considering either buying or leasing the bins, the necessary information under System 2 was extracted to generate the NPV for each options. The calculation of NPV was only to the information under System 2 as it was found to be the most efficient system. In addition, as the cash flows were calculated on the cash outflow basis which is the expenses of the plantations, the lower number of NPV was favourable.

Based on the above information, the NPV of purchasing 10 bins was about RM28 540 and the NPV of leasing the bins was about RM11 470. Since leasing had a lower net present value of cash outflows, it was advisable for the plantation to lease the bin.

CONCLUSION

The main objectives of the study were to identify the most widely used in-field collection systems in Malaysian oil palm plantations, examine the efficiency of each system and focus on the most efficient ones. In achieving these objectives, the primary data collection with the selected plantations licensed by MPOB was conducted. The plantations were selected randomly based on the criterion of the terrain types as mentioned in the methodology section. The data collection was carried out using interviews and the distribution of questionnaires through email to gather the relevant productivity data. According to the above-mentioned results and discussion, the questionnaires were filled out primarily by estate managers, which is consistent with the survey's intention to capture as much as responses from the estate managers as operational activities were controlled by them. From the survey, it was found that the most widely used in-field FFB collection system is System 1 where the FFB were collected from beneath the oil palm trees and were brought to the platform for collection

TABLE 9. DETAILED EXPENSES AND ASSUMPTIONS BETWEEN BUYING AND LEASING

	Buy	Lease	Note (if any)
Capital expenditure for 10 bins	RM165 000	-	Based on the average price per unit of bin reported by the respondents under System 2.
Maintenance cost/yr	RM1 200	-	There is not much cost needed to maintain the bin except applying grease to prevent rust and corrosion.
Average FFB production/yr	10 800	10 800	The average FFB production reported by plantations under System 2.
Lease rental/yr	-	RM2 700	Derived based on the differences in transportation cost between the lessee and the owner of the bin which amounted to RM0.25/t in System 2.
Depreciation/yr	RM33 000	-	Straight-line method using 5 yr useful life.
Discount rate	7.5% / yr	-	Based on the profit rate quoted by SME Bank for small business financing (SME Bank, 2021)
Term	5 yr	5 yr	-
Tax rate/yr	24%	24%	-
NPV (RM)	28 540	11 470	In the buying versus leasing decision, the NPVs of the financing cash flows for both options are calculated and compared and the lowest cost option should be selected.

and then directly sent to the mill by the mainline transportation. Based on the findings of this study, this system is still the most preferred even if it has certain disadvantages including the requirement of high labour participation and multiple handlings of FFB. However, due to these drawbacks, this system was found to be inefficient as compared to System 2. The use of bins in System 2 was able to increase the FFB production at the minimal cost of operation. Despite the advantage of the collection bin, the study did not suggest the usage of bin be combined with the use of a platform. This is because the combination of these two methods was found to increase the monthly operational cost as compared to that of System 1 and System 2. In addition to the foregoing, the study recommended that plantations lease the bins rather than buy them because it was determined to be more cost-effective. The study's conclusions gave the plantations some direction as they plan their operational business strategy. It is also significant to note that the study's findings were restricted to only plantations with flat and undulating terrains because plantations with other types of terrain are likely to have different cost structures.

The study would like to suggest that plantations that have more than 50% of their terrain in flat or undulating areas move forward with the integrated work system as described in System 2 of the study. This recommendation is based on the results and discussion as the aforementioned. The productivity is anticipated to rise with the proposed system. The method also reduces the number of times FFB is handled improving the calibre of the FFB gathered and ultimately enhancing the company's profitability. The fact that the full integration of the bin system into the work process was found

to lessen reliance on manual labour and partially minimise the losses resulting from the labour shortage issue.

ACKNOWLEDGEMENT

The authors would like to acknowledge the assistance of other research officers of Techno-Economics Research Unit for the insight and expertise that greatly helped in the completion of this project. In addition, the authors would also like to thank all staff of the Techno-Economics Research Unit for their assistance and commitment throughout the whole process of this study.

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