



SMART MOBILITY FOR CHILDREN WITH CEREBRAL PALSY: A SYSTEMATIC REVIEW OF SMART WHEELCHAIRS WITH MECANUM WHEEL TECHNOLOGY

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Abstract: This study explores the direction, trends, and core focus of research on smart wheelchairs using mecanum wheel technology for children with cerebral palsy. Employing a Systematic Literature Review (SLR) guided by the PRISMA protocol, relevant articles were selected from the Scopus database covering publications from 2019 to 2024. Bibliometric analysis using VOSviewer was conducted to map author networks, keyword co-occurrences, and research trends. The review highlights a notable increase in publications beginning in 2017, peaking in 2019, reflecting rising academic interest in mobility solutions for children with special needs. Although publication frequency declined in subsequent years, a resurgence was noted in 2023 and 2024. A drop in 2025 signals ongoing research gaps, especially in addressing the needs of children with cerebral palsy. Keyword analysis reveals a shift from purely mechanical design toward integration of adaptive learning, skill development, and user support, with frequent terms such as *need*, *skill*, *training*, *attitude*, and *educational software*. The findings underscore the interdisciplinary nature of the field, with contributions from engineering, special education, rehabilitation, and psychology. The United States, United Kingdom, and India dominate in research output, with increasing contributions from Malaysia and Brazil. In conclusion, future smart wheelchair development should go beyond technical innovation to include educational and psychosocial considerations. Advancing this field requires sustained interdisciplinary and international collaboration to create inclusive, adaptive, and sustainable mobility solutions for children with disabilities.

Keywords: Cerebral Palsy, Smart Mobility, Chair wheels, Mecanum, Assistive Technology.

INTRODUCTION

Cerebral palsy (CP) is a motor development disorder caused by brain damage occurring during early life stages (Luthfiyah et al., 2022). Children with CP typically experience significant challenges in movement, maintaining body balance, and performing daily activities independently. In this context, assistive technology plays a crucial role as a supportive solution to enhance the mobility and independence of children with CP. Innovations in this field have progressed rapidly, ranging from conventional manual wheelchairs to automated wheelchairs, and have now evolved into smart wheelchairs (Mawaddah & Sartinah, 2025). Smart wheelchairs are designed using modern technologies such as sensor systems, artificial intelligence (AI), and integration with Internet of Things (IoT)-based devices. One notable innovation is the use of mecanum wheels, which are special omnidirectional wheels that allow flexible, multi-directional movement. This feature is highly beneficial for children with CP as it enables them to navigate more easily in confined or complex spaces. Therefore, the development of smart mobility technology based on mecanum wheels has become a vital focus in creating more adaptive and child-friendly assistive solutions (Mais, Zusfindhana, & Kismawiyati, 2021).

Although numerous studies have addressed the development of wheelchairs for individuals with disabilities, there remains a limited number of investigations that specifically focus on smart wheelchairs equipped with mecanum wheels for children with cerebral palsy (CP). Several previous studies have made important contributions—for instance, researchers have designed intelligent wheelchairs controlled by brain signals, although these models have not incorporated omnidirectional wheel technology (Syakura et al., 2021). Other researchers have concentrated on the implementation of sensors for automatic navigation and obstacle avoidance. Meanwhile, (Mais, Zusfindhana, & Megaswarie, 2021) evaluated the technical performance of mecanum wheels in enhancing the maneuverability of smart wheelchairs, but their study did not address the specific needs of children with CP. Although each of these studies offers valuable insights into technological advancement, there has not yet been an integrated approach that systematically examines research trends and developments in the context of smart mecanum wheelchairs for children with CP.

This study proposes a distinct approach by conducting a systematic review using the PRISMA protocol to select and filter relevant scientific literature. The primary data source is Scopus, one of the leading academic databases that hosts high-quality publications. To analyze the relationships among research themes and keywords, this study utilizes VOSviewer, a bibliometric mapping tool that enables detailed visual analysis. This strategy allows for the construction of a comprehensive research landscape, the identification of research gaps, and projections for future technological developments in a more structured and data-driven manner.

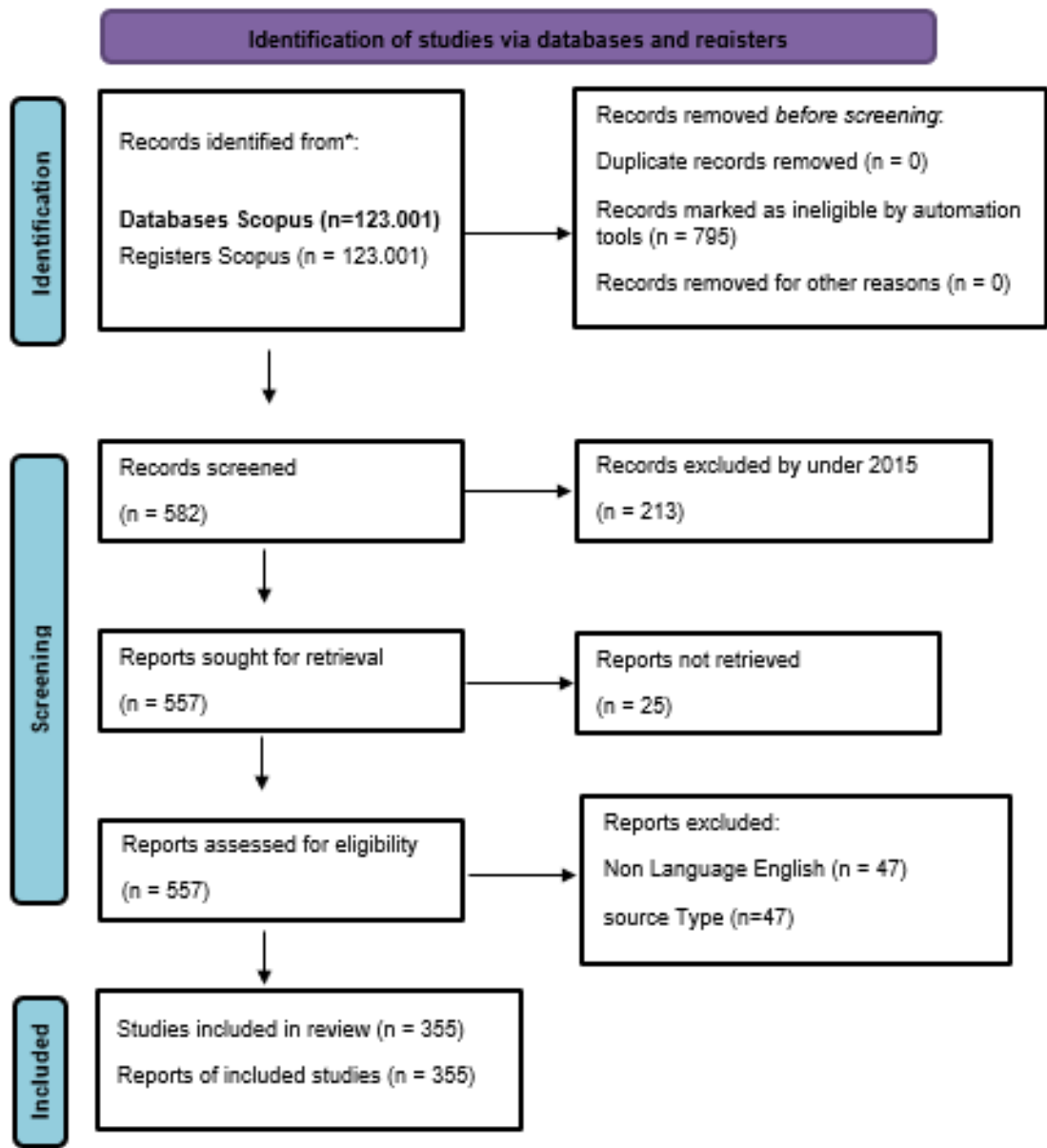
Recognizing the importance of this issue, this study seeks to answer a central question: What are the recent trends, key areas of focus, and existing research gaps in the development of smart wheelchairs with mecanum wheel technology for children with cerebral palsy over the past five years. To explore this, a Systematic Literature Review (SLR) was conducted, combining both quantitative and qualitative approaches. Through this review, the study hopes to contribute meaningfully to the ongoing development of assistive technologies that support mobility for children with special needs. More than just mapping the existing research, this work aspires to guide future innovations that are not only technologically advanced, but also inclusive, compassionate, and grounded in the real-life needs of children and their families.

METHOD

This study employs a Systematic Literature Review (SLR) approach to collect, screen, and analyze scientific articles discussing smart wheelchairs equipped with mecanum wheels to support the mobility of children with cerebral palsy (Siswanto, 2010). The research design is qualitative in nature and based on document analysis, referring to the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) as the primary framework for screening and reporting literature data. There is no direct interaction with human subjects, as the study focuses entirely on reviewing relevant scholarly publications (Ramamurthy et al., 2024). The data source was the Scopus database, with the publication period limited to the years 2019 through 2024. The search strategy involved keywords such as *“smart wheelchair,” “mecanum wheel,” “cerebral palsy,”* and *“assistive technology for mobility.”* The PRISMA protocol served

as a structured method for identifying and collecting relevant journal articles from Scopus.

Figure 1. PRISMA Protocol for Smart Mobility in Cerebral Palsy: Focus on Smart Wheelchairs



The data collection procedure was carried out through a systematic search process and selection based on inclusion and exclusion criteria. The selected articles were peer-reviewed journals indexed in Scopus, written in English, published within the last five years, and directly relevant to the topic of smart wheelchairs using mecanum wheel

technology for children with special needs, particularly those with cerebral palsy. Articles that were not fully accessible, did not specifically address children with CP, or were sourced from non-journal publications such as institutional reports or dissertations were excluded from the analysis.

All eligible articles were analyzed using VOSviewer to generate a bibliometric map showing connections between authors, research trends, and keyword distributions over the past five years. The data analysis began with the extraction of metadata from each article, including title, authors, publication year, keywords, and abstract. This was followed by bibliometric analysis based on keyword co-occurrence and author collaboration (co-authorship), which was then visualized in the form of thematic maps. Subsequently, a thematic content analysis was conducted to identify the direction and focus of the reviewed studies. The validity of the findings was strengthened through source triangulation, by comparing visual mapping results with manual article review. The reliability of the analysis was further supported by internal peer-review among the research team members.

This study was conducted through an online-based review and analysis process, centered within the Department of Special Education at Muhammadiyah University of Lampung. Through this systematic approach, the research aims to generate a comprehensive mapping of knowledge related to the development trends of smart wheelchairs with mecanum wheels for children with cerebral palsy. The findings are expected to contribute meaningfully to shaping future directions in the innovation of assistive technologies, making them more effective, targeted, and responsive to the specific needs of children with disabilities.

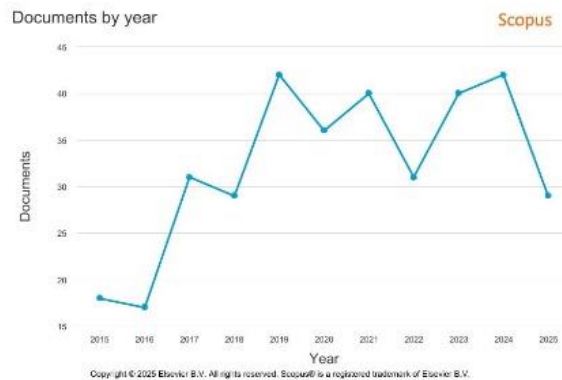
RESULT AND DICSUSSION

A. Results

Based on the conducted study, the following results were identified:

1. Publication Trends in Smart Mobility for Children with Cerebral Palsy: Mecanum Wheelchairs

Figure 2. Research Trends in Smart Mobility for Children with Cerebral Palsy: Mecanum Wheelchairs



Based on the "Documents by Year" chart from the Scopus database, it is evident that the number of publications related to smart wheelchair technologies—particularly aligned with the theme “*Smart Mobility for Children with Cerebral Palsy: A Systematic Review of Smart Wheelchairs with Mecanum Wheel Technology*”—has experienced notable fluctuations from 2015 to 2025. In the early years, specifically 2015 and 2016, the number of published documents remained relatively low, under 20 publications. This suggests that interest in smart mobility innovations and assistive technologies such as mecanum wheels was still limited at the time.

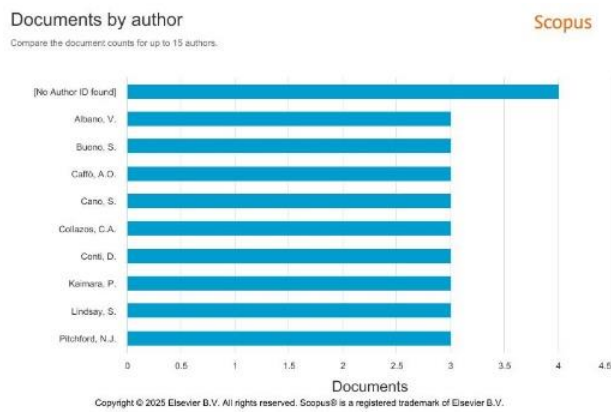
A sharp increase began in 2017, with over 30 publications, and continued to rise, reaching its peak in 2019 with approximately 42 documents. This trend reflects growing academic interest in innovative mobility solutions, in line with the advancement of supporting technologies such as automated control systems, intelligent sensors, and omnidirectional wheel systems. Although a slight decline occurred in 2020, the number of publications rebounded in 2021. However, the most significant drop was observed in 2022, likely due to a shift in global research priorities during the COVID-19 pandemic, which focused more on public health and crisis management.

Publication trends recovered in 2023 and reached a second-highest point in 2024, indicating renewed interest in the development of assistive technology—particularly in the area of smart mobility devices. However, in 2025, the number of publications declined sharply again. This indicates that there remains ample opportunity for future exploration, especially in the context of smart wheelchair development using mecanum wheels tailored to the needs of children with cerebral palsy.

Overall, these fluctuations demonstrate that research in adaptive mobility technologies continues to evolve but has yet to be fully focused on user groups with special needs, such as children with cerebral palsy. Therefore, this systematic review is crucial in providing a comprehensive mapping of the field, identifying major trends, and guiding future research agendas toward more inclusive and impactful assistive technology development.

2. Authors in Smart Mobility Research for Children with Cerebral Palsy: Mecanum Wheelchairs

Figure 3. Authors in Smart Mobility Studies for Children with Cerebral Palsy: Mecanum Wheelchairs



The "Documents by Author" chart from the Scopus database shows that contributions to the topic of smart wheelchairs using mecanum wheel technology for children with cerebral palsy are relatively evenly distributed among several researchers. Most of the featured authors such as Albano, V. (Stasolla et al., 2021) (Stasolla et al., 2016) (Stasolla et al., 2015), Buono, S. (Conti, Di Nuovo, et al., 2017) (Conti, Commodari, et al., 2017) (Conti et al., 2020), Caffò, A.O. (Stasolla et al., 2021) (Stasolla et al., 2016) (Stasolla et al., 2015), Cano, S. (Aristizábal et al., 2017) (Köckerling et al., 2019) (Vázquez-Cano et al., 2015), Collazos, C.A. (Aristizábal et al., 2017) (Flórez-Aristizábal, Cano, Collazos, Solano, et al., 2019) (Flórez-Aristizábal, Cano, Collazos, Benavides, et al., 2019), Conti, D. (Conti et al., 2020) (Conti, Commodari, et al., 2017), Kaimara, P. (Kaimara, 2023) (Kaimara et al., 2021), Lindsay, S. (Lindsay et al., 2019) (Lindsay, 2020), and Pitchford, N.J. (Pitchford et al., 2018) (Layachi & Pitchford, 2024) each contributed three publications to the field.

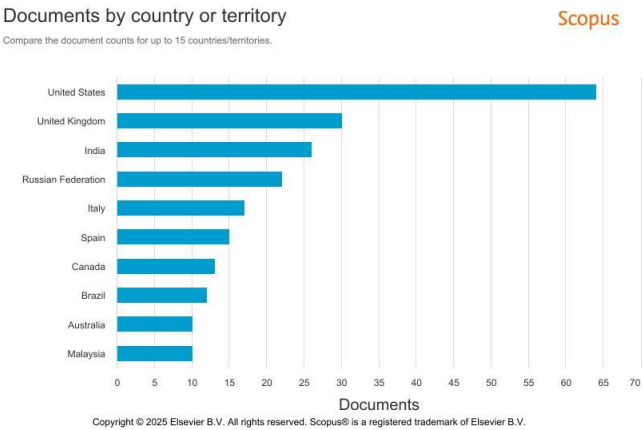
This indicates that no single author dominates the research landscape. Instead, there is a diverse involvement of scholars from various disciplinary backgrounds, including technology, psychology, rehabilitation, and inclusive education, all actively engaging in the development of assistive technologies for children with special needs.

Interestingly, the category [No Author ID found] appears as the most prolific, with more than four publications. This suggests that some documents are not yet properly linked to registered author profiles in the Scopus system, likely due to metadata indexing issues. This highlights the importance of improving the accuracy of scientific indexing systems to better manage researcher identification.

The fact that no single individual dominates the publication output suggests that research on smart mobility and mecanum wheel technologies for children with cerebral palsy remains open and highly collaborative. This presents opportunities for researchers to expand their networks and initiate cross-institutional collaborations, while also exploring untapped areas of inquiry. Consequently, systematic studies like this one are essential for identifying key contributors, mapping scholarly trends, and fostering strategic research synergies that support the development of effective and inclusive assistive technologies.

3. Countries in Smart Mobility Research for Children with Cerebral Palsy: Mecanum Wheelchairs

Figure 4. Countries in Smart Mobility Studies for Children with Cerebral Palsy: Mecanum Wheelchairs



The chart illustrates the distribution of scientific publications by country in relation to the topic of smart wheelchairs using Mecanum Wheel technology for

children with cerebral palsy. Based on data from Scopus, the United States emerges as the leading contributor, with nearly 65 publications. This reflects the country's strong commitment and investment in assistive technology development, particularly in the area of mobility for children with special needs.

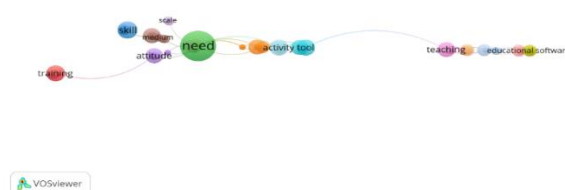
The United Kingdom ranks second, contributing approximately 30 publications, followed by India, Russia, Italy, and Spain, each with between 15 and 25 publications. These countries possess well-established research infrastructures and technological development frameworks, supporting innovation in biomedical engineering, inclusive education, and assistive technologies.

Meanwhile, countries such as Malaysia, Australia, Brazil, and Canada also show meaningful contributions, though still trailing behind Western nations. The participation of countries in Asia and South America highlights their potential for engaging in international collaboration, particularly in the development of assistive technologies that are contextually relevant, affordable, and responsive to the local needs of children with disabilities.

Therefore, mapping publication contributions by country is crucial to providing a global perspective on research focus within the domain of smart mobility. These findings not only help identify centers of excellence in smart wheelchair development, but also serve as a strategic reference to promote international cooperation and guide research directions that are more inclusive and adaptive particularly for advancing Mecanum wheel-based smart wheelchair solutions in developing countries such as Indonesia.

4. Network in Smart Mobility Research for Children with Cerebral Palsy: Mecanum Wheelchairs

Figure 5. Network Visualization in Smart Mobility Studies for Children with Cerebral Palsy



The figure above presents a keyword co-occurrence network generated using VOSviewer software. This visualization illustrates the relationships between frequently appearing terms found in literature on *Smart Mobility for Children with Cerebral Palsy*, particularly studies focusing on smart wheelchairs with Mecanum Wheel technology. The term “need” appears at the center of the network and represents the most prominent node, indicating that user needs are a central focus in the studies analyzed.

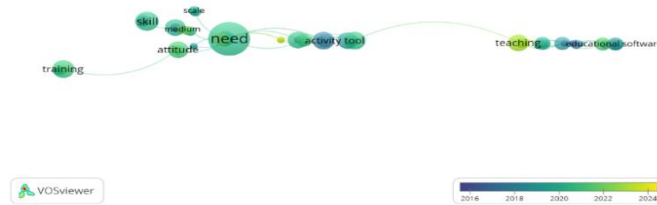
Keywords such as “activity,” “tool,” and “teaching” are closely linked to “need,” reflecting that fulfilling the mobility requirements of children with cerebral palsy is strongly associated with user engagement, assistive devices, and educational strategies. Additionally, terms like “skill,” “attitude,” and “training” highlight the importance of user competencies, mindset, and preparation in the successful implementation of assistive technologies.

The appearance of the keyword “educational software” also suggests a strong connection between mobility aids and learning technologies, supporting the perspective that smart wheelchairs serve not only as transportation tools but also as components of adaptive educational systems. Other keywords such as “medium” and “scale” point to the emphasis on measurement tools and evaluation methods used to assess the effectiveness of these technologies.

Overall, this visualization demonstrates that research on smart wheelchairs for children with cerebral palsy extends beyond mechanical or technical dimensions. It encompasses user-centered design, education, skill development, and the integration of software solutions. These findings underscore the importance of conducting systematic studies to guide the advancement of intelligent mobility technologies that are responsive to the diverse needs of children with special needs.

5. Overlay in Smart Mobility Research for Children with Cerebral Palsy: Mecanum Wheelchairs

Figure 6. Overlay Visualization in Smart Mobility Studies for Children with Cerebral Palsy: Mecanum Wheelchairs



The image above presents an overlay visualization generated using VOSviewer software. This visualization illustrates the temporal evolution of keywords within the field of *Smart Mobility for Children with Cerebral Palsy*, with a particular focus on smart wheelchair technologies utilizing mecanum wheels. The colors in the graphic represent the timeline of keyword usage, ranging from blue (indicating earlier years, around 2016) to yellow (indicating more recent research up to 2024).

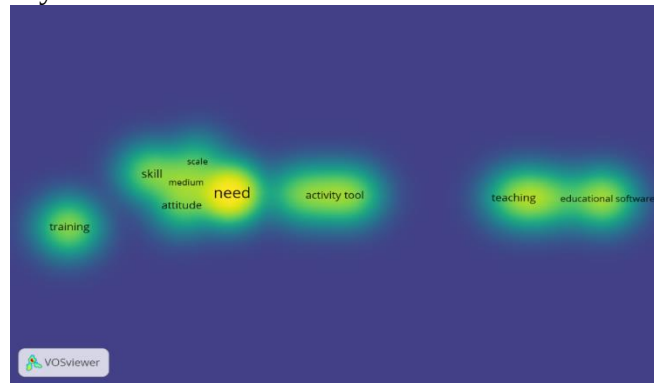
The keyword "need" appears in the central and largest node, highlighting that user needs have consistently been the primary focus across numerous studies. Terms such as "training," "attitude," and "skill" emerged in earlier years (indicated in blue), suggesting that earlier research emphasized user readiness, skill development, and attitudes toward mobility technologies.

Meanwhile, terms like "teaching," "activity," and "tool" began to appear during the mid-phase, indicating a shift toward integrating technology with educational and functional activities. The term "educational software," which appears in yellow and at the latest point in the timeline, reflects a newer research trend specifically, the integration of assistive devices with learning software.

Overall, this visualization shows how research focus has evolved from purely technical and user-preparation aspects to a more comprehensive approach that combines education, technology, and individualized needs. These findings reinforce the importance of developing smart wheelchairs that not only support physical mobility but also promote independence and facilitate learning processes for children with cerebral palsy in a holistic manner.

6. Density Visualization in Smart Mobility Research for Children with Cerebral Palsy: Mecanum Wheelchairs

Figure 7. Density Visualization in Smart Mobility Studies for Children with Cerebral Palsy: Mecanum Wheelchairs



The image above displays a keyword density visualization generated using VOSviewer software, based on a literature review themed “*Smart Mobility for Children with Cerebral Palsy: A Systematic Review of Smart Wheelchairs with Mecanum Wheel Technology.*” This visualization illustrates the frequency of keyword appearances across the analyzed documents. Yellow areas represent the highest frequency of occurrence, while green and blue indicate moderate to lower levels of keyword density.

The term “need” appears as the most dominant keyword, highlighted in bright yellow, reflecting that fulfilling the mobility needs of children with cerebral palsy is the main focus of current research. Surrounding this central term are other significant keywords such as “skill,” “attitude,” and “medium,” emphasizing the importance of user competencies, mindset, and the role of supportive media or tools.

Additionally, keywords like “activity” and “tool” also show relatively high frequency, indicating that these mobility aids are intended to support children's daily functional activities. On the other hand, terms such as “teaching” and “educational software” suggest an emerging connection between mobility technology and educational contexts, although they appear less frequently than the dominant terms.

Overall, this density map reveals that scientific research on smart mobility for children with cerebral palsy places strong emphasis on individual needs, while also incorporating educational approaches, training, and the use of technology as a means to enhance autonomy and improve quality of life.

B. Discussion

The results of this systematic review reveal that the development of smart wheelchair technologies using mecanum wheels for children with cerebral palsy has shown dynamic progress over the past decade. A notable rise in publications began in 2017 and peaked in 2019, reflecting growing attention toward innovative mobility solutions tailored to the needs of children with disabilities. Although a decline occurred in the following years, publication trends resumed a positive trajectory in 2023 and 2024. The sharp drop in 2025 highlights significant potential for future research, particularly targeting children with cerebral palsy.

The distribution of author contributions indicates that research in this area remains open and collaborative, without being dominated by any single individual or institution. This demonstrates that the field is still expanding and offers ample room for further exploration. The involvement of researchers from diverse disciplines including engineering, psychology, special education, and rehabilitation emphasizes the need for interdisciplinary approaches in designing effective and user-centered assistive technologies. Globally, the United States, the United Kingdom, and India emerged as the most prominent contributors, while countries such as Malaysia and Brazil represent the growing engagement of regions in Asia and South America.

Through bibliometric analysis covering keyword co-occurrence, overlay visualization, and density mapping it is evident that user needs have become a primary focus of research. Keywords such as *skill*, *training*, *attitude*, *activity*, and *tool* consistently appear, indicating that smart wheelchairs are viewed not merely as mobility devices but also as tools that support daily activities, learning, and the development of independence. The appearance of terms such as *teaching* and *educational software* in recent visualizations signals a shift toward integrating mobility technology within educational systems.

Overall, this study contributes significantly to mapping global trends and research directions in the development of smart wheelchairs powered by mecanum wheel technology. The results highlight the importance of combining technological innovation, educational perspectives, and individualized support to create assistive tools that are not only technically advanced but also socially impactful and functionally relevant. This research also encourages stronger cross-disciplinary and

international collaboration in designing inclusive, sustainable, and contextually responsive mobility solutions for children with cerebral palsy.

Table 1. Results and Discussion of Smart Mobility Literature Review for Cerebral Palsy Wheelchairs

Aspect	Key Results
Trend Publication	The number of publications has increased since 2017, peaking in 2019. The trend rose again in 2023–2024 but dropped sharply in 2025, indicating opportunities for further research.
Author Distribution	There is no dominance by any individual or specific institution. The research is collaborative and multidisciplinary, involving fields such as technology, psychology, education, and rehabilitation.
Country Contribution	The United States, the United Kingdom, and India are the main contributors. Asian and South American countries such as Malaysia and Brazil have also begun to actively participate
Keyword Focus	The word “need” appears at the center, followed by <i>skill</i> , <i>training</i> , <i>attitude</i> , <i>tool</i> , and <i>activity</i> highlighting the importance of user-related aspects and learning.
Technology-Education Integration	The emergence of the terms <i>teaching</i> and <i>educational software</i> indicates a shift in approach from purely mechanical to one that is integrated with education.
Research Implication	There is a need for smart wheelchair designs that are not only technologically advanced but also support learning and independence for children with cerebral palsy in a holistic and inclusive manner.

CONCLUSION

This study highlights the dynamic growth of research on smart wheelchairs using mecanum wheel technology for children with cerebral palsy over the past decade. A surge in publications since 2017, peaking in 2019, reflects increasing interest in mobility-based technological solutions. Although a decline followed, research activity rose again in 2023–2024, while a drop in 2025 suggests ongoing opportunities for further exploration.

The research landscape is collaborative and interdisciplinary, involving experts from engineering, special education, psychology, and rehabilitation. The United States, United Kingdom, and India lead in contributions, with growing involvement from countries like Malaysia and Brazil.

Bibliometric analysis shows strong emphasis on user needs, with keywords like need, skill, training, and educational software indicating that smart wheelchairs are seen as both mobility aids and learning tools.

In conclusion, future designs should integrate both technical innovation and educational relevance to create inclusive, effective assistive technologies for children with cerebral palsy.

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