



## Original article

A systematic literature review on humanitarian logistics using network analysis and topic modeling<sup>☆</sup>Jin Ju Kim<sup>a</sup>, Hyunmi Jang<sup>a,\*</sup>, Saeyon Roh<sup>b</sup><sup>a</sup> International logistics and Port Management, Graduate School of International Studies, Pusan National University, Busan, Korea<sup>b</sup> International Logistics, Plymouth Business School, Plymouth University, Plymouth, United Kingdom

## ARTICLE INFO

## Article history:

Received 20 June 2022

Accepted 17 October 2022

## Keywords:

Humanitarian logistics

Systematic literature review

Keyword network analysis

Topic modeling

## ABSTRACT

The aim of this paper is to conduct a systematic literature review to understand the research trends, identify area of improvements and recommend the future research direction in humanitarian relief logistics (HRL). Using Netminer 4.0, keyword network analysis, keyword frequency analysis, and topic modeling analysis were undertaken. As a result, it has been identified that the number of studies on HRL continuously increased since it mounted in the mid-2010s, with the main issues changing by period. Keyword network analysis and keyword frequency analysis discovered that establishment of the HRL identity and disaster response, preparation and recovery were the main issues from 2005 to 2009. Whereas followed by education and practical logistics flow (2010 – 2014) and provision and coordination (2015 – 2019) to be the main focused area of research. Through topic modeling analysis, nine topics (*preparation, coordination, stakeholders, sustainable development, facilities location, recovery, supplying and sourcing, emergent response, transportation, supplying and sourcing*) were extracted. *Facilities location* was the most frequent topic that studied in the number of papers. Meanwhile, *recovery, preparation, stakeholders, and emergent response* showed downward trends but *facilities location, coordination, and supplying and sourcing* showing upward. This study is significant in the sense that it suggests research trends in different approach using keyword network analysis, keyword frequency analysis, network analysis and topic modeling which are one of the first attempts in research trend analysis in HRL field. This study will support HRL studies by understanding macroscopic and comprehensive way and set as a steppingstone for future research direction.

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## 1. Introduction

The COVID-19 pandemic has emphasized the importance of humanitarian relief logistics (HRL) as a field of study. Van Wassenhove (2006) highlighted that HRL started to be recognized as integral to any relief operation. The range of supply chain and logistics costs constitute between 62% and 79% of all costs as they are key to saving time and costs in humanitarian response, building HRL capacities should be an important objective of humanitarian investments (Van Wassenhove, 2006).

In HRL research, there have been many attempts to analyze current research trends and set future research directions, including

the analysis of research trends from 2005 to the early 2010s— where studies focused on HRL in general and its importance with traditional literature review methods. Latter studies mainly adopted the bibliometric methodology, analyzing and forecasting major research trends by determining the influential papers based on related statistics (e.g., number of articles and citations) and through clustering to uncover affiliations among authors.

However, utilizing network science and leveraging network modeling for research trend in HRL is scarce. Although network analysis has been applied in other fields of study, (e.g., sociology, economics, business administration, etc.) it has seldom used in HRL. Only Zary et al. (2014) conducted research trend analysis with respect to citations and co-citations to analyze knowledge networks. Network analysis is distinguished from other existing methodologies which it allows unearthing significant findings; it does so by supplementing statistical analysis methods (Lee, 2012). Using network analysis to analyze research trends in HRL can therefore open up a perspective not seen in previous analyses.

<sup>☆</sup> The findings of this study have been presented in the 25th International Symposium on Logistics (ISL21) on 12<sup>th</sup> and 13<sup>th</sup> July 2021.

\* Correspondence to: 2, Busandaehak-ro, 63beon-gil, Geumjeong-gu, Busan 46241, Korea.

E-mail address: [jangh01@pusan.ac.kr](mailto:jangh01@pusan.ac.kr) (H. Jang).

The current study comprehensively reveals HRL research trends using text-mining methods—keyword frequency analysis, keyword network centrality analysis and topic modeling. First, highly important and frequently mentioned keywords are identified with keyword frequency analysis with two phases – Term frequency (TF) analysis and TF-IDF (Term Frequency-Inverse Document Frequency) analysis in time series manner. Second, key issues in HRL are determined using a keyword network analysis method that calculate the frequency of simultaneous appearance of key words and trends vis-à-vis their time series to examine Further, key research topics in HRL are determined using topic modeling analysis along with examining changes that occur within the time series. The utilization of these research trend analysis methods is noteworthy for their abilities to provide objective and comprehensive views on the HRL research trends and set further research direction effectively.

## 2. Literature review on humanitarian logistics

Many research have been conducted to summarize research HRL trends and set future research direction (Table 1). Kovács and Spens (2007) and Overstreet et al. (2011) provide the fundamental framework to understand HRL using qualitative research methods. Natarajarathinam et al. (2009) classified and summarized supply chains in crises into five frameworks. Altay and Green (2006) summarized HRL operational research (OR) and management system (MS literatures); Galindo and Batta (2013) conducted research trend analysis on HRL OR/MS to bridge the post-2006 research lacuna. Meanwhile, HRL research trend analyses on optimization models (Caunhye et al., 2012; Manopiniwes & Irohara, 2014), transportation models (de la Torre et al., 2012; Safeer et al., 2014), and inventories (Clay Whybark, 2007) were also conducted. Additionally, infectious diseases and biochemical terrorism, refugees, HRL transparency and disasters in certainty can also be found in recent studies (Dasaklis et al., 2012; Seifert et al., 2018; Khan et al., 2019; Masudin & Fernanda, 2019).

Most pre-2013 studies adopted the traditional literature review methodology excluding the attempt to use meta-analysis (Kunz & Reiner, 2012). Since then, systematic literature review was widely conducted (Abidi et al., 2014; Leiras et al., 2014; Zary et al., 2014; Nurmala et al., 2017; Chiappetta Jabbour et al., 2017; Banomyong et al., 2019). The increase in the number of related studies made it possible to apply the systematic literature review methodology (Chiappetta Jabbour et al., 2017; Banomyong et al., 2019). Systematic literature review can reduce authors' subjective views which otherwise seen in traditional literature reviews (Jeong & Park, 2019). Using bibliometric method and network analysis, the systematic literature review is found to be an outstanding research trend methodology that enables in-depth analysis (Fahimnia et al., 2015; Akter & Wamba, 2019). In particular, the use of keyword network analysis—which forms and analyses networks based on the frequency of simultaneous appearance of keywords—makes it possible to determine relationships among research topics and specific issues related to certain topics, while also bringing forward new insights into knowledge development (Choi et al., 2011; Jeong & Park, 2019).

Zary et al. (2014) used both the bibliometric method and network analysis for research trend analyses of HRL for the period 2001–2014. They sought to determine the development status of studies related to HRL by leveraging the bibliometric method, and clarified leadership and knowledge networks by performing citation and co-citation network analyses (Zary et al., 2014). However, the limitation of co-citation analysis lies in that the first author is mainly considered and to secure legitimacy of literature review, it demands to study the articles in detail. (Bhattacharyya & Verma, 2020).

Meanwhile, social network analysis (SNA) also conducted to explore social networks related to HRL by analyzing patterns of communication in organizations involved in HRL operation (Álvarez & Serrato, 2013) and the characteristics of online user networks in disasters (Kim & Hastak, 2018).

Therefore, the current study aims to uncover HRL research trends by using network analysis in an innovative manner (e.g., topic modeling analysis and keyword network analysis). To the best of our knowledge, this attempt is the first of its kind in HRL research trend analysis.

## 3. Network text analysis

Network Text Analysis (NTA) encode the relationships between words in a text and constructs a network of the linked words (Diesner & Carley, 2004; Popping, 1999). It is based on the thinking that 'texts can be represented as networks of concepts' (Paranyushkin, 2011, p. 3), and 'the extracted networks contain representations of social structure' (Diesner & Carley, 2005, p. 2). By using network text analysis, researchers can interpret relationships among concepts that were not previously known (Diesner & Carley, 2005; Paranyushkin, 2011).

In network text analysis, the influence of each node in the network is measured through network centrality analysis (or keywords, if it is a keyword network); it attempts to identify the most influential keywords and understand the meaning and intent delivered in the entire text (Park & Jeong, 2013).

Degree centrality is the key indicator in centrality analysis that shows the number of connections of a certain word have with others. Words with high degree centrality are those keywords that convey the research topic (Song et al., 2018). The greater the number of direct connections a node has with neighboring nodes, the higher its degree centrality. Betweenness centrality measures the mediating role one node plays in building a network with other nodes; the node undertaking this role can have a great impact on controlling the information flow. Betweenness centrality is measured in terms of node proximity; concepts with high betweenness centrality create various meanings in the overall text (Park & Jeong, 2013) and are useful in finding connectivity between two different research topics (Jeong & Kim, 2018).

Topic modeling, identifies the topics latent in the text of existing materials and documents and analyses the ways in which topics interconnect (Blei, 2012). Latent Dirichlet allocation (LDA) is the most commonly used topic modeling technique because it extracts topics based on highly correlated words by calculating the frequency of simultaneous appearance of keywords in a massive document dataset (Blei, 2012; Nam & Nam, 2020). LDA topic modeling postulates follows. A document consists of several topics which emerge from the synthesis of words and these words are intentionally selected by the authors. The topic distribution of the document can be assumed by examining the distribution of observed words in the document. In other words, unlike the general clustering technique—wherein each document is allocated a single topic—LDA posits that 'documents exhibit multiple topics, and each document exhibits the topics with different proportion' (Blei, 2012, p. 3). Therefore, it is possible to estimate topics hidden in the document by determining the ratio of topics in the document and the probability of a word being included in the topic. (DiMaggio et al., 2013). As LDA topic modeling is advantageous in reducing data volume, generally uses simple algorithms, and producing consistent topics it is frequently utilized in studies in a large volume of documents that look to pinpoint topics (Yang et al., 2019; Nam & Nam, 2020). In addition, as topic modeling is conducted automatically, it can reduce a high cost

**Table 1**  
Meta-analysis of previous literature review in HL.

	Altay and Green (2006) OR/MR research in disaster operation management	Kovács and Spens (2007) HRL in disaster relief operations	Clay Whybark (2007) Issues in managing disaster relief inventories	Natarajathinam et al. (2009) Managing supply chains in times of crisis: a review of literature and insight	Overstreet et al. (2011) Research in HRL
Scope	OR/MR literature in disaster operations management	Literatures on HRL	Literatures related to inventory in HRL	SCM-related literatures in disaster situation	HRL literatures related to sudden onset disasters
Objective of research	To suggest future research directions by studying OR/MR literature	To discover and explain characteristics of HRL in disaster relief operation	To enlarge the scope of inventory research in HRL and suggest framework for research not specified	To suggest future research direction by studying current situation and trends of SCM-related disaster situation	To provide basic framework for HRL studies
Search Techniques	Keywords in databases; citations from papers	Keywords in databases; citations from papers	Keywords in databases; citations from papers	Keyword search in SCM-related journals	Keyword search in database
No. of article	109	not specified	19 * (inaccuracy)	118	51
Time coverage	1980–2004	– 2006	1986–2005 * (inaccuracy)	1975–2008	–2009
Included paper	All phases of disasters and types of disasters according to IFRC definition	HL literatures of all types and stages of disasters	Literatures related to inventory in HL	SCM literatures related to all types and stages of disasters	HL literatures related to sudden onset
Included journal	Academic OR/MR literatures	Academic journals, practitioner journals, web sites	not specified	Academic SCM, OR/MR literatures Casebooks related to SCM Only peer-reviewed journals	Not specified (Only searched websites commented: EBSCOHOST, GOOGLE SCHOLAR, etc.)
Classification	Yes	No	No	Yes	Yes
Data analysis	Quantitative & qualitative	Qualitative	Qualitative	Quantitative & qualitative	Quantitative & qualitative
Differentiation	The first OR/MR literature review in HL	First to develop a framework of HL	Focusing on specific area of inventory	The first SCM literature review in disaster situation	The first to suggest a framework for future studies based on constraint theory
Methods of study	Traditional literature review	Traditional literature review	Traditional literature review	Traditional literature review	Traditional literature review
Scope	de la Torre et al. (2012) Disaster relief routing: Integrating research and practice	Caunhye et al. (2012) Optimization models in emergency logistics a literature review	Optimization models in RHL	Dasaklis et al. (2012) Epidemics control and logistics operations: a review	Kunz and Reiner (2012) A meta-analysis of HRL research
Objective of research	O/R studies on supply and distribution of relief goods and on-site interview To analyze and suggest O/R models of transportation in HL useful for both academic and field parts	Optimization model - related literatures in RHL	To identify research gap and suggest future research direction	Literatures related to epidemics and bioterrorism in HRL	Literatures on HRL
Search Techniques	Keyword search in database	Keyword search in database Using reference literatures	Keyword search in database Using reference literatures	To identify current state of HL studies related to epidemics and to examine the possibility for business logistics to be applied & suggest future research direction Keyword search in database	To identify current research trends and suggest future research direction
No. of article	Not specified	Half of optimization related literatures after 2006 (No correct number)	73	73	Keyword search in database Bibliography list by Peter Tatham of HUMLOG Inst. 174
Time coverage	Not specified	2006–2011	Not specified	Not specified	–2011
Included paper	Transportation-related literatures in HL	Optimization-related literatures before and directly after disaster (not including restoration period)	Optimization-related literatures before and directly after disaster (not including restoration period)	Exclusion of seasonal epidemics or long- term illness	Only peer-reviewed publications
Included journal	Academic journals, interviews, newspapers, publications of aid agencies etc.	Academic journals, books, materials of conference	Academic journals, books, materials of conference	Academic journals, handbooks, reports of aid organization, database of governments or international organization	Academic journals
Classification	Yes	Yes	Yes	Yes	Yes
Data analysis	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative
Differentiation	Acceptance of opinions from academic and occupational domains focusing on transportation in HRL	Providing general insights on main subjects of HRL	Providing general insights on main subjects of HRL	Focusing on epidemics	Analyzed broadest and used content analysis as main methodology
Methods of study	Traditional literature review	Traditional literature review (Content analysis)	Traditional literature review (Content analysis)	Traditional literature review	Systematic literature review (content analysis)

(continued on next page)

Table 1 (continued)

	<b>Galindo and Batta (2013)</b> Review of recent developments in OR/MS research in disaster operations management	<b>Leiras et al. (2014)</b> Literature review of HRL research: Trends and challenges	<b>Safeer et al. (2014)</b> Analyzing transportation and distribution in emergency HRL	<b>Manominwes and Irohara (2014)</b> A review of relief supply chain optimization	<b>Zary et al. (2014)</b> The contribution of scientific productions at the beginning of the third millennium (2001–2014) for HRL: A bibliometric analysis
Scope	OR/MS-related literatures in disaster operations management	Literatures on HRL	Literatures on transportation in HRL	Literatures on optimization in HRL	Literatures in HRL
Objective of research	To evaluate how OR/MS research in DOM has evolved and to what extent based on the gaps identified by <b>Altay and Green (2006)</b>	To identify research trends and suggest future research direction	To identify current research trends on transportation model and suggest future research direction	To identify trend, gaps, and results of studies on optimization and suggest future research direction	To identify up to date research trends and development using bibliometric & social network method
Search Techniques	Keyword search in database	Keyword search in database	Not specified	Keyword search in database	Keyword search in database
No. of article	155	228	Not specified	50	583
Time coverage	2005–2010	1980–	Not specified	2004–2014	2001–2014
Included paper	Academic literatures on OR/MS in HL published only in English	Only academic and peer-reviewed articles	Literatures on transportation in HRL	Literatures on optimization models in HRL	Academic literatures in HRL (2001–2014)
Included journal	Academic journals	Academic journals	Yes	Academic journals	Academic journals
Classification	Yes	Yes	Yes	Yes	Yes
Data analysis	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative	Quantitative
Differentiation	Identifying gaps by <b>Altay and Green (2006)</b>	The most extensive literature review	Organized transportation models systematically	Focusing on optimization in HL	Using bibliometric method
Methods of study	Traditional literature review	Systematic literature review	Traditional literature review	Traditional literature review	Systematic review (bibliometric analysis)
	<b>Abidi et al. (2014)</b> Humanitarian supply chain performance management: A systematic literature review	<b>Won et al. (2017)</b> Literature review and research trend analysis in disaster logistics	<b>Nurmala et al. (2017)</b> Humanitarian-business partnerships in managing HL	<b>Chiappetta Jabbour et al. (2017)</b> An analysis of the literature on HL and supply chain management: Paving the way for future studies	<b>Seifert et al. (2018)</b> Humanitarian supply chain management responding to refugees : A literature review
Scope	Literatures on SC performance management in HL	Literatures on HL	Partnerships in managing HL	Literatures on HL	Literatures related to refugees in HL
Objective of research	To identify up to date performance measurement, management in HL, and categorize its indicators and define gaps and challenges	To identify HL research trends and suggest future research direction	Literatures on partnership between HL and business logistics	To suggest future literature direction by systematically organizing latest HL and SCM (HLSCM) literatures	To map and analyze the literature on HL related to refugee crisis response
Search Techniques	Keyword search in database	Keyword search in database	Keyword search in database	Keyword search in database	Keyword search in database
No. of article	52	178	36	87	53
Time coverage	1970–2012	2002–2016	–July 2016	Not specified	1989–2016
Included paper	Peer-reviewed articles, book chapters, master theses	Previous HL literatures focusing on natural disasters	Only academic and peer-reviewed articles (excluding indirectly HL such as military related papers)	Not specified	Peer reviewed Including keywords from field SCM and refugees
Included journal	EBSCOHOST, Google Scholar, ABI/Informs, Elsevier	Academic journals	Academic journals	Academic journals	Academic journals
Classification	Yes	Yes	Yes	Yes	Yes
Data analysis	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative
Differentiation	The first systematic approach on performance measurement and management in HL	Categorized previous literatures using various classification standard	The first systematic review on partnership between HL and business logistics using CIMO	Organizing literatures by encoding	The first literature review on HL related to refugees
Methods of study	Systematic literature review	Traditional literature review	Systematic literature review	Systematic literature review	Systematic literature review (Using Atlas.ti program)
	<b>Behl and Dutta (2019)</b> Humanitarian supply chain management: A thematic literature review and future direction of research	<b>Banomyong et al. (2019)</b> A systematic review of humanitarian operations, HRL, and humanitarian supply chain performance literature 2005 to 2016	<b>Khan et al. (2019)</b> A systematic review of performance enhancement of HRL through transparency: Current status and perspectives	<b>Masudin and Femandia (2019)</b> A review of literature on types, stages of tsunami and earthquake disaster in Indonesia	<b>Shafiq and Soratana (2019)</b> HL and supply chain management – a qualitative study
Scope	Literatures on HRL	Literatures on HRL	Literatures on transparency in HRL	HRL Literatures on recovery of Indonesian earthquake and tsunami	Literatures on HO-LSCM

(continued on next page)



Table 1 (continued)

Objective of research	To suggest future research direction by performing extensive literature review and organizing thematically	To explore methodologies for conducting comprehensive literature review and identify main research themes and clusters in HRL	To systematically review the barrier to and benefits of transparency in HRL	To identify gaps and future research direction by updating and organizing Indonesia disasters-related literatures	To identify areas needing future improvement in HO-LSCM by reviewing previous literatures
Search Techniques	Keyword search in database	Keyword search in database	Keyword search in database Searching in transparency international website	Keyword search in database	Keyword search in database
No. of article	362	52	47	25	73
Time coverage	2018–2017	2005–20016	2004–	2005–2017	–2017
Included paper	Research papers written in English	Not specified	Only peer reviewed when from database; including all published or unpublished materials related to transparency	Published articles	Peer-reviewed papers focusing on operational efficiency and effectiveness
Included journal	Articles, articles in press, conference papers, books, book chapters, conference review, editorial notes and reviews	Academic journals	Academic journals and websites related to transparency	Google Scholar, Science Direct, Emerald Insight, etc	Not specified
Classification	Yes	Yes	Yes	Yes	Yes
Data analysis	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative	Quantitative & qualitative
Differentiation	Providing a thematic outline of HRL studies	Using systematic literature review method	Systematically organized literatures focusing on transparency in HRL	Used classification and coding for limited literatures on disasters in Indonesia	Focused HO operational efficiency and effectiveness
Methods of study	Systematic literature review	Systematic literature review	Systematic literature review (Using CIMO approach)	Systematic literature review	Traditional literature review

of time and efforts for the researchers, which indicates topic modeling is a potentially good fit for exploratory literature reviews (Asmussen & Møller, 2019). Furthermore, it helps to extract highly soluble topics by examining time-series changes in the embedded topics with massive data which is appropriate for research trend analysis.

Reorganizing applying the table of Kunz and Reiner (2012, p. 118)

#### 4. Research process

##### 4.1. Research design

The main purpose of this study is to identify the HRL studies and analyze the time sequential changes. For this, keyword analysis and topic modeling analysis were conducted using NetMiner 4.0 software. After keywords were extracted from the abstracts, they were analyzed using frequency analysis, centrality analysis, and topic modeling analysis. To identify the time-series flow, all the analyses were segmented into time periods.

##### 4.2. Research process

###### 4.2.1. Data collection

Data was collected from SCOPUS database using the keywords 'Humanitarian & Logistics', 'Humanitarian & Supply chains', 'Disaster & Logistics', 'Disaster & Supply chains', which were selected after examining the keywords in previous literature reviews.

4,269 papers were initially collected and examined their titles and abstracts to assess their relevance to this study. 1,058 papers were selected after excluding papers which were irrelevant, overlapping, or without abstracts.

###### 4.2.2. Data pre-processing

Data pre-processing is the basis for accurate network analysis. Since keyword extracting programs use simple comparison to detect identical words, words with the same meaning written in different ways (special characters, uppercase, or abbreviations) could erroneously be classified as several different words and a compound word could be detected as separate words. To prevent such errors, it is necessary to perform data pre-processing, that is, cleaning papers and making an exemption dictionary, designation dictionary, and synonym dictionary.

Cleaning a paper refers to converting all words to lowercase and removing punctuation, white-spaces, and special characters. Dictionaries are applied to the cleaned documents.

An exemption dictionary includes commonly used but non-value-added words not to be extracted as subjects of words analysis such as *study*, *research*, *method*, *analysis*, *humanitarian*, and *disaster*. A designation dictionary includes compound nouns conveying important ideas. For example, to prevent the compound noun *decision support* from being divided into *decision* and *support*, the unit '*decision support*' is added to the designation dictionary. A synonym dictionary clubs together words with similar meanings under a single word. For instance, in a synonym dictionary, *earthquake*, *disastrous earthquake*, *earthquake disaster*, *earthquakes*, are unified in a word, *earthquake*.

After applying these three dictionaries to the 4,525 words initially extracted using NetMiner 4.0 program, we collected 2,925 keywords of subjects of analysis.

To conduct keyword network analysis, a 2-mode network composed of words and sentences, or words and paragraphs has to be converted into a 1-mode network composed of words and words. Inner Product was employed as proximity measure method to convert the 2-mode network into a 1-mode network. Inner Product measures the similarity of keywords by considering the frequency of simultaneous appearance of keywords. The more frequently two

**Table 2**  
Research Design.

	Analysis Element	Detail
Research subject	keywords	Text keywords in abstracts of related studies
Keyword analysis	Frequency analysis	TF (Term Frequency) analysis TF-IDF (Term Frequency- Inverse Document Frequency) analysis
Topic modeling analysis	Centrality analysis Topic analysis	Degree centrality and betweenness centrality analysis LDA (Latent Dirichlet allocation) topic modeling

keywords appear in the same paper and in many papers, the higher the value of Inner Product becomes. As Inner Product expresses its result value in whole number, it is possible to interpret intuitively.

We filtered unimportant words using Term Frequency-Inverse Document Frequency (TF-IDF) value in batches. TF-IDF works by determining the relative frequency of words in a specific document compared to the inverse proportion of that word over the entire document corpus. Therefore, words that are common in a single or a small group of documents tend to have higher TF-IDF numbers than common words such as *articles* and *prepositions* (Ramos, 2003, p. 2). After simulating different TF-IDF values, we examined the result of extracted words and decided a cut-off point for mass filtering. Common words such as *uncertainty* and *complexity*, or comprehensive meaning words like *optimization* and *response* were included in the target of exception. As a result, we selected 0.828 of TF-IDF value as cut-off point for keyword filtering. Finally, we extracted 2,897 keywords after applying exemption dictionary, designation dictionary, synonym dictionary, and a 0.828 cut-off point to the initial 4,525 keywords.

#### 4.2.3. Bibliometric analysis and keyword frequency analysis

For the basic bibliometric analysis, we considered the number of published articles by year, the top journals contributing to the HL field, and the top mentioned disasters in the articles.

In keyword frequency analysis, we conducted Term Frequency (TF) analysis and TF-IDF analysis. After obtaining the results of the two frequency analyses, comparative analysis and time sequential analysis were performed.

#### 4.2.4. Keyword network analysis

To identify core keywords and main issues in HRL, keyword network analysis using 1-mode network data was performed focusing on degree centrality and betweenness centrality analysis. The analysis was conducted by time periods to help examine time-variant characteristics.

#### 4.2.5. Topic modeling analysis

Since the LDA algorithm runs on the training set and the test set is used to validate the result, it is necessary to undergo the process to input several parameters into topic modeling program and select the topics comparing results to extract final topics (Asmussen & Møller, 2019). As parameters,  $\alpha$  value,  $\beta$  value, iteration, and topic numbers are used.  $\alpha$  value indicates the concentration of topical focus. If  $\alpha$  value increases, papers intend to concentrate on specific topics; if  $\alpha$  value decreases, papers discuss a wider variety of topic groups.  $\beta$  value concerns dispersion of words in topics. As  $\beta$  value rises, distribution of the words becomes varied, and as it lowers, keywords are concentrated in specific topics (Choi & Kim, 2019). The closer to zero both  $\alpha$  value and  $\beta$  values are, the higher is the accuracy of topic

modeling (Moon, 2020). Iteration means to perform sampling repeatedly to make topics allocated generally (Choi & Kim, 2019). The criteria for selecting the right number of topics are to find the balance between a useable number of topics and minimum complexity (Asmussen & Møller, 2019). Although the right number of topics can vary largely depending on the purpose of analysis, researchers can decide the number of iterations and topics through trial-and-error (Asmussen & Møller, 2019; Moon, 2020). In this analysis, we use 1 as  $\alpha$  value, 0.01 as  $\beta$  value, 1000 iterations and 9 topics as parameters.

After distributing all the documents into each topic group, it is necessary to label the topics. Since labeling of topics can be influenced by researchers' subjective decision, we lowered the risk wrong naming by examining the words with high probabilities, titles and abstracts of articles of the corresponding topic groups with synthetic judgment.

To figure out main topics of HRL easily and observe changes in them, we conducted topic modeling network visualization and time-series analysis. Table 2

## 5. Research result

### 5.1. Bibliometric analysis

There were 1,058 journal articles related to HRL until 2019 (Table 3 and Fig. 1). The fact that the number of published articles in this area soared after 2009 reconfirms the statements that “there were only a handful of articles on HRL up till 2005” (Kovács et al., 2009, p. 506) and “There was a sharp increase in the number of publications on HRL, especially after 2009” (Leiras et al., 2014, p. 103).

Table 4 shows HRL papers published in journals, among which, *Journal of Humanitarian Logistics and Supply Chain Management* took the top spot by publishing 11.6% of all papers. The top 8 journals published 345 (33.4%) of 1,058 papers.

Table 5 shows the frequency of the mention of disasters. Natural disasters such as earthquakes, floods, hurricanes, tsunamis, cyclones

**Table 3**  
Number of published papers by year.

Year	pcs of papers	Year	pcs of papers
1986~2004	13	2012	68
2005	2	2013	59
2006	3	2014	93
2007	11	2015	88
2008	9	2016	120
2009	40	2017	105
2010	27	2018	158
2011	49	2019	213
<b>Total</b>	<b>1058</b>		

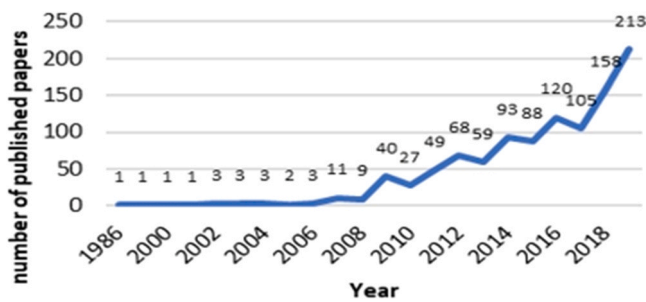


Fig. 1. Trend of number of published papers.

Table 4  
Top publishing journals contributing to HRL.

Name of journal	no.
Journal of Humanitarian Logistics and Supply Chain Management	123
Annals of Operations Research	52
International Journal of Disaster Risk Reduction	35
European Journal of Operational Research	35
Socio-Economic Planning Sciences	29
Production and Operations Management	29
Transportation Research Part E: Logistics and Transportation Review	28
International Journal of Production Economics	23
<b>Total</b>	<b>345</b>

Table 5  
Frequency of disasters mentioned in papers.

Disaster	pcs	ratio	Disaster	pcs	ratio
earthquake	279	47.5	typhoon	10	1.7
flood	96	16.4	rainy season	8	1.4
hurricane	70	11.9	epidemic	8	1.4
tsunami	33	5.6	drought	6	1.0
conflict	24	4.1	famine	4	0.7
cyclone	19	3.2	snowstorm	3	0.5
war	15	2.6	starvation	1	0.2
landslide	11	1.9	Total	587	100

Table 6  
Chronological TF, TF-IDF high ranking words (2005-2019).

Rank	2005–2009 (period 1)			2010–2014 (period 2)			2015–2019 (period 3)					
	Word TF	pcs	Word TF-IDF	pcs	Word TF	pcs	Word TF-IDF	pcs	Word TF	pcs	Word TF-IDF	pcs
1	preparation	12	united nations	4	community	35	emergency supplies	13	community	67	reduction	25
2	coordination	11	restriction	4	coordination	25	vehicle routing	10	coordination	59	product	24
3	community	9	private sector	4	principle	21	property	10	government	52	donation	22
4	communication	7	performance measurement	4	communication	19	personnel	10	disruption	45	partner	21
5	safety	6	partnership	4	shortage	18	education	10	decision makers	45	trust	21
6	disruption	6	equipment	4	preparation	18	option	9	supplier	44	equity	20
7	rescue	5	vulnerability	3	supplier	17	heuristic algorithm	9	manager	42	arrival	20
8	performance measurement	5	treatment	3	humanitarian action	17	feasibility	9	route	41	sustainability	20
9	manager	5	staff	3	procurement	16	equipment	9	collaboration	40	sensitivity analysis	19
10	integrates	5	routing	3	trade off	15	delay	9	road	39	intervention	19
11	health care	5	reconstruction	3	source	15	advantage	9	resilience	39	assistance	19
12	government	5	quick response	3	government	15	robustness	8	recovery	39	agility	19
13	combination	5	partner	3	safety	14	logistic operations	8	health care	36	united nations	19
14	victim	4	pctst for profit	3	collaboration	14	lead time	8	stakeholder	35	unit	18
15	united nations	4	logistic operations	3	training	13	integer linear programming	8	preparation	35	provision	18

were mentioned often, with *earthquake* appearing most frequently (47.5%). On the other hand, man-made disasters like conflict, war, starvation were mentioned marginally.

5.2. Keyword frequency analysis

2,897 keywords were used for keyword frequency analysis for TF and TF-IDF. TF analysis measures the frequency of appearance of keywords of all documents. If a word has high TF value, it can be understood to have high importance as a broad subject of research. However, the fact that a word appears in several documents means that the word has less importance in a specific document. Since TF-IDF value is measured by calculating the frequency of each word in a specific document, it is a consistent and effective indicator of how much significance each word has in a particular document (Nam & Nam, 2020). Furthermore, this method is suitable for identifying a particular important word which cannot be identified by TF analysis. Two frequency analyses were executed dividing the period from 2005 to 2019 into three five-year periods (Table 6).

As period 1 (2005-2009) is the initial stage, attempts to define HRL and confirm its importance appeared. Words such as *disruption, safety, preparation, rescue, victim, private sector, united nation, reconstruction, quick response, not for profit* dominated this period.

In period 2 (2010-2014), interest in practical logistics increased. High TF value ranking words such as *supplier, shortage, source, and procurement*; high TF-IDF value ranking words like *vehicle routing, emergency supplies, lead time, and robustness* confirm these flows. The appearance of logistics optimization related words like *integer linear programming* and *heuristic algorithm* shows these trends as well. On the other hand, it was possible to verify the man-power management concerns through the words like *education, training, and personnel*.

In period 3 (2015-2019), the cooperation among HRL actors were assumed to be the main topics. Eight out of 15 TF high-ranking words were related to co-operations such as *coordination, community, government, manager, decision maker, supplier, collaboration* and *stakeholder*: five out of 15 TF-IDF high-ranking words were related to cooperation concerns such as *intervention, trust, intervention, assistance, united nations*. Considering that *road* and *route* were included in high TF value words

and *sensitivity analysis* used for predicting business profitability or availability of funding are in high TF-IDF rank words group, it can be inferred that relief supplies arrangement was the main issue at that time. In addition, high TF-IDF ranking words like *donation, equity, unit, provision* show that supplies were the main issue in that period.

The highest TF ranking word in all periods is *community*. Considering with the words such as *coordination, government, supplier, manager, decision makers, collaboration, communication, coordination* in a community was a main issue in all periods. In addition, with the high TF-IDF ranking words such as *feasibility, sensitivity analysis, and equipment*, research to assess the feasibility in HRL progression was conducted actively.

### 5.3. Keyword network analysis

To identify the key topics studied, network centrality analysis was conducted centring on degree centrality and betweenness centrality per period.

#### 5.3.1. Time variant degree centrality

Degree centrality of a keyword is measured by the total amount of direct links with other nodes (Zhang & Luo, 2017). A word with high degree centrality is connected to many concepts and variables and consequently features prominently in the literature (Moon, 2020; Song et al., 2018).

In periods 1, 2, and 3, the keywords with highest degree centrality were *united nations, education, and provision* respectively and they represent main subjects of research per period. In period 1, *united nations, reconstruction, survivor, early warning system, restriction, attack, protection, affected area, sharing* have high degree centrality, confirming that the top issues of that time were damages, response, and post-disaster restoration and through them, researchers at that time tries to emphasize the importance of HRL. This trend can be interpreted as an effort to address the damage caused by the 2004 Indonesia tsunami, 2008 Sichuan earthquake, and 2008 Myanmar cyclone, and so on. A different trend appeared in period 2. Words such as *robustness, travel times, simulated annealing, relief distribution centers, deviation, data uncertainty, inventory control*, reflect an endeavor to conduct HRL research concretely. Meanwhile, considering the exceptionally high degree of centrality of *education* and the words such as *leader and candidate*, personnel training can be assumed to be a core subject at that time. In period 3, words related to transportation or facilities like *provision, agility, equity, accessibility, product, routing, and depot*, and those related to cooperation such as *trust, united nations, and partner* had higher degree of centrality.

#### 5.3.2. Time variant betweenness centrality

Betweenness centrality measures the 'mediation' function of a node in a network. If a node is located in a way that other nodes have to pass through it, then this node is considered important and very likely to have a high betweenness centrality (Zhang & Luo, 2017). The words which have high betweenness centrality take the lead in fusion and connection of research topics and play an vital role in creating various meanings in the documents. In period 1, keywords related to damages, response, and post-disaster rehabilitation have high betweenness centrality value (in addition to high degree centrality as mentioned before). Words like *chaos, disturbance, survivor, affected area; early warning system, treatment, satellite; and equipment, reconstruction, protection* indicate that studies were conducted

on disaster damage, emergency response and rehabilitation respectively. The distinct characteristic of period 2 was that *disaster affected regions, press, intervention, nutrition, and conflict* showed high betweenness centrality value. Since this was the period of the Sudanese and Syrian civil wars and the refugee crisis, it can be assumed that these words reflect the broadening of the scope of research on relief activities. In period 3, words with high betweenness centrality were *provision, feasibility, trust, reduction, equity*. Especially, the betweenness centrality of *provision* was much higher than others. Words such as *provision, accessibility, agility, assignment and depot* suggest that research on supplies of relief goods was being conducted. In addition, the appearance of a new word, *sustainability*, showed that a new area of interest had emerged.

#### 5.3.3. Comparison between degree and betweenness centrality and network map in all periods

Words with high degree centrality act as hubs of sub-groups whereas, high betweenness centrality represents information flow mediation. Considering that studies focus on high degree centrality words, practical logistics flow became a main topic turning words like *provision, product, agility, vehicle routing, accessibility, and routing* into hubs. Furthermore, studies revolved around participants and cooperation between them in HL making the words *united nation, partner, trust, staff, and employee* hubs. Meanwhile, high-ranking words in betweenness centrality can be considered to be acting as intersection points connecting the meanings between sub-structures. Especially, *sensitive analysis, feasibility, sensitive analysis* which have higher betweenness centrality values than degree centrality values, suggest that researchers were seeking solutions to uncertainty in HL. Besides, *staff and equity* which showed relatively high degree centrality values but low betweenness can be understood as mainly influencing formation of meaning in sub-groups.

The network map shows different aspects of each period. In period 1, keyword networks were broadly divided into 6 clusters (Fig. 2). Perhaps, this being the beginning of HRL research, researchers were focusing on several separate topics. In period 2, several loose clusters and individual nodes were detected, indicating that the research focus was expanding, and new directions were being explored. For period 3, a tight network can be seen. This can be elaborated that as more studies were conducted, the density of the network became tighter. Although the illustration of the network map of all periods looks similar to the map of period 3, it is denser as it considers all periods as target.

### 5.4. Topic modeling analysis

Topic modeling is a method that extracts latent topics from a collection of papers and analyses how trends of topics change over time or how a specific topic is composed (Nam & Nam, 2020). In this study, we distributed topics in HRL studies not in subjective topic classification but in probability distribution by using the LDA method. Table 7–9

#### 5.4.1. Extracted topic network

In extracted topic network analysis, 9 topics from HRL related papers using LDA were extracted. The extracted topics were *coordination, sustainable development, preparation, recovery, stakeholders, facilities location, transportation, emergent response, and supplying and sourcing* (Table 10).



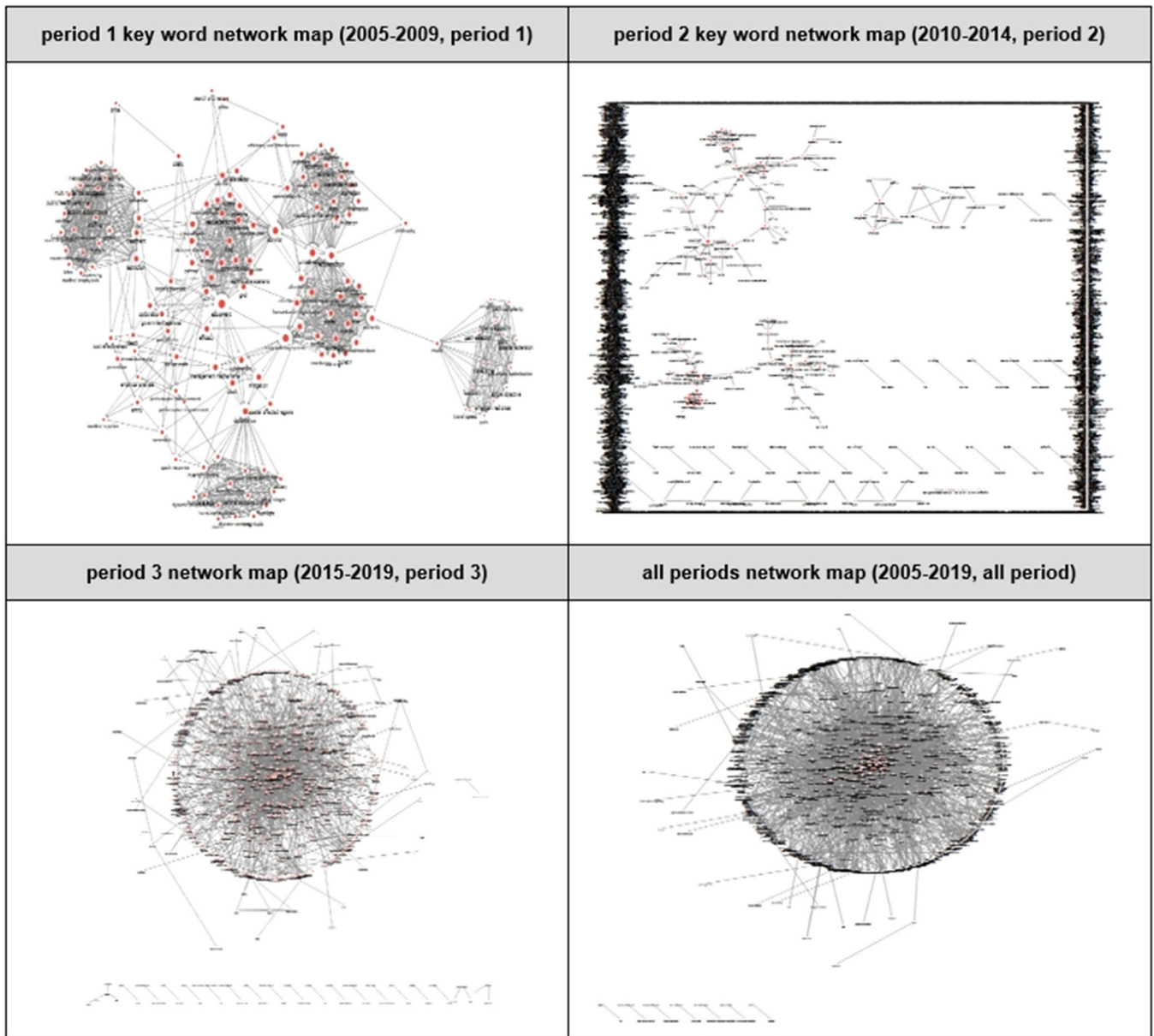


Fig. 2. Key word network map by period.

Table 7  
TF, TF-IDF Ranking (2005-2019).

Rank	Word TF	Frequency	Word TF-IDF	Frequency	Rank	Word TF	Frequency	Word TF-IDF	Frequency
1	community	111	united nations	28	9	collaboration	58	trust	26
2	coordination	95	product	28	10	recovery	55	reduction	26
3	government	72	equity	28	11	communication	54	build	26
4	preparation	65	donation	28	12	safety	53	agility	26
5	supplier	63	property	27	13	route	53	staff	25
6	disruption	63	partner	27	14	health care	53	sensitivity analysis	25
7	manager	60	feasibility	27	15	victim	49	equipment	25
8	decision makers	58	advantage	27	Total		962		399

**Table 8**  
Chronological degree centrality and betweenness centrality high ranking words (2005–2019).

Rank	2005 -2009 (period1)	Degree Centrality	2010 -2014 (period2)	Degree Centrality	2005 -2009 (period1)	Between -ness Centrality	2010 -2014 (period2)	Between -ness Centrality	2015 -2019 (period3)	Between -ness Centrality
1	united nations	0.26950	education	0.05333	equipment	0.19917	emergency supplies	0.06000	provision	0.09931
2	Re construction	0.26950	robustness	0.04296	authority	0.18364	delay	0.05849	feasibility	0.06433
3	survivor	0.25532	option	0.04000	chaos	0.16859	disaster affected regions	0.05433	trust	0.06199
4	equipment	0.21986	emergency supplies	0.03852	early warning system	0.16713	press	0.04972	reduction	0.05994
5	treatment	0.19149	delay	0.04000	disturbance	0.16481	option	0.04917	equity	0.05533
6	staff	0.19149	travel times	0.03556	survivor	0.13950	depot	0.04861	united nations	0.05469
7	early warning system	0.18440	simulated annealing	0.03556	united nations	0.09543	transshipment	0.04857	donation	0.05151
8	restriction	0.17731	relief distribution centers	0.03556	restriction	0.08716	disaster relief vehicles	0.04798	accessibility	0.04591
9	attack	0.17731	leader	0.03556	Re construction	0.07445	education	0.04217	employee	0.04389
10	protection	0.17021	interval	0.03556	staff	0.05463	industry	0.03464	agility	0.04191
11	unit	0.16312	disaster mitigation	0.03407	treatment	0.05282	product	0.02559	assignment	0.03761
12	personnel	0.16312	deviation	0.03259	protection	0.04551	intervention	0.02484	depot	0.03692
13	affected area	0.16312	data uncertainty	0.03111	satellite	0.04307	nutrition	0.02476	product	0.03608
14	staffing	0.15603	candidate	0.03111	unit	0.03807	accuracy	0.02020	sustain	0.03541
15	sharing	0.15603	inventory control	0.03111	affected area	0.03563	conflict	0.01731	ability	0.03311

**Table 9**

Degree centrality and betweenness centrality high ranking words in all periods (2005–2019).

Rank	2005-2019	Degree Centrality	2005-2019	Betweenness Centrality
1	provision	0.04634	united nations	0.05299
2	united nations	0.04526	provision	0.05176
3	partner	0.04310	feasibility	0.04735
4	trust	0.03987	trust	0.04061
5	donation	0.03987	donation	0.03869
6	staff	0.03879	partnership	0.03746
7	product	0.03772	vehicle routing	0.03728
8	agility	0.03664	employee	0.03384
9	employee	0.03556	sensitivity analysis	0.03247
10	vehicle routing	0.03448	product	0.03232
11	feasibility	0.03448	advantage	0.03180
12	equity	0.03448	staff	0.03170
13	accessibility	0.03448	option	0.03161
14	sensitivity analysis	0.03341	sustainability	0.03076
15	routing	0.03341	equity	0.03039

Forming of each topic has been considered composing words and titles and abstracts of articles. In case of *coordination, preparation, supplying and sourcing*, the top-ranking word determined the topic name. The subject of the topics like *stakeholders, recovery, facilities location, transportation* could be inferred easily by considering topic composing words. In case of *sustainable development* and *emergent response*, we selected topic names by looking at topic composing words and titles and abstracts of papers as choosing topic names based on only high-ranking words could lower accuracy. Especially, for *sustainable development*, we named the topic taking into account the top 10 topic probability words such as *training, principle, education, sustainability* and the words at rank 11 (*waste*) and 13 (*debris*), all together. We judged that continuous development through education and environmental sustainability through proper waste disposal was involved in the subject of *sustainable development*.

Seeing the representative articles of each topic, literature on cooperative work in HRL by [Balcik et al. \(2010\)](#) could be an example of topic 1, *coordination*. They commented that as various and complicated participants are involved in HL, mutual cooperation between them in HL is important above all things but it left much to be desired compared to cooperation in business logistics. In topic 2, *preparation*, [Duran et al. \(2011\)](#) introduced pre-positioning model and presented results after applying it. For topic 3, *sustainable development*, [Kovács and Spens \(2011\)](#) and [Habib and Sarkar \(2017\)](#) can be cited as examples. [Kovács and Spens \(2011\)](#) pointed out the shortage of training programs for generating expertise and [Habib and Sarkar \(2017\)](#) agonized over the selection of TDDMS (Temporary Disaster Debris Management Site) during a disaster response period. As an example of topic 4, *stakeholders*, the study on optimization model for decision making between interested parties in HRL by [Regis-Hernández et al. \(2017\)](#) can be cited. The study in which [Liberatore et al. \(2014\)](#) studied the restoration plan of supply networks after disaster falls into topic 5, *recovery*. For the example of topic 6, study on optimization model for positioning of facilities by [Hong et al. \(2012\)](#) can be given. [Tatham et al. \(2015\)](#) revealed that 3D printing technology has potential to be used effectively for responding to natural disasters. This is an example study for topic 7, *emergent response*. In topic 8, *transportation*, Wang et al. (2014) tried applying ‘multi-objective open location-routing model’ to the Sichuan disaster case to find a solution for locating supply facilities and planning transportation management. Lastly, for topic 9, *supplying and sourcing*, the study in which efficiency in supplying relief

**Table 10**  
Documents distribution by topic.

Topic	topic name	1 words	T/P	2 words	T/P	3 words	T/P	4 words	T/P	5 words	T/P
topic1	coordination	coordination	0.09	government	0.05	collaboration	0.033	barrier	0.033	manager	0.032
topic2	preparation	preparation	0.056	agility	0.042	communication	0.038	decision support system	0.038	disaster preparation	0.026
topic3	sustainable development	training	0.035	humanitarian action	0.025	sustainability	0.02	sourcing	0.02	principle	0.017
topic4	stakeholders	community	0.074	NGO	0.047	procurement	0.042	stakeholder	0.042	organization	0.04
topic5	recovery	disruption	0.062	resilience	0.047	performance measurement	0.035	recovery	0.035	food supply chain	0.035
topic6	facilities location	evacuating	0.036	shelter	0.034	victim	0.032	commodity	0.032	facility location	0.028
topic7	emergent response	health care	0.064	drug	0.03	humanitarian logistics planning	0.028	casualty	0.028	collection	0.024
topic8	transportation	road	0.049	route	0.038	schedule	0.025	budget	0.025	path	0.025
topic9	supplying and sourcing	supplier	0.069	rescue	0.039	shortage	0.034	reliability	0.034	refugee	0.028
Topic	topic name	6 words	T/P	7 words	T/P	8 words	T/P	9 words	T/P	10 words	T/P
topic1	coordination	logistics service provider	0.024	partnership	0.023	trust	0.022	expert	0.022	partner	0.02
topic2	preparation	combination	0.018	respondent	0.017	manager	0.016	safety	0.016	flexibility	0.016
topic3	sustainable development	RFID	0.016	participant	0.014	vaccine	0.013	education	0.013	option	0.013
topic4	stakeholders	donor	0.028	donation	0.023	fund	0.022	information system	0.022	critical success factors	0.019
topic5	recovery	community	0.017	vulnerability	0.016	source	0.015	asset	0.015	satisfaction	0.015
topic6	facilities location	equity	0.021	distribution center	0.021	trade off	0.019	minimization	0.019	depot	0.018
topic7	emergent response	staff	0.021	storage	0.018	access	0.016	equipment	0.016	personnel	0.014
topic8	transportation	vehicle routing	0.016	disaster affected regions	0.013	delay	0.013	social cost	0.013	last mile distribution	0.012
topic9	supplying and sourcing	emergency supplies	0.021	loss	0.019	unit	0.017	analytic hierarchy process	0.017	product	0.016

\*T/P = Topic Probability

**Table 11**  
Number of related literatures by topic and their ratio.

Topic	Number of literatures	Ratio (%)
coordination	128	12.2%
preparation	107	10.2%
sustainable development	98	9.4%
stakeholders	109	10.4%
recovery	85	8.1%
facilities location	165	15.8%
emergent response	94	9.0%
transportation	146	14.0%
supplying and sourcing	113	10.8%
Total	1045	100.0%

goods focusing on the aid auction process, studied by [Ertem et al. \(2010\)](#) can be given as an example.

[Table 11](#) below illustrates the number of literatures by topics and their weightage. The number of related literatures is almost similar for all topics. Topic 6, *facilities location*, has the maximum literatures at 165, followed by *transportation* (146) and *coordination* (128). Meanwhile, *recovery* has the least number of related literatures, 85.

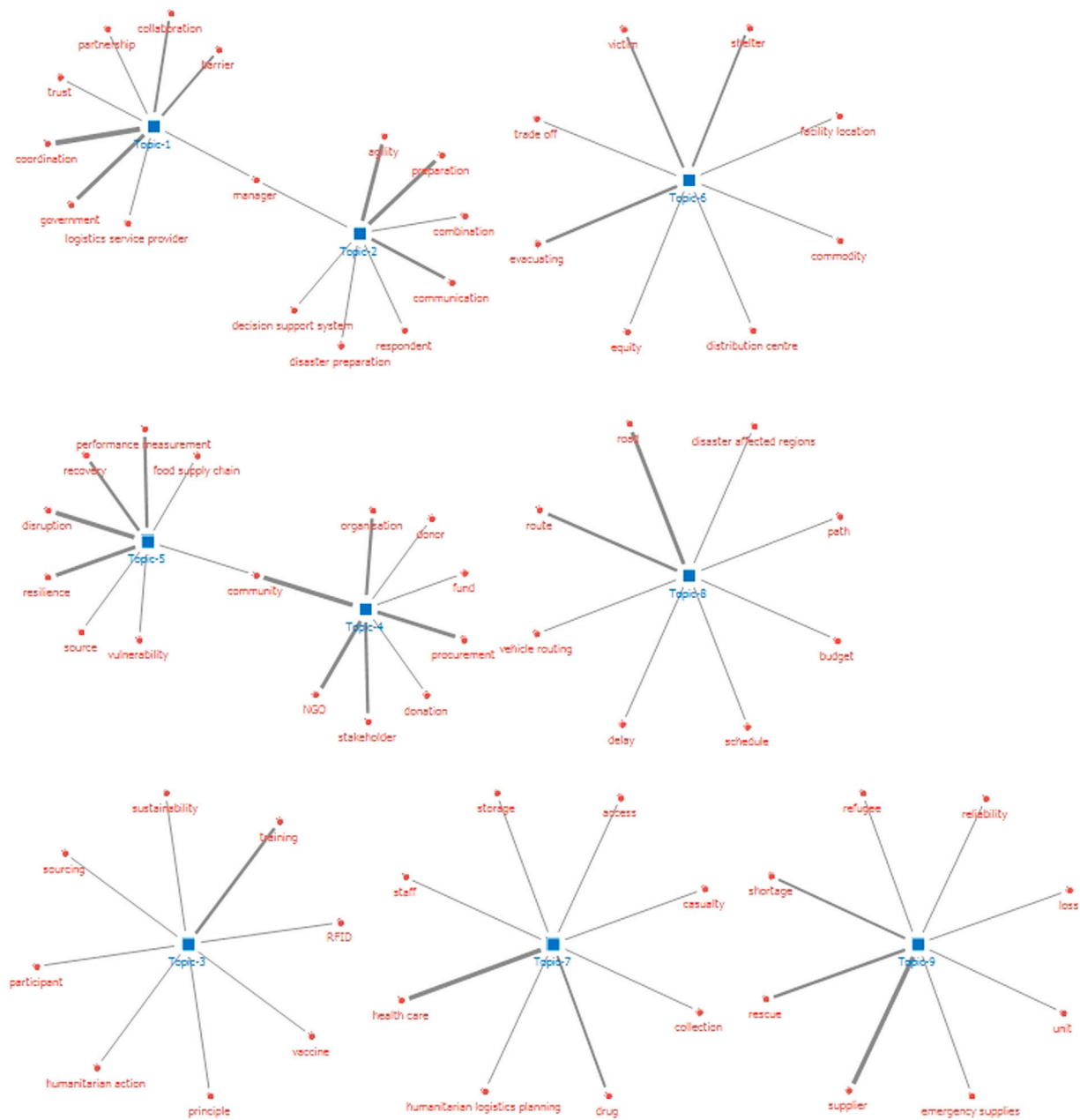
[Fig. 3](#) below presents visualization of topic modeling network. Through the visualized network, the structures between topics can be easily figured out which would be difficult to understand with only keywords. From the figure, it can be confirmed that five out of nine topics, *facilities location*, *sustainable development*, *transportation*, *emergent response*, and *supplying and sourcing* are individually organized. Furthermore, it can also be seen that *preparation* and *coordination* are connected through the *manager* and *stakeholders* and *recovery* are connected by the *community*. In the light of these facts, *manager* is understood as the main agent of cooperation and disaster preparation and *community* is the main agent of party directly involved in HRL and disaster recovery.

#### 5.4.2. Topic analysis by period

Time-variant changes of topics over the three periods was analyzed ([Table 12](#) and [Fig. 4](#)). In period 1, the most common topic was *preparation* with a weight of 21.5% followed by *stakeholders* (15.4%) and *recovery* (15.4%). This shows that *preparation* and *recovery* were the main focus of studies in the early stage of HRL research. In addition, from the fact that *emergent response* took larger portion compared to other periods, it is confirmed that results from topic modeling are similar to ones from network analysis. In period 2, the weightage of all topics was distributed evenly in general. However, *facilities locations*, which was least addressed in period 1 (3.1%), had the greatest percentage share in period 2 (17.1%). In addition, the proportions of *transportation* and *supplying and sourcing* increased as well. Judging from this, it can be verified that as studies on HRL proceeded, practical logistics flow issues gained attention. That the portion of the topic, *sustainable development* in period 2 was highest among all periods shows that education was researched most at that time. In period 3, there was large difference in ratios between topics. Topics whose proportions increased sharply such as *facilities location*, *transportation*, *supplying and sourcing* in period 2, increased slightly or maintained their position, but in case of *coordination*, its weight rose largely, approximately by 6%.

#### 5.4.3. Topic analysis by year

[Table 13](#) presents the extracted topics examined from 2005 to 2009. Until 2010, 9 of all the topics had not been introduced. Especially, no study was found on *coordination* and *sustainable development* until 2008. However, from 2011, throughout all topics, continuous studies kept progressing without high portion differences by year. Though, as to topics such as *coordination*, *sustainable development*, *transportation*, *supplying and sourcing*, wide variation of



topic1: coordination, topic2: preparation, topic3: sustainable development, topic4: stakeholders, topic5: recovery, topic6: facilities location, topic7: emergent response, topic8: transportation, topic9: supplying and sourcing

Fig. 3. Topic modelling network map.

portions by year was witnessed especially in *transportation*. With regards to portion difference between topics, in general no dramatically large gaps were found from 2011. However, in 2017 the largest deviation of ratio between *facilities location* (19.1%) and *recovery* (4.8%) was detected while in 2015 the smallest deviation between *coordination* and *facilities location* (14.8%) and *recovery* (8%) was spotted.

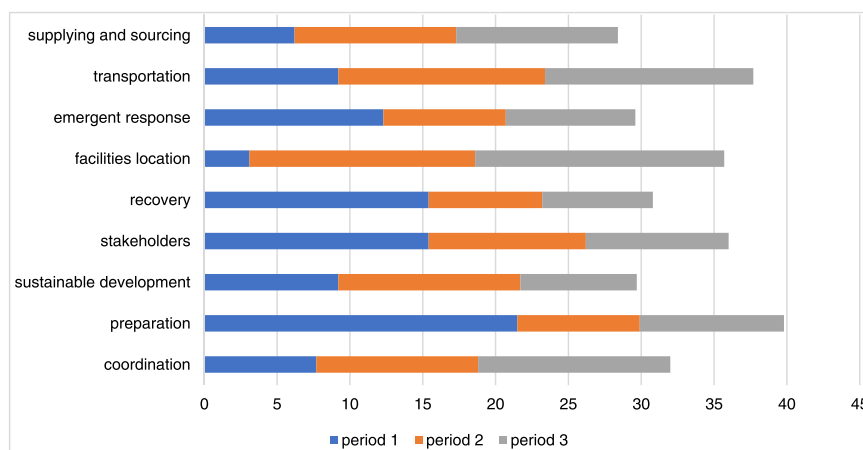
The Fig. 5 below shows the declining and rising trends of each topic by year. The topic revealing apparently decreasing tendency is *preparation*. Its portion between topics by year declined significantly from 66.7% in 2006 to 11.3% in 2019 falling by over 55%. Topics like, *preparation*, *stakeholders*, *recovery* and *emergent response* showed

downward trends by and large as well. However, topics like *coordination* and *supplying and sourcing* showed a weak upward-trend and the topic of *facilities location* continued a rising curve accounting for 18.3% (2016), 19.1% (2017), 19% (2018), and 15% (2019). Looking at 2019 alone, 32 of literatures on *facilities location* were published recording 1 ranking topic followed by *coordination* (31), *transportation* (28) and *supplying and sourcing* (28). These data indicate that in initial and middle stages of HRL studies, response or restoration of disasters or participants and expert education in HRL were the main focuses, but as time went by, logistics flow and cooperation were gradually paid more attention by researchers and this trend is predicted to continue hereafter.



**Table 12**  
Number and weight of related literature by period.

Topic	2005-2009 (period 1)		2010-2014 (period2)		2015-2019 (period3)	
	Pcs.	Ratio	Pcs.	Ratio	Pcs.	Ratio
coordination	5	7.7	33	11.1	90	13.2
preparation	14	21.5	25	8.4	68	9.9
sustainable development	6	9.2	37	12.5	55	8.0
stakeholders	10	15.4	32	10.8	67	9.8
recovery	10	15.4	23	7.8	52	7.6
facilities location	2	3.1	46	15.5	117	17.1
emergent response	8	12.3	25	8.4	61	8.9
transportation	6	9.2	42	14.2	98	14.3
supplying and sourcing	4	6.2	33	11.1	76	11.1
<b>total</b>	<b>65</b>	<b>100.0</b>	<b>296</b>	<b>100.0</b>	<b>684</b>	<b>100.0</b>



**Fig. 4.** Bar chart of weight of literatures by period.

**Table 13**  
The number and ratio of literatures related to topics by year.

Pub Date	coordination		preparation		sustainable development		stake holders		recovery		facilities location		emergent response		transportation		supplying and sourcing		Total	
	pcs	ratio	pcs	ratio	pcs	ratio	pcs	ratio	pcs	ratio	pcs	ratio	pcs	ratio	pcs	ratio	pcs	ratio	pcs	ratio
2005	0.0	0.0	0.0	0.0	0.0	0.0	1	50.0	0.0	0.0	0.0	0.0	1	50.0	0.0	0.0	0.0	2	100	
2006	0.0	0.0	2	66.7	0.0	0.0	1	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3	100	
2007	0.0	0.0	2	18.2	0.0	0.0	0.0	0.0	3	27.3	0.0	0.0	1	9.1	3	27.3	2	18.2	11	100
2008	0.0	0.0	1	11.1	0.0	0.0	0.0	0.0	1	11.1	2	22.2	3	33.3	2	22.2	0.0	0.0	9	100
2009	5	12.5	9	22.5	6	15.0	8	20.0	6	15.0	0.0	0.0	3	7.5	1	2.5	2	5.0	40	100
2010	7	25.9	4	14.8	3	11.1	6	22.2	4	14.8	2	7.4	0.0	0.0	0.0	0.0	1	3.7	27	100
2011	3	6.1	3	6.1	7	14.3	7	14.3	1	2.0	5	10.2	7	14.3	9	18.4	7	14.3	49	100
2012	10	14.7	3	4.4	11	16.2	5	7.4	2	2.9	11	16.2	7	10.3	7	10.3	12	17.7	68	100
2013	8	13.6	5	8.5	4	6.8	4	6.8	7	11.9	11	18.6	4	6.8	10	17.0	6	10.2	59	100
2014	5	5.4	10	10.8	12	12.9	10	10.8	9	9.7	17	18.3	7	7.5	16	17.2	7	7.5	93	100
2015	13	14.8	10	11.4	11	12.5	8	9.1	7	8.0	13	14.8	8	9.1	8	9.1	10	11.4	88	100
2016	16	13.3	13	10.8	11	9.2	7	5.8	11	9.2	22	18.3	10	8.3	21	17.5	9	7.5	120	100
2017	13	12.4	8	7.6	10	9.5	10	9.5	5	4.8	20	19.1	15	14.3	13	12.4	11	10.5	105	100
2018	17	10.8	13	8.2	10	6.3	19	12.0	12	7.6	30	19.0	11	7.0	28	17.7	18	11.4	158	100
2019	31	14.6	24	11.3	13	6.1	23	10.8	17	8.0	32	15.0	17	8.0	28	13.2	28	13.2	213	100
<b>Total</b>	<b>128</b>	<b>12.3</b>	<b>107</b>	<b>10.2</b>	<b>98</b>	<b>9.4</b>	<b>109</b>	<b>10.4</b>	<b>85</b>	<b>8.1</b>	<b>165</b>	<b>15.8</b>	<b>94</b>	<b>9.0</b>	<b>146</b>	<b>14.0</b>	<b>113</b>	<b>10.8</b>	<b>1045</b>	<b>100</b>

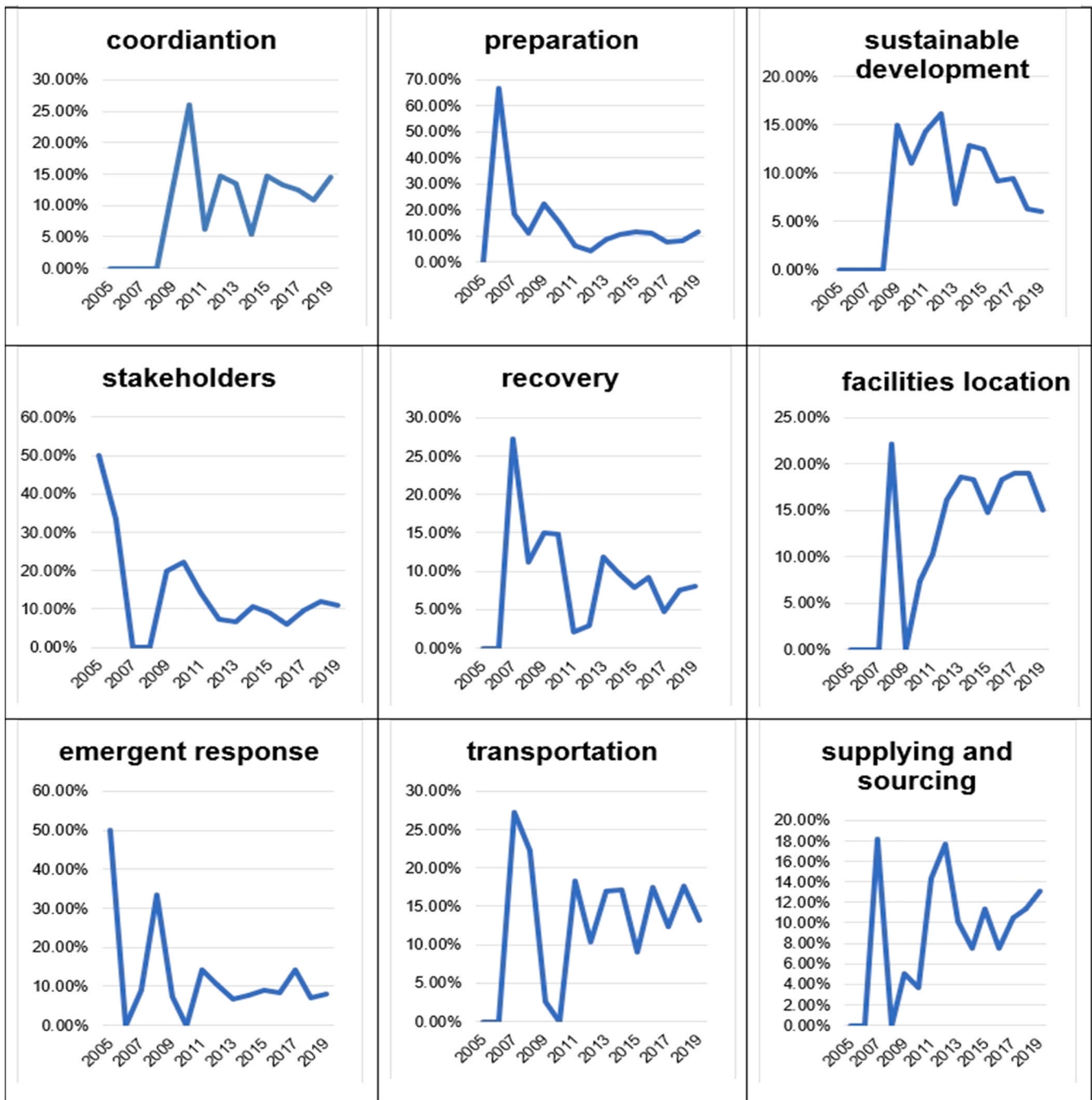


Fig. 5. Graph of time-variant topic ratio.

## 6. Conclusion

To objectively and systematically determine research trends in HL and suggest future research tasks, the current study analyzed the frequency of keywords in articles and reviews related to HL published between 2005 and 2019. It did so by dividing the data into three five-year periods and performing keyword network analysis and topic modeling analysis. The results of the three analyses in each time period are as follows.

The main research topics in papers published between 2005 and 2009 were disaster damages, countermeasures, restoration, and the establishment of identity in HL. These can be found in the TF hypernoms seen in this time period (e.g., *preparation, disruption, rescue, victim*) or in TF-IDF hypernoms (e.g., *private sector, partnership,*

*vulnerability, quick response, not for profit*). We included terms such as *united nations, reconstruction, survivor, early warning system, protection, and affected area* in the degree centrality hypernoms, and terms such as *equipment, chaos, and disturbance* in the betweenness centrality hypernoms. This step is supported by the fact that among the nine topics extracted during topic modeling analysis (i.e., *preparation, coordination, stakeholders, sustainable development, stakeholders, emergent response, recovery, facilities location, transportation, supplying and sourcing*), the superordinate topics of period 1 were *preparation* (21.5%), *stakeholders* (15.4%), and *recovery* (15.4%).

From 2010 to 2014, the main research interest was the physical flow of HL and the education of hands-on workers in the field. This is seen from the fact that terms such as *emergency supplies, vehicle routing, heuristic algorithm, feasibility, delay, lead time, integer linear*

programming, personnel, and education dominated among the TF-IDF hypernyms during this period, and degree centrality hypernyms included *robustness, travel times, simulated annealing, relief distribution centers, data uncertainty, inventory control, and education*. The research topics seen in this period were evenly distributed overall, with no one topic standing out; nonetheless, *facilities location, transportation, and supplying and sourcing* were superordinate topics, and many studies also focused on *sustainability vis-à-vis education*.

From 2015 to 2019—a period during which research on HL increased explosively—the focus was on mutual cooperation among logistics stakeholders or the transport and supply of relief goods. We included words such as *coordination, government, collaboration, route, and road* in the TF hypernyms, and *partner, trust, arrival, sensitivity analysis, agility, and provision* in TF-IDF hypernyms. Keywords related to transport, facilities, and location selection (e.g., *provision, equity, accessibility, product, routing, and depot*) as well as those related to cooperation (e.g., *trust and partner*) ranked highest in terms of degree centrality. This is seen in the fact that the betweenness centrality of *provision* in the same period is remarkably higher than that of other keywords. As for topics, the ratios of occurrence of *facilities location, transportation, and supplying and sourcing*, all of which had rapidly increased in period 2, increased slightly or remained the same, while that of *coordination* increased significantly (i.e., by approximately 6%).

The topics that received the most attention between 2005 and 2019 were the supply of relief goods in the community and mutual cooperation. This is seen in the frequency of hypernyms in all periods (e.g. *community and coordination*) or in degree centrality hypernyms (e.g. *provision, united nations, partner, trust, agility, vehicle routing and accessibility*) or betweenness centrality hypernyms (e.g. *united nations, provision, feasibility, partnership and sensitivity analysis*). In terms of topic, *facilities location* had the highest ratio (15.8%), followed by *transportation* (14.0%) and *coordination* (12.2%); these findings confirm once again that in all periods, supply and mutual cooperation were the topics that received the most attention.

Conversely, the topic showing the most obvious decrease was *preparation; recovery, emergent response, and stakeholders* also showed a declining trend by and large, as well. On the other hand, each of *coordination, facilities location, and supplying and sourcing* showed a slight increase. These findings suggest that while earlier studies on HL had focused on disaster situations (such as disaster response or recovery), more recent studies have paid more attention to actual HL flow and mutual cooperation; the implication here is that more research will be conducted on such topics in the future.

This study has a significant contribution by undertaking research trend analysis from a new and objective perspective based on keyword network analysis, keyword frequency analysis, and topic modeling analysis. The results herein can be used as a steppingstone by which to set future research direction by determining the HRL research findings in a macroscopic and comprehensive way. The three analytical methods all demonstrated similarities, ultimately proving that these methods are significant.

Nonetheless, the current study lies certain limitations. Keywords were limited to four types and the analytical subjects were also limited to academic papers and reviews; in this sense, analyzing a large body of data was challenge. Additionally, healthcare HRL literature was included so there were certain limitations in terms of exclusively determining the logistics characteristics. Therefore, further direction into research trend analysis could derive more abundant search results by expanding the scope of search words (e.g. 'relief' and 'emergency'). Furthermore, the analytical subjects could be extended to conference papers, news articles, interviews, and data analyzed by various institutions. By comparing those results with the existing data on academic research trends and determining the gap would be possible to uncover research topics that could assist in the rollout of HRL. Moreover, additional studies should be

conducted on HRL policies, customs clearance management, and waste disposal all of which are topics currently known to receive less attention from researchers.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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