

# Trends and Developments in Empty Container Repositioning Research

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Container imbalance occurs when there is an excess of empty containers in one location and a shortage in another due to the difference in import and export activity. The situation has become a critical challenge for shipping lines and the logistics industry. One of the most important things to do to handle this situation is the empty container repositioning (ECR), which means shifting of empty containers from regions of excessive volume to regions where their availability is scarce. This study aims to identify the development, trends and research gaps associated with the research related to empty container repositioning. A bibliometric analysis was performed on 232 Scopus-indexed articles that have been published over the span of 50 years which is from 1972 to 2024. The analysis shows that the research on ECR has progressed through three phases where the first phase of slow growth followed by a significant rise after 20 years and rapid growth in publications in the last decade. The study found that there is a vast literature exists on container shipping optimisation but there is still more scope, especially in terms of incorporating carbon emissions and sustainability, reflecting a growing emphasis on environmental impacts in logistics research.

**Keywords:** bibliometric analysis; containerisation; empty container repositioning; factoring analysis; thematic evolution

## I. INTRODUCTION

Container shipping is one of the key elements of the global trade as it contributes to around 80% of the overall world's trade volume (UNCTAD, 2021). As the areas with higher imports build up a large stock of empty containers while areas with higher exports suffer from a shortage of them, this causes an issue in green logistics. Such imbalance costs a lot on transportation and subsequently increases fuel consumption and hence harm the environment (Notteboom & Rodrigue, 2009). This situation has resulted to empty container repositioning (ECR). ECR is significant as it affects the efficiency of global supply chains and gives direct impact to shipping costs, times and port congestion. As the global freight sector undergoes a sustainability transition, focusing on systemic efficiency and environmental impact reduction, ECR emerges as a key area for intervention. Strategies that optimise ECR can directly contribute to sustainable freight

systems by reducing empty runs, optimising asset utilisation and integrating with low-carbon multimodal solutions. This positions ECR not just as an operational problem, but as a strategic component in the broader shift towards green logistics, a theme increasingly highlighted in literature on transport sustainability transitions. As noted by Ribeiro *et al.* (2025), spatial and regional dynamics strongly influence sustainability transitions, including those in the transport sector. Linking ECR with these broader sustainability transition principles highlights its contribution to circular and low-carbon transport systems through improved spatial efficiency and resource optimisation.

Based on the dynamic factors in trade imbalance that affects the movements of international shipments and unpredictable shipping schedules, together with difficulties in obtaining data on the movements and handling of empty containers, the research on this area is limited. The research on ECR has gathered little academic attention for several reasons.

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Initially, primary focus on container logistics is more on loaded containers due to its direct impact on profits, makes the operational costs on ECR overly emphasised. Empty container is regarded as an operational concern and most research works tend to determine the centrality of core logistics operations such as inventory control and transportation scheduling, which are considered more critical. This has led to ECR being classified as a sub-problem of container logistics implying less significance to it compared to the significance of container logistics in a supply chain. Additional fuel consumption and carbon emissions gained attention as sustainability issues became a concern among practitioners and researchers. Despite that, there was a shift in the recent years, where ECR is acknowledged more as an important concept connected with sustainability and the successful application of the technological advancements in such fields as data analytics and optimisation. With the increasing efforts toward attaining operational efficiency and environmental sustainability, ECR is emerging as a key driver to enhance logistics performance in the industry.

Since the direction of the research in ECR is getting more attention than before, it is crucial to understand the trends and developments of ECR research to provide valuable insights in this field of study. This study seeks to provide a synthesis of the trends surrounding ECR by conducting a bibliometric analysis and presenting the direction of future research in ECR. The objective of this bibliometric analysis is to examine several key research questions. First, it seeks to identify the publication trend of research in ECR. Second, it aims to determine the authors and sources that are the primary contributors to this field. Finally, the analysis explores the research themes that have driven the development and expansion of ECR, providing insight into its evolution and impact.

## II. METHODOLOGY

### A. Search Strategy

Bibliometric analysis is a quantitative technique used to study the academic publishing in literature. It systematically examines the published documents to identify trends and relationship between published works (Ninkov *et al.*, 2022). Empty container repositioning has been in the literature for

over 50 years since the first publication in 1972. Bibliometric analysis shows that the second publication emerged two decades later and it has increased since then.

In this research, the dataset was downloaded from Scopus database on 27 September 2024. The keyword that needs to be captured is empty container repositioning. The search query for empty container repositioning involves multiple terms, as not many documents use the exact term. Other terms considered for empty include unloaded, idle and void. For repositioning, there are several other terms used that described the same meaning and represent the documents from logistics such as logistics, redistribution, distribution, management, movement, transfer, allocation, fleet and imbalance. When the documents were check according to subject area, there are few documents about empty container that were not related to container logistics. In order to exclude these documents, the keywords pesticide and cylindrical are exclude from the search title. These documents were excluded using “and not” function. The asterisk was used as a truncation symbol to capture all variations of the root word. The search keyword is TITLE ((empty OR unload\* OR idle OR void AND container) AND (reposition\* OR logistic\* OR handling OR redistribut\* OR distribut\* OR manag\* OR movement OR transfer OR allocat\* OR fleet OR imbalance) AND NOT (pesticide OR cylindrical)). The search yielded 233 documents. There was one Erratum in Document Type, and it was removed leaving a total of 232 documents for further analysis. Articles, conference papers, book chapters, reviews and books are accepted for analysis. Figure 1 illustrates the data retrieval process for this study.

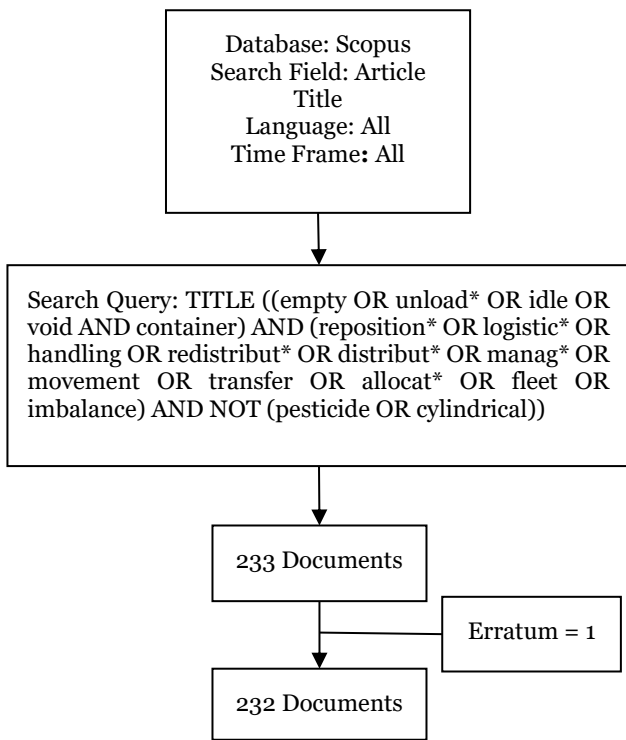


Figure 1. Data retrieval procedure

Source: Figure by authors

### B. Data Cleaning and Harmonising

The dataset was initially downloaded in CSV format and subsequently processed using the specialised bibliometric tool, biblioMagika (Ahmi, 2024). The data was further analysed, and tables and graphs were developed on Microsoft Excel to present and visualized the findings. Consequently, author names, author IDs, affiliations and keywords were cleaned and refined using OpenRefine (Ahmi, 2023). These elements were thoroughly checked and any inconsistencies were cleaned and standardised using OpenRefine's clustering techniques. This step was important in order to avoid errors which are common in huge bibliographic databases, such as variation in spelling, for example, British and American English and variation in the spelling or writing style of

authors' names. The OpenRefine clustering and reconciliation functionalities had been used to address such issues since they are powerful tools of data analysis. The tool's ability to detect similar and non-identical data through different clustering methods allows the standardisation of author names, affiliations and keywords. Once the data was thoroughly cleaned and harmonised, it became suitable for an in-depth bibliometric analysis.

The cleaned data was analysed using two bibliometric analysis tools. First, VOSviewer, a standalone bibliometric software developed by Van Eck and Waltman (2010), was employed to visualise the relationships between keywords and to map their thematic evolution over time. The main advantage of VOSviewer is its capacity to generate complex and aesthetic keyword co-occurrence networks that provide a notion of the intellectual topology of the research area. Furthermore, to perform more advanced bibliometric analysis, Bibliometrix, an R package developed by Aria and Cuccurullo (2017) was adopted. One area that Bibliometrix was particularly helpful is in analysing the relationships between authors, countries and keywords. It also divided the keywords into separate groups based on themes related to research areas which was helpful in analysing the common trends and focuses of the data set. In combination, these tools provided multiple facets of the bibliographic data and provided adequate means for a comprehensive examination of the content and organisation of the research field of study.

### C. Descriptive Analysis

#### 1. Publication trends

There are 232 documents on ECR were published from 1972 to 2024. Figure 2 shows the trend of cumulative number of publications over time with a fitted trend line represented by a quadratic equation.

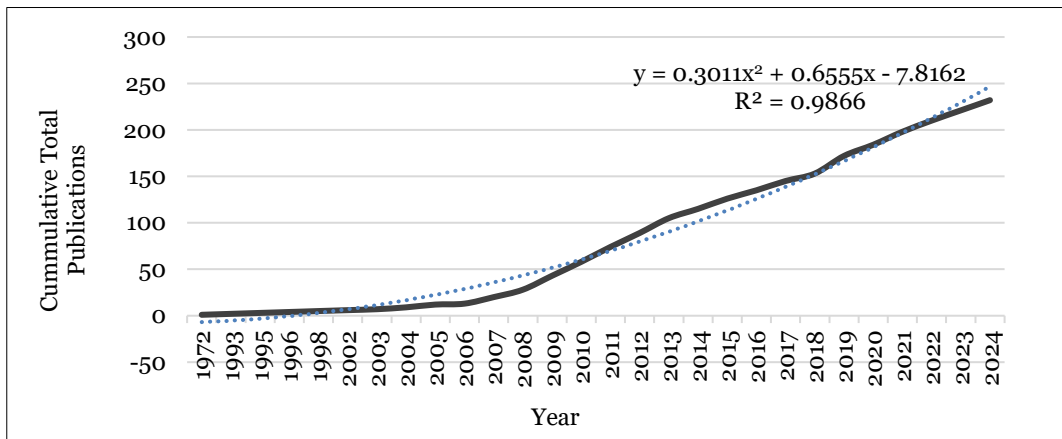


Figure 2. Cumulative Growth of Publications Over Time (1972-2024)

The *y*-axis represents the cumulative number of publications accumulated over the years. The values increase as the axis goes up. The *x*-axis shows the timeline of the publications spanning over 50 years. There are two lines in the figure. The solid black line denotes the actual cumulative number of publications over time. The dotted line is the fitted trend line, defined by equation  $y = 0.3011x^2 + 0.655x - 7.8162$ . The trend line shows that the tendency for cumulative number of publications to increase as the years increase based on the positive value of 0.3011. This equation suggests that the number of publications is increasing exponentially in this field. How well the trend line fits the actual data is presented by R-squared, or coefficient of determination (Hahn, 1973). The R-squared value of 0.9866 is quite close to 1. This indicates that the quadratic model captures the trend accurately and provide an excellent fit for this data.

Overall, the trend can be divided into three phases. The first phase is from the year 1972 until around the year 2000 where the growth in the cumulative number of publications is relatively slow. This is supported by the fact that no publications were made for 20 years after the first article was published in 1972. The second phase is from the year 2000 to around 2010, during which the cumulative number of

publications accelerated and interest in ECR grew significantly. After that the publication rate continued to grow rapidly from 2010 until 2024, indicating an increase in research activity and contributions.

The contributions from research activity can be seen in the most productive source titles. Table 1 highlights the top 15 of source titles in ECR with Transportation Research Part E: Logistics and Transportation Review lead in the source titles with 12 documents and towering 1188 citations, proving its significant impact. The second and third source title also contributes to the productive source titles but with lower citations. Maritime Economics and Logistics published eight documents with 291 citations and Maritime Policy and Management with seven documents and 213 citations. Transportation Research Part B: Methodological and European Journal of Operational Research rank fifth and sixth respectively, with five publications each, making a significant impact with 415 and 365 citations. On the other hand, Logistics Journal and AIP Conference Proceedings have similar number of publications as compared to seven other source titles but contribute significantly a smaller number of citations revealing that they may have low impact or visibility.

Table 1. Most Productive Source Titles

Source Title	TP	TC
Transportation Research Part E: Logistics and Transportation Review	12	1188
Maritime Economics and Logistics	8	291
Maritime Policy and Management	7	213
Sustainability (Switzerland)	6	42
Transportation Research Part B: Methodological	5	415
European Journal of Operational Research	5	365
Journal of Dalian Maritime University	5	10
Computers and Industrial Engineering	4	157
European Transport Research Review	3	50
Journal of Wuhan University of Technology (Transportation Science and Engineering)	3	8
Journal of Transportation Systems Engineering and Information Technology	3	11
AIP Conference Proceedings	3	4
Logistics Journal	3	0
Transportation Research Record	3	49
Journal of Transport Geography	3	56

Note: TP=total number of publications; TC=total citations

2. Most influential documents

Table 2 presents the most influential documents in ECR. The most influential document is published by Shintani *et al.* (2007). It stands out at 303 citations suggesting its significant impact in the field. This paper designs container liner shipping service networks by simultaneously addressing ship

deployment and empty container repositioning. They use two-stage approach and genetic algorithm and conclude that including empty container repositioning in ship routing leads to more insightful solutions. The focus on profit maximisation does not account for carbon emissions or other environmental concerns, which are increasingly important in the shipping industry.

Table 2. Highly Cited Documents

Author	Year	Title	Source	TC
Shintani K.; Imai A.; Nishimura E.; Papadimitriou S.	2007	The container shipping network design problem with empty container repositioning	Transportation Research Part E: Logistics and Transportation Review	303
Crainic Teodor Gabriel; Gendreau Michel; Dejax Pierre	1993	Dynamic and stochastic models for the allocation of empty containers	Operations Research	296
Cheung R.K.; Chen C.Y.	1998	A two-stage stochastic network model and solution methods for the dynamic empty container allocation problem	Transportation Science	219

Meng Q.; Wang S.	2011	Liner shipping service network design with empty container repositioning	Transportation Research Part E: Logistics and Transportation Review	216
Choong S.T.; Cole M.H.; Kutanoglu E.	2002	Empty container management for intermodal transportation networks	Transportation Research Part E: Logistics and Transportation Review	188
Song D.P.; Dong J.X.	2012	Cargo routing and empty container repositioning in multiple shipping service routes	Transportation Research Part B: Methodological	171
Dong J.X.; Song D.P.	2009	Container fleet sizing and empty repositioning in liner shipping systems	Transportation Research Part E: Logistics and Transportation Review	151
Li J.A.; Leung S.C.H.; Wu Y.; Liu K.	2007	Allocation of empty containers between multi-ports	European Journal of Operational Research	149
Lam S.W.; Lee L.H.; Tang L.C.	2007	An approximate dynamic programming approach for the empty container allocation problem	Transportation Research Part C: Emerging Technologies	132
Shen W.S.; Khoong C.M.	1995	A DSS for empty container distribution planning	Decision Support Systems	127
Li J.A.; Liu K.; Leung S.C.H.; Lai K.K.	2004	Empty container management in a port with long-run average criterion	Mathematical and Computer Modelling	116
Song D.P.; Dong J.X.	2013	Long-haul liner service route design with ship deployment and empty container repositioning	Transportation Research Part B: Methodological	106

Crianic *et al.* (1993) with 296 citations claims second place among the most cited documents in ECR with the study focusing on dispatching empty containers to meet export demands and repositioning them for future needs using dynamic and stochastic models. Cheung and Chen (1998) and Meng and Wang (2011) published documents with more than 200 citations group. Cheung and Chen (1998) addressed the dynamic empty container allocation problem by formulating it as a two-stage stochastic network to minimise costs by applying a stochastic quasi-gradient method and hybrid approximation procedures. Meng and Wang (2011) introduced a network design for the liner shipping problem that combines hub-and-spoke and multi-port-calling

operations while considering empty container repositioning and developed a mixed-integer linear programming model for optimisation. Most of other influential documents have a common in their research which focusing on optimising the management of empty container within the liner shipping systems. The most common optimisation techniques used by these influential authors are integer programming (Meng & Wang, 2011; Choong *et al.*, 2002; Song & Dong, 2012; Song & Dong, 2013) and heuristic approach (Shintani *et al.*, 2007; Dong & Song, 2009; Li *et al.*, 2007). The authors who contributed significantly to the most influential documents are Song D. P. and Dong J. X., who co-authored three articles that are among the most highly cited documents. Their

articles mainly concern liner shipping services, which are the key element of the containerised transportation system. They emphasise on the choice of the best routing plans and the identification of the right size of containers. Their works underline the significance of these factors in the context of increasing the effectiveness of global shipping.

### D. Intellectual Structure

#### 3. Relationship Among Authors, Countries and Keywords in ECR

Figure 3 illustrates a highly interconnected and active research community in ECR. This Sankey diagram is developed using bibliometrix (Aria & Cuccurullo, 2017). The relationship is based on top 20 authors, the countries they are associated with and the research they are involved in. The prominent authors are Jin Z. H, Song D. P, Dong J. X and Cai J. X. These authors seem to be working on various research topics, indicating their active involvement in research. This suggests that they could be leading figures in ECR.

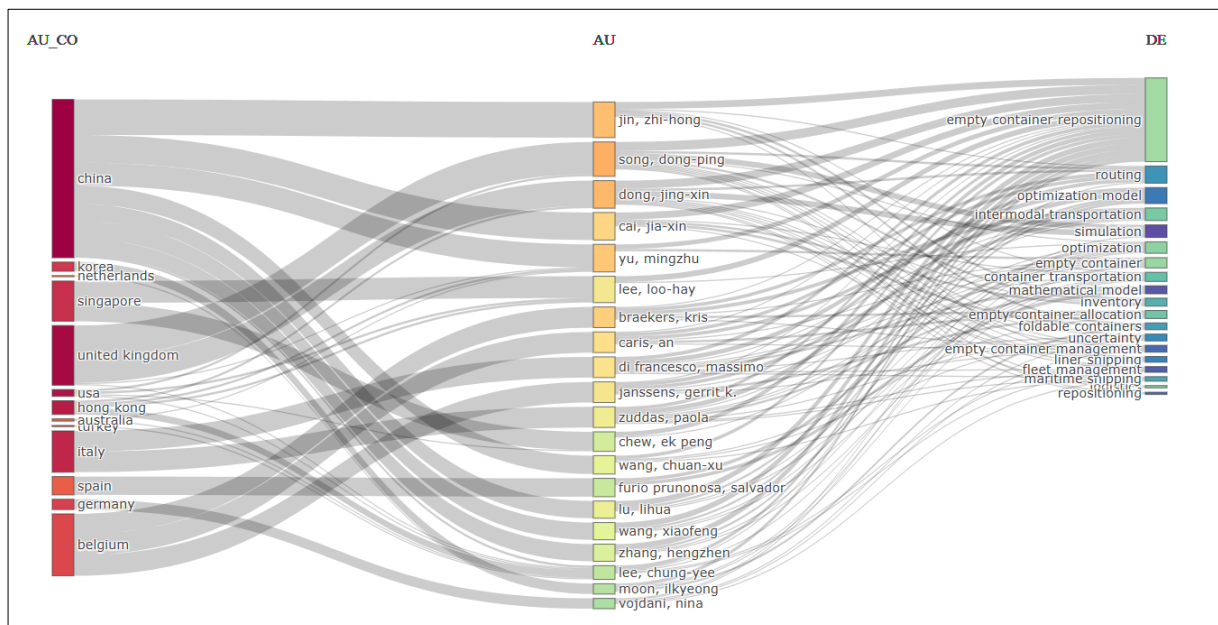


Figure 3. Relationship of Top 20 Authors, the Countries and Keywords

The left column lists various countries and their connection to the central column shows where the authors are based. It appears that China has the most significant contribution in terms of research, as presented by the thicker connections, followed by other countries like United Kingdom, Belgium and Singapore. The right column displays the keywords used by these authors in their documents. Empty container repositioning has link with many authors across the globe, which emphasises the importance of this issue in the global supply chain and transportation. Keywords such as routing, optimisation model and simulation suggest a trend toward using advanced quantitative techniques to solve ECR problems. Other important keywords used by the top 20

authors are intermodal transportation, foldable containers and maritime shipping.

#### 4. Thematic Evolution of ECR

VOSviewer (Van Eck and Waltman, 2010) is used to create a thematic evolution in ECR. It is presented by Figure 4 which denotes the keywords used by all authors in the dataset. The size of circles represents the frequency of the keywords used in the documents. The connections between these circles represent relationships for instance co-authorship and co-citation between the documents. The larger the circle, the more influential or frequent the element it represents and the stronger or more numerous the connections, the more

significant the collaboration or thematic overlap (Aria & Cuccurullo, 2017). The most noticeable keyword is empty container repositioning which is identified as a focus area of the network. This term has the largest circle, which means it is the most associated with other terms and is the most recurrent keyword. The colour gradient from blue to yellow signifies the evolution of keywords representing research topics over the years. Earlier studies that were presented by blue and purple colours focused on keywords like genetic

algorithm, allocation and network design. Maritime shipping, routing, ocean carriers and cargo are closely related to ECR suggesting that maritime logistics and transportation are heavily researched areas in ECR in the green colour which was the focus around the year 2015. More recent research displayed by yellow colour is moving toward carbon emissions, container leasing and pricing, pointing to more sustainable and reasonable solutions in ECR.

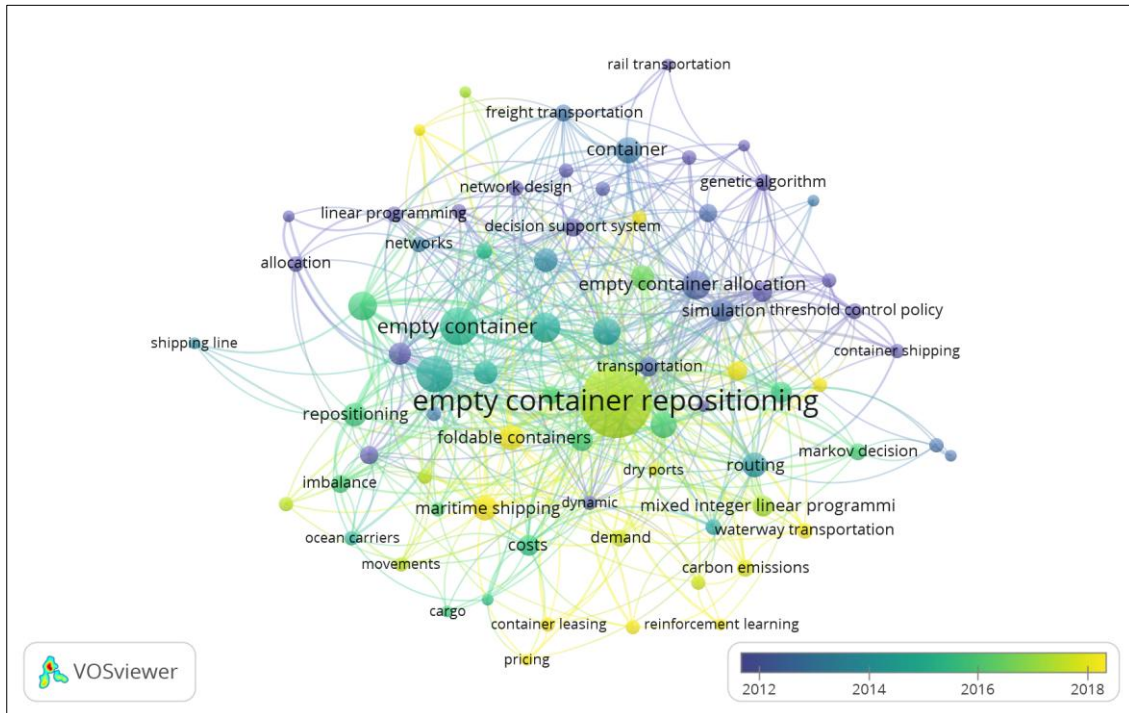


Figure 4. Thematic Evolution of Empty Container Repositioning

Overall, the depicted diagram is helpful in presenting the growth of the keywords used by authors representing issues and methodologies evolution over time in the research in ECR. It is therefore could highlight the future direction of the research in this field.

### 5. Keyword factorial analysis

A factorial analysis was built using bibliometric (Aria & Cuccurullo, 2017) to illustrate the clusters in future directions of research in ECR as presented in Figure 5. There are three clusters created from the keywords used by the authors of ECR publications. The closer keywords and cluster together indicating stronger co-occurrences. The green cluster focuses on simulations, stochastic modelling and threshold control policies related to container shipping which highlights the

applications of mathematical and probabilistic model to manage uncertainty in container shipping. The red cluster is the smallest cluster, emphasising on freight transportation and cargo repositioning along with the challenges in the freight transportation field involving container imbalance. The global trade imbalance between different regions results in the transportation of empty containers from surplus areas to deficit areas where customer demand exists (Abdelshafie *et al.*, 2022). Repositioning is an issue arising from trade imbalances faced and when dealing with supply and demand across the globe, ocean carriers play an important role. The biggest cluster is the blue one involving many keywords used by the authors. It is the most extensive cluster and covers empty container logistics, supply chain management, rail transportation, dynamic programming, optimisation and carbon emissions.

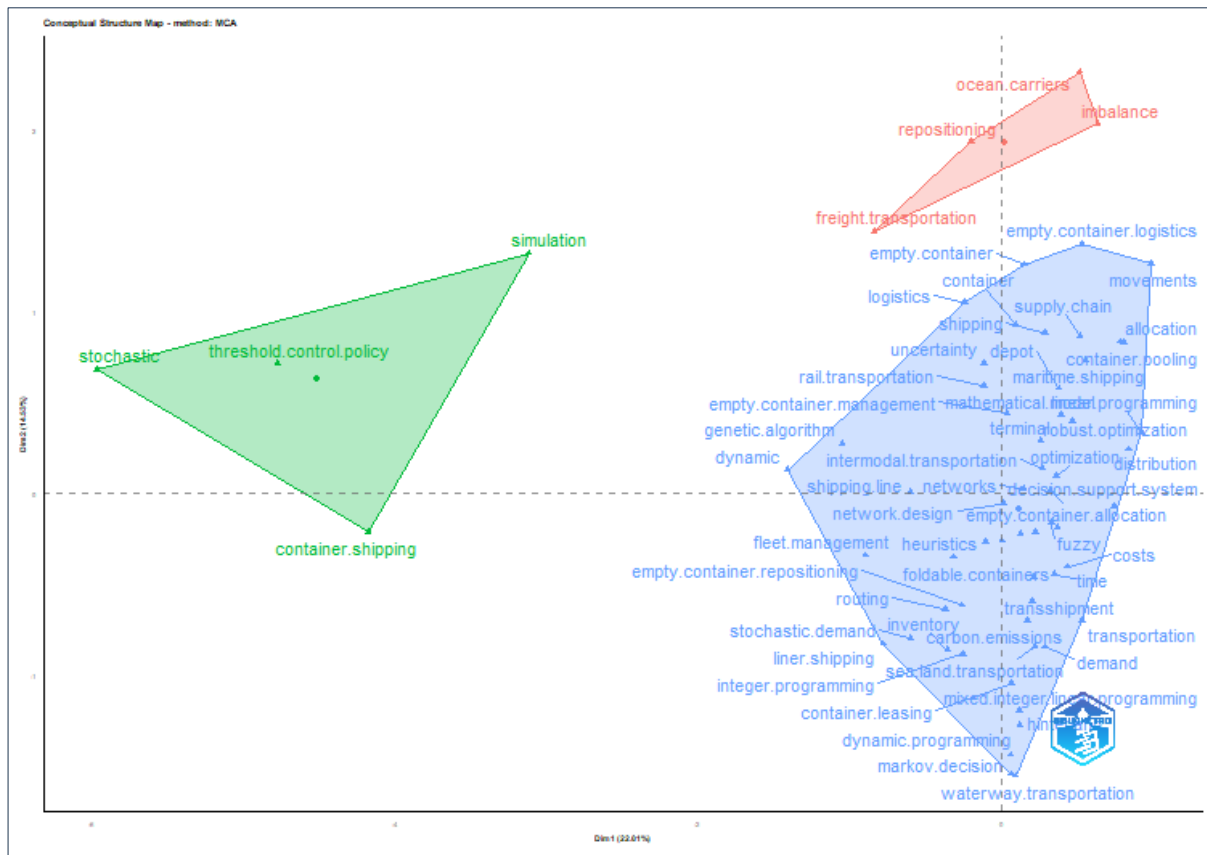


Figure 5. Keyword Factorial Analysis

The key observations that can be drawn from Figure 5 is the size of the clusters. The smallest cluster represents emerging topics that have not yet been extensively explored yet. It indicates the area with high potential for growth and could become significant trends in the future. Researchers have opportunity to pioneer studies in these areas and contribute novel insights on this field of work. Nevertheless, this does not imply that the area represented by the largest cluster lacks opportunities for further exploration. Future research might be conducted by combining the keywords between clusters and exploring on multidisciplinary research.

### III. DISCUSSION AND CONCLUSION

Academic research on ECR, spanning 232 articles published in Scopus database between 1972 and 2023, has been analysed using bibliometric tools. These tools include trend analysis, identification of the most influential sources and authors, exploration of relationships between authors and countries, keywords evolution and keywords clustering analysis. The research on ECR has progressed through three

phases: slow growth initially (1972--2000), a significant rise in interest (2000--2010) and rapid growth in publications (2010--2024). The comprehensive review identified Transportation Research Part E: Logistics and Transportation Review as the most influential source and have made significant contributions in terms of total publications and citations. Although other journals have published the numerous numbers of articles, their visibility is low measured by citation scores in comparison. Several scholars have published their works, with the identified work by Shintani *et al.* (2007) depicting container shipping network design and empty container repositioning as major themes in most contributions. This shows that the research activity in this field is constantly increasing which points to important developments in this area during this period, both in terms of the number of publications and their citations. Factorial analysis reveals important strategies for identifying promising future research directions. The factorial analysis as in Figure 5 reveals clusters that map directly onto the key challenges of transitioning to sustainable container transport. The large blue cluster, encompassing 'optimisation', 'carbon

emissions' and 'supply chain management' underscores the central role of advanced analytical models in achieving decarbonisation goals. Future research here could focus on multi-objective optimisation that simultaneously minimises costs and emissions, incorporating variables like alternative fuels and slow steaming. The green cluster, focused on 'simulation' and 'stochastic modelling' highlights the importance of managing uncertainty; a critical factor for integrating volatile renewable energy sources and assessing the impact of new environmental regulations. Digitalisation, through AI and real-time data, can enhance these models for dynamic ECR decision-making. The small red cluster, dealing with 'freight transportation' and 'imbalance' represents an underexplored frontier. This is where macro-level policy incentives (e.g. carbon pricing, empty container repositioning mandates) and circular economy principles (e.g. standardising container designs for cross-line use) could be investigated. The weak interconnection of this cluster with others suggests a significant gap in research that links operational ECR models with broader regulatory and economic frameworks. The approach of grouping research by clusters and finding interdisciplinary opportunities in areas of overlap and grouping research by similar fields and finding new specialisations gives a methodical approach to research. Combinatorial optimisation from overlapping fields may yield synergistic results when applied to container shipping,

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which is a field where stochastic approaches to logistics have not been examined adequately but may yield novel solutions when combined with other less interfaced keywords. In addition to this, consideration of sustainability, digitalisation and supply chain will also enrich the future research in this field. This mutual alignment ensures that the research addresses both the advancement of knowledge and the demands of the current global logistics management sector, driving significant breakthroughs. Consequently, while further enhancements and diversification of operational functions persist, the prospect of their negative effects arising due to environmental disruptions becomes more challenging. This has also directed attention towards sustainability which has become more relevant especially where carbon emissions are concerned. The research regarding the carbon emissions and their possible solutions has become popular among the researchers working in different fields. More researchers are focusing on how organisations can ensure that increased efficiency in operations is not achieved at the expense of the environment and sustainability.

## IV. ACKNOWLEDGEMENT

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