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# Uncertainty handling in containerized logistics: Unitary Traceability Object approach

1<sup>st</sup> Siraprapa Wattanakul

*College of Arts, Media and Technology*  
*Chiang Mai University*  
Chiang Mai, Thailand  
siraprapa.w@cmu.ac.th

2<sup>nd</sup> Napaporn Reeveerakul

*College of Arts, Media and Technology*  
*Chiang Mai University*  
Chiang Mai, Thailand  
napaporn.r@cmu.ac.th

3<sup>rd</sup> Sbastien Henry

*DISP Laboratory*  
*University of Lyon, University Lyon 1*  
Lyon, France  
sebastien.henry@univ-lyon1.fr

4<sup>th</sup> Yacine Ouzrout

*DISP Laboratory*  
*niversity of Lyon, University Lyon 2*  
Lyon, France  
yacine.ouzrout@univ-lyon2.fr

**Abstract**—The transit time of transportation and port clearance is considered as the second most salient risk in the global supply chain. This further affects the accurate estimation of shipment lead time due to the high variability. This research proposes to explore the behaviour of uncertainty influencing the global logistics chain. A literature review is conducted with the classification of logistics roles (shipper, ship liner, Port: Fundamental and Port: Intermodal) to present how the uncertainty currently influence the decisions of each logistics role in strategical, tactical and operational problem. It is found that uncertainty occurred during the logistics operation influence to all logistics roles and it is transferrable to the adjacent logistics role. The Unitary Traceability Object such as smart container has opportunity to monitor the logistics operation and extract the behaviour of uncertainty in the operation. This information further supports the planning decisions to respond/treat the uncertainty.

**Index Terms**—Uncertainty, Global Logistics, Smart Container, Unitary Traceability, Internet of Things

## I. INTRODUCTION

Global supply chain managers considered that the transit time of transportation and port clearance is the second most salient risk due to the high variability of logistics lead-time. In addition, the prediction accuracy is the third salient risk since it interlink to the high variability of lead-time [1]. In others words, the prediction of logistics lead time is difficult to estimate as the range of transit time is wide by several factors. A number of studies that include risk and uncertainty to the consideration of global logistics problems in order to prevent the high impact threats such as natural disaster, terrorism. However, uncertainty can occur at any point in the chain

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threatening the operation time and cost during the logistics operation.

It is interesting to reduce the negative impact of uncertainty such as lead-time variability. Thus, the monitoring and analysis into the logistics operation is proposed to identify the potential uncertainty eligible for the treatment. With the Unitary Traceability Objects (UTO), it offers capabilities to monitor and capture data during the operation in real-time. Such as the case of smart containers proposed by Traxens [2], it collects data of the container position and timestamp in real-time through the travelling globally. This data offers opportunity to get insight into the operation. In addition to the visibility of individual container status, the visibility into uncertainties of the logistics operation is available to be extracted in real-time in the environment of internet-of-things.

Therefore, in order to propose a treatment reducing the impact of operational uncertainty based on the UTO efficiently, this paper conducts a preliminary study to explore the behaviours of uncertainties influencing the containerized logistics actors and then to identify opportunity for reducing the uncertainty impact during the logistics operation using UTO. The paper is organized as follows: Section 2 presents the background of containerized logistics operation, Section 3 proposes the methodology of structural literature review, Section 4 shows the classification result of logistics roles decision influenced by uncertainty, Section 5 proposed implication of result and opportunity of applying UTO for uncertainty monitoring, Section 6 concludes the paper.

## II. BACKGROUND

### A. Containerized logistics operation with uncertainty

Major global logistics agents involves shipper, carrier (sea and hinterland), port and consignee. They have a role to deliver

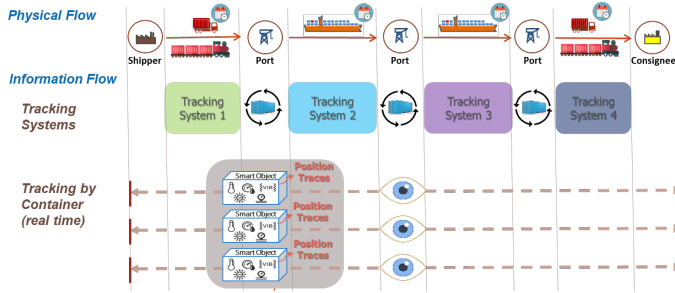


Fig. 1. Containerized logistics; physical flow and tracking information flow

shipment as the planned timetable as illustrated in the Physical Flow of Fig. 1. Before the logistics executes, the logistics plan are made beforehand. From the origin point, shipper manages the packing of cargos and send them to the port of origin within the time schedule. Next, the port loads export containers to the ship liner when it arrived. Then, the container ship sails through ports as defined in the ship route plan. If the container needs a transshipment, it will be unloaded at the port of transshipment and will wait for the scheduled container ship for loading again. Once containers arrive at the port of destination, they will be discharged to the port yard waiting for the hinterland transportation (e.g. truck, train, barge) to pick up. For the container with intermodal transferring, the next hinterland trip allocates a scheduled transportations until the container reach the consignee.

The container might face the regular operation uncertainties such as port congestion, equipment breakdown, waiting queue, etc. occurred randomly in high probability [3]. Ship liners believes that 90% of their schedule unreliability sources is the unexpected waiting time and productivity at port/terminal [4]. The uncertainty can influence to each other among the logistics agent. However, there is not many researches study to the behaviour of uncertainty influencing the containerized operation in the chain level.

### B. Unitary Traceability Object (UTO)

Traceability is an effective method that records the trace of production occurrence. The traceability data are used to optimize the production in the supply chain such as scheduling, resource utilization or unexpected event detection. By the current traceability system in containerized logistics as shown in the Fig. 1, the traceability data are monitored separately by each logistics agent. This limits the analysis of production in the chain level, specifically for the uncertainty that tends to influence the adjacent operation.

Unitary Traceability Object is an object that has ability to collect traceability data along the production process [5]. The smart container as proposed by Traxens Company [2] has abilities to be the unitary traceability object to capture traceability data in the containerized logistics operation. The smart container captures parameters of container storage such as temperature, humidity, vibration, etc. and parameters of container logistics such as position and timestamp. Collected

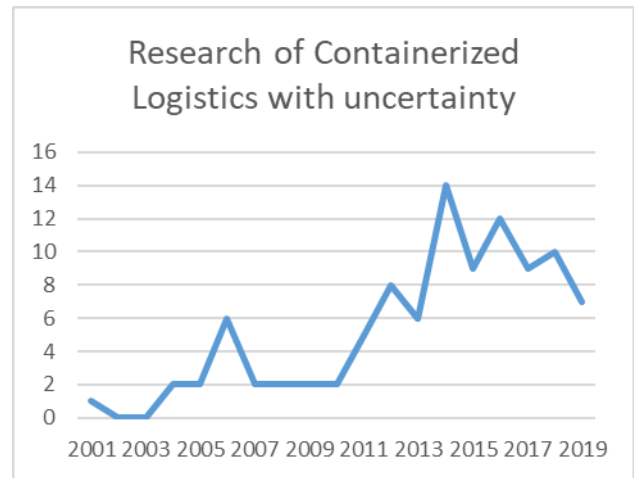


Fig. 2. Statistics of researches in containerized logistics with uncertainty (2001 to 2019)

data transfer via GSM or satellite in real time to the central storage on the cloud; therefore, traceability data of the logistics operation are available through the chain. This allows visibility to track and analyse the operation.

In addition, the smart container is proposed to extend the capability of its traceability data by the proactive monitor the uncertainty during the operation in near real-time. The situation can be analysed with insight information supporting the decision react to the situation effectively [6]. Therefore, in order to identify opportunity for applying UTO capabilities to treat uncertainty in the containerized logistics, the literature review are determined in the following sections.

## III. METHODOLOGY

In order to clarify how uncertainties in the containerized logistics influencing to each logistics agents, this study conducts a literature review within main bibliography sources: Scopus and Web of Science. Search terms consist of three groups of keywords: 1) container, 2) logistics, supply chain, multimodal or intermodal, 3) uncertainty or delay. The search results 157 journal articles. Then, authors review the articles and filter the list with 99 articles remaining only the studies handling the uncertainty in the global containerized logistics. The result set ranges from the year 2001 to 2019 with more research interest since year 2011 (Fig. 2).

*Note:* this literature search is a preliminary study aiming to explore the uncertainties affecting in the global containerized logistics chain. The terms of uncertainty represents in keywords of uncertainty and delay. However, after conducting this study, uncertainty in containerized logistics, can be broadened to congestion, interdependency, stochastic, machine breakdown and transit time. These keywords extends a larger result set of literature searching. The further study, which requires more precision such as the study into the uncertainty handling method, suggests including these keywords.

## IV. RESULTS

### A. Classification of the logistics roles influenced by the uncertainty

The logistics roles consists of Shipper, Ship liner, Port: Fundamental, and Port: Intermodal. The port roles are distinguished iFundamental provide fundamental service transferring container from/to vessel to/from hinterland transportation. The Port: Intermodal performs the same activities of Port: Fundamental but with addition restrictions controlling the quality of container connectivity to hinterland (e.g. time, cost). The decision problems of each logistics roles are then classified in the decision level of strategical, tactical or operational stating with the uncertainty influencing to the decision. The result is illustrated in Table 1.

#### 1) Shipper

The uncertainty influences shippers in the global viewpoint of logistics chain. This group of researches study in the impact of risk and uncertainty to the logistics network in the global viewpoint, which can be benefit not only to the shipper but also to the logistics carrier and port.

- Strategical problem

The problems majorly concerns in the change of network stability as follows:

- *Network vulnerability*: influenced by severe threats such as economic pressure, terrorism, natural disasters, security and safety of the route. The studies only assess the impact of these uncertainties influencing to the network, however, the treatment or improvement of resilience depends on individual logistics agent.
- *Network capacity flow*: due to the uncertainty of demand, the change of capacity results the container traffic that can influence the service capabilities and competitive advantage of both transport carriers and port [7]–[9]. For the shippers, traffic is analysed to identify the potential changes in the flow such as disruptions, security, the transferring between each logistics agents [10].

- Operational problem

The uncertainty during the operation in global view are identified to analyse the impact in time, cost and security. For example, Arikan et al. analysed impact of transportation lead-time variability to economic and environmental performance [11].

#### 2) Ship Liner

Change of market and demand uncertainty is the major uncertainty impact to ship liners due to the main service of container ship benefits from economies of scale. Therefore, their strategical and service planning decisions are to control the demand uncertainty by balancing the demand of container capacity and the vessel service sizing.

- Strategical problem

For carriers to develop shipping network, pricing scheme and future investment, the market and logistics demand are estimated to get the optimal economic advantage [12], [13]. Furthermore, in order to maximize the profit, the others factors causing addition cost are considered to prevent/control on the selected routing such as port choice selection [14], port perturbation [15] and fuel cost [16].

- Tactical problem

The demand uncertainty is also the main influencer to the planning of ship liners. In order to maximize the profit, the demand capacity and the ship space should be in equal. Therefore, the planning of ship size, sequence of sail timing on the route, allocation of container on the ship (both full and empty container), and etc. include the demand uncertainty into the planning model [17]–[21].

- Operational problem

Shippers expect the ship liner to maintain the schedule reliability. Base on the result set of this study, Only two researches study in the delay of vessel, predicting the probability of vessel delay [22], [23].

#### 3) Port: Fundamental

Demand uncertainty also influences to the port similarly to the ship liner and together with the stochastic arrival of transportations. Even with several kinds of uncertainties, port requires to deliver the container transferring speed as contracted with the ship liners. Therefore, a major challenge for the port is the operation time under various uncertainties.

- Strategical problem

Coping with the capacity uncertainty to improve stability for port service as follows:

- *Port competitiveness and connectivity*: a port with stable processing time and network connectivity for cargo distribution can attract shipper/ship liners. In order to improve its competitiveness, the assessment of container flow proposed to handle with the uncertainty of congestion and demand [24], [25].
- *Port infrastructure*: port service can be interrupted by the change of climate, water level, demand. These uncertainties are considered in the port infrastructure to improve flexibility of port service [26]–[28][13,36,wos2].
- *Port resilience*: hazardous and emergency events can harm port security and cause disruption to the port. Safety policy and transportation network proposed to reduce the vulnerability [29], [30]

- Tactical problem

As mentioned that port operation time is a significant index, therefore, the planning of the port involves the port resource management synchronizing to meet the service level agreement. The

TABLE I  
CLASSIFICATION OF THE LOGISTICS ROLES INFLUENCED BY THE UNCERTAINTY

	Strategical (42)		Tactical (40)		Operational (17)	
	Problem	Influencer	Problem	Influencer	Problem	Influencer
<b>1. Shipper (14)</b>	<b>(10)</b>		<b>(0)</b>		<b>(4)</b>	
	Network vulnerability	economic pressure, severe risks	-	-	Risk analysis: operation	security, time, cost
	Capacity flow	demand uncertainty				
<b>2. Ship Liner (21)</b>	<b>(6)</b>		<b>(13)</b>		<b>(2)</b>	
	Competitiveness	demand uncertainty	Ship planning	demand uncertainty	Risk analysis: operation	delay
	Risk analysis: cost	disruption, policy			Arrival prediction	stochastic arrival
<b>3. Port: Fundamental (27)</b>	<b>(11)</b>		<b>(10)</b>		<b>(6)</b>	
	Competitiveness	demand uncertainty	Resource planning	external stochastic, operation time	Risk analysis: interdependency	lead time, delay, congestion
	port infrastructure	climate, water level, demand			Risk analysis: breakdown	delay and cost
	Port resilience	hazardous/emergency events				
<b>4. Port: Intermodal (37)</b>	<b>(13)</b>		<b>(17)</b>		<b>(7)</b>	
	Competitiveness	quality of connection, travel time, cost, throughput	Transit flow planning	traffic	Risk analysis: flow	flow time, delay, fault diagnosis
	Port Infrastructure	economic performance, congestion	Resource allocation	delay		
	Network flow	traffic congestion, disruption, transit time	Transport allocation	time-restriction, capacity, delay		
	Tracking policy	delay, unexpected event				

problems are such as berth allocation [31]–[33], crane scheduling, container yard storage planning [34], [35]. These operations handles with stochastic arrival of containers and reducing delay either from the vessel or from the hinterland transportation [32], [36], [37].

- Operational problem

Port operation is analysed to identify risk and impact such as the lateness of container [38], the closure of port-of-entry [39], port [4], and machine breakdown [40]. The impact results mainly in time dimension.

4) Port: Intermodal

This logistics role is the most interest area in handling uncertainty. Quality of connectivity, transit time and cost are priorities.

- Strategical problem

- *Port competitiveness*: researches analyse the risk in the quality of connection to hinterland e.g. port

throughput, travel time and cost [41]–[43].

- *Port infrastructure*: the infrastructure models propose to cope with congestion, transshipment time/delay, capacity expansion, etc. [44]–[46].

- *Network flow*: uncertainty in traffic congestion, disruption and transit time are analysed to improve the hinterland network flow [47]–[49].

- *Tracking policy*: technology such as RFID proposes the visibility to shipment delay and unexpected events in terminal operation [50]–[52].

- Tactical problem

Concerning in the uncertainty of delay in transferring, several studies propose models for the transferring under the uncertainty of time and capacity, to allocate resources(staff, facilities, inter-terminal transportation) [53]–[56], to allocate transportation slot [57]–[60], to allocate space in real-time [61], [62] or to plan the container move based on traffic flow [63]–[65].

- Operational problem

The operation of container flow propose to analyse flow timing [66]–[68], the delay and missing of transshipment [69], port operation handling time [70], [71] in order to understand the time constraint and minimize transfer time/delay.

## V. IMPLICATION

### A. Role of uncertainty in containerized logistics

There are three major kinds of uncertainty influencing in the containerized logistics as follows:

1. *Demand uncertainty* effecting the capacity load of containers, balance of network flow and competitiveness of all logistics agent. It affects the strategy of logistics agent to acquire the capacity load to gain profit from the market. Then, it affects the tactical planning to allocate adequate facilities for the logistics.

2. *Severe risk/economic pressure* this kind of uncertainty has high potential to freeze and damage the logistics operation with high impact. However, the chance of occurrence is low. Therefore, the handling of this uncertainty is in strategical level.

3. *Operational uncertainty* this uncertainty occur in daily stochastic during the operation resulting an uncertain to shipment schedule and cost. It occurs during the operation in more frequent than the other uncertainties as mentioned above.

### B. Current uncertainty handling approaches

According to the proportion of research studies, there are two major approaches handling uncertainty. The strategical level handles the high impact uncertainty of demand uncertainty and severe risk/economic pressures. The tactical level handles the more frequent uncertainty which mostly occurs during the operation.

The operation of Ship liners, Port: Fundamental and Port: Intermodal are interconnected and the uncertainty of each agent can be interconnected during the operation as well. For example case of shipment delay, Ship liners operate the sailing with uncertainty in delay arrival time. According to the statistics of global schedule reliability of container ship, the pattern of ship arrival are vary in each year (as shown in Fig. 3.) [72]. Then, the Port: Fundamental needs to receive this stochastic arrival to the port operation. In some cases, port offers an acceleration to the port operation and absorbs the delay by changing the plan of port resources. On the other cases that the port cannot offer the acceleration, the vessel has to wait the next available time slot for berthing and this is also the change to port planning as well. Somehow, the port receives the trace of uncertainty influencing to the port operation which can be transferred to the next process stage of Port: Intermodal.

The result set of this study also show that the port planning concerns the stochastic arrival of transportation. The Port: Intermodal which is in the further logistics stage, particularly concerns the quality of connectivity and transit time as the

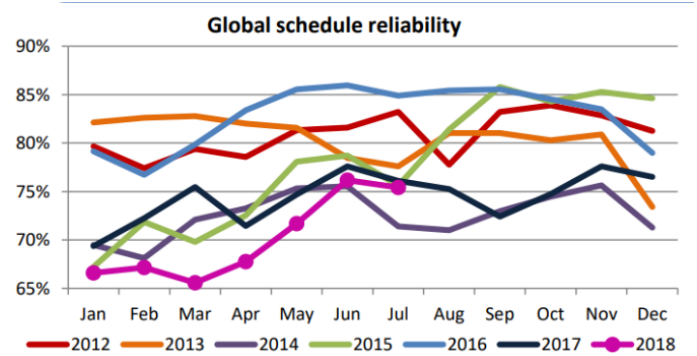


Fig. 3. Statistics of global container vessel schedule reliability (2012 to July 2018), Source: Sea-Intelligence Maritime Analysis

most of the decision problems of Port: Intermodal are related to the timing.

Therefore, the uncertainty tend to be transferrable among the logistics adjacent in the form of container operation timing. It could be more complex for the Port: Fundamental since it is in the center of the chain receiving/transferring containers to several modes of transportation. However, the recent studies of this result set analyse the impact of uncertainty to a specific case such as the congestion or machine breakdown or stochastic arrival of vessel. However, in the operation, there can be several uncertainty influencing in the environment. The ability to capture and analyse the behaviour of uncertainty in operation time is expected to support the decision of operation planning in tactical level.

### C. Uncertainty handling: UTO approach

The outstanding abilities of the UTO compliments the uncertainty monitoring as follows:

- UTO monitors the object movement through the logistics travelling.

This compliments the monitoring of uncertainty in the logistics chain. The trace of uncertainty occurring at any point of chain can be captured, on the ship, on the port or during the transit.

- Each UTO is in the internet-of-things environment.

Not only one instance that is capturing the operation data. At the same time, several UTOs are capturing data. The analysis of uncertainty relation embedded in each logistics activity is possible.

- UTO captures logistics operation time in real-time.

The uncertainty such as stochastic arrival of ship is difficult to identify the pattern due to the sea sailing faces various kinds of external factors. With the more recent of information, the trend of stochastic is possible to predict in a more accurate.

In shorts, UTO offers the opportunity to acquire the information of uncertainty of operation time flowing through the logistics chain. Further, the relationship of uncertainty trace among operation activities can be identified. Later, the planning to cope with this uncertainty becomes more accuracy.

## VI. CONCLUSION

The high variability of global logistics transit time leads to the interest of studying in uncertainty, especially the uncertainty occurred during the operation. The literature review conducts to explore how each logistics role in the containerized logistics is influenced by uncertainty. The result of classification proposes the relation of uncertainty to each logistics role in each decision level. The implication presents the interconnected of uncertainty among the logistics role in the chain, however, the behaviour of the uncertainty relation among these parties are not studies. The UTO which has capabilities travelling into the operation to capture the operation time, offer the chance to acquire the operation data embedded with uncertainty in operation time. The behaviour of uncertainty is then possible to quantify. This paper has not clarified the uncertainty extraction method or the relationship of uncertainty and the logistics transit time. The further study is suggested.

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