# <u>Applying tThe Fuzzy FMEA tTo Rank Risks in the Monthong Durian</u> <u>Supply Chain Applying the Fuzzy FMEA to rank risks in the Monthong</u> Durian Supply Chain

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### ABSTRACT

Thai raw durians and processed durian products has gained popularity among both domestic and international consumers. The demands of these goods were dramatically increased over the past several years. However, there are risks occurred in the production of raw durians and durian products. In this study, the supply chain of Monthong durian was diagnosed and categorized. It was found that there were 4 main stakeholders in the chain consisted of the supplier, the manufacturer, the distributor, and the retailer. The processes responsible by each stakeholder and risks associated to each process were gathered using the classical FMEA technique. There were total of 64 risks in this supply chain. To relax the limitations of traditional FMEA, fuzzy FMEA technique and FRPNs were used to evaluate the collected data. The risks were finally classified into 3 types as high, intermediate, and low. There were 7 risks identified as high risks. Those concluded "insufficient fresh water", "fluctuated durian price", "storms", "too much rain", "clogged drainage", "pest diseases", and drought.

#### Keywords

Durian, FMEA, fuzzy, reliability, risk analysis

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### Introduction

Durian is one seasonal kind of fruits that has gained popularity among the Asian consumers. The durian plantation areas in Thailand (especially the Monthong cultivar) have been consistently increasing due to large demand domestically and internationally. Durian price has been increasing every year. In the years 2015-2019, the average price of durian had increased 18.83% per year (from 46.96 Baht/kg to 99.86 Baht/kg)<sub>4</sub>

With the support from the Thai Government, MonThong durian has been pushed as one of the successful "value-added" agricultural products in Thailand (Thomya & Taotagoo, 2019). Some well-known durian processed products among Thais and the Asian tourists are such as durian paste, fried durian and durian candies. Due to the potential of the crop, the supply chain of the MonThong durian has been greatly enlarged over the past decades. Not only local farmers are interested in successfully planting durian trees, but many businesspeople have also been interested in investing in MonThong durian plantation. Furthermore, there are those along the supply chain who can earn their livings on Monthong durian related businesses.

However, to start a business related to Monthong durian, there are some risks that should be considered. Many new farmers have failed to plant durian trees perhaps due to the lack of knowledge and the understanding of how to solve problems properly when facing with problems and/or crisis.

For example, in the years 1995 and 2011, the floods damaged almost all durian farms in Nonthaburi (Nonthaburi (Thongdara et al., 2013). In 2020, the COVID-19 virus had prevented

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durian exportation causing the price to drop significantly (National, 2020).

Failure Mode Effect Analysis (FMEA) technique is one of the most widely used methods in identifying risks in a system. For example, FMEA technique was also used in service industry (Geum et al., 2011). Haur et al. (2013) performed FMEA risk analysis of the bird nest production process. Voltarelli et al. (2018) applied the technique to analyze the risks of sugar cane harvesting,

However, there were two drawbacks of using the FMEA technique alone. First, the risk assessment of products or systems based on Risk Priority Number (RPN) values could cause realworld problems Since in real life events, not all factors were equal. Second, the FMEA technique was too dependent on the experience of the experts (Liu & Zhou, 2014). Therefore, FMEA technique has been widely merged with fuzzy techniques to overcome the limitations of the traditional FMEA technique.

-There have been many studies that adopted the fuzzy FMEA techniques. Wessiani and Sarwoko (2015) used the fuzzy FMEA technique to assess the risk of the poultry feed industry. It was found that the traditional FMEA technique identified 89 risks in animal feed production. But when using the fuzzy technique, it was found that there were only 39 risks that should be dealt with. Yin et al. (2019) used fuzzy algorithms to control the speed and degrees of unmanned machinery that was used to grow rice, resulted in an improvement in accuracy and a reduction of errors in the path of rice cultivation that may occur. Moreover, fuzzy FMEA techniques were applied in various applications such as planning risk management evaluating organic rice risks in the supply chain (Rohmah et al., 2015), and evaluating marine supply chain risk (Wan et al., 2019). The used of fuzzy technique FMEA provided reasonable results for arranging these risk prioritythis risk priority.

To our knowledge, there has not been any study that attempt to rank risks of any agriculture commodity crop during the plantation stage. Even as of now, there are still some countries whose economy rely heavily on agricultural commodity crop like Thailand. This research can still potentially provide some useful knowledge or benefits to those under developed and developing countries.

In this research, a fuzzy FMEA technique was used to identify the potential risk in the supply chain process of the Monthong durian. The analysis was made to the entire supply chain of durian related business. The focus was on durian plantation stage.

### Literature Review

-At present, the trend of a healthy and environmentally friendly is becoming more and more popular with consumers and manufacturers. The world was becoming more aware of food, health, and safety, making organic food more popular. In Thailand, one of the most popular organic products was rice. Unfortunately, organic rice has very low productivity compared to normal farming and there are many several risks. Whether it is the characteristics of the species, seasons changing. All of these factors are difficult to control for agricultural products (Paveerat & Thammanoon, 2020). In general, the agro-product industry was already very risky compared to other industries, regardless of the weather. fluctuation of agricultural object prices, and financial uncertainty in investment of this industry. Several studies have been conducted to assess and identify risks in the industry by using FMEA tool (Peyman et al., 2020). The agricultural technology management system has certain role in promoting the development of agriculture (Yu et al., 2020) whether it is a matter of raise agricultural productivity or increase agricultural demand for land (McGowan & Vasilakis, 2019).

A widely used risk management tool in engineering was the Failure Mode and Effect Analysis (FMEA) as it was a technique that could identify and eliminate potential failures in systems (Ahmet & Mehmet, 2012). In addition, FMEA can be applied in a wide variety of industries, such as in agriculture, the FMEA technique was used to prioritize the risks that might affect the cultivation of oyster mushroom (Andriansyah et al., 2019).

The fuzzy FMEA model is the mostpopular approach that assesses the shortcomings

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of RPN. Several fuzzy FMEA techniques have been widely used to overcome the problems of traditional FMEA (Khuankrue et al., 2017). The obvious benefit of the fuzzy FMEA in this study manu

was to take care of imprecise and vague judgement (Srivastava et al., 2018).

### **Methodology**

In this research, the entire supply chain of Monthong durian was established. Stakeholders along the supply chain were interviewed to identify functions and risks of durian-related business starting from the plantation stage based on (Wessiani & Sarwoko, 2015).

Once the risks were identified, the values of Severity (S), Occurrence (O) and Detectability (D) were assessed by stakeholders. Then, the calculation of the fuzzy risk priority numbers was done following (Gan et al., 2011), Stakeholders' weights were assessed and the Fuzzy Risk Priority Number (FRPN) for each risk was calculated. The defuzzified values were calculated using the Mean of Maxima method (MOM) selected out of the three types of the Maxima method including the First of Maxima Method (FOM), the Last of Maxima Method (LOM), and the MOM. The MOM had the advantage of better covering all the data and valuations than the FOM and the LOM (Ozdemir, 2010).

The defuzzified values were calculated by using Maxima method which categorized into 3 types which including first of Maxima Method (FOM), last of Maxima Method (LOM), and mean of Maxima Method (MOM). In this research, the Mean of Maximum technique (MOM) was chosen to be used as tool to <u>analyse</u> the data due to this technique had the advantage of covering all the data and valuations. In contrast of FOM and LOM which covered only low and high value respectively.

### **Results and Discussion**

Supply Chain of Monthong Durian Products

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There were typically four main stakeholders in the supply chain of Monthong durian. Those were consisted of the supplier, the manufacturer, the distributor and the retailer. The roles for each stakeholder were described below: \_\_\_\_\_1. Supplier

In this stage, the most relevant stakeholders were the farmers who grow durian trees. Their responsibility was categorized into 4 main duties consisted of surveying the area to plant the Monthlong durian, planting the durian, caring and maintenance, and harvesting the durian.

—2. Manufacturer

The main function of the manufacturer was to add the value to the durian bought from the supplier by processed them to increase product value. Moreover, products had to be certified by acquiring safety standard in order to be able to export them to foreign countries.

\_\_\_\_\_3. Distributor

In Thailand, the stakeholder who bought durians from the farmers was called "Long". Longs were the middlemen in this supply chain. They made advanced contracts with farmers before harvesting durians to ensure that they had sufficient durian supply for their customers. They were required to pass the safety standard before exporting any good internationally.

4. Retailer

Retailers can range from traditional markets such as flea markets, department stores, and even in the form of durian truck stalls (wandering around and usually stop at any busy street, village, or inside any local market). Most of them received durians from the distributors.

The functions for these stakeholders were listed in Tables 1-4. According to the FMEA technique, risks and their associated potential impacts were also listed for each function as shown in Tables 1-4.

Ratings based on Gan et al. (2011) were assessed by interviewing stakeholders in the supply chain. The stakeholders who got interviewed were the owners of durian farms/manufacturers/distributors/ and smallscaled retailers in Chumphon and Chanthaburiprovinces. Both provinces were ranked the first and the second in terms of durian plantation areas in Thailand,

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Tab	le 1 FMFA a	nalysis of the suppliers (f	armers)	Formatted Table
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Function	Risk Code	Risk	Potential Effect	Formatted
Survey the area to plant the				Formatted
Survey for water supply	R1	Insufficient fresh water	Unable to grow durian until	• Formatted
· · · · ·			harvestable	Formatted
•	R2	Poor water quality or	May cause the durian tree to	Formatted
		toxic water	die or may affect the fruit,	Formatted
			resulting in poor quality	Formatted
			durian	Formatted
Pick the plantation area	R3	The weather for	Burning or falling leaves	Formatted
with suitable weather		planting is too hot	causing the durian tree to	
	5.4	<b>T</b> 1 0	die or grow slowly	Formatted
<b>▲</b>	R4	The weather for	Burning or falling leaves	Formatted
		planting is too cold	causing the durian tree to	Formatted
	R5	Drought in the	die or grow slowly Unable to grow durian until	Formatted
<b>▲</b>	КЭ	plantation area	harvestable	Formatted
	R6	Too much rain in the	Excessive rainfall may	Formatted
<b>A</b>	K0	plantation area	cause waterlogging or	Formatted
		plantation area	flooding, especially when	Formatted
			there is a lack of well-	Formatted
			prepared drainage	Formatted
			management. This will	Formatted
			cause the durian tree to die	Formatted
			or grow slowly.	Formatted
	R7	Storms in the	May cause damage to the	Formatted
		plantation area	durian tree or even kill the	Formatted
		-	tree	Formatted
<b>_</b>	R8	Earthquake in the	May cause damage to the	Formatted
		plantation area	durian tree or even kill the	Formatted
	<b>D</b> .*		tree	Formatted
Pick the plantation area	R9	The soil condition is	Can be toxic to durian tree	Formatted
with suitable soil		too acidic		
conditions	<b>D</b> 10	The soil are litter '	Can be tonic to during the	Formatted
<b>A</b>	R10	The soil condition is too alkaline	Can be toxic to durian tree	Formatted
	R11	There are toxic	The soil lacks nutrients that	Formatted
<b>A</b>	<u>кп</u>	contaminants in the	are not suitable for	Formatted
		soil	cultivation	Formatted
Planting Monthong durian		5011		Formatted
Pick the suitable	R12	Planting in the	Water may not be sufficient	Formatted
plantation period	<b>A</b>	inappropriate season	for cultivation or there may	Formatted
1 I · · · ·		<u>.</u>	be an unfavorable	Formatted
			environment for the growth	Formatted
			of durian tree	Formatted
Prepare the planting of	R13	Weeds are still leftover	Weeds steal for food from	Formatted
durian tree (plow the	_	on the field	the durian tree, causing the	Formatted
plantation area)			durian tree to grow slowly.	Formatted
	R14	No drainage or clogged	May cause waterlogging	Formatted
		drainage	resulting in the roots to rot	Formatted
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Function	Risk Code	Risk	Potential Effect
Specify the planting	R15	The clearance between	Not convenient to use
spot		the trees are too	additional
		narrow	equipment/machines in the
	DIC	<b>T</b> 1 1	area
<b>▲</b>	R16	The clearance between	Too costly/not cost effective
	D 17	the trees are too wide	Manager and the CC since and the second
<b>A</b>	R17	The actual plantation	May not get sufficient water
		does not locate in the	supply and also may cause a
		specified spot	problem to the drainage
	<b>D</b> 10	The sheet sheet sheet is a	system
Choose plantation	R18	The chosen plantation	Waste too much water
method		method is not suitable	
Come and maintanance		for the area	
Care and maintenance	R19	Loging the money days	Losa monay from the fallon
Maintenance before the harvesting period	K19	Losing the money due to the fall of	Lose money from the fallen
(years 1-3)		supplementary crop	price of the supplementary
(years 1-3)		price (crops planting	crop
		on the empty space	
		around the durian	
		plantation area hoping	
		to gain additional	
		income)	
	R20	The existing durian	Lose money re-planting and
<b>▲</b>	<b>R</b> 20	tree dies or gets	repairing the durian,
		diseases	resulting in not being able to
		uiseases	sell during early in the
			market
	R21	Too little water	Can cause the durian tree to
<b>A</b>	AC21	100 Intile Water	grow slowly due to the lack
			of nutrients or the durian
			tree may die
	R22	Too much water	Waterlogging for a long
<b>A</b>			period of time can cause the
			durian roots to rot and may
			cause the durian tree to die
	R23	Improper pruning	Slow down flowering and
A			fruiting processes
	R24	Got insect or pest	Damage the durian tree and
<b>A</b>	•	diseases	also cost more to eradicate
		<b>A</b>	the insects or pests
	R25	Too much sunlight	Can cause the leaves of the
<b>A</b>	<b>_</b>	<u></u>	durian tree to burn
*	R26	Too much fertilizer	Can cause the durian tree to
<b>A</b>			become pale and die and
			cost more to buy chemical
			fertilizer
	R27	Too little fertilizer	Can cause the durian to
<b>▲</b>		<b>^</b>	grow slowly because of the
			lack of nutrients
Care just before getting	R28	Too little water	The leaves of the durian tree

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Function       Risk Code       Risk       Potential Effect         the durian fruit (years 4-5)       R29       Too much water,       May turn the fruit back to the leave,         R30       Too much water,       May turn the fruit back to the leave,       Can cause the durian tree to become pale and die and cost more to buy chemical fertilizer,         R31       Too little fertilizer,       Can cause the durian tree to come out fruiting slowly and the taste of the durian fruit was not good,         R32       Trim too many flowers,       May lose some durian fruits         R33       Trim too much fruit,       May lose some durian fruits         R34       Thin too little fruit,       May lose some durian fruits         R35       Durian fruit was stolen,       Lose profit,         R36       Excessive durian       Durian branches were         weight,       broken causing damage to all durian fruit,       all durian fruits         Harvesting,       Harvesting,       Harvesting,         Harvest durians,       R37       Miscount the age of the durian fruit,       cut os soon resulting in the soil causing damage to all durian fruit,         R38       Accidentally cut unripe,       Unrian       fallen on the ground,       fallen on the ground,         R39       Purian is accidentally       Durian fruit will be       fallen on the ground,	<b>E</b>			
(years 4-5)       not grow out         R29       Too much water       May turn the fruit back to         May turn the fruit back to       the leave         R30       Too much fertilizer,       Can cause the durian tree to         become pale and die and       cost more to buy chemical         fertilizer,       Can cause the durian tree to         cost more to buy chemical       fertilizer,         Can cause the durian tree to       come out fruiting slowly         and the taste of the durian       fruit was not good,         R33       Trim too many flowers,       May lose some durian fruits         R34       Trim too little fruit,       May lose some durian fruits         R35       Durian fruit was stolen       Lose profit,         R36       Excessive durian       Durian branches         Weight       broken causing damage to       all durian fruit,         Harvesting       This causes the durian to be       durian         Kast       Accidentally leave the       sold resulting in the loss of income,         M39       Purian is accidentally Durian       fruit will be       fallen on the ground         Accidentally leave the       Can cause the durian to       durian on the ground       damaged and cannot be sold or can be sold or can be sold or can be sold or can be sold or c	Function the during fruit	Risk Code	Risk	Potential Effect
R29       Too much water, the leave, R30       May turn the fruit back to the leave, Can cause the durian tree to become pale and die and cost more to buy chemical fertilizer, Can cause the durian tree to come out fruiting slowly and the taste of the durian fruits         R31       Too little fertilizer, R33       Can cause the durian tree to come out fruiting slowly and the taste of the durian fruits         R33       Trim too many flowers, R33       May lose some durian fruits         R34       Trim too much fruit, May have too many durian fruits         R35       Durian fruit was stolen, Lose profit, B36       Lose profit, Excessive durian         R35       Durian fruit was stolen, Weight, B4rvesting, Harvesting, Harvesting, Harvesting, Harvesting, R37       Durian fruit, May have too many durian to sold resulting in the poor taste, Units causes the durian to be durian on the ground damaged and cannot be sold or can be sold at a very cheap price, R40         R41       Durian prices are fluctuated, Unitan on the ground after harvesting       May lose money due to the ether tharvesting fluctuated         R41       Durian prices are fluctuated       May lose money due to the fluctuated         R42       Fail to get a certificate       Cannot export products         Department of Agriculture to be able to export durian process of getting the certificate takes too much time Acquire durian fruits from farmers       Lose sales opportunities				-
R30       Too much fertilizer, Can cause the durian tree to become pale and die and cost more to buy chemical fertilizer,         R31       Too little fertilizer, Can cause the durian tree to come out fruiting slowly and the taste of the durian fruits.         R32       Trim too many flowers, R33       May lose some durian fruits.         R33       Trim too much fruit May lose some durian fruits.       May lose some durian fruits.         R34       Trim too much fruit May lose some durian fruits.       May lose some durian fruits.         R35       Durian fruit was stolen.       Lose profit         R36       Excessive durian       Durian branches were weight.       broken causing damage to all durian fruits.         Harvesting       Harvesting       This causes the durian to be       the durian fruit cut too soon resulting in the poor taste.         R38       Accidentally cut urinj       Durian fruit will be       damaged and cannot be oid or can be sold at a very cheap price.         R40       Accidentally leave the fluctuated       May lose money due to the fluctuated       become infected and spoil the durian, on the ground damaged and cannot be sold or can be sold at a very cheap price.         R40       Accidentally leave the fluctuated       May lose money due to the fluctuated         May lose money due to the fluctuated       May lose money due to the fluctuated         R41       Durian processing manufacturer       Cannot expor	(years 4-5)	P20	Too much water	May turn the fruit back to
R30       Too much fertilizer       Can cause the durian tree to become pale and die and cost more to buy chemical fertilizer.         R31       Too little fertilizer       Can cause the durian tree to come out fruiting slowly and the taste of the durian fruit was not good.         R32       Trim too many flowers       May lose some durian fruits         R33       Trim too much fruit       May lose some durian fruits         R33       Trim too much fruit       May lose some durian fruits         R34       Trim too little fruit,       May lose some durian fruits         R35       Durian fruit was stolen       Lose profit         R36       Excessive durian       Durian branches were         weight       bruke durian fruits       all durian fruits         Harvesting       Harvesting       This causes the durian to be         Harvest durians       R37       Miscount the age of       This cause the durian to be         durian       sold resulting in the poor tase.       Unripe durians cannot be       urian         M39       Durian is accidentally cut unripe       Unripe durians.       cause the durian to be         R39       Purian is accidentally       Durian fruit will be       fallen on the ground       damaged and cannot be sold or can be sold at a very cheap price.         R40       Accidentally leave the       Can	Å	R29	100 much water	
R31       Too little fertilizer,       Can cause the durian tree to come out fruiting slowly and the taste of the durian tree to come out fruiting slowly and the taste of the durian fruits.         R32       Trim too many flowers,       May lose some durian fruits.         R33       Trim too many flowers,       May lose some durian fruits.         R34       Trim too little fruit,       May lose some durian fruits.         R34       Trim too little fruit,       May lose some durian fruits.         R35       Durian fruit was stolen,       Lose profit.         R36       Excessive durian       Durian branches were         weight,       broken causing damage to all durian fruits.         Harvesting       Harvesting       This causes the durian to be durian, sold resulting in the poor taste.         R38       Accidentally cut unrip       Unrine branches were income.         Marvest durians       R37       Miscount the age of the durian cause the durian to be durian more.         R39       Durian is accidentally cut unrip       Unrip durians cannot be sold or can be sold at a very cheap price.         R40       Accidentally leave the durian, to the durian, to the durian, to the durian on the ground damage and cannot be sold or can be sold at a very cheap price.         R41       Durian processing manufacturer         Process       Risk Code       Risk       Potential Effect		P30	Too much fortilizor	· · · · · · · · · · · · · · · · · · ·
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Agriculture to be able to export durian products R43 The process of getting the Lose sales opportunities certificate takes too much time Acquire durian fruits from farmers		R42	Fail to get a certificate	Cannot export products
export durian products R43 The process of getting the Lose sales opportunities certificate takes too much time Acquire durian fruits from farmers				
R43 The process of getting the Lose sales opportunities certificate takes too much time Acquire durian fruits from farmers				
certificate takes too much time Acquire durian fruits from farmers	export durian products			
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		Acquire d	durian fruits from farmers	
A	Locate durian fruit			ian Unable to sell durian

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Process	Risk Code	Risk	Potential Effect
suppliers		fruits for the demand	products
	R45	Durian fruit has a high price	Lose profit
	R46	Buy poor quality durian	May not be able to process
			the durian or may get bad
			quality of the final products
	R47	Sorting durian grade in a wrong	May result in high
		category	production cost or high raw
			material cost
		Marketing	
Identify the customers	R48	May have too little demand	Lose profit or too much
			inventory
<b>A</b>	R49	Get cheated by the buyer or get the	Lose profit or loss of
		money late	opportunity
		Table 2 Disk of distributor	
Dragoga	Risk Code	Table 3. Risk of distributor	Detential Effect
Process	KISK COUR	Registered certification	Potential Effect
Cot cortified by the	<b>P</b> 50		Connot export products
Get certified by the Department of	R50	Fail to get a certificate	Cannot export products
Agriculture to be able to			
export durian products	D51	The process of getting the cortificate	Lose sales opportunities
<b>A</b>	R51	The process of getting the certificate takes too much time	Lose sales opportunities
	٨	cquire durian fruits from farmers	
Locate durian fruit	R52	Cannot obtain sufficient durian fruits	Unable to sell durian
suppliers	KJ2	for the demand	products
suppliers	R53	Durian fruit has a high price	Lose profit
Distribute products	R54	Not enough products to deliver to	Lose credibility and profi
Distribute products		various stores within the network.	Eose creatonity and prom
	R55	Order cancel from the store	Lose profit
<b>A</b>	R56	Accidents during the logistic process	The products are damaged
<b>A</b>			and cannot be sold
		Marketing	
Identify the customers	R57	May have too little demand	Lose profit or too much
	A		inventory
		Table 4. Risk of retailer	
Process	Risk Code	Risk	Potential Effect
~		eceived products from Distributor	
Gather products	R58	Distributor has insufficient supply	Lose sales opportunities
from the distributors	5.50		• • •
<b>A</b>	R59 I	Distributor is unreliable and sometimes	Lose sales opportunities
	-	may not deliver products on time	
<b>X1</b>		Retail the products in the market	T (1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
Identify possible	R60	No connections	Lose profit due to unable to
listribution channels	DCI		sell products
<b>A</b>	R61	Too many retailers resulting in the	Market share and profit are
Retail the products	R62	tense competition Too little demand	decreased Unsold durians are spoiled,
		'L'o o litte domoon d	Lincold dymono one oneiled

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Process	<b>Risk Code</b>	Risk	Potential Effect
	R63	Too much demand	Lose sales opportunities
	R64	Products are sold with bad quality	Lose credibility

Calculation of FRPN Values	product both domestically an
	Columns 3 and 4 in Table 6 rep
Linguistic Term and fuzzy numbers in this study were assessed as criteria in triangular distribution forms. The assessment was made only for the	factor weights of severity and were based on the FMEA tech factor weight of each TM
severity and occurrence factors as shown in Table 5. The detection factor was assumed to be 1 since	evaluating the questionnaire a respondent. The numbers were i
in this study it was assumed that once the even occurred, it was automatically detected.	form (a, b, c), where a represent b represents the most likel represents the upper bound of th
After the respondents assessed risk scores (from 1	

to 5: 1 = yery low, 2 = low, 3 = intermediate, 4 = high, 5 = yery high), FRPNs were calculated. We assumed the weights of experts as  $h_i$ , i = 1,...,4, shown in Table 6. In Table 6,  $TM_i$ , i = 1,...,4, represented each respondent.  $TM_2$  and  $TM_3$ received the highest weights since both responders were specialized and worked in all processes in the supply chain.  $TM_4$  received the lowest weight since the respondent had relatively smaller expertise in management and distribution of

nd internationally. presented the fuzzy occurrence which hnique. The fuzzy was assessed by answered by each in triangular fuzzy ts the lower bound, ely value, and c he assessment.

The calculation of the rating factors and weight factors followed the steps similar to Gan et al. (2011). The FRPN values were then calculated. The resulting FRPNs for all stakeholders are shown in columns 1-4 in Tables 7. Additionally, the defuzzied values by the Mean of Maxima (MOM) method were shown in the fifth column of Tables 7. Finally, the rankings of risks were shown in the last column of the same table.

<b>▲</b>		Table 5. Ling	guistic	terms and f	uzzy nu	mbers	for sev	erity and	d occurrence	
				Lin	guistic	Term				
	Score		Fuzz	y Number	for Sev	erity	Fuzz	y Numl	per for Occur	rence
	1	Very low	0	0	0.05		0	0.05	0.10	
	2	Low	0.05	0.08	0.10		0.10	0.15	0.20	
	3	Intermediate	0.10	0.15	0.20		0.20	0.30	0.40	
	4	High	0.20	0.30	0.50		0.40	0.50	0.60	
	5	Very high	0.50	0.75	1.00		0.60	0.80	1.00	
Tab	<b>le 6.</b> We	ighs of the resp	ondent	s and the		$TM_1$	0.25	(0.2	,0.3,0.5)	(0, 0.05, 0.1)
corres	ponding	fuzzy factor we	eights f	for severity		$TM_2$	0.30	(0.2	,0.3,0.5)	(0.2, 0.3, 0.4)
		and occurrence	ce			TM <sub>3</sub>	0.30	(0.2	,0.3,0.5)	(0.4, 0.5, 0.6)
	h <sub>i</sub> l	Fuzzy Factor	Fu	zzy Factor		$TM_4$	0.15	(0.05,	0.08,0.10)	(0.1,0.15,0.2)
		Weight for	V	Veight for						
		Severity	0	ccurrence						
		-								

		Table 7. Defuz				
Risk Code	Min	Most Likely	Max	Defuzzied	Ranking	
R1	4.43	4.44	4.47	4.45	1	
R2	3.28	3.31	3.40	3.33	18	
R3	3.53	3.54	3.57	3.55	12	
R4	3.37	3.37	3.38	3.38	16	
R5	3.66	3.66	3.69	3.67	7	
R6	3.89	3.89	3.91	3.90	4	
R7	4.02	4.02	4.04	4.02	3	

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isk Code	Min	Most Likely	Max	Defuzzied	Ranking	Formatted	(
R8	2.07	2.09	2.16	2.11	60	Formatted	(
R9	3.14	3.15	3.16	3.15	27	Formatted	(
R10	2.74	2.75	2.79	2.76	49	Formatted	(
R11	2.89	2.89	2.91	2.90	41	Formatted	(
R12	3.13	3.14	3.19	3.15	28	Formatted	(
R13	2.86	2.86	2.89	2.87	44	Formatted	
R14	3.82	3.83	3.87	3.84	5	Formatted	
R15	3.05	3.05	3.03	3.04	34	Formatted	
R16	2.74	2.74	2.76	2.75	51	Formatted	
R17	2.82	2.81	2.76	2.79	48	Formatted	
R17	3.64	3.65	3.66	3.65	8	Formatted	
R19	2.83	2.84	2.89	2.86	45	Formatted	
R19 R20	3.13	3.13	3.12	3.12	30	Formatted	-
R20 R21	3.40	3.42	3.49	3.44	13	Formatted	
R21 R22	3.34	3.36	3.42	3.37	17	Formatted	
R22 R23	3.21	3.23	3.27	3.24	22	Formatted	
R23 R24	3.69	3.69	3.71	3.70	6	Formatted	
			2.74		52	Formatted	
R25	2.71 2.86	2.71 2.88		2.72	40	Formatted	
R26			2.99			Formatted	
R27	2.91	2.94	3.05	2.97	37	Formatted	
R28	2.73	2.75	2.81	2.76	50	Formatted	
R29	2.58	2.60	2.66	2.61	56	Formatted	
R30	3.04	3.06	3.13	3.08	33	Formatted	
R31	2.64	2.66	2.73	2.67	54	Formatted	
R32	2.87	2.88	2.92	2.89	43		
R33	2.78	2.79	2.84	2.81	47	Formatted	
R34	2.38	2.40	2.48	2.42	58	Formatted	
R35	3.54	3.56	3.65	3.58	10	Formatted	
R36	2.99	3.00	3.01	3.00	36	Formatted	
R37	2.97	3.00	3.15	3.04	35	Formatted	
R38	3.38	3.41	3.55	3.44	14	Formatted	
R39	3.28	3.31	3.40	3.33	19	Formatted	
R40	2.89	2.91	2.96	2.92	39	Formatted	
R41	4.04	4.04	4.07	4.05	2	Formatted	
R42	3.50	3.53	3.66	3.56	11	Formatted	
R43	3.26	3.29	3.37	3.31	20	Formatted	
R44	2.62	2.62	2.64	2.62	55	Formatted	
R45	3.18	3.18	3.17	3.17	25	Formatted	
R46	3.08	3.09	3.16	3.11	32	Formatted	
R47	2.86	2.88	2.95	2.90	42	Formatted	
R48 R49	2.91 3.06	2.94 3.09	3.04 3.20	2.96 3.12	38	Formatted	
R50	3.26	3.28	3.34	3.29	21	Formatted	
	3.20	3.28	3.24	3.29	21	Formatted	
R51					9	Formatted	
R52 R53	3.62 3.18	3.64 3.18	3.70	3.65	26	Formatted	
R55 R54	3.36	3.38	3.44	3.39	15	Formatted	

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Ranking	Defuzzied	Max	Most Likely	Min	Risk Code
23	3.24	3.29	3.22	3.21	R55
29	3.15	3.22	3.13	3.11	R56
46	2.86	2.93	2.84	2.82	R57
64	1.78	1.87	1.75	1.71	R58
57	2.45	2.54	2.42	2.39	R59
59	2.29	2.38	2.25	2.22	R60
61	2.11	2.17	2.09	2.07	R61
53	2.68	2.78	2.65	2.62	R62
63	1.85	1.86	1.84	1.84	R63
62	2.00	2.00	2.00	2.00	R64

Figure 1 contains the plot of the defuzzified values versus their rankings. In this figure, the defuzzified values could be grouped into three risk levels. The first risk level was the one from the highest ranking until the graph started to flatten (at around the ranking number 7). The second risk level was the flatten zone between ranking numbers 8-56. Finally, the last risk level was the steep downward trend between ranking numbers 57-64.

Table 8 contains risks in the first risk level (highrisk group). The risk of insufficient fresh water (ranked the first) can be reduced by the new farmers since they can try to search for the plantation location where fresh water is available. Some risks were in fact related to each other. For example, not enough fresh water is related to drought. Also, some risks in this table were from the heavy rainstorms which are unavoidable. This is similar to the risk of insect or pest diseases or price fluctuation. On the other hand, the risk of no drainage (ranked number 5) can be relatively easier to mitigate.

The risks ranked middle or low could be considered if mitigation approach was costeffective. This paper also illustrates when applying technology into agriculture, it could help farmers to better manage their production efficiently.

	Table 8. High risk group		conclusions or recommendations in this document		Formatted	
Ranking	Risk Activity	Value	are those of the authors and do not necessarily	1///	Formatted: Font: 12 pt	
1	Insufficient fresh water	4.45	reflect the views of the sponsors.	//	Formatted	C
2	Durian prices are fluctuated	4.05	<b>_</b>		Formatted: Font: 12 pt	
3	Storms in the plantations	4.02	References	K	Formatted: Font: 12 pt	
4	Too much rain in the	3.90			Formatted	
	plantation area				Formatted	C

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5	No drainage or clogged	3.84
	drainage	
6	Got insect or pest diseases	3.70
7	Drought in the cultivation	3.67
	area	

### Conclusion

Stakeholders in the supply chain of Monthong durian were the supplier, the manufacturer, the distributor and the retailer. Our results identified 64 risks using the classical FMEA technique. However, when considering the risks using the FRPNs, it was suggested that there were only 7 risks posed as high-risk using the fuzzy FMEA technique. Insufficient fresh water came up as the first rank in the analysis. Other high ranks were related to drought, no drainage, rainstorms, pest diseases, and price fluctuation.

We believe that the results of our study could be used not only as a guideline for Monthong durian farmers, but also for other types of farmers in the tropical climate similar to Thailand. The technique used in this study can also be adapted to classified risks in other applications.

#### Acknowledgement

This study was funded by the Faculty of Kasetsart University, Bangkok, engineering, Thailand However, any opinions, findings

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