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Risk Factors of Perishable Product Supply Chain: Literature Review and A Proposed Framework for Future Research

Abstract: - United Nations statistics show that about one-third of globally transported perishable products are annually wasted due to damage. Where in the perishables supply chain is most likely to go wrong and how can this be corrected or prevented? This article aims to review the literature 50 articles related to the risk factors of perishable products supply chain and cluster the risk factors of perishable products supply chains. Identifying 140 risk factors from 235 risk factors through duplication filtering. And the researcher therefore clusters of risk factors with hierarchical clustering (divisive: distance matrix) into 19 clusters by KNIME machine learning. These findings offer valuable insights for future research on orchid's supply chain risk management for sustainability in Thailand, top global orchid exporter. For the benefit of orchid supply chain stakeholders in Thailand can develop appropriate and sustainable supply chain risk management in the future. Thailand 3rd National Logistics Development Strategy (2017-2021) emphasizes cold chain logistics to elevate agricultural and industrial supply chains to meet standards. Implementing a cold chain system is vital to reduce losses, enhance traceability, and lower production costs.

Keywords: Perishable Product, Risk Factor, Logistics, Supply Chain

I. INTRODUCTION

Perishable products are a group of products with high humidity, water activity level above level 0.9, short and limited shelf life, and prone to deterioration, damage, and perishability, if not properly managed throughout the supply chain. Deterioration can be caused by many reasons such as physical deterioration, enzymatic deterioration, chemical degradation, etc. Perishable products include fresh fruit, fresh vegetables, seafood, dairy products, flowers, and other products that require specific handling. [1]

According to statistics from the United Nations, one-third of all consumer products transported worldwide are damaged and must be thrown away for waste every year.

In the United States, products waste in transit amounted to $ 218 billion, and in Europe $ 143 billion. From the above statistics, it begs the question of why the transported products and raw materials have such a high damage ratio. Where in the perishables supply chain is most likely to go wrong and how can this be corrected or prevented? [2]

In the past, about 30 - 40 % of Thai agricultural products are product waste during storage, transportation, and distribution before reaching the consumer. But if the temperature can be controlled throughout the supply chain, the loss can be reduced to less than 5 % only. However, the potential of cold chain logistics in Thailand has a continuous growth rate according to market demand. As of the end of February 2023, there are 197 juristic persons operating warehouse activities and storage of chilled or frozen products (TSIC 52101), with a total registered capital of 11,099 million baht, and activities for transporting chilled or frozen products by road (TSIC 49331) total 229 persons, total registered capital 1,172.00 million baht. The appropriate temperature for the product is different. [3]

From the above information, the researcher is interested in risk management in the supply chain for perishable products. This article aims to review the literature related to the risk factors of perishable products supply chain

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and cluster the risk factors of perishable products supply chains. To provide basic information for risk factor analysis in the perishable product supply chain in the next step.

II. DETERIORATION OF PERISHABLE PRODUCTS

The deterioration of perishable products can be divided into 3 types:

1) Physical deterioration: due to physical forces such as fracture, bruising, caused by pressure, impact, compression during harvesting, transportation, processing, storage, germination, biting insect, etc.

Physical deterioration is the main cause of subsequent chemical and microbial deterioration. Due to injuries from fractures or bruises which may be prevented by using anti-impact materials. Deterioration also contributes to accelerating nutrients to react with enzymes or to react with each other or with the environment, such as oxygen, moisture in the atmosphere, etc.

Physical deterioration may be due to the following reasons:

- Processing, such as freezing, which causes large ice crystals to pierce the cells and tear them when frozen food is melted, will cause the food to lose liquid.

- Improper storage conditions, such as the use of poorly watertight packaging in fresh or frozen foods, can cause evaporation, resulting in weight loss and dry skin. In the case of dry food, water will seep through the packaging. Food will absorb water back in, resulting in increased moisture, loss of crispness or clumping together, and is also a major cause of deterioration from microorganisms.

2) Enzymatic degradation: Enzymes are proteins that are found in both plant and animal organisms. Enzymes are responsible for catalyzing reactions in living cells and tissues, such as the breakdown of large molecules of nutrients into smaller ones and accelerating the synthesis of various substances within cells. When plants and animals are harvested or slaughtered for meat use as food, enzymes that continue to act catalyze the breakdown of food molecules, e.g., ripening fruits, turning their color from green to yellow, turning starch into sugar, making fruit sweet and soft, etc.

During preparation, the food may be peeled, sliced, minced, or crushed, causing the enzymes in the food to meet more substrate molecules, thereby accelerating its deterioration. Lypase and Lypoxidase are enzymes that catalyze fat degradation commonly found in food and cause rancidity in milk, meat, plants, and high-fat fresh foods. Pectinase accelerates the degradation of pectin, a polysaccharide binder that strengthens the cell structure of fruits and vegetables, making them soft and tender. In addition, pectinase enzymes also cause freshly squeezed fruit and vegetable juices that have been left to separate layers to not be as homogeneous as newly squeezed juices.

3) Chemical deterioration: deterioration due to chemical reactions between food components, between food and packaging, or between food and environment. Chemical deterioration includes:

- Non-enzymatic browning reactions

- Rancidity due to lipid oxidation

III. SUPPLY CHAIN RISK

Risk is the likelihood or probability that the outcome of an operation will not turn out as expected. In fact, the results will be good or bad depending on the composition and the relationship between the elements. Whenever any decision is made there is always more or less a risk. This risk is not dependent on how confident the decision maker is, but the outcome of a decision in either direction carries a different risk. [4]

Logistics and supply chain management is an issue that concerns many organizations from upstream to downstream businesses and their customers. Good management results in the development of a lean organization to reduce lead time and lost time in the process. This can be seen that the supply chain is systematically arranged as if every process was connected in the same chain. Hence it can be said that every step is continuous and cannot be allowed to be interrupted. Therefore, most supply chain problems are caused by unpredictable risks such as natural disasters, labor conflicts, supplier bankruptcies, war threats, and political violence, etc. These problems all result in system interruptions or delays in receiving inputs and may affect sales and increase costs. [5]

Organizations should have measures to prevent or mitigate the effects of such problems. Organizational managers generally focus on balancing storage, capacity, and support systems throughout the supply chain. But this must depend on the cost factor, quantity, selling price, quality, service level, safety, and product value. Leading manufacturers have aimed at risk classification to identify impact risk mitigation strategies. Hence, risk management is a key issue underpinning supply chain effectiveness so that process flows are not interrupted. These issues are related to supply chain risk mitigation. Unfortunately, most organizations tend to make improvised plans that have little impact on the supply chain. Overlook major problems that may have a serious impact, such as raw material quality problems that will cause the production line to be delayed. If the problem product is delivered to the customer, it will reduce the customer's credibility and look for a new supplier who can deliver the product as needed, etc. For leading organizations, they often hedge risks with backup strategies such as buffer inventory, establish spare parts systems, reserve capacity, install backup power systems, use more than one supplier, etc. These are the challenges of management. In particular, the skill to decide on strategies that can reduce risks and minimize the impact on performance.

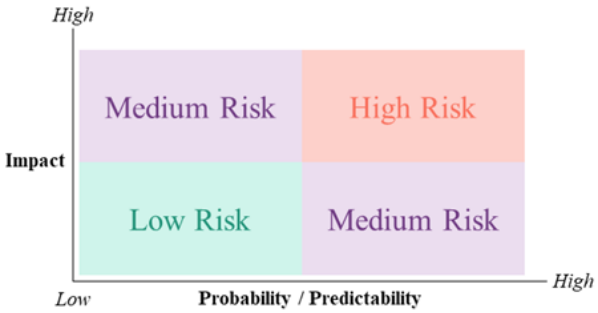

Fig. 1 The level of impact of the risk factors

IV. METHODOLOGY

Data Sources

The researcher searched for research articles and academic articles on the perishable product supply chains. The researcher searched from 1993 to 2023 and found that there was a continuous trend of increasing and there was a noticeable increase in the number of studies in 2014 as shown in Fig. 2.

The researcher reviewed literature 50 articles on risk factors of perishable product supply chains. Sources from journals included in the Scopus, TCI, and government and private sectors involved in perishable product supply chains are shown in Fig. 3.

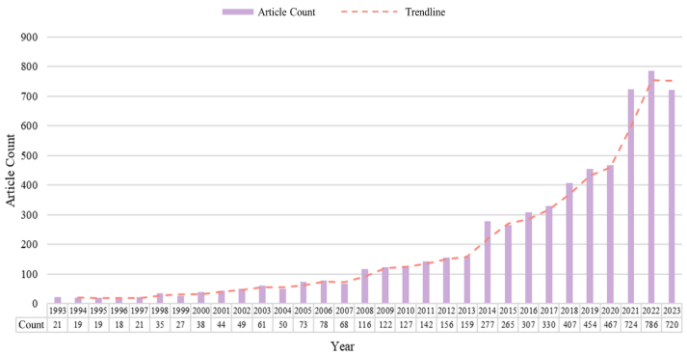

Fig. 2 Number of articles on the perishable product supply chains 1993 - 2023

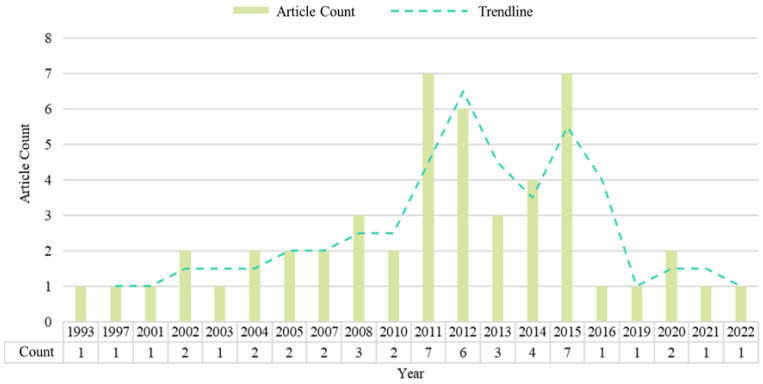

Fig. 3 Number of articles of literature review

The researcher was able to collect 235 risk factors of perishable product supply chain. The risk factors from each literature are similar but may be termed differently depending on the author's context. Therefore, the researcher considers adjusting the words of the corresponding or corresponding risk factors into words, phrases, and sentences used to communicate with the corresponding content for orderliness and convenience. For machine learning to cluster the risk factors of the perishable product supply chain in the next order.

Tools

The researcher is considering using the KNIME which is a data analytic platform in the form of machine learning.
For processing and risk factor analysis of perishable products supply chains.

KNIME or Konstanz Information Miner is an open-source data analysis program. KNIME has been ranked by Gertner as a leader in data analytics and machine learning for many years. KNIME is a data analysis program that can be used in a variety of applications such as text mining, image processing, and can be linked to R or Python to create deep learning. The strength of KNIME is its graphical user interface with drag-and-drop functionality to create data analysis procedures. The KNIME process begins with data collection, data preparation, data analysis, and data visualization. Allows users to use the program without having to learn programming. There are many reasons why KNIME is a comprehensive program and is popular with data analysts, such as the fact that KNIME is used by a wide variety of fields such as marketing, manufacturing, industry, and academic. In addition, KNIME also has a fully published learning resource. Users can find

application examples in a variety of data analytics fields such as customer intelligence analytics, social media, finance, industry, pharmaceutical and healthcare, retail, and government, etc. Also, KNIME is an open-source program that can be used free of charge and without limitations, making this program very attractive and worth trying for users. However, the limitation of KNIME is that it takes up quite a lot of computer memory during program execution, and installing additional commands and extensions of the program will cause the program to slow down even more. Including if the user is not familiar with using this type of program before, users may need more time to learn and understand the operation of the program. [6]

The researcher considers the algorithm used in data management in 2 parts:

1) Duplicate of risk factors

From the collection of risk factors of perishable product supply chain. The researcher found many coherent risk factors. The researcher wants to filter the risk factors, so the researcher uses the “Duplicate Row Filter Algorithm” of KNIME for convenience, speed, and orderliness in managing large amounts of data.

This node identifies duplicate rows. Duplicate rows have identical values in certain columns. The node chooses a single row for each set of duplicates ("chosen"). You can either remove all duplicate rows from the input table and keep only unique and chosen rows or mark the rows with additional information about their duplication status. (Fig. 4) [7]

Fig. 4 KNIME machine learning: Duplicate row filter

2) Cluster of risk factors

Machine Learning is teaching computer systems to learn by themselves. The computer learns from the input data to find a program or pattern that will be used to find the answer to the next data. Machine learning can be divided into 3 types:

(1) Supervised learning: It teaches computers by data that has results or goals to learn and predict the results of input data again.

(2) Unsupervised learning: It teaches computers by using data without solutions to learn and find the relationship of the data by itself. It is learning without an instructor.

(3) Reinforcement learning: This is learning in which the computer pays special attention to the environment, such as Google's AlphaGo, which calculates and finds new ways based on the changing environment.

There are many types of models that are used in machine learning. One of the most used models is the clustering model, which is an unsupervised learning model that has no goal or no model for the outcome. This is a model used to group data that has not been grouped before. By segmenting data from similarities, for example, grouping customers according to the shopping behavior of customers who have similar characteristics will be the same type of customers. One popular clustering model for clustering data is “Hierarchical Clustering (Divisive: Distance Matrix)”. By clustering into the same large cluster and separating the dissimilar clusters indefinitely into *n* groups that cannot be further separated

Hierarchically clusters the input data using a distance matrix. This node works only on small data sets because it has cubic complexity. There are two methods to do hierarchical clustering. [8]

Fig. 5 KNIME machine learning: Hierarchical clustering (DistMatrix)

V. RESULT

The researcher used Machine Learning to manipulate the data: (1) Duplicate of Risk Factors by Duplicate Row Filter and (2) Cluster of Risk Factors by Hierarchical Clustering (Divisive: Distance Matrix). Both items are algorithms of KNIME Machine Learning as shown in Fig. 6 and the details are as follows.

(1) Duplicate of risk factors by Duplicate row filter.

From a literature review of 50 articles. The researcher was able to collect 235 risk factors for the perishable product supply chain. The researchers found a large number of coherent risk factors. The researcher wants to filter the risk factors, so the researcher uses the Duplicate Row Filter Algorithm of KNIME for convenience, speed and orderliness in managing large amounts of data. Therefore, it was found that only 140 risk factors could be filtered.

(2) Cluster of risk factors by hierarchical clustering (divisive: distance matrix)

From the risk factors of the perishable product supply chain that have been duplicated, 140 risk factors.

The researcher then performed a clustering of risk factors. By considering elements related to the supply chain as

a criterion for clustering risk factors, including;

- 19 fields of risk factors, consisting of rules, production processes, harvesting, handling, transportation, storage, marketing, waste disposal, farmers, information, demand, technology, packaging, yield, price, labor, raw materials / supply, economy, and environment.

- 2 sides of risk factors, consisting of external, and internal.

- 7 stakeholders of risk factors, consisting of supplier, agriculturist, exporter, customs department, road transport, air freight, and importer.

The researcher grouped the risk factors using hierarchical clustering (divisive: distance matrix). It was found that KNIME machine learning can clustering up to 60 clusters. But if the number of clusters is determined, the result of clustering that can clearly be distinguished is to use the field of risk factors as a criterion for stratification. Using the risk factor field as a criterion, 19 perishable product supply chain risk factors can be clustered according to the number of risk factor fields. The details are shown in Table II.

Table II Cluster of risk factors of perishable product supply chain [9] – [58]

Cluster (Hierarchical Cluster Assigner)	RISK	ID
Cluster_01 Rule	Destination countries take phytosanitary and regulatory measures to further discourage imports	Risk_022
	Government subsidies and protection policies generate excess production capacity	Risk_032
	Good Agriculture Practices (GAP)	Risk_033
	Lack of integration between government agencies, private sector and agriculturists	Risk_048
	Laws controlling the importation of plant varieties	Risk_059
	Policy to promote renewable energy from plants	Risk_077
	Price of biomass, fuel and energy	Risk_079
	promotion of import-export from the government sector	Risk_085
	Retail law	Risk_093
	Scenarios of additional restrictions on green policies	Risk_095
	Setting standards	Risk_096
	Strictly regulations from regulators, both domestic and overseas	Risk_103
	The agricultural futures market did not develop because the government intervened in the market	Risk_109
	The cost of certification, procedures, delays and customs procedures	Risk_112
	Trade barriers in the form of phytosanitary and animal sanitary standards	Risk_116
	The pledge policy at a higher price than the market distorts the market	Risk_122
	The process of obtaining a pest free certificate has been delayed	Risk_124
	Uncertainty in government policy	Risk_134
Cluster_02 Production Process	Cost of high-quality system	Risk_016
	High cost quality control and inspection system	Risk_037
	Lack of costs	Risk_045
	Management and operational risks	Risk_062
	Production Planning	Risk_083
	Production process	Risk_084
	Uncertain supply capacity	Risk_133
Cluster_03 Harvest	Duration of harvest season	Risk_023
	Harvest season	Risk_034
	Harvest yield	Risk_035
	Unstable harvest due to weather conditions.	Risk_138
Cluster_04 Handling	Failure of material handling technology	Risk_028
	Low changeability/flexibility of cold chain transport	Risk_061
	Process and material handling equipment are lagging, resulting in delays in delivery time for inbound and outbound warehouses	Risk_081
	The degree of mechanization of the Material handling is low	Risk_115
Cluster_05 Transportation	Lack of planning to support private investment in logistics center	Risk_019
	Logistics and infrastructure risks	Risk_027
	Maritime and rail transport is limited	Risk_029
	The airport has insufficient space to support export products	Risk_036
	Traffic	Risk_040
	Uncertainty of traffic conditions	Risk_050
	Delays in the return of shipping equipment (e.g. containers) result in out of stock or deterioration	Risk_051

Cluster (Hierarchical Cluster Assigner)	RISK	ID
	Many trucks do not have return cargo	Risk_052
	The product arrived at the airport late	Risk_060
	The standardized configuration of distribution vehicles is low	Risk_063
	Failure of exports in the public transportation process	Risk_064
	Failure of transportation equipment	Risk_110
	High cost of logistics	Risk_125
	Hygiene of transportation equipment	Risk_127
	Lack of professional transport operators	Risk_130
	Lack of professional transportation route optimization capabilities and unreasonable transportation routes increase transportation costs	Risk_136
Cluster_06 Storage	Cold rooms have high energy consumption and high noise, which negatively affects the ecology	Risk_013
	Hygiene of storage areas	Risk_024
	Equipment for post-harvest cooling or preliminary cooling of temperature controlled trucks	Risk_039
	Operation in low temperatures cannot be fully guaranteed	Risk_070
	Post-harvest temperature reduction or preliminary temperature reduction were not effective. and the adjustment and control of the temperature does not meet the specified criteria.	Risk_078
	Technology of post-harvest temperature reduction or preliminary temperature reduction	Risk_107
	temperature and humidity of the cold room	Risk_108
	The degree of automation of the cold storage is low, which wastes human resources	Risk_114
	The geographical distribution of cold storage is uneven, and the capacity is very insufficient	Risk_118
Cluster_07 Marketing	Competitive country	Risk_014
	Cost of marketting	Risk_017
	New competitors can enter easily	Risk_053
	The competitive situation of flowering plants	Risk_056
	The exporter has an agreement to purchase orchids with the buyer on credit term	Risk_065
	Lack of research on marketing, distribution, and public relations	Risk_066
	Lack of study and analysis of problems in the market of existing trading partners	Risk_069
	Market volatility, wholesale, and retail	Risk_111
	Marketing	Risk_117
Cluster_08 Waste Disposal	Improper disposal of processing waste	Risk_041
	Responsibility for perishable goods	Risk_092
Cluster_09 Agriculturist	Agriculturist change their occupations and abandon their agricultural areas	Risk_003
	Agriculturist lack strength in business	Risk_005
	Agriculturist lack the knowledge of agricultural technology.	Risk_006
	Agriculturists misrepresentation of testing quality	Risk_007
	Agriculturist's union	Risk_008
	Lack of labor in the agricultural sector	Risk_049
	The trust between agriculturists and collectors is not strictly about commitments	Risk_128
Cluster_10	Small exporters are not supported in information and technology	Risk_042

Cluster (Hierarchical Cluster Assigner)	RISK	ID
Data	State research does not meet market needs	Risk_058
	Information system collection and processing	Risk_099
	Lack of young researchers due to lack of systems and motivation	Risk_102
	The level of information provided in the distribution process is low.	Risk_119
Cluster_11 Damand	Demand size uncertainty for standard products/high quality products	Risk_020
	The entry of demand for the product	Risk_021
	The market demand was inconsistent with the quantity and quality of orchid production at different periods	Risk_080
	Uncertain demand	Risk_121
	Demand cost	Risk_129
	Price sensitive demand	Risk_132
Cluster_12 Technology	Lack of technological development and innovation for the orchid industry	Risk_057
	Operation technology	Risk_071
	Refrigeration technology is generally lagging behind	Risk_091
Cluster_13 Package	Lack of development of packaging systems for orchids	Risk_046
	Packaging materials	Risk_073
	Packaging performance	Risk_074
	Packing rate	Risk_075
	The low standard of packaging cannot be recycled and pollutes the environment	Risk_120
Cluster_14 Product	Some exporters take advantage of farmers in weighing and measuring	Risk_015
	Consumer confidence in terms of product traceability	Risk_087
	Quality of product	Risk_094
	Ripeness of the produce	Risk_097
	Short shelf-life products	Risk_098
	Shortage of goods due to agricultural problems	Risk_100
	Some organic agricultural products are adulterated	Risk_101
	Uncertainty of the quantity of products	Risk_135
Cluster_15 Price	Product price is lower than cost	Risk_030
	The price of orchid flowers is too low in some periods	Risk_082
	The rate of return depends on the buy-sell price	Risk_123
	Fluctuating product prices	Risk_126
Cluster_16 Labor	High handling costs due to lack of labor	Risk_038
	Labor cost problem	Risk_043
	Lack of skilled industrial labor	Risk_055
	The cost of employment tends to increase	Risk_113
Cluster_17 Raw Material / Supply	Biomass cost	Risk_001
	Advertising the sale of factors of production that are exaggerated	Risk_004
	Agriculturist discovered new orchid varieties but only used them in a narrow circle	Risk_009
	Cost of raw material procurement	Risk_018
	Fluctuations in raw material prices	Risk_031
	Lack of a center for sorting good quality orchids	Risk_044
	Lack of good plant varieties	Risk_047
	Lack of seeds, fertilizers, and pesticides	Risk_054
	Material handling	Risk_067
	Orchid varieties lack diversity	Risk_072
	Quality of raw materials	Risk_088

Cluster (Hierarchical Cluster Assigner)	RISK	ID
	Raw material procurement	Risk_089
	Raw material quantity	Risk_090
	Supply cost	Risk_104
	Supply path change	Risk_105
	Supply scenarios	Risk_106
	type of raw material	Risk_131
	Unreliable cheap raw material supplier	Risk_137
Cluster_18 Economy	Changes in currency exchange rates	Risk_010
	Changes in financial institutions regarding credit	Risk_011
	Expansion of industrial zone	Risk_025
	world economy slowing down	Risk_026
	Factory shutdown situation	Risk_140
Cluster_19 Environment	Climate and environmental changes	Risk_002
	Natural disasters	Risk_012
	Quality of produce under climatic variability	Risk_068
	Water management	Risk_076
	Agricultural pest problems	Risk_086
	Pests	Risk_139

VI. CONCLUSION

Based on the compilation of risk factors associated with perishable product supply chains from 50 literature reviews, 235 risk factors were compiled. The researcher then duplicate of risk factors with the Duplicate Row Filter, leaving only 140 risk factors. And the researcher therefore clusters of risk factors with Hierarchical Clustering (Divisive: Distance Matrix) into 19 groups as shown in Fig. 7.

Risk factors reviewed in this article can be used for the future research on orchid's supply chain risk management for sustainability in Thailand. The researcher is interested in orchid's supply chain risk management for sustainability in Thailand because orchids generate high income for Thailand both within the country and abroad. Thailand is the country with the highest export volume of orchids in the world. Thailand has 183 genera and 1,224 species. The top 3 popular Thailand orchids are Dendrobium, Oncidium, and Mokkara. The top 3 exporters are as follows: Krung Thep Maha Nakhon, Nakhon Pathom, and Samut Prakan, respectively. For the benefit of orchid supply chain stakeholders in Thailand can develop appropriate and sustainable supply chain risk management in the future. The framework for future research is shown in Fig. 8.

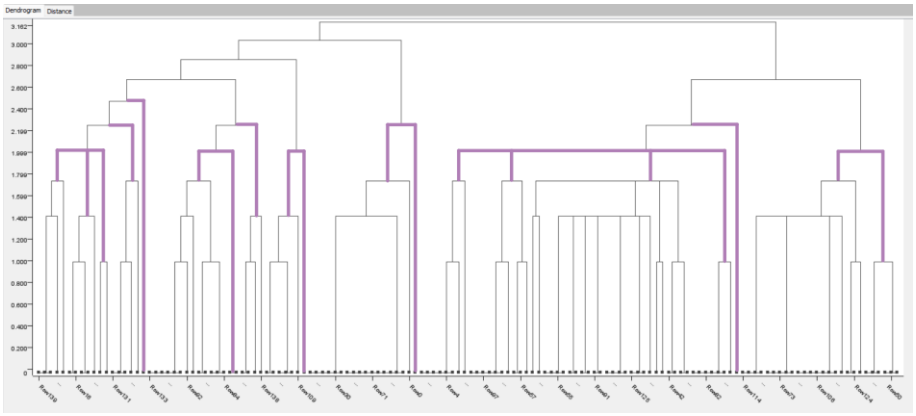

Fig. 7 Cluster of risk factors by hierarchical clustering (divisive: distance matrix)

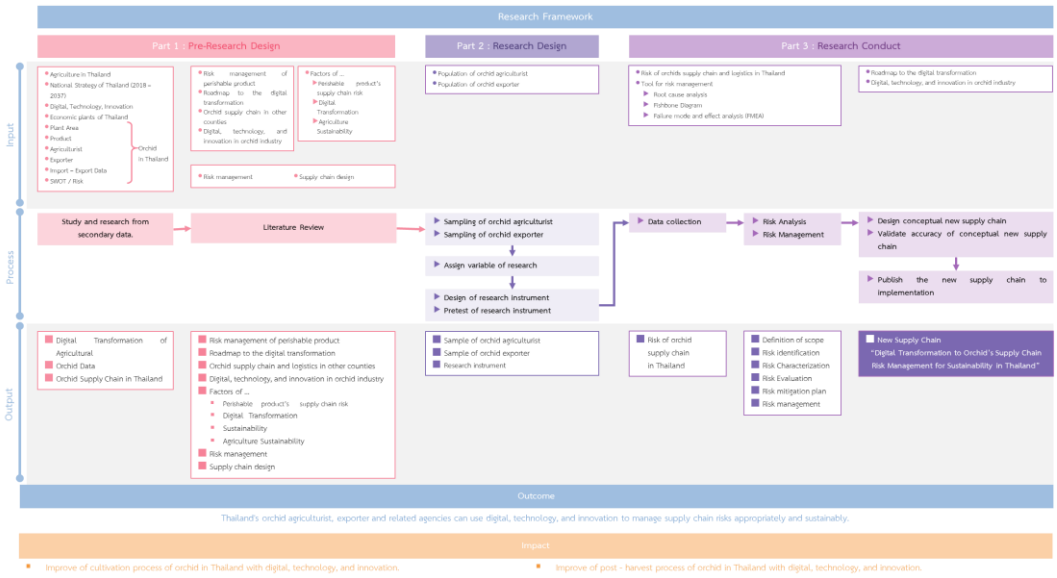

Fig. 8 The framework for future research

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