A REVIEW OF THE KEY COMPONENTS DRIVING DECISION-MAKING IN THE TRANSITION FROM ICE TRUCKS TO BE TRUCKS WITHIN THE FREIGHT SECTOR

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ABSTRACT

In South Africa road transportation dominates freight movement, with most freight transportation performed by road, using mainly trucks for larger payloads. Efforts to reduce road-based logistics are underway, however full reliance on trucks cannot yet be eliminated due to its current high demand and the complexity of moving goods. With an increase in the demand to be sustainable from the perspectives of operational, environmental and economic considerations, the planning of operations aligned with these goals are emphasised. The study aims to reduce adoption uncertainty by illuminating the multidimensional considerations to be considered surrounding battery electric trucks (BETs) adoption and enable vehicle operators to ease disruption to their operations. A literature review was done to identify the decision-making aspects that influence the adoption of BETs in global freight applications. Existing literature was analysed from technological, operational and financial perspectives, highlighting the critical aspects to consider when making decisions. The review included the analysis to conceptualise the information deemed important to transition vehicles and identifying current trends indicating focus areas within literature. The synthesis emphasises the decision-making factors and implications on stakeholders within the road freight sector with the identification of industry challenges that should be addressed. The factors can enable informed decision-making for policymakers, industry leaders and researchers considering the shift to electromobility.

Keywords: Decision-making, Freight transportation, Sustainability, Technology adoption.

1. INTRODUCTION

The global demand towards sustainability drives the need to seek solutions within the transport industry for greener technology implementation. However, the shift to greener technologies like battery electric trucks (BETs) present complex challenges, such as determining their suitability within operations and their impact on the total costs whilst balancing the uncertainties regarding charging infrastructure requirements (Alanazi, 2023). The adoption of new vehicle technology within current logistics operations such as short-distance deliveries require the identification of the important decision-making factors that influence the ultimate implementation of certain vehicle types. Krug, Knoblinger and Qvist (2023) states that BETs have emerged as a possible solution to the reduction of the negative impact that emissions from road transportation have on the environment, especially in the context of shorter distance applications (Haubner, 2024). With stakeholders seeking guidance on the impact of the implementation of technology such as BETs, it creates an opportunity to improve the quality of delivery operations while improving organisational strategies (Engholm et al., 2024). With factors such as

congestion, regulations and unclear policies to guide sustainable transportation, it becomes important to create clear roadmaps when considering new technology implementation into current operations.

The exploration of the gaps and considerations within this systematic review of relevant literature aims to conceptualise the information needed to transition to electromobility. It highlights current focus areas and research trends for effective implementation strategies and key challenges needed to be addressed. Although the foundational understanding of the components through a literature search is important, this is seen as an initial starting point before the comparison will be done to the South African or developing country context.

2. REVIEW OF LITERATURE

The transition from fossil fuel-based transportation systems to low-emission vehicles involves adopting cleaner energy sources, supported by technology, policy and operational practices (Jelti et al., 2023). Such a transition could take decades to be complete or never globally change away from fossil fuel-based technology in full. The extent and speed of any transition will be driven by the combination of feasibility levels achieved across technological, operational and financial aspects. Given the broad uncertainty regarding the considerations within the possible transition to sustainable freight transportation, informed decisions need to be made that can ensure sustainable implementation of technology. As the shift is a multifaceted and broader shift than merely the focus on implementing new vehicle technology (Qadir et al., 2024), it includes aspects such as energy supply, energy storage, operational changes and transport policy adjustments. A preliminary search in literature found that studies focus on the impact that a technology transition can have on an organisation's environmental footprint as well as the economic considerations (Sharif et al., 2024).

There remains limited clarification within literature on the decision making and holistic planning needed to be considered in freight operations, leading to organisations being unsure regarding their implementation strategy especially pertaining sustainable practices as highlighted in The Triple Access Planning approach (Lyons et al., 2024). From the stakeholder perspective within the broader adoption ecosystem, the collaboration potential is an essential part of the implementation of the key elements needed for the transition. To ensure a successful implementation within the freight sector, it is essential to highlight critical considerations that will need to be addressed in planning. The feasibility of using vehicles from a technical perspective is important but also justifying the operations should be considered as this has a financial impact involved for a business considering a more sustained impact within company operations (Garrido-Moreno, Martín-Rojas and García-Morales, 2024). Given many unique challenges within freight transportation, and especially in the Southern African context, the decision to implement a technology that can lead to possible disruptions is not considered lightly. Although the drive for alternative solutions within the road freight sector is demanded, a key driving factor remains the cost factor related to the transition (Aryanpur and Rogan, 2024). The assessment of the technical feasibility within the specific operational contexts is reliant on the technology readiness and long term predicted impact of the vehicles.

The aim of doing a scientometrics analysis within a systematic literature review is to identify and analyse the key components and factors that influence stakeholders when making the decision to adopt battery electric vehicles as opposed to conventional vehicles (Leydesdorff, 2001). This analysis quantitatively examines the research outputs to identify trends, assess the impact and map the collaborations that offer insights for strategic and

policy decisions. The synthesis of the information within existing research in this analysis intends to provide an understanding of the relative contributors that influence logistics operations and are considered important planning aspects for sustained implementation of technology. The focus is to gain perspective on the quantitative aspects within research which can hold valuable information to consider when analysing the content of the research field for further qualitative analysis.

3. OBJECTIVES

The main objective within this study was to gain perspective of the focus areas within current research regarding the integration of BETs within freight operations. The main objective is broken up into the following sub-objectives to comprehend the findings:

- The analysis of the growth rate of literature publication regarding the transition to BETs and decision-making in terms of implementation.
- The identification of the highest publishing countries with the most research and higher interest in the adoption of the technology.
- The analysis of the keyword co-occurrences within literature with the aim to gain perspective on the interconnected themes and trends within literature.

4. RESEARCH METHODOLOGY

This study has been done as part of an exploration to investigate what research has been done regarding the steps to transition to battery electric vehicles within freight delivery by using literature sources to identify co-occurrences within current research. Data were collected from Scopus, Web of Science, Ebscohost and Google Scholar to ensure comprehensive coverage of research. The primary question is a broad and complex statement in the perspective of a technology transition. To ensure a more focused and manageable analysis, the question is broken down into four specific sub-questions. This approach aims to allow a more detailed exploration of the distinct components in the perspective of stakeholders and to address each of them systematically for clear insights.

In the context of sustainability within logistics and stakeholders involved, the technical capabilities of vehicles, the operational considerations within their current processes and the impact it has on the financial aspects of businesses are the focus areas for logistics companies (Özlü & Çelebi, 2024). An additional key consideration of stakeholders is the use of existing guidelines or best practices to follow in terms of the three identified focus areas. It is presumed to be important to explore whether there are existing planning frameworks or resources to guide decision-making for those interested to transition to new technology (Hovi et al., 2020). The sub-questions were derived from the primary research question as given in Table 1. The development of the search strings was performed by a trial-and-error approach where the various combinations of relevant keywords and synonyms were tested until the search results yielded articles with relevant information to the research questions. The search strings that were used within the different databases with its corresponding sub-question aimed at finding related publications can be seen in Table 1.

The data were statistically analysed to interpret findings presented graphically as well as in text. Tools such as VOSviewer, Excel, R and Bibliometrix were used for keyword analysis and other geographical aspects to clearly understand the patterns and relationships that are within research pertaining to decision making within electromobility. The key findings from the analysis are synthesised to reflect an understanding of the ideas presented in literature.

Table 1: Research question and sub-research questions with the derived database search strings

Main research question:	
What are the key components and features that influence the decision making towards the adoption of battery electric trucks for short distance delivery operations compared to the conventional diesel trucks?	
Sub question	**Search string**
1. What are the key vehicle specifications or features that are needed for trucks used within delivery operations?	(Truck OR Freight OR Fleet) AND (Feature OR Requirements OR Specification) AND (Delivery OR Distribution OR Collection) AND (Logistics OR Transport) AND ("Selection criteria" OR "Decision making")
2. What are the operational considerations and performance measures within freight transportation operations?	(Freight) AND (Operation) AND (Management OR Consideration) AND (Measure OR Benchmark OR Indicator) AND (Performance) AND (Logistics OR Transport OR Road)
3. What important cost aspects must be included in the comparative analysis between conventional trucks and battery electric trucks?	(Truck) AND (Electric) AND (Diesel OR Conventional OR "Internal combustion engine") AND ("Total cost of ownership" OR Cost OR "Life cycle") AND (Comparison OR Analysis OR Assessment) AND (Transport OR Logistics)
4. Are there current best practices or guidelines to plan towards transitioning to new truck technology?	(Transition OR Adoption) AND (Strategies OR Planning) AND ("Business model" OR "Best practices" OR Guidelines OR Methods) AND (Truck)

5. SCOPE AND LIMITATIONS

The authors used four databases to gather information on literature related to decision-making for the transition to BETs. The databases provided valuable research articles and may be limited on industry specific content. The network visualisation tool VOSviewer was used to analyse the co-occurrence networks of keywords. This analysis included all keywords within the gathered content for interpretation. The co-occurrence network was constructed to visually identify any relevant and valuable findings from current research within the topic. An analysis of other bibliometric data was also done to relatively place the information within the timing of publication and geography of the research.

6. DATA ANALYSIS AND INTERPRETATION

The key findings addressing the primary question of the review are presented here with an overview of the focus areas that has a major impact when implementing vehicles such as battery electric trucks into freight transportation. An initial analysis was done on 20 August 2024 to investigate the current state of research related to the topic. An updated search was done on 22 January 2025 to obtain the results for the analysis of the metadata from the database searches to gain a relative perspective of the research published by this date and to ensure a full dataset for the 2024 publication year was included.

6.1 Yearly Growth in Publications

The growth in publications over the span of a stated period, can indicate the increased interest and acknowledgement of the specific topic or research area. Given the bar chart in Figure 1 the research towards the adoption of BETs have increased from 2015 to 2024. From 2014 to 2018 there is a steady growth in the publications which shows an interest within the topic although the scale was still relatively small. Although the publications from 2018 to 2019 have a slight decline, from 2019 to 2024 a sharper increase can be noticed in publications indicated by the trendline in Figure 1. This rise can be an indication of more attention and interest related to BET adoption. The trend within the decade of publications shows a clear progression in the research field contributions. The interest in electromobility adoption within operations is increasing and it is evident that more research on this topic can increase implementation rate and effectiveness (Alarcón et al., 2023).

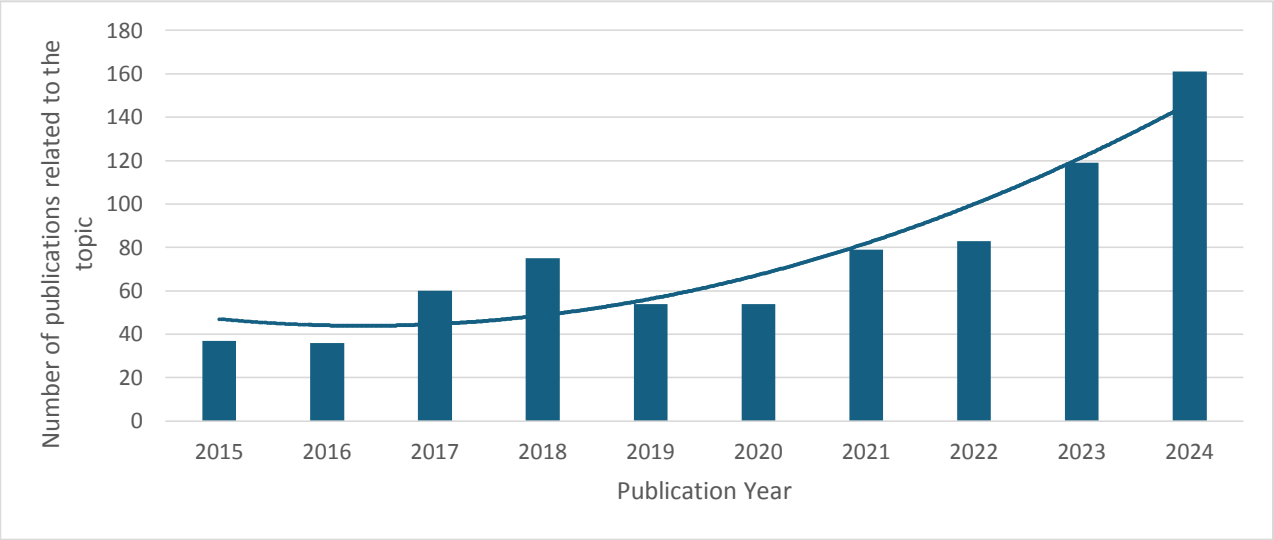

Figure 1: Growth rate in publications from 2015 to 2024

6.2 Countries with the Highest Number of Publications

The top 10 countries were taken with the highest number of publications within this gathered research products. In Table 2 the top 10 countries can be seen, indicating that research in the adoption of more advanced technologies such as BETs are more prominent in developed countries. This is an indication that countries like the United States of America, EU nations and China prioritise sustainable implementation and invest into the research thereof. Current published research aimed at more developed country situations, cannot necessarily as easily be adopted to fit developing country needs as well. With small contributions from developing countries, the increase in interest and involvement in the topic of sustainable development topics is important to addressing the global challenges.

The bar chart in Figure 2 shows the top 10 countries with the highest number of publications related to the topic as well as the number of publications from South Africa. The United States of America has the highest number with 86 publications followed by China with 57 publications.

Table 2: Top 10 countries with the highest number of publications

Rank	Countries	Number of Publications
1	United States of America	109
2	China	66
3	Germany	60
4	Italy	41
5	Netherlands	39
6	United Kingdom	21
7	Canada	21
8	Sweden	15
9	Spain	15
10	Brazil	14
37	South Africa	3

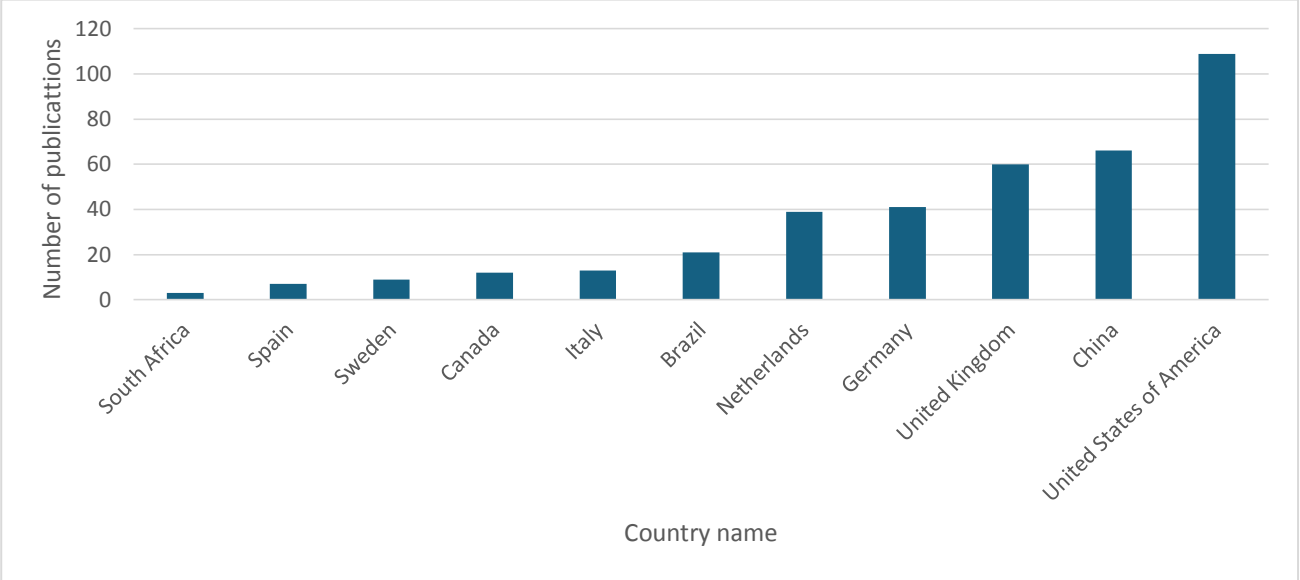

Figure 2: Top 10 highest publishing countries

6.3 Co-Occurrences of Keywords

As validation the co-occurrences of the keywords used within the articles gathered through the various database searches were extracted to form an understanding of the collective interconnection of terms used in research. The literature defined keywords that are most frequently used are clustered together and the co-occurrences of these words are used to gather information from the body of research related to important relationships within the research topic (Radhakrishnan et al., 2017). From the network plot presented in Figure 3 that was created using VOSviewer, there are key findings observed from the literature sources which indicate the core themes, trends within the identified research and validating that the articles are relevant to the topic being researched. The minimum number of occurrences was set at 5 to ensure that keywords that are relevant but might not be used that often is not left out. This resulted in 367 out of 5926 keywords that fall within this range ensuring that the focus is not too narrow but also include topics that could have significant connections within the view of the research landscape. The identified

keywords were grouped based on the association strength or link strength within the publications. The link strength quantifies with a positive numerical value, the relationship between two items namely the number of publications in which two terms co-occur. The total link strength of an item reflects the cumulative strength of its connections to all other items in the network. As a result, the keywords fall within 5 clusters with the biggest cluster consisting of 166 items. The keyword with the highest occurrence is “trucks” with a link strength of 1374, followed by “greenhouse gases” with 54 occurrences and a link strength of 900. “Decision making” occurred 94 times with a link strength of 776, “automobiles” occurred 94 times with a link strength of 726 and finally, “freight transportation” occurred 76 times with a link strength of 702. Figure 3 visualises the relationship between frequently used keywords in the gathered literature, based on their co-occurrence across publications. The larger keywords with higher link strengths can be seen in Figure 3 with the smaller dots indicating keywords that have lower occurrences. The link strength is an indication of the high relevancy within the gathered literature due to the keyword being used in conjunction with other keywords on a high number of occasions.

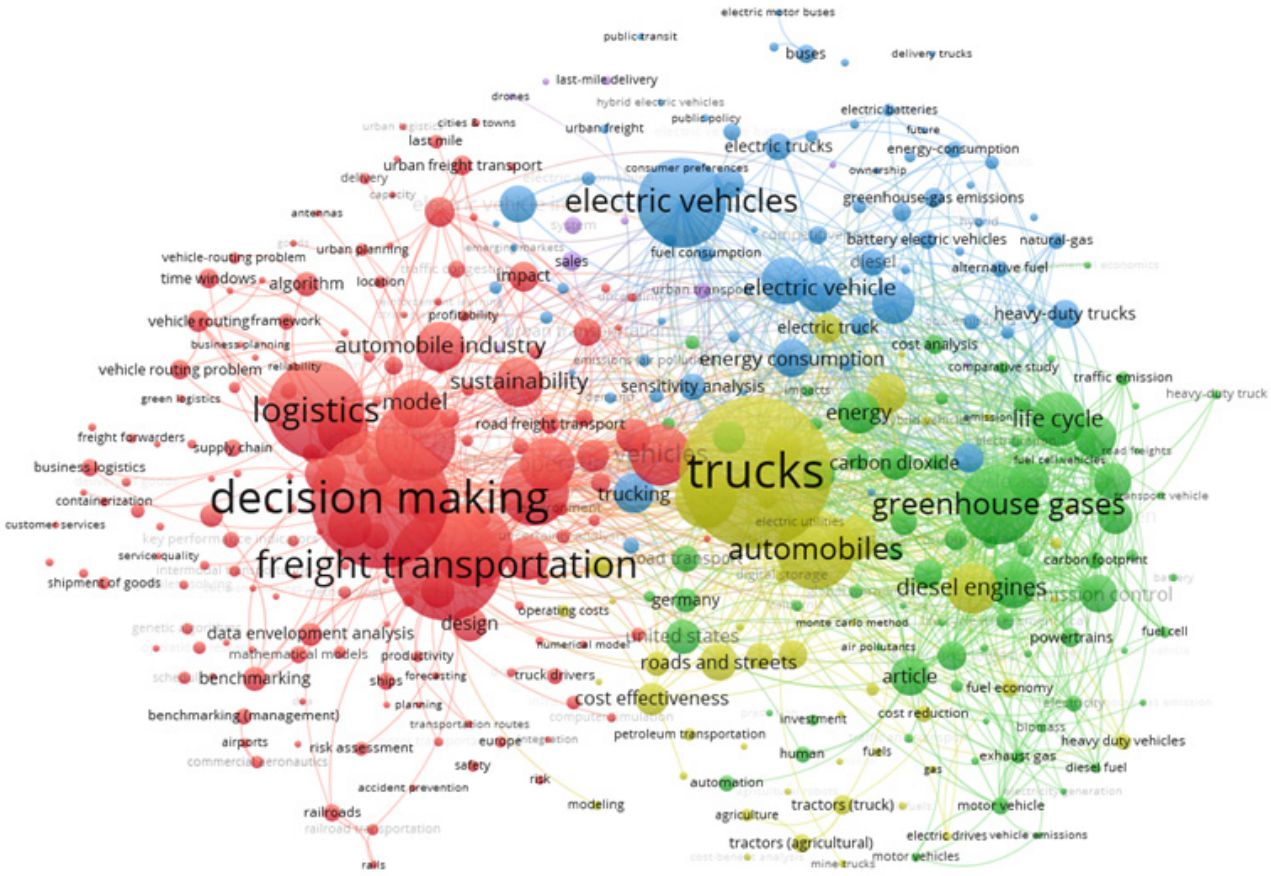

Figure 3: Co-occurrences map of author keywords

The five clusters indicated in Figure 3 by the different colours can be observed and an analysis of the keywords within each cluster revealed the trends and the dominant common topics that are reflected within each cluster. Out of the total of 367 keywords, the distribution of these keywords is given, indicating the stronger focus and higher density of keywords falling in the decision-making within logistics and freight transport research focus. The following information was observed to be reflected within each of the clusters:

- Decision-making within logistics and freight transport (red): 166 keywords.
- Road based transportation and automobile mobility (yellow): 74 keywords.

- Greenhouse gases and emissions (green): 68 keywords.
- Electric vehicles and sustainable vehicle technologies (blue): 49 keywords.
- Customer-focused logistics and deliveries (purple): 10 keywords.

According to the co-occurrence analysis that can be seen in Figure 3 produced using VOSviewer, within literature, electric vehicles and trucks are separate focus areas with clear links between the two based on the map, but it is researched separately instead of it being expected to be categorised under vehicles and electric vehicles. Public transport is excluded from the electric vehicles and not a focus point for electrification even though it is not the focus of the research question, the collaboration opportunities are not acknowledged in the widespread research neglecting a link between the different transportation applications. Although the shift to alternative drivetrain technology for vehicles is commonly seen as result of the demand to reduce greenhouse gas emissions within the transport industry, the co-occurrence map reveals that there is not a clear link between studies focussing on the strategic decisions within freight transport and logistics and the mitigation of greenhouse gas emissions. It is however acknowledged that trucks mainly used for freight transportation on roads are a major contributor to the emissions and as a result have the potential to significantly reduce emissions and contribute to net-zero targets being reached. The focus of vehicle implementation is driven by the cost-effectiveness and profitability of the technology. The results indicate that most research focus on whether it is technically feasible and profitable for company operations. Until this is the case it might not be desirable for companies to implement till the incentives and benefits outweigh the cost of implementing the technology. The four maps in Figure 4 were obtained by focussing the analyses on specific keywords and seeing the links between that keyword and other words based on the keywords being used together within literature.

In Figure 4a the decision-making related to freight transportation and vehicles used is a complex problem with different elements to consider and has a range of considerations that will take more collaboration to initiate solutions. Evident here is the absence of links to the keywords of Emissions and Greenhouse Gases in the decision-making process for freight transportation, logistics and trucks. Freight transportation, specifically road transport by means of heavy-duty vehicles are significant contributors to greenhouse gas emissions and this is highlighted in Figure 4d where the keyword focussed on is freight transportation with a significant link to trucks. From the literature obtained the articles focussing on decision-making, as shown in Figure 4a, indicate that profitability within logistics is often prioritised and not reducing or addressing greenhouse gas emissions despite the growing demand for sustainability. Research on electric vehicles is dominantly on smaller vehicles and larger vehicles like trucks are seen as a separate category, highlighted in Figure 4b and c. This is potentially a missed opportunity for collaboration between the industries for increased service implementation within the electromobility realm.

The complexity of the problem, with all the considerations and possible trade-offs, underscores the need for improved stakeholder collaboration for effective development and finding holistic solutions within mobility across the various vehicle sectors.

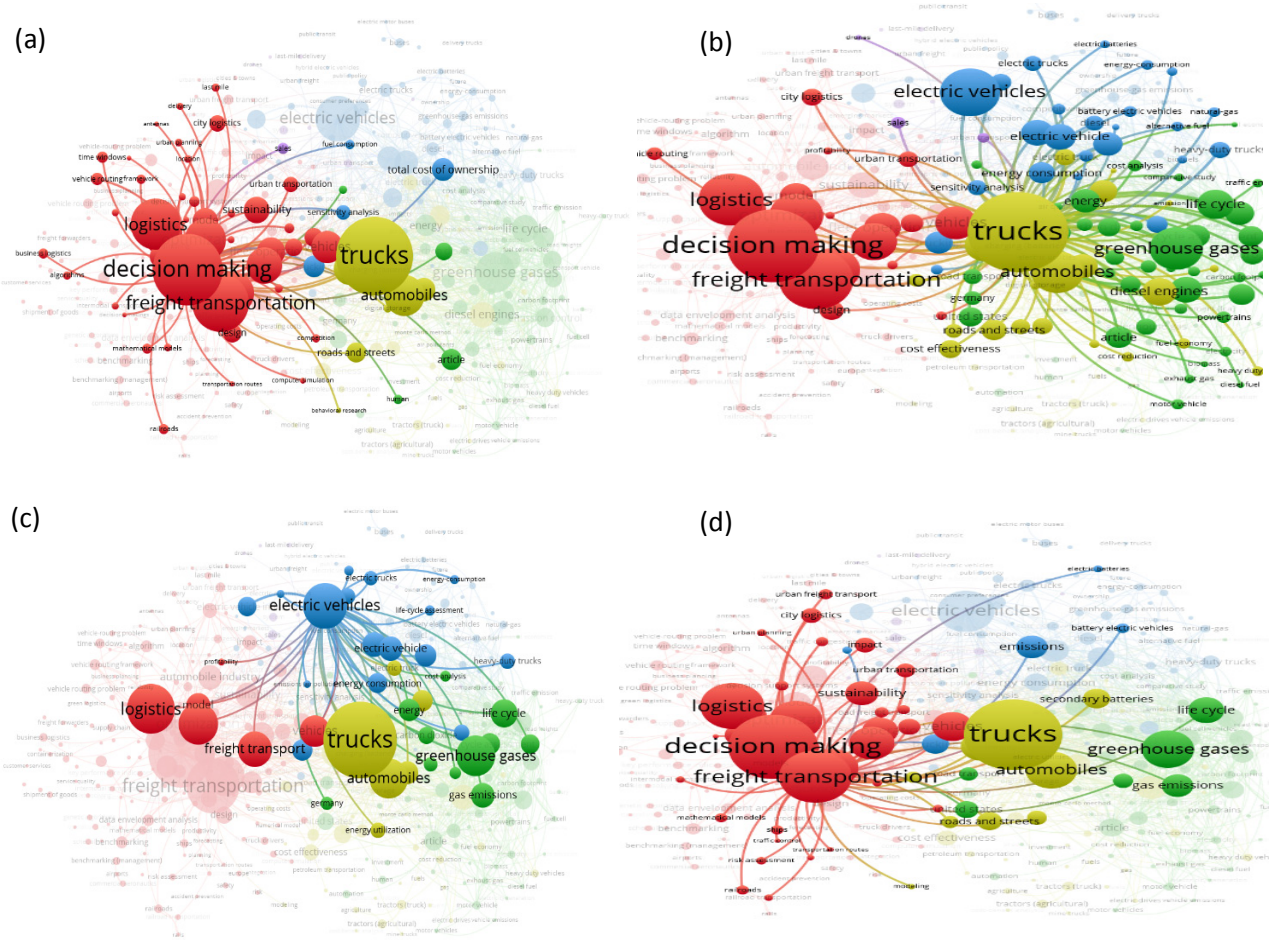

Figure 4: A focus on specific key words indicates the linkages to other keywords existing in the literature: a) Decision-making, b) Trucks, c) Electric vehicles, and d) Freight transportation

7. FINDINGS

The review revealed a variety of critical points and gaps that might possibly be underexplored in the literature related to the adoption of battery electric trucks in the freight sector. The lack of specific application-based research makes it challenging to have an estimation of the real-world impact given certain applications that could be relevant within the current context of logistics. It is evident that the influence of weather conditions and the geographical aspect of an application cannot be neglected due to its importance related to the energy consumption (Zhou et al., 2017). This aspect in the long term can have a major impact on whether the conditions are suitable for the adoption of electric vehicles. The perceptions of vehicle users and owners with regards to the adoption remain uncertain, with assumptions within literature in terms of vehicle life being predicted as the real-world scenarios remain unclear. Although the different chargers and charging strategies are being researched and planned out, it is still dependent on the application and geography to analyse which strategy is best to implement, complemented by planning that needs to be done to suit the type of charging strategy (Noll et al., 2022).

Current operations exhibit variability and the ability to adapt when changing to new technology will become more important. This means that the resilience of the operations and operations planning will become more important as the adoption of electric vehicles is increased. Technology advancements are expected to enable higher feasibility of vehicle adoption in various applications as a result of possible lower prices due to improved

technology and greater uptake (Jahangir Samet et al., 2024) The consideration of various trade-offs such as energy recovery and battery degradation as well as the variability of actual required battery capacity versus the battery capacity that are implemented within the vehicles are important (Hunter et al., 2018).

Cost considerations and the profitability aspect of a decision remains prominent compared to the desire to have environmental sustainability within operations according to Pajić, Andrejić and Kilibarda (2021). This trend can be seen throughout and has a dominant impact on the planning towards decarbonisation. The pressure on governments to reduce emissions will increase as the demand grows for adopting alternative technology and this may benefit smaller companies in the long term if legislation is in place to assist in the adoption (Özlü & Çelebi, 2024). From a South African perspective, the focus on the research is limited for larger electric vehicle adoption, although there is industry professionals interested in the technology and transition. A notable gap observed in the analysis is the absence of a strong linkage between the decision-making processes in freight transportation despite the environmental impact of this sector being well-documented, the terms of “emission” and “greenhouse gases” are not prominently the driving force behind decision making. From the literature, challenges in South Africa will add different contexts to the problems and the adaptation of solutions to fit the specific geographical concerns will be needed (Melander & Nyquist-Magnusson, 2022). The external factors like availability of sufficient chargers creates hesitancy for implementation, highlighting the need for real-world evaluation before implementing the solution (Gao et al., 2017). The adaptation of the market in terms of the vehicles being sold will become more important as the uptake increases, with higher production demands of new battery electric vehicles and lower production of the current ICE vehicles (Bal & Vleugel, 2018; Gray et al., 2022). Vehicle utilisation according to Lyu, Pons, and Zhang (2023) should be considered a determining factor within the analysis of implementing BETs, as this can indicate the potential of better planning for charging and understanding practical challenges which can bridge the gap of uncertainty. The importance of planning for the adoption is widely acknowledged with the unavoidable transition to sustainable solutions becoming more generalised.

8. CONCLUSION

The transition to battery electric trucks within freight transportation is gaining global attention, and research related to the transition steps an increasingly more explored topic. The study explored the relevance of the interrelated aspects within decision-making factors that influence the adoption of BETs. The study showed a steady growth of publications over time as well as the geographical focus of the papers to highlight the rising awareness of adopting sustainable freight transport solutions. By analysing the keywords through a co-occurrences analysis, the study identified the key focus areas within research. One of the key findings is the lack of influence that emissions and greenhouse gasses has as drivers for decision making in the research analysed. Understanding the co-occurrence patterns provides valuable insights of focus areas, prevailing themes and trends within research of emerging technologies. These findings are therefore the foundation for future exploration of the collaborative efforts needed within freight transportation towards electromobility and shed light on the research focus areas that need to be considered when decisions are made regarding this transition.

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