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Failure Mode and Effects Analysis (FMEA) for Identifying Trade Barriers of Perishable Goods in Iran: Case Study of Bushehr

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Abstract

Foreign trade of perishable goods faces an environment full of uncertainties and depends on many different factors in its various components such as cold chain logistics requiring significant effort to maintaining of quality and reducing of costs and abating corruptions. Trade of perishable goods is an integral part of the cold chain with potential challenge source and one the facilitator part of these barriers is sophisticated reefer terminal. This study aims at identifying and assessing the cold chain challenges of maritime foreign trade of perishable goods in Iran. This study aims to be a future reference for more academic and professional research in perishable goods trade in the field of identification of refrigerated trade barriers and policy making in ports through examining the types of risks inherent in the various operational levels of perishable goods trade in port and developing specific risk mitigation strategy. Data on Bushehr Port facilities were collected and analyzed. First, the risk of perishable goods identified by using failure modes and effects analysis, then scored, and RPN (Risk Priority Number) was calculated for each one. The level of risk calculated with SPSS software and the identified items prioritized and analyzed. Results showed the most risks were related to the lack of standard refrigerated structures, disorderly frequency of vessel and shortage of reefer container. Results show that potential risk of perishable goods in ports is at critical level. Suitable and sophisticated reefer terminal of port as a link in foreign trade play an important logistical role. The need to detect barriers of cold trade, to develop refrigerated facilities, to commit to staff training and continuous improvement of software and hardware are recommended.

Keywords: *Cold Chain, Foreign Trade, Perishable Goods, Marine*

1. Introduction

Growth of global trade of perishable goods has led to development of cold chain. Each year, thousands of tons of fresh and chilled goods ar lost because of barriers of cold chain. In order to have a commercial transaction, there needs to be a surplus at one location (origin), a demand at another (destination) and the physical capability to carry the goods from the

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origin to the destination (Rodrigue, 2014). Globalization and its related growth have led to development of several newfound markets in temperature-sensitive goods trade (Bonuedi, 2013). The international market of fruit and vegetables was among the first markets of the agro-food sector to completely embrace globalization (Compés López, 2012). Perishable goods become even more important part of trade because of very short shelf-life (Negi and Anand, 2015) and should be transferred at the earliest and shortest time possible. Perishable goods trade takes advantage of phenomenon of demographic and economic dynamics which gives it an extra competition advantage that helps expanding production of short-life goods and access to international market (Milner et al. 2000) via great increase in shipping traffic between different parts of the world (Gattuso, 2012). However, perishable goods export is prone to a variety of risks including, slow trend of inspection and quarantine (Milner et al. 2000), transport cost, cold storage and translocation in ports (Miler and Harsh, 2015). These risks and their concomitant effects have resulted in poor performance of port over the years. For example, aim of perishable goods trade is delivery of goods in just of time with fresh quality.

It is increasingly evident that identification of export barriers and methods of removing barriers will be amongst critical components of international trade interactions. In addition, although extensive academic research has explored the barriers of refrigerated trade in logistics part and its services (Twrdy and Elen, 2010) and effective factors of technology, policy and non-tariff limitation in supply chain, identification of port barriers, its procedures and interaction between active organization has been investigated much less. This study aims to be a future reference for more academic and professional research in perishable goods trade in the field of identification of refrigerated trade barriers and policy making in ports through examining the types of risks inherent in the various operational levels of perishable goods trade in port and developing specific risk mitigation strategy.

2. Analysis of the Present Situation

2.1. Foreign Trade

According to agriculture ministry and based on Iran customs' report (Summary of Economic Developments in the Country, 2013), refrigerated trade (export-import) includes five groups of meat, fish (aquaculture), aquiculture, orchard products and processed food. The value of refrigerated trade of Iran during 2010-2013 is presented in Table 1.

2.2. Cold Store Infrastructure

Superstructures of refrigerator trade in any country are meant to build cold storage and cold room. Their presence and proximity to centers of production will reduce the loss of product and timely delivery at any time of year. In 2014, 1285 workshops were engaged in providing storage services across the country of which, 628 (%48/9) and 657 (%51/1) workshops provided the main activities of storage cooling, respectively.

Total of 676 workshops have primary and secondary activity, 684 workshops have one circuit hall under zero, 3554 workshops one circuit hall above zero and 784 workshops two circuit halls (Table 2).

Table 1: Value of Refrigerated Trade of Iran 2010-2013

Trade	**Group**	**Value (Million Dollars)**			
		2010	2011	2012	2013
Export	Meat	198	225	329	350
	Aquaculture	148	204	25	52
	Aquiculture and orchard products	3589	3412	3875	2940
	Processed food	1388	1677	1832	1781
Import	Meat	1094	1057	920	699
	Aquaculture	76	61	60	97
	Aquiculture and orchard products	5097	5618	9495	9326
	Processed food	2964	3227	3906	3361

Table 2: Iran's cold storage details and types

Year	Cold store no.	A circuit hall under zero			A circuit hall above zero			Two circuit hall			Nominal capacity
		No.	Space(m^2)	Content (m^3)	No.	Space	Content	No.	Space	Content	
2011	537	477	188115	811753	3295	938887	4250233	743	246429	1101817	1520077
2014	676	684	238720	1042901	3554	1086879	4719831	784	274091	1188257	1830754

Source: (Investigation of warehousing services, 2014)

2.3. Theoretical Basis and Literature Review

Theoretical basis consists of 3 parts, cold chains, types of refrigerated containers and failure mode and effect Analysis.

2.3.1. Cold chains

The cold chain is a science, a technology and a process all at the same time. It is a science since it requires the understanding of the chemical and biological processes linked with perishability. It is a technology because it relies on physical means to insure appropriate temperature conditions along the supply chain. It is a process, since a series of well-defined tasks must be performed to prepare, store, transport and monitor temperature sensitive products (Rodrigue, 2014).

Cold chain is the logistics system that provides ideal condition to the perishable goods from the point of source to the point of consumption through thermal and refrigerated packaging methods and logistical planning to protect the quality and increase the shelf life of these shipments (Negi and Anand, 2015).

Cold chain saves fresh produce from degradation, humidity, and improper exposure to temperature, and keeps them frozen, fresh and chilled (Bishara, 2006). A typical cold chain model is shown in figure 1.

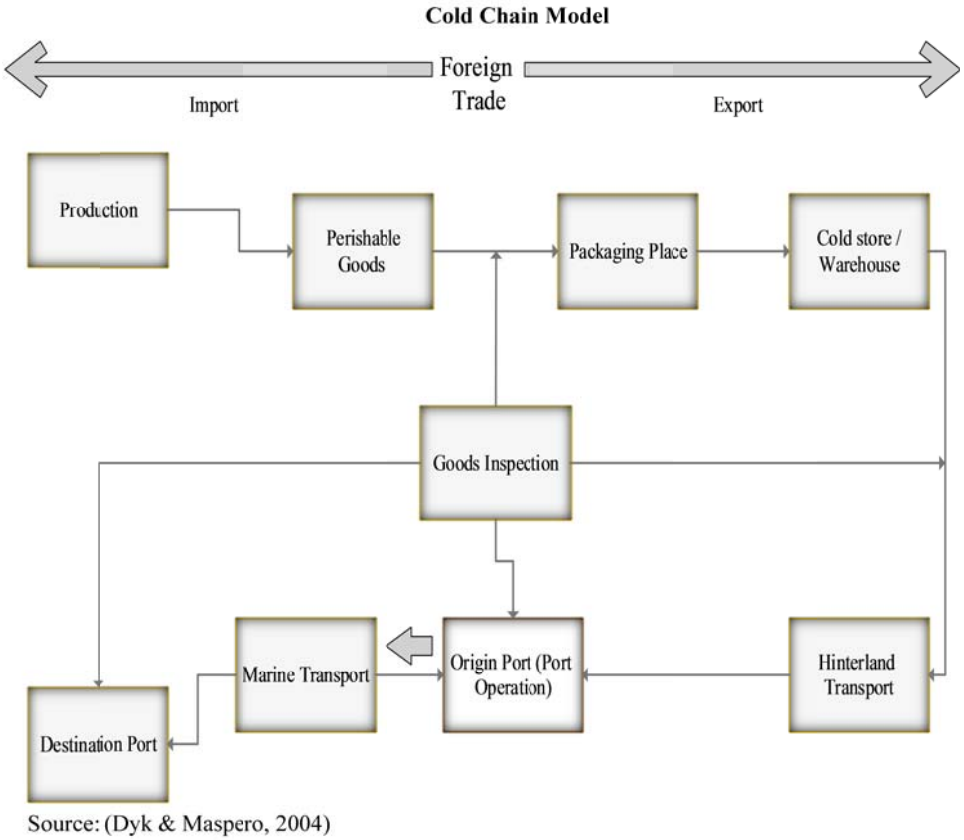

Fig. 1: cold chain model

According to above cold chain model, there are 10 steps in trade of perishable goods as follows:

S1-Foreign trade:Foreign trade is defined as trade with other countries that involves the exchange of capital, goods and services across international borders or legal territory. The world economies are taking shape by factors such as globalization, technological development, institutional consolidation, consumer empowerment, government policies and industrial liberalization (Milner et al., 2000).

Foreign trade can be classified in three different types or flows depending on the origin and destination of a container within the terminal (Dussán, 2012):

A transshipment container is the one which is discharged from the ship, stored in the yard and transported to another vessel.

Import flow comprises all containers entering the terminal from sea vessel and exiting it by inland transportation, either road or rail.

Export containers are those containers coming by inland transportation and leaving the terminal by vessel.

S2-producer: in economic prospect, large producers are active in export and usually combine produce and export activity, so use of daily international market information (Tetteh & Nguni, 2009). In this step, producer dispatches goods for pre-cooling process after harvest (Freibothe et al., 2013).

S3-Perishable goods: Refrigerated goods include “cold’ and “Frozen” goods which need different temperature levels to keep and ensure quality of goods during marine transport and supply chain. Cold goods often contain fruit and require temperature around 0°C or more (Banana 12-13°C) while frozen products need temperature of -18 ° C or even less which include meat, fish and dairy products. In addition to the food, one of the most lucrative parts of cold chain is pharmaceutical products (Bishara, 2006). Of course, specialized chemical products, paint and glue has also entered this chain (Tamimi et al., 2010).

Depending on the type of product being transported through the cold chain, specific temperature standards are enforced. Although optimal transport temperature is product specific and a wide variety of temperature settings can be selected, five temperature standards are among the most prevalent (Rodrigue, 2014):

- Deep freeze (-28 to -30 Celsius). The range of coldest temperature that can be maintained by conventional refrigerated units.
- Frozen (-16 to-20 Celsius). Used for transporting frozen meat, including beef, poultry and pork.
- Chilled (2 to 4 Celsius). This range comprises the standard temperatures in a refrigerator
- Pharmaceutical (2 to 8 Celsius). The temperature range at which most pharmaceutical goods, like vaccines, are transported.
- Bananas (12 to 14 Celsius). The temperature range is chosen for one of the world's most produced fruit that usually its ripening controls during the shipment.

S4-Packaging: Packaging is required to ensure the physical protection of the product; their purpose is to guarantee that goods reach their destination in the conditions set out in the contract. It is important to be aware of its basic functions in choosing packaging, which include: to contain a certain amount of a product, to protect the product and to aid in product handling and distribution (Sáenz, Cruz, & Lam, 2009).

S5-coldstore: Facilities of cold storage are typically ’private” or” public”, or a joint. They often feature higher ceilings, more individual cold storage rooms, multiple product holding temperatures (but predominantly +4^{o}C (fresh produce, and -18 and -24^{o}C for frozen) (Bledsoe, 2009).

According to usage, cold storage is divided to two types of hall: one mode circuit hall temperature remains in, under zero or above zero and two mode circuit hall temperature with interchangeable modes (Investigation of Warehousing Services, 2014).

S6-Multimodal transport: This may include long haul refrigerated equipment including truck/trailer combinations, containers, specially designed rail cars, and equipment appropriate for air transport. Local delivery equipment may include smaller truck/trailer units, truck units, or even units that are well insulated but lack integral refrigeration equipment (Bledsoe, 2009).

S7-Origin port: In this step, refrigerated container connects to power plug and is constantly monitored via operation team after goods arrival (Haasbroek, 2013). Goods will stop in refrigerated terminal till specified time and schedule to destination port. In this period, container will pass port operation, custom procedure and inspection (Tetteh & Nguni, 2009).

S8-Marine transport: Containers will transfer from yard to harbor and load on vessel, then connect to power source of vessel (Freibothe et al., 2013).

S9-Destination port: After arrival to port, container will be inspected by customs experts. Import reefer container is connected to power plug in port fast. So, after passing custom procedure, it will be released to customer.

S10- Inspection: before preload the product is physically inspected in production center, in the cold, in destination port, and in distribution centers in order to identify any stains, rust, holes, tears and corruption (Sáenz, Cruz, & Lam, 2009).

2.3.2. Types of refrigerated containers

According to container handbook, there are two types of refrigerated containers (Wild, 2016):

-Porthole containers: Porthole containers are thermally insulated and have two sealable openings on the end walls. Porthole containers always need to be refrigerated by external means.

- Integral containers: It has an integrated refrigeration unit which is secured to the end wall of the container. These containers are operated using three-phase electric power.

2.3.3. Failure mode and effect analysis

In today's changing world, every individual, group or business process is continuously exposed to some ambiguities in their daily activities. This confusion and uncertainty can be either a result of internal factors like poor decisions or the inability to control the position or the results of external threats or modified environment. Measurement and detection of the internal factors like human characteristics such as confidence and the mental situation is difficult. External factors are usually measurable and we can give possibilities based on historical data (Jóhannsson , 2015) FMEA technique is deductive method which is defined to study the defects in the system. The technique is based on the characteristics of the error components, and structures of functional components (salc, 2012). Failure modes and effects analysis (FMEA) is a method for analyzing potential problems of reliability or adverse events in the early stages of the development cycle to overcome the problem easier (Anin et al., 2015). FMEA can provide qualitative descriptions of potential problems performance (failure modes, root causes, effects, and maintenance) and can extent to error qualitative frequency and/ or estimates of effect. This systematic approach is designed to identify cases of potential error causes and their effects on system performance (Anin et al., 2015). The standard of FMEA evaluation is based on the occurrence, severity, and detection for each risk event. The multiplication of these values obtains a Risk Priority Number (RPN) RPN = Occurrence x Severity x Detection (Anin et al.2015).

Conducting a FMEA, the reviewed product/ process/ service/system is normally broken down into smaller items/subsystems. For each item, the following seven steps are performed:

Step 1: Identify components and associated functions
Step 2: Identify failure modes
Step 3: Identify effects of the failure modes
Step 4: Determine severity of the failure mode
Step 5: Identify cause(s) of the failure mode
Step 6: Determine probability of occurrence
Step 7: Identify controls
Step 8: Determine effectiveness of current controls
Step 9: Calculate Risk Priority Number (RPN)
Step 10: Determine actions to reduce risk of failure mod

2.4. Literature Review

Cold chain is a new sector in international trade. Therefore, it is acceptable that producer of perishable

products needs a fully advanced cold chain sector. A review of scientific researches revealed various gaps in cold chain around the world.

Negi and Anand, (2015) and Bhardwaj and Palaparthy (2008) found capacity and insufficient space, lack of refrigeration equipment, poor infrastructure, poor cold chain technologies and mismanagement as, major concerns of the cold chain. Cold chain of perishable products trade requires well-trained and motivated workforce, more efficient port operations, improvement of infrastructure and congestion reduction at terminals, good operating system requirements (Heap, 2006) (Freibothe et al. 2013). Warehouse operations across the entire chain and suitable hardware cold storage facilities are recommended to maintain and sustain the quality as well as increase the shelf life of the produce (Yanfang et al, 2015). Another bottleneck which is found from literature includes irregular refrigerated container shipping lines and lack of fast access to refrigerated containers (Prentice and Mclachin, 2008). Tetteh and Nguni (2009) and Stander (2014) also found different gaps like rules and regulations of the countries, the slow process of customs clearance, handling of the truck in terminals. Cold chain plays an important role in trade of perishable products but it may have some weak links.

3. Methodology

3.1. Data Collection

Information and data related to barriers have identified and collected through literature review, observation, and face to face interview, phone conversations with professionals, experts and specialists in the field of trade about Bushehr perishable goods.

The study was performed in three active parts of trade of perishable goods (port, shipping and customer). All barriers were put in worksheets and distributes among population of study. Then, all worksheets were gathered in appointed time. The population of study involved experts of refrigerated container terminal, active shipping in the refrigerated goods transport and active traders in this field.6 people of refrigerators yard' experts, 5 people of shipping, and 6 traders were chosen so they could provide relevant information.

3.2. Failure Mode and Effect Analysis

It is necessary to identifiy risk parameters based on FMEA, including the severity and probability of occurrence and detection. In this study, the severity refers to the magnitude of the end effects (outcome) of system failure. Occurrence refers to the frequency of occurrence of root cause, and finally, detection pointes out the probability of detecting a root cause before failure occurrence (Hoseynabadi et al. 2010). Severity, occurrence and detection parameters are rated based on a numerical scale, generally from 1 to 10.

In the next step, the risk priority number (RPN) is calculated for each of the barriers to explain the mitigation strategy. The standard of FMEA evaluation is based on the occurrence, severity, and detection for each risk event. The multiplication of these values obtains a Risk Priority Number (RPN) RPN= Occurrence x Severity x Detection (Hoseynabadi et al.2010).

In general, in FMEA method, there is no RPN basic value basis to be compared with and to delermine risk levels. determined. Therefore, in this study, statistical method was used to determine the level of risk and analysis of data. For this purpose, an indicator of risk or liability level of risk was determined by SPSS software and then, the risk levels specified based on indicators, finally, the mean of RPNs and their standard deviations were calculated as follows:

$$X = 1/N \sum_{i=1}^{N} x1 = \frac{X_1 + X_2 + \ldots + X_n}{N} \quad (1)$$

X= arithmetic mean

N= the number of data

Xi = Data (RPN)

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (X_i - \overline{X})^2} \quad (2)$$

X= Data Mean

Xi= Data (RPN)

N= the number of data

3.3. Analysis

3.3.1. Definition of components functions

With regard to mode of marine transport in the perishable products trade, various elements and components involved. But, we identified three groups of components:

Shipping: its function is to provide timely and appropriate maritime transport.

Port: its function is to fit to load and unload vessels at all time.

Cargo Owner: its function is to receive or deliver goods from / to vessels in port after completing the port/customs formalities.

4. **Results**

4.1. Results of the Level of Risk

RPN is an important tool for rating failure modes and causes of errors. Error analysis and RPN determination need severity, occurrence and detection which are usually "scale 10-point. The ratings problem systems for each scale are provided in Tables 3 to 5.

The severity rating indicates how significant of an impact the effect is for trade of perishable goods. Severity can range from unnoticed effects to critical effects.

The probability of occurrence can be determined from historical data or estimated from known

probabilities of similar events. Here a scale of 1-10 has been defined as follows.

The effectiveness of the controls in place needs to be determined to estimate its usefulness to avoid failures. Here, a scale of 1-10 has been defined as follows:

In order to determine the level of risk and data analysis, at first, means and standard deviations of RPNs were calculated (Table 6). Then, identified risks were prioritized. Based on statistical analysis with SPSS software, 144.46 average and 74.59 standard deviation for 23 risks were calculated. In order to determine the cut-off point, a standard deviation above and below of mean as the cut-off point was chosen.

Accordingly, all of the risks that their priority number are less than below limit of risk (RPN<69.86) have natural conditions, the risks that their priority number are more than high limit of risk (219.06<RPN) have abnormal condition, the risk that their priority number are between high and low risk limit (219.06>RPN>69.8) have abnormal conditions and are in average limit.

Table 3: FMEA Severity Ranking

Rating										**Degree of severity**
1	2	3	۴	5	6	7	8	9	10	
Unnoticed effects	Relatively low effects	Low effect	Noticeable effects	Relatively moderate effects	Moderate effects	Relatively high effects	High effects	Significant effects	Critical effects	

Table 4: FMEA Occurrence Ranking

Rating	Likelihood of occurrence	Probability
1	Remote likelihood of failure	1 in 1.000.000
2	Low likelihood of failure	1 in 300.000
3	Infrequent failure	1 in 25.000
4	Occasional failure	1 in 2.000
5	Relatively moderate failure rate	1 in 500
6	Moderate failure rate	1 in 100
7	Relatively high failure rate	1 in 20
8	High failure rate	1 in 8
9	Almost certain failure rate	1 in 3
10	Certain failure rate	1 in 1

Table 5: FMEA Detectability Ranking

Rating	Detectability Level	% Detectability
1	Certain	95 – 100
2	Almost certain	90 – 94
3	High	80 – 89
4	Relatively high	70 – 79
5	Moderate	60 – 69
6	Relatively moderate	50 – 59
7	Occasional	35 – 49
8	Infrequent	20 – 34
9	Low	0 – 19
10	No detectability	0

Table 6: Mean and standard deviation of RPN

SD	M	
74.59	144.46	RPN
74.59+144.46=219.06		219.06<High limit RPN
69.86-219.06		Average limit RPN between 69.86-219.06
144.46 - 74.59=69.86		69.86>Low limitRPN

Based on the results on Table 7, in failure mode of unfitness of shipping, 4 risks are in the range of average limit and two risks are in the high risk limit, in failure mode of unfitness of port, 12 risks are in the average limit and one risk within high-risk limit and 2 risks in the average limit, in failure mode of unfitness cargo owner, 2 risks are in the average limit and a low risk is at low-risk limit. After prioritizing risks, measures of control aimed at reducing the level of risk. control measures are carried out on the basis of experts' conditions and opinions, finallythe effect and probability of occurrence were reduced. (Table 8).

Table 7: Risk Priority

Failure Mode		Cause of Effect	RPN	Ranking
Shipping	Long Stop of laden container in yard	Irregular frequency of vessel	111.53	2
	Request for payment of port dues	Irregular frequency of vessel	288.59	3
	Transferring cargo to Adjacent port	Some lines tend to return empty containers	147.53	2
		Shortage of empty container	250.35	3
		Irregular frequency of vessel	147.53	2
		No direct transport to some ports	79.12	2
Port	Limited acceptance of container	Small refrigerated yard	176.47	2
		Shortage of plug	198.18	2
		Lack of standard reefer structure	319.06	3
	Time-consuming repair of container especially in top row	Weak support of repair and maintenance	122.76	2
	Unfitness time of delivery of container to customer or loading on vessel	Lack of movement, loading &unloading equipment	86.47	2
		Malfunction of movement, loading &unloading equipment	167.29	2
	Arrival of smaller vessel	Limitation of harbor an channel draft	163.00	2
	Long delay of container in yard	Disorder and interruption software	90.06	2
	Long stop of laden container in yard	Irregular work time	37.18	1
	Long stop of vessel in anchorage	Harbor limitation	178.41	2
	Long procedure of gate out container for stuffing	Lack of knowledge of exit customs door ‘clerk	137.94	2
	Incorrect loading/discharge	Lack of employer’s knowledge	109.71	2
	Stop of export container	Customs/port formality	177.47	2
	Stop of laden container	No connection to railway	37.18	1
Cargo owner	Non-delivery of documents to shipping on time	Documents Problems from the client	68.06	1
		Custom formality	180.59	2
		Shortage of reefer truck	51.12	1

Table 8: FMEA worksheet

Failure Mode		Effect of Failure	Cause of Effect	Current control, Detection
Shipping	Long Stop of laden container in yard	Decrease of export (import)	Irregular frequency of vessel	----------
	Request for payment of port dues	Decrease of export (import)	Irregular frequency of vessel	----------
	Transferring cargo to Adjacent port	Decrease of export (import)	Some lines tend to return empty containers	----------
		Decrease of export (import)	Shortage of empty container	Coordination with shipping before export
		Decrease of export (import)	Irregular frequency of vessel	----------
		Decrease of export (import)	No direct transport to some ports	----------
Port	Limited acceptance of container	Decrease of export (import)	Small refrigerated yard	Investment of port or private co
			Shortage of plug	Cooperation with operation employer
			Lack of standard reefer structure	Investment of port or private co
	Time-consuming repair of container especially in top row	Decrease of export (import)	Weak support of repair and maintenance	Investment of private co
	Unfitness time of delivery of container to customer or loading on vessel	Decrease of export (import)	Lack of movement, loading &unloading equipment	----------
		Decrease of export (import)	Malfunction of movement, loading &unloading equipment	Implementation of PM/CM programs
	Arrival of smaller vessel	Decrease of export (import)	Limitation of harbor an channel draft	----------
	Long delay of container in yard	Decrease of export	Disorder And interruption software	Support of IT department
	Long stop of laden container in yard	Delay in laden /discharge	Irregular work time	Control with operation department
	Long stop of vessel in anchorage	Delay in loading and discharge	Harbor limitation	----------
	Long procedure of gate out container for stuffing	Delay in laden/ discharge	Lack of knowledge of exit customs door 'clerk	Regular training of employer
	Incorrect loading/discharge	Cargo Damaging/corruption	Lack of knowledge of employer	Regular training of employer
	Stop of export container	Decrease of export operation	Customs/port formality	Coordination of port with other active organization
	Stop of laden container	Delay in delivery cargo	No connection to railway	----------
Cargo owner	Non-delivery of documents to shipping on time	Decrease of export (import)	Documents Problems from the client	----------
			Customs formality	Coordination between port and customs
			Shortage of reefer truck	---------

5. Discussion and Conclusions

The inherent barriers of perishable product trade especially in Iran, Bushehr port and mitigation strategies are analyzed. This study contributes to literature in cold chain and trade of perishable goods by providing importance of influencing factors of port on trade. Factors affecting in ports and facilitation of the fresh produces trade had not been investigated in Bushehr. According to the results, the highest risk in shipping group is related to the shortage of empty containers for export with RPN 250/35 and the lowest is to the lack of direct transportation to other ports with RPN79/12, respectively. The highest port's RPN was related to the lack of the standard refrigerated structure and lowest RPN is related to the lack of access to rail and irregular hours of work. the customers' RPNs are located in the average and low-risk limit. Therefore, given the above results, the severity and priority of risks, following control actions should be considered to reduce barriers of perishable products trade:

• Customers (exporter) who have encountered with shortage of empty refrigerated container should coordinate with the shipping's sales department before collecting the goods.

• Malfunction of port loading and unloading equipment is one of the causes of customer dissatisfaction, Therefore, periodic maintenance planning of CM or PM should be performed as a reduction strategy.

• Disorder and disruption of certain software is other factor that slows the export process. Therefore, it is required to strengthen the IT support unit.

• A time-consuming process is port formalities and related units. Thus, with the implementation of cross-border e-commerce application and implementation specified software easing of obstacles is possible.

• Other factors that are without any control action, is outside of the port terminals responsibilities and it is needed to coordinate and plan with other agencies

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