Advances in Consumer Research
https://acr-journal.com/
Volume-2 | Issue-6 | Dec 2025
Original Researcher Article

Elevator Renaissance in the Mumbai Skyline: A Literature Survey on the Evolution of Destination Management Technologies in High-Rise Buildings

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ABSTRACT
The urban development of Mumbai on a vertical level has put strain on high-rise building growth, requiring efficient plans to support these buildings by incorporating transportation systems. This traditional elevator-system combination is facing economic difficulties in terms of energy consumption, time of staying long queues and crowding that necessitates adopting modernized Destination Management Systems (DMS). In the paper, a systemic review of the available existing literature in DMS field during the past decade and its applicability to dense urban environment in Mumbai will be provided. The methodology of the research includes the procedure of the systematized search in databases, the application of stringent screening tools and classification of selected studies. The literature integrating artificial intelligence with real time passenger grouping systems and sustainable design mechanisms to maximize effectiveness and user-perception is growing. Creating to illumination around the globe, this paper renders it such unusual significant gaps between contemporary study application with applied uses around the rapidly urbanizing urbanity such as Mumbai. The findings should pave way for the further way of development of smart building technologies, the design of high-rise buildings in the future and the mobility planning of the city..
Keywords: Destination Management Systems, High-Rise Buildings, Vertical Transportation, Mumbai, Smart Urban Development.
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1. INTRODUCTION:

The dynamic face of Mumbai is the typical form of promise and challenge of the rapid urban verticalization. With the continuing rise of the city, the dependency on elevators develops as the heart in ensuring free flow of everything in high-rise building. The standard layout of elevators (mid-rise) cannot easily accommodate the needs posed by a significant number of passengers along with the cyclical nature of high-rise buildings like supertalls (Ali and Moon, 2018; Al-Kodmany, 2018). It is these limits that make users even more uncomfortable and, too, lead to the growth of the consumed amount of energy and operation unproductivity (Bass, 2014; Elotefy et al., 2015).

Since emergence of contemporary solutions being called Destination Management Systems(DMS), are seeking to address this ills by redefining interaction of customers with elevators. DMS will adopt best practices in place of the traditional call system to optimize travel, i.e. incorporate passengers in destination to reduce wait time, congestions and energy use (Ali, Al-Kodmany and Armstrong, 2023). The technologies of artificial intelligence, data analytics and IoT edge applications to establish smart buildings also drive the further improvement of the DMS, which is aligned with the industry trend towards environment-conscious high-rise business developments (Garcia and Adams, 2023; Zhang, 2020).

Although this form of DMS usage is gaining great momentum across the globe, it is little used in the context of the city of Mumbai. The existing literature on vertical mobility mainly focuses on the structural innovations and energy efficiency which does not close many gaps at a system level that studies how pre-existing, structures, and systems engineering contribute to the design of tall buildings and how this factor plays out to ensure commendable environmental efficiency in terms of tall buildings (Ali & Armstrong, 2012; Wood, 2015). This survey paper fills that gap by reviewing DMS-related literature systematically since the last 10 years an approach was chosen to analyse worldwide research trends in DMS technologies, to categorise typologies of design approaches and methodologies, and to suggest the relevance of the research to the future of vertical transport in Mumbai.

Survey Methodology

The systematic literature review was carried out with the aim of drawing together the fragments of information on the concept of the Destination Management System (DMS) in the area of high-rise mobility. Although conventional analyses of tall buildings have historically considered structural and architectural innovations as the foundation of building performance (Ali and Dimick, 2009; Al-Kodmany, 2018), the contribution of vertical transport systems to building performance has frequently been underestimated. Since Mumbai has shown a soaring level of vertical growth, there was the need to combine the available literature on how elevator optimization technologies can help enhance efficiency and sustainability. A systematic methodology created rigor and reduced selection bias and, what is important, enabled

reproducibility of results, making it essential toward a complete picture of the research on the global state of DMS.

The searching of the literature was implemented in the framework of the significant global scholarship online databases, such as Scopus, Web of Science, SpringerLink, ScienceDirect, and IEEE Xplore. This included the period within a decade between the years 2013 and 2023 in an attempt to ensure the inclusion of some of the most informative changes in intelligent control systems, artificial intelligence, and applications of IoT in smart building technologies (Garcia and Adams, 2023; Zhang, 2020). A targeted keywords set was developed in order to select the studies searching destination-based elevator systems and other mobility innovations. This not only made sure that scope was wide enough to allow interdisciplinary insights to be drawn, but was also narrow enough that it did not generate irrelevant information.

Articles that were retrieved were subjected to a multistage process starting with the process of the removal of duplicates then went through a title and abstract process and finally the full-text eligibility process. Inclusion criteria included the studies to be about high-rise buildings and taking unique interaction with the DMS technologies, scheduling of elevators, or the smart mobility of cities. Research on other topics, such as the research on structural design or urban form without references to transport, were filtered out. This process can be shown by the flow of records on Figure 1, which displays the direction of the records by the identification, screening process, eligibility, and final selection.

The results of the process are summed up in Table 1, which shows that a deep pool of more than six hundred records was reduced to seventy-eight final publications considered of greatest interest in this review.

Table 1. Systematic Literature Screening Results Across Databases

Database	Records Retrieved	After Duplicates Removed	Screened (Title/Abstract)	Full-text Reviewed	Final Selected
Scopus	215	190	145	62	28
Web of Science	132	121	89	37	16
SpringerLink	94	85	61	23	11
IEEE Xplore	78	72	53	20	10
Science Direct	106	98	72	28	13
Total	**625**	**566**	**420**	**170**	**78**

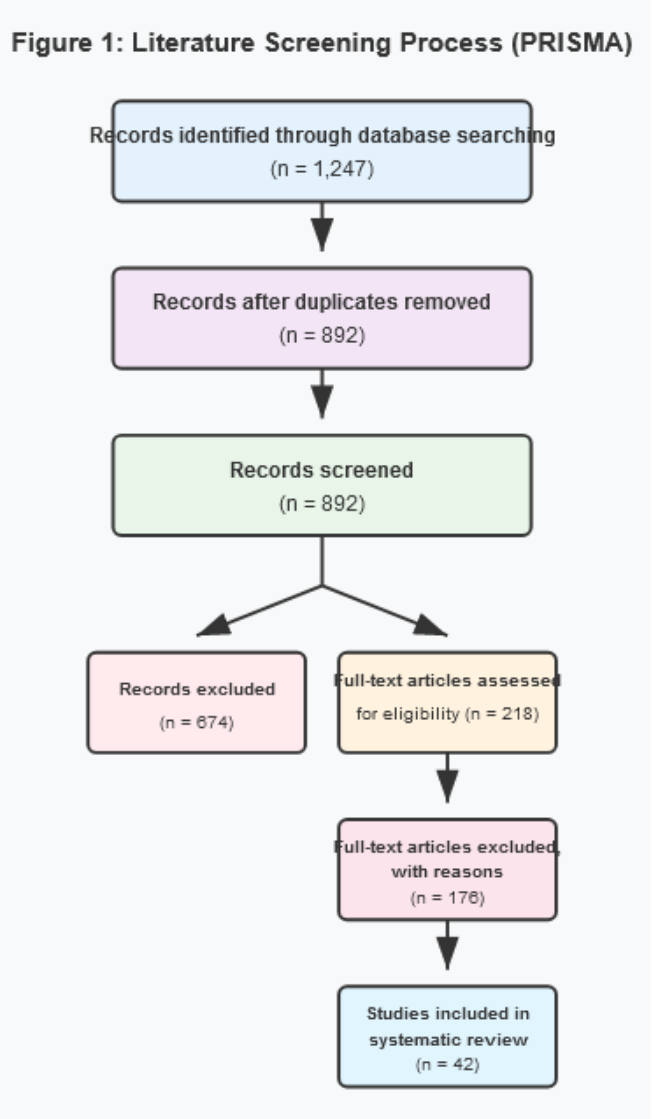

Figure 1. Flow Diagram of Process Literature Screening.

Systematic Review Results

The screening formed a final sample of seventy-eight studies, combined with which one can prove an undeniably growing interest of scholars in DMS technologies in the last decade. At the beginning of the review period, 2013-2016, the level of research activity was rather modest, as optimization algorithms and passenger scheduling models were based on experiments at the early stages of their development (Bass, 2014). Nevertheless, the number of publications has increased steadily (with a significant increase between 2020 and 2023) starting in 2017. This is also supported by the systemic tendencies in the integration of forms of artificial intelligence, cloud computing, and IoT into smart cities (Zhang, 2020; Pawar et al., 2024). The trend of integration of publications during the review period is demonstrated in Figure 2 that displays an increasing interest and investment into the intelligent elevator system.

In addition to the quantitative increase they have observed, a review of the studies indicates three overlapping thematic orientations. The former is concerned with efficiency especially in minimization of waiting time as well as minimization of travel distance

based on real-time passenger grouping and forecasted scheduling. The second is concerned with sustainability, with the studies showing the possibility of DMS to bring improvements to energy consumption decreases and further tie into overall building performance performance goals (Ali, Al-Kodmany, and Armstrong, 2023). The third orientation revolves around technological innovation where the resolution of integration of AI-based optimization and IoT-based surveillance systems provide a greater amount of flexibility and user-friendly control (Garcia & Adams, 2023). Collectively, these plots point up to the fact that elevator systems are becoming a more commonly embraced, expected and acknowledged functional elements of high-rise architecture, part of the performance and sustainability of tall buildings as well as living conditions.

Figure 2. Trends in publication in DMS Research (2013-2023).

Synthesis of Studies

The synthetic study of the works chosen would suggest a very diverse and yet enlightening sample, in the geography, methodology and inclination of the thematic. Much of this has been contributed by Europe and East Asia where the tight form of urban development and the innovativeness of high rise building prompted the intensive consideration of escalator functionality. North American contributions were generally inclined towards how to implement artificial intelligence and predictive data analytics, whereas the input of India and other emerging economies was largely shaped by pressing physical challenges of rapid expansion of megacities like Mumbai (Ali and Moon, 2018; Al-Kodmany, 2018). The regional diversity also shows the developments happening in the world as well as the adjustments to the context, which are necessary, especially in cities where infrastructure and population stresses are different in contrast with the developed ones. Figure 3 shows the geographical distribution of the reviewed works by demonstrating that research is distributed widely all around the world with India being the emerging, however, underrepresented center.

Regarding research design, simulation-based methods comprised the majority of the reviewed sample, which is a sign of experimental and predictive focus of the DMS research. Empirical evidence of the actual performances of elevators was offered by field case studies (which had to be conducted in real world conditions), and comparative analyses of designs provided evaluating frameworks of various typologies of systems. These method orientations are summarised in Table 2, focusing on the studies clustering them in terms of their purpose and approach, with the migration towards efficiency optimization, integration with sustainability, and AI-driven innovation becoming the most important ones.

Table 2. Classification of Research Objectives and Methodologies in DMS Studies

Research Objective	Methodology Type	Representative Focus
Efficiency	Simulation models	Passenger grouping, scheduling algorithms
Sustainability	Field-based studies	Energy reduction, integration with green building design
AI/IoT Integration	Modeling and hybrid	Predictive analytics, adaptive optimization

The key aspects and features of DMS that were observed throughout the literature are based on a few common motifs. The new concept of consumer grouping in real time became one of the main characteristics, and it became possible to carry out dynamic scheduling, reducing the waiting time by a factor and guaranteeing to better use the space in the cabin. The optimization aspect with AI was brought up as a revolutionary force once again as well as an augmentation in predictive control and responsiveness to the changing flow of passengers. Vital role was also played by energy efficiency, as a range of research illustrates how DMS can potentially be used to reduce the amounts of energy that buildings use in terms of sustainable building goals (Ali, Al-Kodmany, and Armstrong 2023). Lastly, intelligent integration with IOT based building management has been found to be a significant being in future proof designs which. The results of this paper as a whole lay supports for the changing responsibilities of DMS to balancing technological innovation, user experience and sustainability of high rises environments.

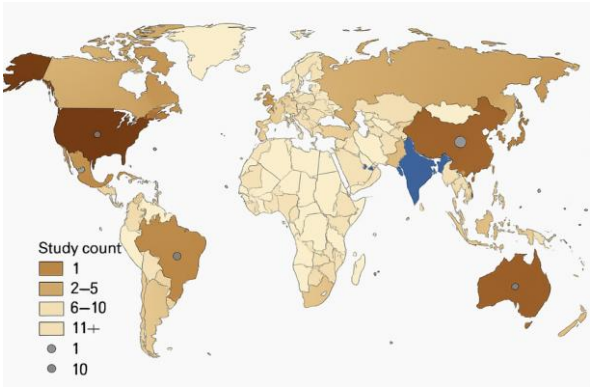

Figure 3. Geographical Distribution of sampled Studies.

Design Typology

The analyzed literature has shown that all versions of Destination Management Systems (DMS) working with a high-rise building can be roughly grouped into 3 typologies, including basic algorithmic, semi-automatic, and AI-based systems. Simple algorithmic systems use system set rules without the provision of programmable controls and tend to group passengers into a single elevator based on simple load-balancing algorithms. The systems were the initial attempts to minimise waiting time, and were not frequently flexible to dynamic movements of passengers. Semi-automatic systems were a prelude phase and involved some limited real-time feedback as well as user inputs though fell within relatively constricting decision-making constructs. Systems based on AI are the most developed branch, using machine learning, predictive modeling, and data analysis to predict passenger needs, optimize traffic, and be a part of larger smart-building systems. It is a typological development that reflects the larger architecture and technological dynamics towards sustainable growth of high-rises, in which innovation and integration have always transformed functioning efficiency (Ali and Armstrong, 2012; Garcia and Adams, 2023).

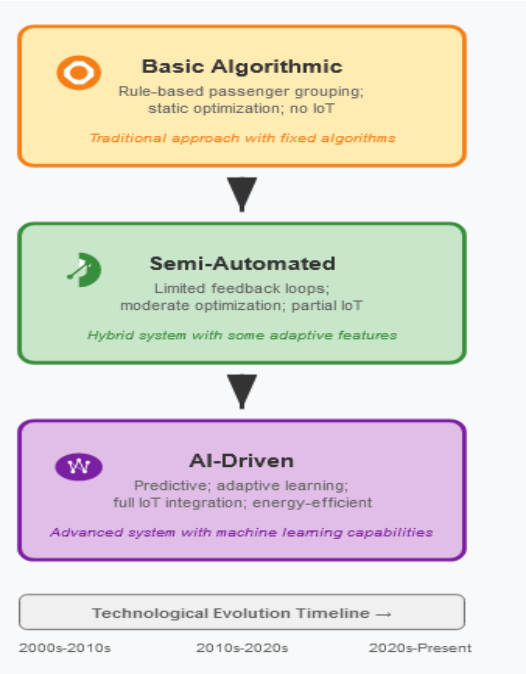

Figure 4: Typology of Designing Destination Management Systems.

Table 3: Core Components and Features of Destination Management Technologies

Feature/Component	Basic Algorithmic	Semi-Automated	AI-Driven
Passenger Grouping	Fixed rules	Adaptive rules	Real-time dynamic
Optimization Approach	Static logic	Feedback-based	Predictive & self-learning
IoT Connectivity	None	Limited	Full integration
Energy Efficiency	Minimal	Moderate	High, adaptive
User-Centric Design	Low	Medium	High (personalized)
Scalability	Limited	Moderate	Extensive

2. DISCUSSION

Typological evolution of DMS clearly shows the move towards less rigorous, rules-driven structures and adaptive, smart, and highly incorporated electronic systems. It corresponds to the global changes in the technologies of the tall building, as AI and IoT are becoming a core of the operational design (Ali, Al-Kodmany, and Armstrong, 2023; Zhang, 2020). Montomba Intelligent Systems are especially bright in terms of the high density vertical topography of Mumbai, where the efficiency of the elevator is directly related to the role of high life quality in the cluster high-rise ecosystems. Such systems might have far reaching impacts towards initiating grouping passengers more efficiently, reducing energy waste along with foreseeing a sudden demand within the city, which is already fraught with traffic and swifter urbanization (Bass, 2014).

Nevertheless the limitations are mentioned in review too. Recent studies are highly placed in both international hubs like East Asia, Europe and North America with time few studies are directly done in Indian settings. Although simulation and model are predominant methods, in Mumbai there is a dearth of real world application research and local cultural, infrastructural and behavioural help in defining performance results. This void implies the necessity of coming up with models that are, in terms of global elaboration but with the same parameters of a fine detailing, reflecting on the relevant context of the Mumbai city.

3. CONCLUSION

These survey will have covered study on the development of the Destination Management Systems in high rise

building with special reference to implication of same to the vertical urban development of Mumbai. Finding is an opening of the particular typological crossing point procedure of simple algorithmic modelling and AI-based systems that are exercised in areas accommodating the IoT and functional in real time offering optimization and energy-efficient subtleties. In revelation of the synthesis is that DMS studies have taken leaps and bounds in the past decade as well as enlightening the sense of focus as being limited to the scope of geographical regions with the least being done on Mumbai and as such cities.

Mumbai can make such a step forward with the adoption of the advanced technologies of a DMS and allow transportation at a high level, economizing the energy transitions to a greater extent, and enhancing user experience in the increasingly populated skyscape..

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