Research Article

Determinants of Durian Post-Harvest Practices Adoption: A Smart PLS Approach

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Abstract | Durian is a commercially valuable fruit with a short shelf life and high susceptibility to deterioration if not handled properly after harvest. Therefore, good post-harvest is vital to maintain the quality of durian. Unfortunately, farmers' adoption of post-harvest practices (PHP) remains low. Agricultural extension services significantly influence farmers' decisions, but studies on their impact on PHP are ambiguous. This study aims to determine the factors affecting the adoption of PHP among durian farmers in Peninsular Malaysia. The combination of the Unified Theory of Acceptance and Use of Technology (UTAUT), the Knowledge-Attitude-Practice (KAP) Model, and extension services are utilised to address some of the contradictions in the literature regarding PHP adoption. Through multi-stage sampling techniques, 400 durian farmers in Peninsular Malaysia were selected for sampling and population. Smart-PLS was employed to analyse and answer the research objectives. The findings of this study indicates that agricultural extension services (β=0.109; t=1.901; p=0.029), attitude (β =0.271; t=4.781; p=0.000), knowledge (β =0.181; t=4.897; p=0.000), facilitating conditions (β=0.115; t=1.073; p=0.044), and effort expectancy (β =0.166; t=2.741; p=0.003) significantly influence post-harvest adoption. In contrast, social influence (β =0.036; t=0.681; p=0.248), and performance expectancy (β=0.048; t=0.771; p=0.220) were found to be insignificant. Special attention should be paid to other factors influencing PHP adoption to support new literature on technology adoption theories or models in future studies. This study is also significant in meeting the National Agrofood Policy 2.0 (2021-2030), drafted by the government to enhance food security and improve international trade.

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Introduction

Malaysia is a tropical country that is very favourable in producing durian. The Department of Agriculture (DOA, 2022) has reported that durian is the most popular fruit in Malaysia, with a higher planting area (85,366 ha) and production (459,747 mt) compared to the other fruits. Durian is native to Southeast Asia, has grown commercially, and contributes to the Malaysian economy with a value of RM 7.49 billion yearly production. Durian exports from Malaysia have shown a growing trend in increasing demand (Chua *et al*., 2023). Thus, the durian industry has synchronized with the National Agro-Food Policy 2.0 (2021-2030) (MAFI, 2021), which requires Malaysia to build up fruit production and meet the export volume to ensure food security. Unfortunately, durian crops have a short post-harvest life at ambient temperatures. Thus, they face problems exporting to distant markets (Ketsa *et al*., 2020). After harvest, durian fruit continues to transform from being physiologically mature, and issues of dehiscence are very common for durians (Jantan *et al*., 2024). With improper post-harvest handling during peak hours, durian will deteriorate between 20-25 % (Tan *et al*., 2020). In order to guarantee that harvested produce reaches the consumer at the highest possible quality, appropriate post-harvest processing procedures and technology are highly required (Elik *et al*., 2019). Therefore, it is critical to conduct studies on post-harvest management techniques to increase durian quality and shelf life. Although maintaining and extending the shelf life of harvested fruits requires adopting post-harvest measures, post-harvest technology, and handling procedures are still not widely used (Underhill *et al*., 2020). Inconsistent with Mutungi *et al*. (2023), farmers have poorly adopted the selected post-harvest technologies. Supported by previous studies, adopting agricultural technology or practices is still poor (Dhraief *et al*., 2018; Biru *et al*., 2020).

Essentially, there are a few theoretical models that can be used to explain the technology adoption, such as The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh *et al*., 2003) and Knowledge-Attitude-Practice (KAP) (Schwartz, 1976). The UTAUT model offers a comprehensive insight into technology adoption as it has been developed from eight primary adoption models such as the Theory of Reasoned Action (TRA), Motivational Model, Theory of Planned Behaviour (TPB), Technology Acceptance Model (TAM), Model of PC Utilization (MPCU), Innovation Diffusion Theory, Social Cognitive Theory and Combined TAM and TPB (Venkatesh *et al*., 2003; Chang, 2012). KAP model is generally used to explain agriculture practice adoption (Chuang *et al*., 2020; Chepchirchir *et al*., 2021), such as post-harvest practices (PHP) adoption (Khatun and Rahman, 2019). Nevertheless, adopting the employment KAP model on-farm practices is still ambiguous (Kambey *et al*., 2021).

Performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC) are the primary constructs of UTAUT that significantly contribute to practice adoption. Abu *et al*. (2020) found PE significant for PHP adoption. Supported by the previous study, PE positively impacts farmers behaviour in agricultural technology adoption (Nejadrezaei *et al*., 2018; Xie *et al*., 2022). EE has also positively impacted behaviour (Rahi *et al*., 2019; Xie *et al*., 2022). Previous studies have also proven that other constructs of UTAUT, like SI (Termezai *et al*., 2017; Wang *et al*., 2023) and FC (Kattel *et al*., 2020), also have a positive and significant effect on agriculture technology and practices adoption. Studies on constructs of the KAP model, such as attitude and knowledge, are essential in determining the farmers' decision to use agriculture technology or practices like post-harvest. Attitude is vital in the evaluation of a specific behaviour (Almutairi *et al*., 2020), while knowledge is essential to strengthen farmers' skills and improve their farm productivity (Williams, 2018; Mashi *et al*., 2022) because knowledge is the foundation for farmers to adopt technology (Khurshid *et al*., 2022). Besides, enhanced knowledge and a favourable attitude toward PHP, significant reductions in losses can be achieved, and improve the economic outcomes of farming (Anitha *et al*., 2019). Empirical studies have found that attitude (Zeweld *et al*., 2017; Chuang *et al*., 2020) and knowledge (Rahman *et al*., 2018; Almutairi *et al*., 2020) have a positive correlation between adoption in agriculture practice among farmers. Additionally, agricultural extension services (ES) are essential for the dissemination of agricultural innovations to farmers (Altalb *et al*., 2015; Yusuf *et al*., 2024) and can influence the decisions used by farmers (Dhraief *et al*., 2018; Xu *et al*., 2023). ES are platforms for gaining the appropriate information that influences technology adoption (Abbasi and Nawab, 2021). Unfortunately, studies on ES in agricultural practices and adoption are still limited (Antwi-Agyei and Stringer, 2021; Tamsah and Yusriadi, 2022). In promoting better durian PHP adoption, this study focuses on identifying the relationship between ES, EE, PE, SI, FC, attitude, and knowledge with PHP adoption among durian farmers in Peninsular Malaysia.

Materials and Methods

Research design and sample

The study employed a quantitative research design to collect data from the respondents. Moreover, through cluster and simple random sampling, 400 durian farmers in Pahang, Johor, Perak, and Kelantan were chosen as the population, which are among the states in Peninsular Malaysia that have the highest concentration of durian producers (DOA, 2022). In order to get the data for the study, administrative questionnaires and structured interviews were employed as data collection methods. The ten sections also comprise the instruments used: Post-harvest profile, demographic profile, dependent variables (PHP adoption), and independent factors (ES, EE, PE, SI, FC, attitude, and knowledge). Likert Scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used to measure all items except knowledge, which ranges from 1(do not know) to 5 (quite know).

Research framework and data analysis

To better understand PHP adoption, UTAUT (Venkatesh *et al*., 2003) and KAP (Schwartz, 1976) models were adapted to identify the relationship between factors of EE, PE, SI, FC, attitude, knowledge, and ES as a new construct with PHP adoption among durian farmers in Peninsular Malaysia. The information gathered underwent analysis with smart-PLS, which specifically targets the correlation coefficient.

Results and Discussion

Demographic and post-harvest practices profile

Based on the demographic profile (Table 1), Most durian farmers in Peninsular Malaysia are between 51 and 60 (33.75%), followed by the age between 41-50 years old (25.75%), 61-70 years old (17.25%), 31-40 years old (15.5%), 20-30 years old (4.25%), and 71-80 years old (3.5%). Based on the findings, most durian farmers are middle-aged (40 until 60) which are farmers that actively participate in farming (Al-Amin *et al*., 2020). Besides, most durian farmers are male (93.1%), while only 6.8% are female because males are effortlessly accessing the workforce industry rather than females (Chen *et al*., 2019). Surprisingly, only 1.0% of the durian farmers in the research area do not have a formal education, and 6% study until primary school. However, most have a formal education, with 48.25% of respondents completing their secondary and advanced education (44.75%). The farmers in the study area can be categorized as experienced farmers because they are active farmers with more than ten years of experience. Based on this study, 64.7% of farmers have more than ten years of farming experience, while only

Table 1: *Information on demographic profile.*

Variables	Character	Frequency	Percent	Mean
Age	20-30 Years old	17	4.25	51
	31-40 Years old	62	15.5	
	41-50 Years old	103	25.75	
	51-60 Years old	135	33.75	
	61-70 Years old	69	17.25	
	71-80 Years old	14	3.5	
Gender	Male	373	93.25	
	Female	27	6.75	
Education level	Never attend school	4	1.0	
	Primary school	24	6.0	
	Secondary school	193	48.25	
	Vocational/Technical	18	4.5	
	Higher education	161	40.25	
Farming experience	Less than 10 years	141	35.25	
	11 to 20 years	138	34.5	
	21 to 30 years	56	14.0	
	31 to 40 years	44	11.0	
	41 to 50 years	14	3.5	
	More than 50 years	7	1.75	
Level of post harvest practices adoption	Semi	393	98.25	
	Full	7	1.75	
Types of post-harvest practices adoption	None	11	2.75	
	Cleaning	393	98.25	
	Sorting and grading	393	98.25	
	Treatment	2	0.5	
	Packaging	393	98.25	
	Storage	7	1.75	
	Transportation	378	94.5	
Post-harvest losses	None	21	5.25	16.26
	1-10 %	151	37.75	
	11-20%	139	34.75	
	More than 20%	89	22.25	
Post-harvest practices assistance	None	335	69.0	
	Post-harvest facilities	27	5.5	
	Post-harvest equipment and materials	52	11.0	
	Post-harvest practice training, and manuals	71	15.0	
	Finance	4	0.8	

35.3% have less than ten years of experience. Most respondents have only adopted semi-PHP (98.25%), while others have only 1.75% of full practices. Similar to the findings of the PHP adoption level, 98.25% of respondents were involved with cleaning, sorting, grading, and packaging activities. Additionally, 94.5.0% were involved with transportation, while only 1.75% were involved with storage activities, and 0.5% were involved with the treatment of durians. Most respondents are not implementing storage and treatment because it is only vital for the export market and during the peak season. Other than that, the data of post-harvest losses for durian in Peninsular Malaysia is also recorded at 16.62% which is below the global post-harvest losses of fruit and vegetables that have been reported between 37 to 55% (Opara *et al*., 2021). It suggests that with better understanding and positive attitude toward PHP (Bagheri *et al*., 2019) among durian farmers in current study can indeed help mitigate post-harvest losses in the durian industry. The study has reported that the higher range of post-harvest losses was 1 to 10% (37.75%), followed by 11 to 20% (34.75%), and more than 20% (22.25%). Surprisingly, 5.25% of farmers declared no post-harvest losses of durian fruit on their farms. Many farmers do not directly contribute to marketing activities, and every day, all harvested fruit is collected by a middleman, a collector, or retailers at their farm. Most respondents have declared that their farm only gets assistance for farm maintenance like fertilizer, herbicide, and fungicide, but specific post-harvest practices (69.0%) are not provided in their area. Nonetheless, respondents still agree that post-harvest practice training (15.0%), equipment and materials like a plastic basket for packaging (11%), post-harvest facilities (5.5%), and finance (0.8%) have been provided by the government.

Assessing a measurement model

The internal consistency of each reflective concept in this study was verified using the construct reliability test. The Cronbach's alpha value and composite reliability (rho_a) of all constructs meet the minimum threshold of 0.7, demonstrating sufficient internal consistency and reliability (Hair *et al*., 2017). Additionally, the current study confirmed convergent validity, with the average variance extracted (AVE) scores ranging from 0.657 to 0.829 (see Table 2), meeting the minimum condition of greater than or equal to 0.500. Based on finding, the study's constructs show high internal consistency and convergent validity, which suggests the measurement model is solid and dependable for further analysis.

Table 2: *Result of reliability and validity of model.*

Construct	No of item	Cronbach's alpha	Composite reliability (rho_a)	Average variance extracted (AVE)
ATT	8	0.965	0.966	0.805
EE	6	0.959	0.960	0.829
ES	8	0.963	0.964	0.796
FC	5	0.875	0.943	0.657
KNOW	6	0.901	0.915	0.669
PE	7	0.964	0.967	0.824
PHA	7	0.919	0.926	0.676
SI	3	0.809	0.845	0.721

PHA= Post-harvest adoption; ES= Extension service; ATT= Attitude; KNOW= Knowledge; FC= Facilitating condition; SI= Social Influence; EE= Effort expectancy; and PE= Perceived expectancy.

The discriminant validity can be evaluated using the Heterotrait-Monorail ratio of correlations (HTMT) and the Fornell-Larcker criterion. According to Fornell and Larcker (1981), the square root average variance extracted (AVE) should exceed the correlation coefficient of each construct in the research model to establish discriminant validity based on the results (Table 2). Additionally, the HTMT ratio result (Table 3) has indicated that no value was higher than 0.85 or 0.90, implying that the model's discriminant validity was acceptable and consistent enough for additional analysis (Henseler *et al*., 2015).

Table 3: *Result of heteotrait ration (HTMT).*

	ATT	EE	ES	FC	KNOW	PE	PHAI	SI
ATT								
EE	0.64							
ES	0.466	0.423						
FC	0.577	0.63	0.518					
KNOW	0.187	0.135	0.171	0.131				
PE	0.672	0.824	0.383	0.583	0.161			
PHA	0.603	0.558	0.441	0.462	0.315	0.539		
SI	0.587	0.587	0.434	0.577	0.21	0.683	0.49	

Note: *PHA=Post-harvest adoption; ES=Extension service; ATT=Attitude; KNOW= Knowledge; FC= Facilitating condition; SI= Social Influence; EE= Effort expectancy; and PE= Perceived expectancy.*

Assessing structural model

The relationship between the ES, FC, SI, PE, EE, knowledge, and attitude with PHP adoption was evaluated using the structural model have been demonstrates in Figure 1 and Table 4. Figure 1 a illustrate the path correlation by assessing using the bootstrapping technique, showing a p-value and the coefficient of determination (R^2), variance of the dependent variable. While Table 4 shows the correlation coefficient findings, validated when the t-values are more than 1.64 or p-values less than 0.05 level (Hair Jr and Hult, 2016; Low *et al.*, 2017). Basically, R2 crucial to determine the quality of the PLS model and to determine the model's predictive accuracy. The current research indicates that the PHP adoption model has a moderate level of predictive accuracy, with R^2 values of 0.433. Hair Jr *et al.* (2014) stated that a prediction accuracy level of 0.75 is deemed substantial, 0.5 is classified as moderate, and 0.25 is considered weak. The moderate level of R^2 suggests that the model has some predictive power, but there is room for improvement. It is not a strong predictor of PHP adoption, but it still provides useful insights into the factors influencing adoption. In future, other factors or variables not included in the current model can be added to explain more of the variance in PHP adoption, indicating potential areas for further research or model refinement. Besides, Figure 1 also demonstrate there is 50 reflective indicators across seven independent variables and a dependent variable that can indeed lead to more precise measures of the latent constructs and, in turn, reliable correlations in this study.

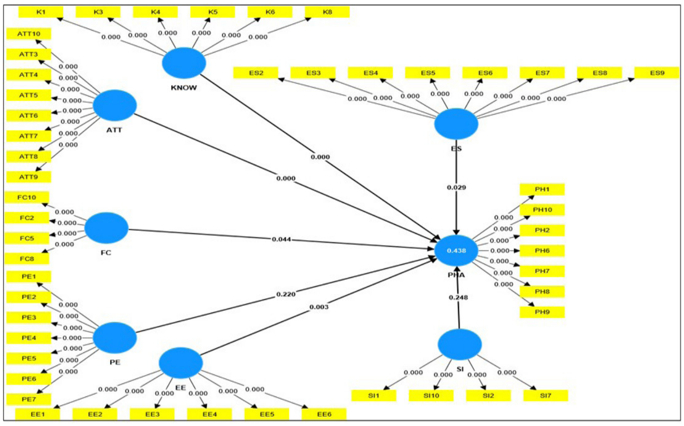

Figure 1: *Result of correlation between factors on post-harvest practices adoption. Note: PHA= Post-harvest adoption; ES= Extension service; ATT= Attitude; KNOW= Knowledge; FC= Facilitating condition; SI= Social Influence; EE= Effort expectancy; and PE= Perceived expectancy.*

Referring to Table 4, the correlation coefficient discovery between ES and the adoption of PHP among durian farmers in Peninsular Malaysia is noteworthy (β=0.109; t=1.901; p=0.029) with weak positive relationship. ES in the study area has proven that it can influence farmers' decision adoption (Dhraief *et al.*, 2018; Adebayo *et al.*, 2022). The role of ES is vital in improving a good agriculture practice (Alzahrani *et al.*, 2023), significantly reducing post-harvest losses (Fatty *et al.*, 2021). ES is important in the adoption of agricultural technology, as indicated by previous research (Wang *et al.*, 2020). The significant positive correlation between ES and PHP adoption among durian farmers in Peninsular Malaysia demonstrates that ES plays a crucial role in influencing farmers' adoption decisions. However, this relationship is not very strong, due to ES in Malaysia more focussing durian field management rather than post-harvest activities. Approved by record list of training provided by the Malaysia Department of Agriculture in 2022, from approximately 63 training sessions specific to durian only eight (8) training sessions are quite related to post-harvest (e.g., product processing and durian technology), and one (1) training specific to post-harvest practices on season fruit in general (DOA, 2023). Basically, ES in Malaysia aware the important of durian industry, but post-harvest practices for durian not being a prioritized because majority farmer are selling their fruit directly or through middleman (Perdana *et al.*, 2016).

Table 4: *Correlation between independent variables and post-harvest adoption.*

Relationship	Std. Beta	SD	t-value	P values	Decision
ES -> PHA	0.109	0.057	1.901	0.029**	Sig.
ATT -> PHA	0.271	0.057	4.781	0.000**	Sig.
KNOW -> PHA	0.181	0.037	4.897	0.000**	Sig.
EE -> PHA	0.166	0.061	2.741	0.003**	Sig.
FC -> PHA	0.115	0.067	1.703	0.044**	Sig.
SI -> PHA	0.036	0.052	0.681	0.248	Insig.
PE -> PHA	0.048	0.062	0.771	0.220	Insig.

Notes: *t-values for one-tailed test: **t-value >1.64 (sig. level 5%). PHA=Post-harvest adoption; ES=Extension service; ATT=Attitude; KNOW= Knowledge; FC= Facilitating condition; SI= Social Influence; EE= Effort expectancy; and PE= Perceived expectancy.*

Additionally, a significant correlation coefficient (β = 0.271; t = 4.781; p = 0.000) between attitude and PHP adoption among durian farmers in Peninsular Malaysia suggests a slightly moderate positive relationship. The majority of durian farmers have positive attitudes towards adopting PHP due to their perceived significance. This suggests that farmers in this study was recognize the importance and benefits of proper PHP, such as reducing losses, improving product quality, and enhancing their profitability. The fact that farmers perceive the significance of PHP leads to a greater willingness to adopt those practices. Consistent with the previous study, this attitude will affect adopting technology and practices (Barua *et al*., 2017; Abu *et al*., 2020). A better understanding of PHP motivates farmers to use post-harvest practices (Bagheri *et al*., 2019; Tama *et al*., 2020).

The previous study declares that knowledge can influence farmers' decisions used (Paul *et al*., 2021; Laksono *et al*., 2022) and have positive correlations with adoption behaviour (Chuang *et al*., 2020). Consistent with the current study, knowledge is correlated with PHP adoption among durian farmers in Peninsular Malaysia (β =0.181; t=4.897; p=0.000) with weak positive relationship. The result suggests that knowledge about PHP does play a role in encouraging adoption, but it is not the only factor. Essentially, durian farmers in Peninsular Malaysia base their knowledge of PHP primarily on their personal experience. However, farmers in current study may need additional support, such as training, financial resources, or awareness campaigns, to encourage them to apply these practices effectively.

Moreover, another current finding found that EE is significant with PHP adoption (β =0.166; t=2.741; p=0.003). Based on the study, most durian farmers in the study area only adopt semi-level PHP because they are easier to carry out. Basically, farmers are more likely to adopt practices that require minimal effort and resources (Adebayo *et al*., 2022) including PHP. Previous study found that simply and low-cost technologies are more likely to be adopted where farmers face significant barriers (Smidt and Jokonya, 2022). Similar to the previous study, EE has a positive relationship with agriculture adoption (Ronaghi and Forouharfar, 2020).

The current study has also found that the correlation value of FC with PHP adoption is significant (β=0.115; t=1.073; p=0.044). Many studies have proven that FC has a significant effect on adopting agricultural technology (Koyu *et al*., 2021; Omar *et al*., 2021). Abu *et al*. (2020) also indicate that FC has a positive significance on PHP adoption. Despite many durian farmers reporting inadequate support in PHP, such as facilities, materials, equipment, training, knowledge, and finances, FC can still influence PHP adoption because farmers might focus on adopting certain aspects of post-harvest practices that are more feasible or offer the most immediate benefits, rather than adopting the full range of practices. Besides that, limited agricultural extension services can even influence adoption by providing crucial knowledge and training that farmers can build upon. The presence of any support, even if deemed inadequate, can still have a positive impact.

The current study also found an insignificant value (β =0.036; t=0.681; p=0.248) between SI and PHP adoption. The study results show that surrounding conditions do not support the decision to use PHP. Most post-harvest facilities are designed primarily for export activities, while simpler PHP methods are applied for domestic use. Additionally, this result implies that PHP adoption tends to be more personal, driven by individual experience, and may necessitate specialized knowledge or tools that are not easily shaped by the surrounding community. Similar to Li *et al*. (2020), SI has no significant effect on the adoption of agricultural technology. This contradicts another study declaring SI significant in agriculture technology adoption (Ronaghi and Forouharfar, 2020; Mzomwe *et al*., 2021).

The current study also indicates an insignificant value for the relationship between PE and adoption of PHP (β=0.048; t=0.771; p=0.220). Using a PHP has offered many benefits to durian farmers, but it does not influence their decision to use PHP. Moreover, despite recognizing the value of PHP, the majority of durian farmers omit practices like treatments and cooling storage to align with market needs. Supported by previous study, durian farmers adjust their PHP to meet market requirements for the sake of market demands and cost-efficiency (Thongkaew *et al*. 2021). Hayat *et al*. (2020) have also agreed that PE is not significant in adopting agricultural technology. However, this is against a study by Abu *et al*. (2020), who found that PE positively correlates with adopting PHP.

Conclusions and Recommendations

The study offers important information about the factors that impact the implementation of durian PHP in Peninsular Malaysia. This research expands on existing knowledge by integrating the UTAUT and KAP models with relevant constructs, providing insights into decision-making about the use of technology and practices in agricultural extension services. As a result, the study of agricultural extension service is reflected as one of the central points of a cohesive body of adoption theory. Henceforward, it is recommended that:

- The government agriculture department should provide better PHP assistance such as facilities, training, and finances to motivate more farmers to adopt the PHP activities.
- Appropriate training tailored to post-harvest methods and technology should also be provided to guarantee that farmers comprehend and are conscious of the significance of adopting PHP measures.
- Future research deliberates many other factors, either internal or external, of theory adoption to improve the comprehension of the use of PHP.

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Novelty Statement

The study's valuable contribution can be highlighted in the extension service as one of the constructs combining the adoption theory to improve the understanding of PHP adoption in Peninsular Malaysia. The study would support the possibility of growing calendula for its petals for medicinal applications and seeds for industrial applications. Moreover, this study also provides the post-harvest profile of durian in the study area, especially on level adoption and post-harvest losses, which are pretty lacking in the current literature.

Author's Contribution

Tengku Halimatun Sa'adiah T Abu Bakar: Contributed to all aspects of the study, including design, data collecting, analysis, and manuscript writing.

Munifah Siti Amira Yusuf: Contributed to the editing the manuscript.

Norsida Man, Nolila Mohd Nawi, and Jasmin Arif Shah: Involved in validating the instrument and research framework and supervising.

Conflict of interest

The authors have declared no conflict of interest.

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