

Mapping Intermodal Transportation Through Bibliometrics

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Abstract— Almost every business operation necessitates the use of intermodal transportation at some stage in the supply chain. This study is aimed to map reputation and interconnectedness among existing literature in the area of intermodal transportation. For this purpose, firstly, bibliometric data of 1758 documents are retrieved using keyword 'intermodal transportation' from the Scopus database. Data has been processed to build bibliometrics between publications, authors, co-authors, sources, citations, affiliation, country of origin. Secondly, the reputation of literature in intermodal transportation being surveyed using citation and network analysis. Finally, considering citations literature of highly cited was reviewed. Opensource software such as table2net, sciencscape, gephi, has been used to build network diagrams. The outcome of this research would lay the groundwork to pursue detailed study in the area of intermodal transportation. Some of the findings are; researchers from the US and Europe are leading in publishing researches in this field; 'intermodal transportation' and 'intermodal transport' are popular keywords among the research fraternity; 'engineering' and 'social sciences' are preferred subject areas; mostly transportation and operations research journals are preferred journals; and increasing trends have been observed in intermodal transportation research since 2005.

Keyword— Bibliometrics, citation, intermodal transportation, literature review, network diagram.

I. INTRODUCTION

Intermodal transportation is a process of transportation of passenger or goods from origin to destination using a combination of different transportation modes. Nowadays, almost every business operation necessitates the use of intermodal transportation at some stage in the supply chain. Supply and demand from international suppliers and customers are on the rise due to effective and efficient intermodal transportation in the supply chain. Transportation infrastructure development such as roads, ports, airports have brought revolution in logistics operational services across the world. Designing a highly responsive and highly efficient supply chain has become extremely important in freight transportation. World trade volume in 2017 increased by 3.6%, which is twice the growth rate in 2016. World container traffic (measured in TEU's) and air freight tonne-km increased by 4.8% and 9.0% respectively in 2017

No doubt, today's logistics operations intermodal transportation observes many benefits over unimodal transportation. Generally, intermodal transportation utilises any one or more channels for transportation form origin to destination as shown in Fig. 1.

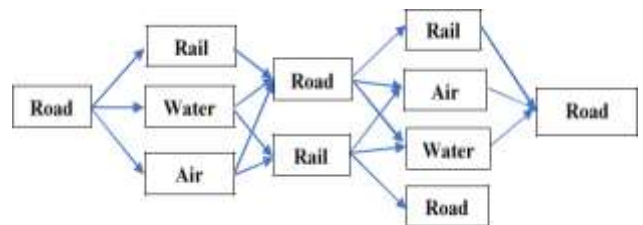


Fig. 1. Typical model of intermodal transportation

A. Objectives of the study:

The study is aimed:

1. To explore existence of academic research in intermodal transportation
2. To conduct citation and network analysis for intermodal transportation literature
3. To conduct systematic literature review of highly cited publications in intermodal transportation.
4. To pinpoint the scope of further research

B. Methodology of the study:

Firstly, 1758 publications were retrieved using 'intermodal transportation' as a basic keyword search in Scopus database as shown in Fig. 2.

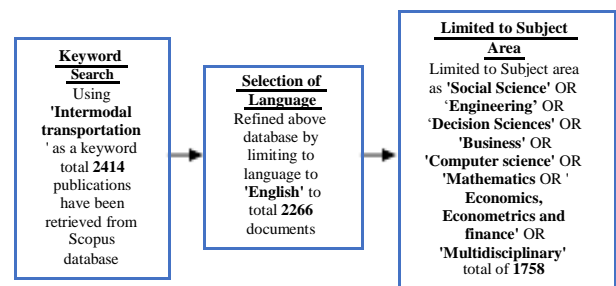


Fig. 2 Keyword research methodology

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Secondly, this retrieved and refined database further analysed by using metrics such as geographical analysis, bibliometric analysis, citation analysis and network analysis

Finally, a systematic literature review will be conducted using leading publications from the leading journals to understand the strength of academic research in the intermodal transportation area.

II. MAPPING INTERMODAL TRANSPORTATION.

In this section geographic, bibliometrics, citations and network analysis has been discussed in detail.

A. Geographical analysis:

Table 1 shows the top 10 countries in intermodal transportation research. Researchers from the United States has more interest in intermodal transportation followed by China and Italy.

Table 1 Top 10 Countries in the area of intermodal transportation research

Country	Number of Publications associated	Country	Number of Publications associated
United States	522	Belgium	68
China	129	United Kingdom	67
Italy	118	Canada	58
Germany	101	Spain	51
Netherlands	78	France	49

Fig. 3 is drawn using gpsvisualizer.com which demonstrates geographical locations of publications and researchers associated with intermodal transportation. The size of the circle indicates that the United States has the highest number of researchers and publications in the area of intermodal transportation



Fig. 3. Geographical locations of publications and researchers associated with intermodal transportation

C. Bibliometric analysis:

Document Type	Number of publications	Document Type	Number of publications
Article	960	Article in Press	8
Conference Paper	706	Note	4
Review	43	Short Survey	3
Conference Review	33	Erratum	1

Fig. 4 reveals that in 1995 there were 76 publications which has fallen to 40 in 2005 and since then yearly publications in intermodal transportation is on rise as indicated by trendline.

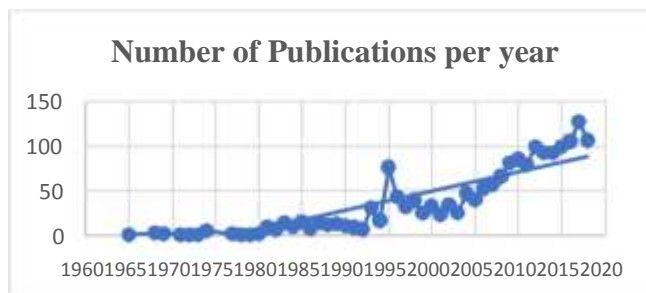


Fig. 4. Yearly publication analysis in intermodal transportation

Table 3. Top 10 author statistics in intermodal transportation

Author	Number of Publications	Author	Number of Publications
Caris, A.	22	Negenborn, R.R.	13
Macharis, C.	19	Ukovich, W.	13
Janssens, G.K.	17	Di Febbraro, A.	12
Anon	16	Fanti, M.P.	12
Dotoli, M.	16	Sacone, S.	11

Table 4. Top 10 keywords statistics in intermodal transportation

Keywords	Number of Associated Publications	Keywords	Number of Associated Publications
Intermodal	446	Freight	158
Transportation	336	Transport	138
Freight	322	Transportation	131
Transportation	266	Planning	121
Intermodal	195	Containers	119
Transport		Logistics	
Railroad		Optimization	
Transportation			

Table 5. Top 10 subject areas statistics in intermodal transportation

Subject Area	Number of Associated Publications	Subject Area	Number of Associated Publications
Engineering	1064	Environmental Science	176
Social Sciences	817	Mathematics	125
Computer Science	360	Economics, Econometrics and Finance	60
Decision Sciences	214	Energy	37
Business, Management and Accounting	197	Earth and Planetary Sciences	28
Engineering	1064	Environmental Science	176

Table 6 Top 10 source titles statistics in intermodal transportation

Source Title	Number of Associated Publications	Source Title	Number of Associated Publications
Transportation Research Record	55	Transportation Congress Proceedings	29
Transportation Research Part E Logistics and Transportation Review	48	Transportation Research Part A Policy and Practice	24
Journal of Transport Geography	38	Transportation Planning and Technology	22
Transportation Quarterly	35	European Journal of Operational Research	21
Railway Gazette International	30	Transport Means Proceedings of The International Conference	20

Though USA tops the list of publications in intermodal transportation, the affiliation statistics shown in table 7 reveals that, European universities are leading in affiliating researches in intermodal transportation.

Table 7 Top 10 affiliation statistics in intermodal transportation

Affiliation	Number of Associated Publications	Affiliation	Number of Associated Publications
Delft University of	53	Vrije Universiteit Brussel, Belgium	20
University of Genoa, Italy	31	University of Zilina, Slovakia	18
Vilnius Gediminas Technical University, Lithuania	26	Mississippi State University, USA	17

Table 9 Top 10 publications in intermodal transportation based on citations received

Year	Publications Title	Authors	Source Title	Number of Citations
2004	Opportunities for OR in intermodal freight transport research: A review	Macharis C., Bontekoning Y.M.	European Journal of Operational Research	309
2004	Is a new applied transportation research field emerging? - A review of intermodal rail-truck freight transport literature	Bontekoning Y.M., Macharis C., Trip J.J.	Transportation Research Part A: Policy and Practice	253
2003	Storage space allocation in container terminals	Zhang C., Liu J., Wan Y.-W., Murty K.G., Linn R.J.	Transportation Research Part B: Methodological	240
2007	Modelling the full costs of an intermodal and roadfreight transport network	Janic M.	Transportation Research Part D: Transport and Environment	206
2014	Multimodal freight transportation planning: A literature review	Stadieseifi M., Dellaert N.P., Nuijten W., Van Woensel T., Raoufi R.	European Journal of Operational Research	173
1981	Containerization and the load center concept.	Hayut Y.	Economic Geography	167

Polytechnic University of Bari, Italy	23	RWTH Aachen University, Germany	17
University of Hasselt, Belgium	21	University of Trieste, Italy	15

Citation analysis

Citation is a measure to determine the qualitative significance of a publication in the academic fraternity. Citation analysis aims to determine the ‘popularity’ of a publication by counting the number of times a publication cited by other publications (Ding and Cronin, 2011)[3]. Bornmann and Daniel (2008) analyzed that citations are “complex, multidimensional and not a unidimensional phenomenon”[4]. However, Hong and Kaur (2008) stated that citations might not be useful for judging the research quality[5].

Out of 1758 retrieved publications in intermodal transportation, only 992 have been cited at least once till the date of retrieval. Table 8 shows total citations received by the publications. It is evident from the increasing trend of citations that researches in intermodal transportations are becoming popular year by year

Table 8 Yearly citations analysis for publications in intermodal transportation

Year	Number of Citations
<2009	1729
2009	456
2010	590
2011	752
2012	971
2013	1100
2014	1294
2015	1563
2016	1777
2017	2028
2018	2371
>2018	159
Total	14790

Table 9 shows list of top 10 cited publications in the area of intermodal transportation

2004	Modelling a rail/road transportation system	intermodal	Arnold P., Peeters D., Thomas I.	Transportation Research Part E: Logistics and Transportation Review	152
2002	Empty container management for intermodal transportation networks		Choong M.H., S.T.,Cole Kutanoglu E.	Transportation Research Part E: Logistics and Transportation Review	143
2005	Optimal location of freight hubs	intermodal	Racunica I., Wynter L.	Transportation Research Part B: Methodological	135
2000	Intermodal and international freight network modeling		Southworth F., Peterson B.E.	Transportation Research Part C: Emerging Technologies	133

Table 10 is a list of top 10 source titles in the area of intermodal transportation. ‘Transportation Research Part E: Logistics and Transportation Review’ is a topmost journal with 48 publications which have been cited 1441 times till date of retrieval of the data used for this research.

Table 10 Top 10 journals in intermodal transportation based on citations received

Journal Title	Number of Publications	Year													Total
		<2009	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	>2018		
Transportation Research Part E: Logistics and Transportation Review	48	119	49	69	82	102	136	117	164	168	189	229	17	1441	
European Journal of Operational Research	21	107	65	68	79	110	97	115	151	146	172	188	8	1306	
Transportation Research Part A: Policy and Practice	25	102	42	48	55	75	77	99	97	110	124	115	7	951	
Transportation Research Part B: Methodological	20	125	43	45	46	67	77	81	85	83	99	136	9	896	
Journal of Transport Geography	38	43	17	19	40	51	69	86	100	138	136	171	17	887	
Transportation Planning and Technology	22	40	10	24	44	53	36	62	59	61	64	47	3	503	
Transportation Research Part D: Transport and Environment	19	42	16	20	29	39	32	38	57	66	74	84	2	499	
Transportation Science	9	119	12	19	17	20	32	45	45	35	42	52	4	442	
Transport Policy	19	10	8	20	13	11	25	45	58	86	61	88	5	430	
Computers and Operations Research	7	13	6	11	25	28	37	42	48	51	58	74	4	397	

D. Network analysis:

Network analysis is a graphical representation used to build the relationship between different statistical parameters. Open source software such as ‘ScienceScape’ and ‘Table2Net’ is used to build a basic network and in turn, is used as basic input for ‘gephi’. With the help of ‘gephi’ we can visualise and explore bibliometrics through graphs and networks. Fig. 5 represents an association between main authors, main keywords and main journals



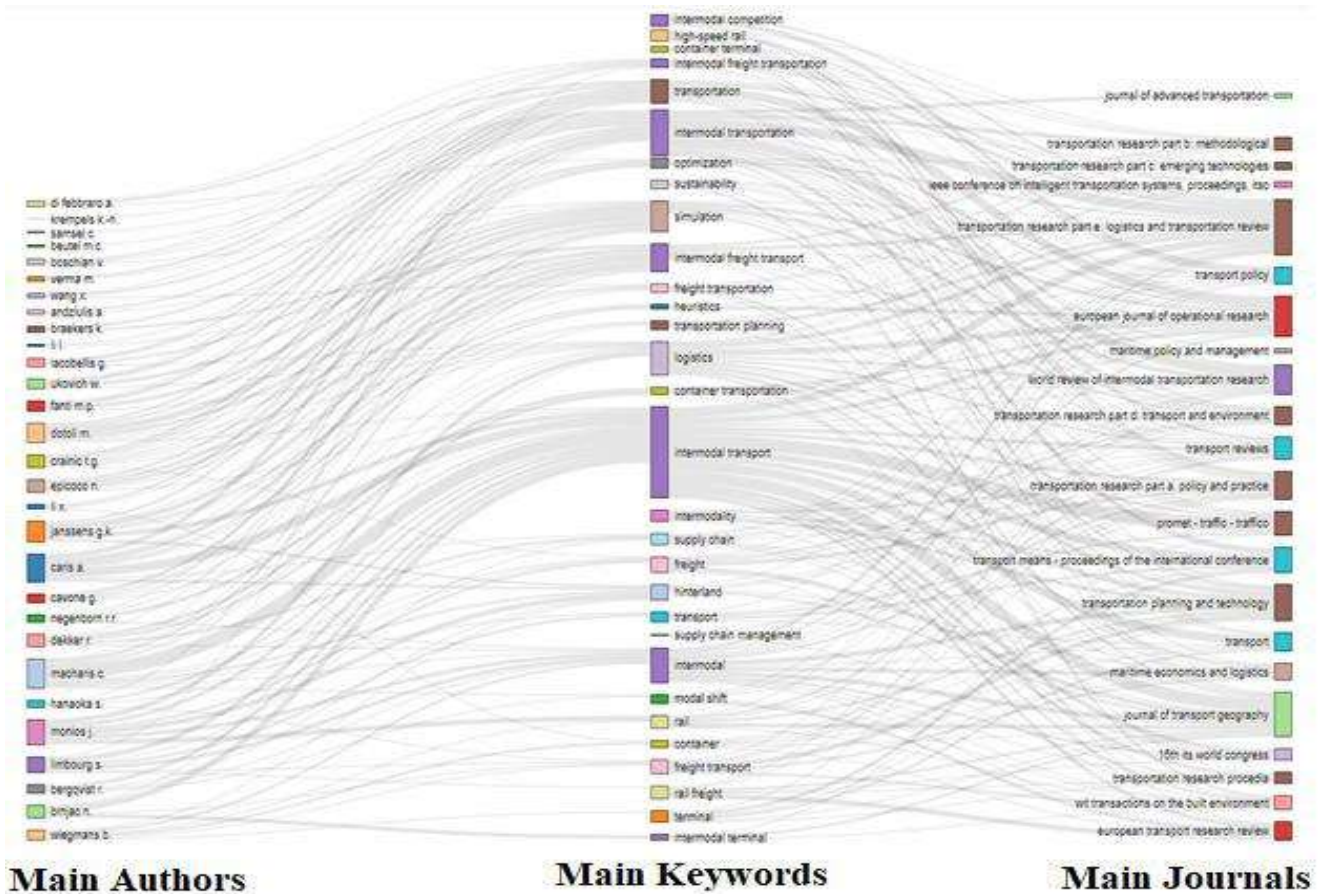


Fig. 5. Network Association of main authors, main keywords and main journals

Fig. 6 is created using authors and author keywords, coappearing in the same papers with the following configuration:

Nodes: 3824 Edges: 11042; Filtering Mode: Remove nodes < 3 links; Disconnected nodes removed: 2358

Further, it is filtered manually setting degree filter to 15-323. It builds a network diagram shown in Fig. 6 with

160 nodes and 413 edges. It is evident that ‘Macharis, C’, ‘Caris, A’ and ‘Janssens, G.K’ are the prominent authors connected with the top keywords ‘intermodal transportation’ and ‘intermodal transport’ as shown in Fig. 6.

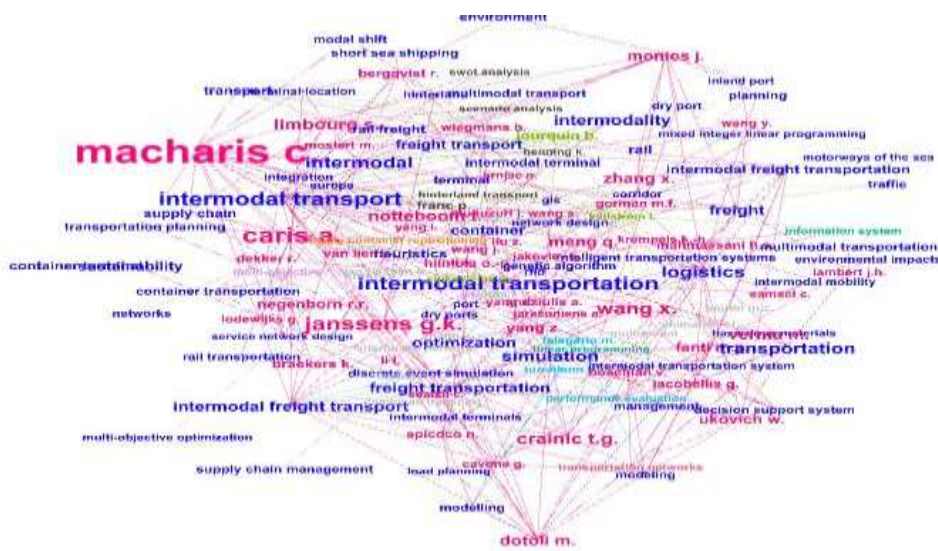


Fig. 6. Network diagram using authors and keywords coappearing in the same papers

Fig. 7 shows association between authors and source titles, coappearing in the same papers with the following configuration: Nodes: 374 Edges: 672; Filtering Mode: Remove nodes < 3 links; Disconnected nodes removed: 3476

Further, it is filtered manually setting degree filter to 6-35. It builds a network diagram shown in Fig. 7 with 54 nodes and 96 edges.

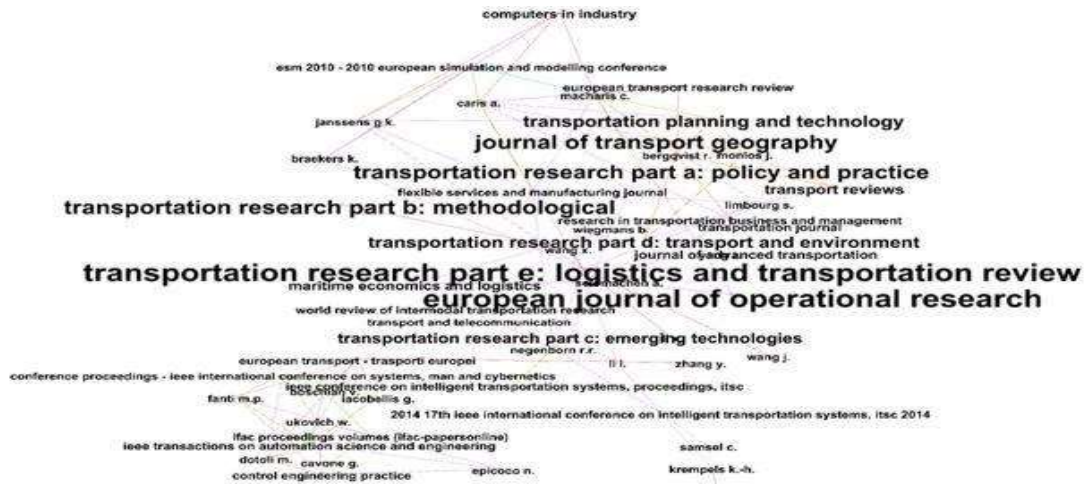


Fig. 7. Network diagram using authors and source titles coappearing in the same papers

In Fig. 7, comparatively big size of the fonts of source titles based on citations received by the publications ‘transportation research part e: logistics and transportation review’, ‘european journal of operational research’ and ‘journal of transport geography’ indicates topmost journals in intermodal transportation. However, despite having maximum number of publications but less citations source title ‘transportation research record’ could not be seen prominently in the network diagram.

Fig. 8, 9, 10, 11 & 12 are partially picked up from original network diagram generated using networks of authors linked by co-publication in intermodal transportation with the following configuration:

Nodes: 1333 Edges: 3013; Filtering Mode: Remove nodes < 3 links; Disconnected nodes removed: 1853

The size of the fonts in these diagrams indicates the most prominent author linked in that network of co-author

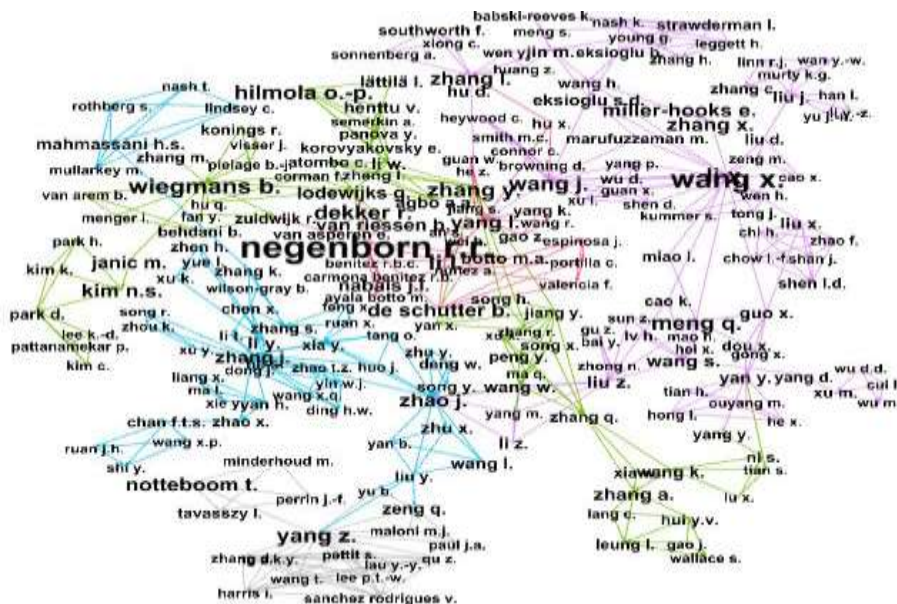


Fig. 8. Network diagram using authors linked by co-publication



‘The issue. traffic, health, environment; intelligent solutions sustaining urban economies’ has been co-authored by 17 authors ‘Bouffier J., Wells A., Dibnah S., Ciolokosz-Styk A., Spallone F., Khoudour L., Goodyer E., Edwards C., Anand S., Convers D., Chirici G., Lasserre B., Raventos T., Kwiatkowski P., Saari H.-K., Groom A., Corvino M.’ which have been reflected in Fig. 12 as a single network.

III. LITERATURE REVIEW

Top cited publications along with few other intermodal transportation publications had reviewed in this section.

Simulation of intermodal transport risks and costs have been studied by Lorenc and Kužnar (2017) considering three different variants through the supply chain. This help to identify risk and take appropriate action to reduce cost[6].

Roso et.al., (2015) studied types of services for three seaport-inland port dyads in three different continents. Understanding of four standard services such as rail drayage transport, transshipment, storage, customs clearance and thirteen value added services such as cleaning, repair, inspection, quarantine, stripping and stuffing, empty container depots, reefer plugs, cross-docking, quality and inventory control, pre-assembly, packing/unpacking/repacking, freight forwarding, and non-drayage container haulage could be used as benchmark for inland ports for devising business portfolio[7].

Stadieseifi et al., (2014) considered tactical, strategic and operational level issues and concluded that integrating different levels of planning might provide more reliability, flexibility, and more important sustainability, generating more efficient solutions for multimodal transportation planning[8].

Metro cities need integrated transport systems consisting of different modes including bus, suburban trains, bicycles considering demand and topography of the area. These might help to improve travel time ratio, travel cost ratio and service ratio. Intermodal transfer facility plays a vital role in intermodal transportation. In metro cities public transport system should be integrated with many other systems such as park and ride facilities, integrated fare and ticketing strategies, quality interchange system and passenger information system. It is necessary that all integrated systems should complement not compete (Shrivastava and O’Mahony, 2010)[9].

Intermodal planning approach has been studied by Goetz et.al., (2007) for seven states by the department of transportation (DOT) in the United States in two different regions. DOT’s are becoming intermodal agencies for planning intermodal transports system efficiently and effectively. However, highway planning’s has been dominant over intermodal approaches[10].

Merrina et al., (2006) discussed random networks and inhomogeneous networks[11].

Role of rail transport in intermodal transportation had been studied by Racunica and Wynter (2005) using hub

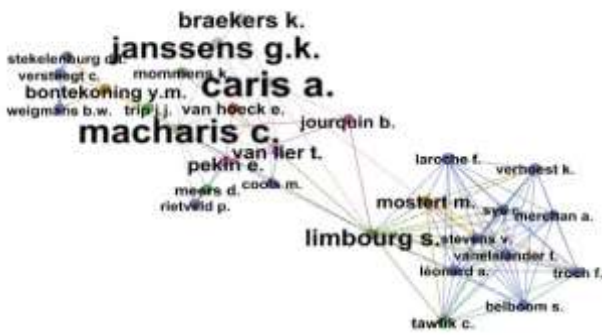


Fig. 9 Network diagram using authors linked by co-publication

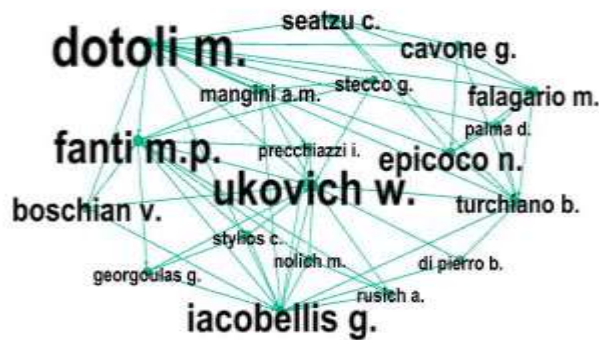


Fig. 10 Network diagram using authors linked by co-publication



Fig. 11. Network diagram using authors linked by co-publication

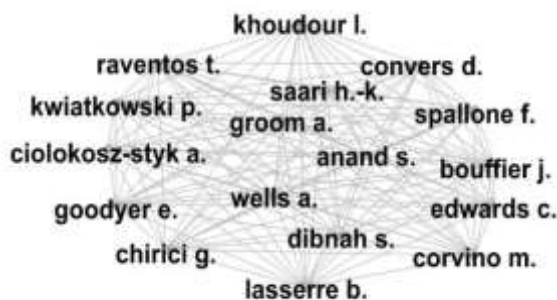


Fig. 12 Network diagram using authors linked by co-publication



and spoke model[12]. The study conducted on 32 terminals in the Alpine region for three cost scenarios. Empirical sensitivity analysis shows that the model appears to be quite sensitive to scale economies

Intermodal transportation is a necessity for moving human or cargoes using different transportation modes. It's an emerging field of operation research which can be explored using different network models (Macharis and Bontekoning, 2004)[13].

Bontekoning et al., (2004) reviewed 92 publications to identify the characteristics of the intermodal research community and scientific knowledge base. They have examined studies related to drayage, rail haul, transshipment, standardisation, multi-actor chain management and control, mode choice and pricing strategies, intermodal transportation policy and planning and all other remaining categories[14].

Arnold et al., (2004) used a linear programming approach for locating rail-road terminals for freight transport. The model had been applied to the Iberian Peninsula using five scenarios considering variations in the supply of transport. They concluded that variation of the relative cost of rail has an impact on location. However, relocation of new terminals within Spain or Portugal will not significantly increase the market share[15].

Choong et al., (2004) studied empty containers movement for potential container-on-barge activities in the Mississippi River basin using integer programming and concluded that a longer planning horizon helps in better empty container distribution[16].

Janic (2003) developed a model to determine the internal and external costs of intermodal and road freight transport networks. He investigated the effects of European Union policy on the prospective competition between two networks from a social perspective[17].

Problems related to storage yards of terminals such as quality control, yard cranes, storage space and IT studied by Zhang et al., (2003). They proposed a rolling horizon approach to reduce workload imbalance in the yard using mathematical programming model in two levels[18].

It's easy to anticipate and understand the need for investments in intermodal transportation using the geography of freight transportation networks. GIS mapping was used to construct and process shipment routes considering different combinations of truck, rail and water transportation. Mapping allows the different mode to be linked together via more than one transportation terminals (Southworth & Peterson, 2000)[19].

Hayut (1981) demonstrated the dynamic development process of a container port system as a five-phase model. He used North American container port as a case study containing implications of containerization to ship operators, ports, and the inland distribution system[20].

IV. FUTURE SCOPE OF THE STUDY & RESULTS

Designing highly responsive and highly efficient supply chain has become extremely important in freight transport. No doubt, today's logistics operations intermodal transportation observes many benefits over unimodal transportation. Many other aspects in association with intermodal transportation could be extended using the

bibliometrics presented herewith to achieve efficiency and effectiveness in the supply chain.

V. LIMITATIONS, IF ANY

Data used in this research is retrieved using the Scopus database only. Though most of the transportation-based journals indexed in the Scopus database, there might be some researches missed out. The citation data used herewith is the Scopus database only, which might differ from other databases. Though, enough care has been taken to check downloaded data sheets, error if any may lead to different interconnectedness in a network diagram. Many other combinations of networks would possible using different input criteria's, but only a few considered in this research paper.

VI. CONCLUSION

Intermodal transportation is a need of the hour in every emerging field. Intermodal transportation research is happening across the world.

Though intermodal transportation developments and research is happening across the world, researchers from the US and Europe have taken lead in publishing researches in intermodal transportation.

The keyword 'intermodal transportation' used for retrieval of the database from Scopus is a popular keyword among the intermodal transportation research fraternity. The subject area for these researches mostly classified under 'engineering' and 'social sciences' category. Since 1985 almost all transportation and operations research journals have been considering intermodal transportation studies for inclusion, however, increased trends have been observed from 2005 till date. Citation analysis reveals that researches published in transportation and operations research journals have been referred by almost all researchers in intermodal transportation. In this paper, network diagram portrays the interconnectedness among authors, citations, co-authors linkage and leading journals in the area of intermodal transportation. This Scopus database based comprehensive research in terms of bibliometrics will lay the foundation for the researchers looking forward to learning popular and significant researches in intermodal transportation for further research.

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VIII. AUTHORS PROFILE



Sanjeev Kadam is an academician in the field of operations management with a mechanical engineering background. Presently he is associated with Amity University Mumbai as an Assistant Professor. He carries versatile military experience in mechanical engineering operations and maintenance field. Also, he had experience in manpower consultancy for oil,

gas, petrochemical, power and manufacturing sectors. His scholarly areas of interest include – operations management and operations research, logistics and supply chain management, business research methods, quality management and project management. He is currently pursuing his PhD

