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A Literature Review On Multimodal Freight Transportation Planning Under Disruptions

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Abstract. This paper reviews publication that focuses on multimodal freight transportation planning under disruptions. In this paper, disruptions are specified by the level of the disruptions occurs and the scope of its effect. This becomes an important distinction since the cause and effect that may occur at different levels. The failure to make this distinction has implications for how we understand and manage. The reviewed papers include those that develop framework, model, and technical procedure for freight transportation. Finally, we provide an outlook of future research directions on the domain of transportation planning.

1. Introduction

Transportation development is directed towards the integration of effective and efficient service and intermodal transportation facilities networks. This integration is in form of interconnection on transportation node that functioned as a meeting point of mode interchange, which is named as intermodal terminal that can provides additional values. The service network is created through the inter-route integration of road, train, sea, air, river and lake transportations regarding the specialty of respective transportation mode. This can be based on the concept of combination of main, feeder, and advanced modes. This intermodal integration provides special challenge to logistic service providers, especially in facing the uncertainty factor that always causes losses.

Uncertainty in supply chain is one of the factors that influence freight transportation movement. Each company has different level of uncertainty [1] [2]. This level of uncertainty depends on the driver of the uncertainty itself, including: delivery lead time uncertainty, price uncertainty, quality uncertainty, and uncertainty in availability. Angkiriwang et al.[3] explained that supply uncertainty is one type of uncertainty in the supply chain context and its can disrupt the supply network.

Disruption is one form of uncertainty. Disruptions in terms of supply network may come from internal and external sources. Internal disruptions may be caused by engine damage, disturbance in import or export, transportation failure, disruption on shipping chain, change on demand, technological innovation, change on material price, and many more. External disruption includes supplier failure, supplier quality problems, oil crisis, accident, and natural disaster [4]. There are many researchers that studied disruptions in the context of supply network. Author [5] reviewed disruption on multimodal transportation network with regard on external factor as optimum point of reference, which was the cost minimization. Authors [6] [7] [8] also reviewed papers on disruption on supply network. Author [6] criticized literature on multimodal transportation network based on transportation planning level (strategic, tactical, and operational levels). Author [7] investigated literature on disruption and resilience on supply network. They used graphic theory reference to differentiate the type of disruption by dividing disruptions into three levels: line, node, and network. While author [8] analyzed literature on disruption with regard to recovery. The topic of disruptions on supply network is highly interesting. This is evident from the high number of research regarding this, as well as there are still many research area in this field that need to be explored further [5] [6] [7] [8].

This paper aims to classify papers on disruptions on multimodal transportation network, specifically for freight transportation by classifying the level and behaviour of disruptions, models solution method, as well as objectives of the model. The final objective is to identify research gap that can be used as the reference for future research.

The rest of this article is organized as follows. Section 2 reviews the literature on multimodal freight transportation under disruption that is broken down into description of the conceptual, models and the solution methods. Section 3, discusses the opportunities for future research based on the identified gaps.

2. Literature On Multimodal Freight Transportation Network Under Disruptions

According to [7], disruptions on supply chain network can be described based on the perspective of network graph theory. They illustrated graph as collection of nodes connected by a link (figure 1). Disruption was analyzed based on 3 levels: node, link, and network, featured also on Figure 1. On multimodal transportation network, node is a transportation facility, such as: intermodal terminal, factory, warehouse, depot, or retailer outlet. Link is the line used to transport goods from one node to another by using trucks, trains, ships, airplanes. Figure 1 shows the location/level of disruptions and its effect on the network. Figure 1b explains disruptions occurs on line level (depicted on line a14), and this disruption hampers the line a14 only. Node disruptions level is explained by Figure 1c, occurs on node n7 and damages node 7 itself, as well as line a7 and a13. Meanwhile the network level disruption is different with the former two that still have the alternative line for freight shipping. Disruptions on network level may not provide alternative line for freight shipping. In Figure 1d, disruptions occur on node 3 and line a2. These disruptions trigger, or hamper disruptions in network level.

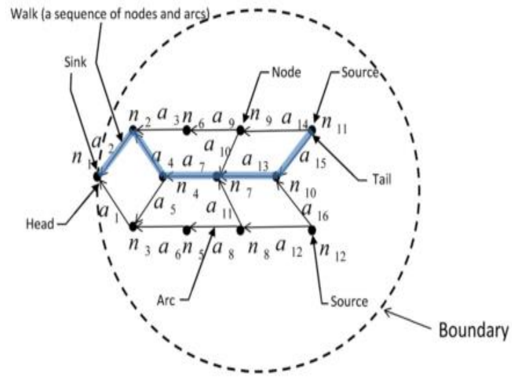

Figure 1. Supply Network[7].

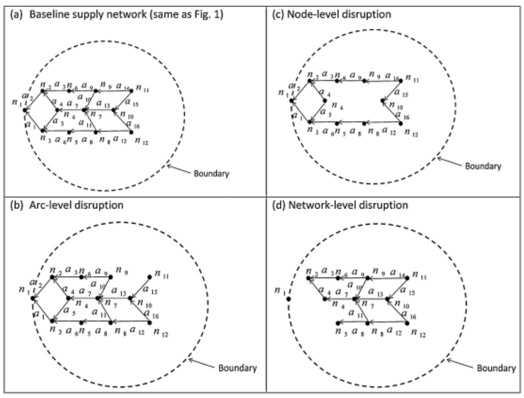

Figure 2. Examples of supply disruptions at links-, nodes-, and network-level [7]

Table 1 explains research progress based on the scope of disruption effect on the network (line, node, or network). Most of research studied disruption on line and node levels. There were only a small number of researches that studied disruption on network level. In addition, some researches were not explained in detail regarding the scope disruption being studied.

Author [7] stated that a clear border must be created between disruptions occurs on line, node, and network levels. This is related to the strategy that must be prepared to face and/or to deal with the disruptions. Some journals clearly stated the scope of the disruption. Nevertheless, there were also some journals did not. From the perspective of graphic theory, if disruptions occurs on line or node level, those line or node only need to remove line and node from the network supply graphic. This is since the disrupted line or node may no longer in function, so that materials cannot pass through those areas, and

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other alternative routes may probably be found. On the other side, if disruptions occurs on network level, alternative routes may probably unable to be made, since the core line or node cannot be used. This probably means that network level disruption occurs when there are more than one type of disruption take place on particular node or line that may causes disruptions on network level.

Table 1. Matrix Supply Network Disruptions.

Disruptions Level	References
Link	Morlok&Chang[9], Gedik *et al.*,[10] , Narayanaswami and Rangaraj[11], Zilko, Kurowicka and Goverde[12], Huang, Hu and Zhang[13], Burgholzer *et al.*, [14], Ishfaq[15], Gedik *et al.[10]*, Azad, Hassini & Verma[16], Uddin and Huynh[17], Miller-hooks, Zhang and Faturechi[18], Pant, Barker and Landers [19]
Node	Di, Lai and Zuddas[20], Liu, Zheng and Zhang[21], Fialkof et al.[22], Uddin and Huynh[17], Miller-hooks, Zhang and Faturechi[18], Pant, Barker and Landers [19]
Network	Daskin & Snyder [23], Starita et al. [24]

Scope of disruption occurs is also depends on the type of disruption itself. Some journals described the definition of disruption clearly, as well as its size. Nevertheless, some journals did not. Those journals only explained that the occurring disruptions intrude the node or line. Table 2 explains the definition and size of disruption. Each disruption has different effect on network. An operational measure of disruptions is used to find out the effect. Clear explanation on how to measure the disruptions will give the good guidance for the paper. Some paper used an operational measure of disruptions clearly, for example delay as a variable used to show the disruptions performance. In addition, Table 2 also explains network performance measure. In the literature, network performance measured through economic goals that defined as a multimodal network cost. This cost usually consists of transfer cost, transportation cost, delay cost, penalty cost, recovery cost etc. On the other hand, some literatures considered other performance measures in this topic area; time (variation of delay, length of disruptions).

Strategies used in facing disruptions are aimed to make the supply network more effective, efficient, resilient, flexible, and adaptive. Planning on facing disruptions divided into three levels: strategic, tactic, and operational planning level [6]. Strategic level is the stage of risk mitigation; tactical level is a preparation stage; and operational level is the stage of stability and recovery [8]. Many paper use flexibility strategy that used in their transportation planning models. This strategy to maintain service level and responsiveness in facing disruptions [3]. Challenge on implementing flexibility is the increasing cost, even though, on the other side, service level increases. Some studies implemented flexibility strategy on transportation route and mode to face disruption. This is concluded in Table 3.

Table 2. Existing Research on Multimodal Transportation Network.

No.	References	Definition of Disruption		Performance Measures
		Conceptual Definition	Operational Measures	
1	Morlok&Chang [9]	Disruption not formally defined.	Level of delay	Total cost
2	Gedik et al[10]	Disruption not formally defined.	Level of delay	Total transportation & delay cost
3	Narayasnawami &Rangaraj[11]	Disruption as an incident involving track unavailability between a pair of a stations in the operational domain and that can lead to violations of some of the critical and/or preferred constraints of the system.	A small time window of delay (delay of service) and disturbance locations.	Delay
4	Zilko, Kurowicka&Goverde [12]	Disruption defined as an unexpected accident that disrupt the railway timetable (case study in track circuit failure in Netherland).	Length of disruption measured from latency time and repair time. Latency time is the length of time the mechanics need to get disrupted site and the repair time is the length of time they need to repair the problem.	Mean of prediction length of disruption.

No.	References	Definition of Disruption		Performance Measures
		Conceptual Definition	Operational Measures	
5	Huang, Hu&Zhang [13]	Disruption defined as an unexpected events (hurricane, the snow disaster, traffic accident etc) happening in one link of the multimodal chain could result in the disturbance of pre-decided transportation activities.	The duration of a disruption event (delay of current transport activity). The duration of disruption events measured by collect historic statistic data of typical disruption events in the specific transport mode.	disturbance in system level
6	Burgholzer et al [14]	Disruption defined as a disturbance in individual sections (links) that can decrease the performance level of a network.	Disruption as an amount of performance level of a network drops when a link disrupted. The model use network performance indicator to measure it.	Transport time
7	Ishfaq [15]	Disruption defined as a incident that caused by external source in supply chain	Disruption measured by delay time.	Transportation cost.
8	Azad et al. [16]	Disruption not formally defined.	No operational measure for disruption	Transportation cost.
9	Uddin&Hyunh [17]	Disruptions defined as incident that disrupt node, link or terminal	Disruptions measured based on link capacity in node, link and terminal. Capacity will be reducing 50% in link and 80% in node and terminal 50% when this point was disrupt. It make the travel time increase.	Transportation cost (transportation cost, transfer cost, penalty cost)
10	Miller-Hooks, Zhang&Faturechi [18]	Disruption defined as a disaster scenario.	Five disruption scenario that define their level of disrupt (bombing, terrorist attack, flood, earthquake, and intermodal terminal attack).	Resilience level
11	Pant, Barker & Landers [19]	Disruption defined as a incident in inland waterway that caused economic losses (supply and demand shortage) for the industries using facilities along this waterways.	Disruption metric used to measure the disruption effect.	Transportation costs
12	Di, Lai&Zuddas [20]	Disruption not formally defined.	No operational measure for disruption	Transportation Cost
13	Liu, Zheng & Zhang [21]	Disruption defined as a machinery breakdown of QCs in work. QCs are the major tools to unload and load containers from the vessels.	Disruption period is multiples time of the unit time. The disruption duration not be calculated accurately but repair workers can give an approximate recovery time according to their experience.	Negative deviation from the originally planned schedule
14	Fialkof et al.[22]	Natural Disaster	Level of delay	Transportation cost.
15	Daskin&Snyder [23]	Disruption defined as a incident that disrupt the system (natural disaster, manmade, etc)	No operational measure for disruption	Transportation cost.
16	Starita et al.[24]	Natural disaster	Banjir	Transportation cost.
17	Chen&Miller-Hooks[25]	natural or human caused disaster	No operational measure for disruption	Transportation cost.
18	Udenta et.al [26]	Disaster and external effects caused by vehicles entering the system	Beta variable to describe whether disruption occurs or not. Beta is a distribution function. If normal, its value is close to zero. While if disruption occurs, its value will be close to 1.	Transportation time and vehicle flow on line
19	Sun&Sconfeld[27]	Disruption on vehicle movement on intermodal terminal	No operational measure for disruption	Holding time
20	Jiang, Wang & Ding [28]	Disruption not formally defined	No operational measure for disruption	Deviation between planning and real condition

No.	References	Definition of Disruption		Performance Measures
		Conceptual Definition	Operational Measures	
21	Ahmadi-Javid&Seddighi[29]	Disruption occurs on production process/capacity disruption (influences location allocation) as well as on delivery process (influences routing)	No operational measure for disruption	Transportation cost.
22	Cui et al.[30]	Disruption not formally defined	No operational measure for disruption	Transportation cost.
23	Hu, Sun & Liu[31]	Dividing disruption based on its source (customers, vehicles, roads)	No operational measure for disruption	Shipping distance addition increase and customer uncertainty level
24	Ivanov et al. [32]	Disruption not formally defined	No operational measure for disruption	Transportation cost.

Tabel 3. Transportations Planning Strategy.

Transportation Planning	Models	Reference
Strategic Planning Problems	Facility Location Problem	Daskin&Snyder [23], Ahmadi-Javid&Seddighi [29]
Tactical Planning Problems	Network Flow Planning	Ivanov et al. [32], Hu, Sun & Liu [31], Cui et al.[30], Ahmadi-Javid&Seddighi [29], Sun&Sconfeld [27], Udenta et.al [26], Chen&Miller-Hooks[25], Uddin&Hyunh [17], Ishfaq [15], Di, Lai&Zuddas [20], Huang, Hu&Zhang [13], Zilko, Kurowicka&Goverde [12], Gedik et al [10], Miller-Hooks, Zhang&Faturechi[18], Burgholzer et al[14], Fialkof et al. [22]Starita et al. [24]
Operational Planning Problems	Routing and Schedulling Problem	Jiang, Wang & Ding[28], Liu, Zheng & Zhang[21], Narayasnawami &Rangaraj[11], Pant, Barker & Landers[19], Azad et al. [16]

Modeling approach is implemented to identify and solve the problem based on the objectives function. According to the models objective, some previous papers solved the problems by using a variety of solution methodologies, such as optimization models, simulation models and heuristic/meta-heuristic model. Table 4 explain about method or approach used in the reviewed papers.

Tabel 4. Solution Methodology.

Solution Methodology	Reference
Optimization Approach/Exact	Narayasnawami &Rangaraj[11], Gedik et al[10], Zilko, Kurowicka&Goverde[12], Huang, Hu&Zhang[13], Ishfaq[15], Miller-Hooks, Zhang&Faturechi[18], Di, Lai&Zuddas[20], Liu, Zheng & Zhang[21], Ivanov et al.[32], Uddin&Hyunh[17], Azad et al.[16], Daskin&Snyder[23], Udenta et.al[26], Sun&Sconfeld[27], Cui et al.[30], Hu, Sun & Liu [31]
Simulation	Burgholzer et al [14]Pant, Barker & Landers [19]
Heuristic/Metaheuristic	Fialkof et al.[22], Starita et al.[24], Jiang, Wang & Ding[28], Ahmadi-Javid&Seddighi [29]
Combination	Chen&Miller-Hooks[25]

3. Conclusions and future research directions.

This paper reviews literatures concerning disruptions on multimodal transportation network, specifically for freight transportation. Disruptions can be divided into three levels: link, node, and network. Most of papers studied disruption on the link and node levels. There are only a small number of papers that studied disruptions on the network level. Beside disruption level, type of disruption also need to be studied further, especially type of disruption in the network (such as high level of natural disaster) [15]. This type of disruption may result in the supply network paralyzed totally.

Proper strategy need to be made to face each type of disruption. Steps done in transportation planning includes: risk mitigation (estimation of probable economic effect), preparedness (estimation of effect on deviation level of performance network), as well as stabilization and recovery (proposing effective, efficient, and flexible recovery strategy). Some strategies used in the above literatures are alternative route, mode, depot, and departure schedule determination. Some literatures also used buffer capacity and inventory, as well as location and allocation determination strategies. Coordination strategy needs to be developed further on this topic of disruption.

Performance measure used in most of literatures was the cost, while some papers used the time as their performance measure. There are many cost components that can be used as performance measure. Especially when cost analysis is combined with transportation network controlling model such as adaptation cost in order to be resilient or robust. On the other side, there is a huge opportunity to research this field with taking more than one performance measures into consideration. In this case, multi criteria decision making approach can be used. In addition, [3] said that the balance between efficiency and flexibility in supply network with disruptions still need to be developed since there were only a few papers did it. It is an interesting topic when facing uncertainty conditions.

Regarding the solution methodologies, there is a big opportunity to use another method that can solve the problems. According to [6], when facing a huge problems, a more sophisticated approaches should be employed to address the complex problems. Dealing with such complex problems may create computational issues and hence approaches to bring more efficient methodology should be made. Various techniques such as parallel computation and algorithms may promise significant improvements in solving huge problems.

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