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Emerging trends in Material Handling Equipment in the Indian context in Warehouses

[1]Rajesh Chander,

Scholar, School of leadership and management, Manav Rachna international institute of research and studies, **Mail ID:** rajeshchander1@gmail.com

[2]Dr Shilpa arora,

Associate professor, School of leadership and management, Manav Rachna international institute of research and studies, **Mail ID:** shilpanarang.slm@mriu.edu.in

Abstract:-

The primary goal of this study is to look into trends in MHEs in India, particularly in warehouse settings. Descriptive research was done, gathering and analysing quantitative data from stakeholders in Indian warehouses. The study revealed the key challenges in AGV adoption, the status of technological adoption in Indian warehouses and the application of AGVs in warehouses in the country. The study's hypothesis testing demonstrated that AGV awareness and understanding have a substantial impact on their prospects in India. The findings of the second research hypothesis suggest that the location of AGV implementation has no major impact on AGV prospects in India. As a result, AGV may be used in any type of project and has a great deal of promise in Indian warehouses. Based on these results, suggestions for practitioners and future scope of research are provided.

Key Words: Material Handling Equipment's, Warehouses, Technology.

1. Introduction:-

The activities that take place in warehouses are key components of modern supply chains (Carli, Digiesi, Dotoli and Facchini, 2020). A major portion of warehouse operations is related to the transportation, loading and unloading of the materials. For handling these materials in a proper manner, there is a need for using Material Handling Equipment (MHEs). The selection of proper MHEs is a significant task in itself. For optimised decision-making while selecting MHE, different parameters need to be considered. The MHEs should contribute to making sure that the operations in the warehouse are perpetual and the expenses associated with it should be justified by the value they add to the operations of the warehouses (Eko Saputro and DaneshvarRouyendegh, 2016). Analytical Hierarchy Process (AHP) can be used for optimisation of MHEs among different alternatives like "forklift, conveyor belt, and automated guided vehicles (AGVs)". The use of all of these three categories depends on the nature of the industry and the materials that are required to be handled (Zubair et al., 2019).

Modern mechanical industries have undergone a transformation thanks to the advancement and enhanced technology of mechanical forklifts. Around the turn of the 20th century, the widespread usage of the forklift truck transformed warehouse processes. A variety of material handling methods are in use, ranging from fully manual to semi-automated but still requiring human management. Work in warehouses has been transformed by forklifts. They enabled the movement of 100 kg by a single individual at a time. Forklifts that are properly maintained and handled safely make lifting and moving cargo a lot easier. Forklifts are the priciest equipment found in warehouses (Pachakawade et al., 2018). The forklift that runs on batteries is a more advanced method of lifting and moving the object that needs to be moved. When fully charged, the forklift's rechargeable battery allows it to operate constantly for eight to ten hours (Sequeira et al., 2019).

With a CAGR of 15.64% from 2022, the Indian warehouse industry is expected to reach $34.99 billion by 2027. Demand in the economy is currently at an all-time high, with 1.4 times more demand than supply in the initial months of 2023. With an additional 140 million square feet built since CY 2016, the nation's Grade-A warehousing stock reached an astounding 177 million square feet (3QCY2023), demonstrating the industry's capacity to expand and adapt according to the expanding needs of diverse sectors. But problems like convoluted supply chains, inefficiencies, growing prices, and increased demand for quick

delivery still exist. Automation in warehouses is being used by the sector to solve these problems and take advantage of the expansion (Invest India, 2024). The COVID-19 pandemic has led to some significant shifts in the warehousing sector in India due to an increase in e-commerce activities in the country. Technological advancements and new, adaptable business forms that take into account many aspects of operations and cost have also resulted from shifting customer behaviour and business needs. Consumers' subsequent emphasis on speed and convenience has led many to purchase online, but the commercial and workplace segments have seen changes as well, including the emergence of smaller, more customer-focused layouts and adaptable office spaces. The industry may be poised for significant expansion in the upcoming years given the rate of demand and the growing level of government support in a number of areas (KPMG India, 2023).

In material handling, automation and automated or semi-automated methods have grown more and more common. Numerous pieces of machinery are employed in the material handling business to move materials from one location to another or to stack vertically in racks. Even while a lot of equipment still requires some mechanical labour, most popular material handling solutions are moving towards being entirely or semi-automated. Organisations striving for smart manufacturing facilities are progressively implementing Industry 4.0 principles and technological foundations. The practices include features like digitalisation, automation, adaptation, and optimisation. This involves utilising robots, "radio frequency identification (RFID), big data analytics, autonomous cars, and the Internet of Things" (Hietikko-Kaukola, 2021).

2. Aim and Objectives:-

The primary aim of this study is to reveal trends in MHEs in India, especially in warehouses. Based on this aim, this study has the following specific objectives.

- To investigate emerging trends in material handling equipment in Indian warehouses.
- To reveal the significant innovations in material handling in warehouses and how they are contributing to increasing warehouse operations efficiency.
- To identify the challenges in integrating automated material handling equipment in the context of Indian warehouses and strategies for overcoming these challenges.
- To examine the role of Automated Guided Vehicles ie Forklift/BOPT/Reach Truck etc in Indian warehouses.

3. Literature Review

3.1 Overview of material handling equipment in warehousing:-

Glock et al., (2021) conducted a systematic review to reveal the technological equipment that can complement humans in manual tasks associated with warehousing. The findings showed that although some devices—like augmented reality (AR) devices—were thoroughly examined, others—like pallet jacks and exoskeletons—were only sporadically examined. Most of the works concentrated on a particular goal, which was either connected to human effort or performance. The findings do, however, also indicate a recent rise in the number of works with an integrated focus, such as mental HF components in conjunction with performance KPIs. Most studies looked at how the tool could help the worker with tasks like picking or searching. Wahab et al. (2022) conducted research to investigate the factors affecting "automated material handling equipment (AMHE)" adoption in warehouses. The results show that although support from management, outside pressure, and expertise have favourable impacts on a comparable outcome, "perceived trust, perceived advantages, and perceived costs" had no statistical impact on AMHE adoption. Furthermore, it was discovered that the connection between perceived trust and AMHE adoption intention had polarised interaction effects according to varying knowledge levels. As a result, this study offers helpful insights into the significance of having a sufficient understanding of AHME in the warehouse industry for their operators. Additionally, the management of storage facilities must prioritise dedicating its financial and technological resources to the deployment of AMHE.

Dev (2022) discussed that warehouse managers may boost output and efficiency while protecting staff from potential mishaps and expediting the flow of merchandise from one location to another with a well-organized material handling system and specialised equipment. The four primary categories of MHEs are "bulk material, industrial trucks, storage and handling, and engineered systems. Pallet racks, shelves, bins, drawers, and stacking frames are examples of storage and handling equipment.

Hoppers, bucket elevators, stackers and conveyor belts are examples of bulk-handling equipment. Forklifts, hand trucks, and pallet trucks are examples of industrial trucks". Wahab and Ab Talib (2021) provide a conceptual framework that clarifies the driving force behind Malaysia's deployment of "warehouse automated material handling equipment (AWMHE)". Five driving aspects are highlighted by the model, which uses the technology, organisation, and environment (TOE) framework. These variables are "perceived technology trustworthiness, perceived benefits, perceived costs, external pressure, and managerial support". Since this work is only a concept, going ahead, field research should be done to generate empirical data that will help to confirm the suggested model.

Seprényi et al., (2022) examined the evolution of MHE and warehouses through antiquity to today. The researchers listed the technological advancements that have been necessary due to the growth of trade, the construction of railroads, and the quickly shifting demands. The technologies being used now and in the future are built on top of these innovations. Of course, as these technologies are always being developed, we can expect even more advancements in the years to come. However, it is hard to say with certainty what the actual future of the warehouse holds. Dza and Kyeremeh (2018) examined the material handling procedure in warehouses in Ghana. The study identified that most of the warehouses in the country do not have primary mechanical instruments for operational efficiency. There is no sign of automation in the warehousing system. In terms of material handling, there is a lack of effort in equipping the employees with the required equipment for material handling for performing such tasks. The survey also showed that Ghana's civil sector lacked almost any in-service instruction on safe material handling procedures. In fact, practitioners handle many kinds of materials, including dangerous chemicals, with their "bare hands and feet" the majority of the time. The survey also showed that most staff declined to use handling and protection equipment when it was made accessible, citing concerns about customs and culture.

3.2 Landscape of Material Handling Equipment Utilization in Indian Warehouses:-

Automated handling systems like as AGVs give up a large capital expenditure in exchange for overall service level, response time, and flexibility. However, it is expensive, and most semi-automated or manual handling procedures are still used in nations like India where labour handling costs are lower and storage space is limited (Shah and Khanzode, 2015). Kumar and Asthana (2023) conducted a case study to showcase the personnel, processes, and operational enhancements of a major Indian e-commerce company (eKart). Even while the nation's logistics scene has transformed due to the E-commerce expansion, favourable government regulations, and spending on infrastructure, the actual situation appears to be different. With the growth of e-commerce and multichannel retail, it has become necessary to change how warehouses and transportation are managed. Positive outcomes from reduced costs, better employee scheduling, and enhanced workflow at the company's central hub suggest a significant chance to enhance procedures nationally and within the organisation.

Ramanathan et al. (2023) identified the key barriers that the warehouses faces in a consumer electric organisation in India with respect to smart manufacturing. The study identified that key barriers include "lack of automation" which requires attention in the long-term focus factor, whereas "Defective Materials from Both Ends, Gap Between Supply and Demand, Multiple Price Revision, and Manpower Balancing Between Pick and off" stand the short term impact. Kumar et al. (2022) revealed the challenges in implementing advanced technologies in warehouses in India. The implementation of advanced technologies in Indian warehouses is at its nascent stage. The study's conclusions demonstrated that the main obstacles preventing the company from implementing smart and environmentally friendly supply-chain procedures in its storage facility are a lack of qualified labour, a lack of purpose and goal, and a lack of government backing.

Ali and Kaur (2022) investigate the efficiency and practices of warehouses pushed by Technology 4.0. The logistics industry has performed well in comparison to international standards thanks to the combined efforts from government backing and the strength of every industry. The sector needs to strengthen its manufacturing and productivity core in order to stay competitive. Bhandari et al. (2023) discussed that material handling systems play a vital role in activities like "aviation, mining, food & potables and shipping for transporting raw material and finished goods". Given the vast amount of typical material handling, among a storehouse's most crucial penetration areas is the order-grasping region. Along with reducing delivery times and total product costs, careful material flow management can also be achieved. The goal of every exploration is to create more effective material running mechanisms. By applying material handling principles, suggested generalisations of material handling may separate non-value-added conditioning from overall operating conditioning and lower material handling risks.

Recent years have seen a sharp rise in Indian frugalness, which has raised the demand for robotisation of material handling in the production and logistics industries.

But still, the industry prefers operators-driven MHE as against AGV because of the cost constraints, In the Indian context the labour cost is far lower compared to the overseas industries, The demand for AGV will come cracking once the availability of cheap manpower reduces in our country but that seems far of view we have a vast pool of workforce but skilling them is the challenge.

3.3 Innovation in material handling equipment for warehouses:-

Efthymiou and Ponis (2019) outlined the implementation of Industry 4.0 in the automation of the material handling process. With the introduction of innovations, a new class of hybrid ("cyber-physical") production systems known as Industry 4.0 has emerged. These machines combine cutting-edge manufacturing processes with creative machine-to-machine (M2M) solutions built around the Internet of Things (IoT). According to a review of the outcome of the research, Industry 4.0 is presently characterised by small-scale test facilities that aim to replicate real-life scenarios; as a result, it lacks large-scale deployments of its innovations for internal logistics and material handling. Tadić et al. (2023) discussed that the process of automation in material handling (MH) in logistics centres is a prerequisite for optimum MH cost and time while aiming at decreasing errors in delivery, minimising damage and enhancing service efficiency for customers. Optimising MH activities by interacting with autonomously smart solutions is one strategy for solving the primary obstacles in the logistics centres' preparation of items for delivery. Specifically, electric forklifts are used by the logistics company, which processes and delivers consumer goods within the city, to carry out MH tasks.

Skapinyecz et al. (2020) offer an advanced approach to process improvement that makes use of Industry 4.0 concepts and might help in the creation of effective forklift MH systems. The researchers suggest that forklift-based MH can be brought to a completely new level of effectiveness by utilising the opportunities presented by "Industry 4.0 (in this case, mainly sensor systems, big data analysis, digital transformation, and real-time data transfer"). This could significantly enhance the general efficiency of a large number of manufacturing systems. Ponis and Efthymiou (2020) conducted a literature review and found that over the past years, there have been significant improvements in the flow of goods and order picking in storage facilities. AGV fleets are becoming increasingly autonomous in their movements throughout the storage facility, and picking robots and automated arms are growing increasingly able to handle a variety of goods and supplies. By enabling them to lend their expertise beyond the confines of the warehouses and reach comparable sorts of deployments worldwide, cloud computing has also significantly contributed to the efficiency improvement of AGV fleets and robotics. Niu and Xiong (2022) compared traditional picking methods and picking algorithms based on "panel picking quantity, pallet occupation, and warehouse space utilization". The space utilisation rate was 100% if all the plates in one bin were stacked to the ideal amount. The research's suggested algorithm can maximise storage capacity use to 100%. With the maximum pallet utilisation and the smallest space for storage utilisation determined by batch collection, the suggested approach has the most obvious benefits with regard to pallet and storage space utilisation.

Automated storage and retrieval solutions improve inventory control efficiency and introduce transparency to factory planning procedures. Integration between the factory planning procedure and inventory control procedures becomes feasible. However, using hardware-software systems from a single vendor comes with a lot of financial costs and doesn't remove the need to modify and redesign the automated control systems that were purchased to fit the requirements of a certain field (scope). Furthermore, a warehouse equipment provider typically isn't able to resolve integration issues when it comes to integrating automated warehousing modules that have been purchased into an enterprise's integrated information environment (IIE) (Kapulin et al., 2017). Custodio and Machado (2020) provide an extensive analysis of recent research on the usage of flexible automation in warehousing. Results indicated that combining automated machinery, data-gathering methods, and leadership tools is essential to creating flexible automated warehousing. It is very difficult to predict what storage facilities will appear like in the future as technology develops, but it can be done to foresee the needs that these facilities will have to meet in order to adjust to the changing market conditions brought about by online shopping, just-in-time manufacturing, product customisation, and omnichannel distribution.

3.4 Research Hypothesis

"H01: Awareness and Understanding of AGVs does not have a significant impact on the Prospects of AGVs in India.

H11: Awareness and Understanding of AGVs do have a significant impact on the Prospects of AGVs in India.

H02: There is no significant impact of where AGV is implemented (in terms of old and existing warehouses, New Warehouses Coming Up, Brownfield Projects and Green Field Projects) on the Prospects of AGV in India.

H12: There is a significant impact of where AGV is implemented (in terms of old and existing warehouses, New Warehouses Coming Up, Brownfield Projects and Green Field Projects) on the Prospects of AGV in India".

4. Methods and materials:-

Selecting an appropriate research method is necessary for any successful scientific exploration. In this section, different methods adopted for completing the study are discussed. This includes different methods such as

4.1 Research approach:-Because of the unique function that research technique plays in the research and the distinctions that exist between the "quantitative and qualitative approaches", it is quite beneficial to take into account each of these approaches and quantify the variations when it comes to measuring and sampling (Mehrad and Zangeneh, 2019). The present study is based on the "***Quantitative approach***". The scientific method and quantitative techniques are the cornerstone of contemporary science. This method of conducting research typically begins with a particular theory, either previously formed or proposed, which gives rise to certain hypotheses that are subsequently rigorously and quantitatively examined, analysed, and assessed in accordance with accepted research protocols (Holton and Burnett, 2005).

4.2 Research design:-This research has adopted ***descriptive research design.*** When it comes to using a single sample without a comparator group in the research design, descriptive studies can be conducted. Their main objective is to characterise the sample's attributes in relation to the attributes that are present, which makes them helpful in formulating hypotheses (Omair, 2015).

4.3 Research philosophy*:*-Scientific discoveries are guided by research paradigms, which are based on presumptions and principles (Park et al., 2020). The present research will be based on ***"Positivist Philosophy".*** Studies that follow positivism typically use quantitative methods to establish explanatory correlational or causal linkages, favouring empirically based results from high sample sizes (Park et al., 2020).

4.5 Data collection method:- This research is based on the ***Primary*** method of data collection. For the collection of primary data, a ***5-point Likert Scale-Based questionnaire*** is used. Primary sources offer unfiltered data and firsthand evidence. Artworks, statistical data, and interview transcripts are a few examples. Direct access to the topic of the study is facilitated by primary research (Streefkerk, 2018).

4.6 Data analysis tools:-Quantitative analysis is a mathematical approach used to collect and assess quantifiable, verifiable data. This approach is used to evaluate many commercial or research factors as well as performance. It entails analysing data using statistical and mathematical methods (Saharawat, 2024). The quantitative analysis for this research will be carried out using ***SPSS and AMOS*** software.

5. Results and Discussion:-

5.1 Demographic Responses:

The outcome of the research suggested that about 30 per cent of the respondents belong to the 31-40 age group, 95.8% were male and 3.6% were female, 44.6% had diplomas and 43.5% were gaduates. About 28.6% have more than 25 years of experience while 17.4% have 6-10 years of experience indicating a good mix of professionals based on their overall industry experience.

5.2 Validity and Reliability:

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.940
Bartlett's Test of Sphericity	Approx. Chi-Square	4553.228
	df	465
	Sig.	.000

Table 1: KMO and Bartlett's test outcome

To assure the validity and reliability of the data collection instrument (questionnaire) used, KMO and Bartlett's Test were used. The KMO measure of 0.940 and Bartlett's test result of p = 0.000 suggest that factor analysis is appropriate for this dataset. A KMO value of 0.8-1 is considered to be good. A significant value of less than 0.05 is optimal for factor analysis to pass Bartlett's test of sphericity. This implies that the variables are connected and appropriate for factor analysis because the correlation matrix is not an identity matrix. The variables are acceptable for factor analysis since there are significant correlations between them, as confirmed by Bartlett's test and the KMO value.

5.3 Descriptive Analysis

From the descriptive analysis of the data, it is identified that respondents generally perceive that the cost of AGV, its limited awareness, cheap labour, AGV reliability and infrastructural constraints are major barriers to its AGV adoption, in the Indian scenario. The respondents also agree that robotics, AI and automation are increasingly used in Indian warehouses. Augmented reality, predictive maintenance and data analysis are also being used in Indian warehouses. The respondents also think that AGVs are cost-effective, enhance the accuracy of inventory management, increase order fulfilment efficiency and have skilled labour. The respondents also agree that AGVs can be integrated with WMS, consider it safe and agree that they possess a good understanding of AGV applications.

5.4 Hypothesis Testing:

The first research hypothesis for the study is as follows:

"H01: Awareness and Understanding of AGVs does not have a significant impact on the Prospects of AGVs in India.

H11: Awareness and Understanding of AGVs do have a significant impact on the Prospects of AGVs in India."

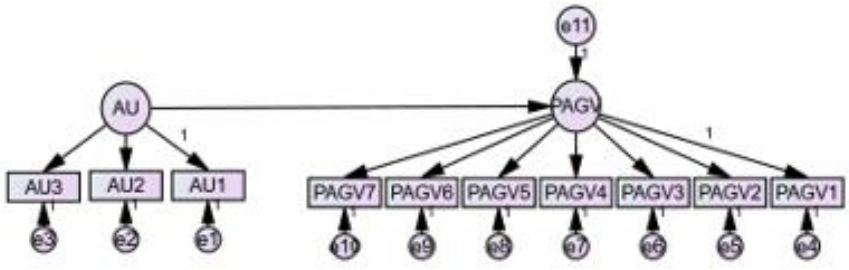

Figure 1: SEM Analysis:

To test this hypothesis, the first Chi-Square test was done. The observed value was 78.071 with 34 degrees of freedom, the related p-value is less than 0.001. This shows that the model is statistically significant, implying that the observed data match the hypothesised model.

"Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P
PAGV	<---	AU	.675	.076	8.839	***
AU1	<---	AU	1.000			
AU2	<---	AU	1.031	.073	14.206	***
AU3	<---	AU	1.117	.069	16.181	***
PAGV1	<---	PAGV	1.000			
PAGV2	<---	PAGV	1.028	.068	15.048	***
PAGV3	<---	PAGV	1.114	.068	16.433	***
PAGV4	<---	PAGV	1.084	.070	15.478	***
PAGV5	<---	PAGV	.944	.077	12.271	***
PAGV6	<---	PAGV	.850	.085	10.010	***
PAGV7	<---	PAGV	.922	.081	11.441"	***

Table 2: Regression Weight for the first hypothesis

The regression weight analysis is conducted that suggests a relatively high positive association between AGV awareness and understanding (AU) and AGV prospects (PAGV) in India. The critical ratio (C.R.) of 8.839 and a p-value less than 0.001 indicate that this association is statistically significant. The variance analysis also suggested that the constructs exhibit significant variability, which aids in correctly representing the relationships within the data. To check the model fit, the Goodness of Fit Index was used, providing the value of 0.908 indicating a good fit.

Overall, the SEM results show that there is a considerable positive association between awareness and understanding of AGVs and their prospects in India. The regression weight (β) of 0.675 indicates a statistically significant link (p-value < 0.001). The model's fit indices generally indicate that the model is moderately fitted to the data, with some indices indicating a good fit and others indicating room for improvement, particularly the RMSEA score.

Based on these findings, the null hypothesis is rejected, resulting in the acceptance of the alternate hypothesis signifying that awareness and understanding of AGVs do have a significant impact on the Prospects of AGVs in India. This suggests that efforts to raise awareness and understanding of AGVs may have a favourable impact on their adoption and prospects in India. Allied Market (2020) also acknowledged the increased AGV use in India. The report indicated that AGVs are used in practically every industry, including "logistics, automotive, food and beverage, manufacturing", and more. Furthermore, enterprises in India's e-commerce market are implementing AGVs to increase efficiency and cut labour costs. Factors propelling the expansion of the India AGV market include a surge of need for automation and AGVs in various sectors, as well as increased "safety, accuracy, and productivity". Furthermore, lower labour costs in organisations are helping to drive market expansion. Yet, high initial investment costs and a lack of flexibility in non-repetitive jobs are impeding the expansion of India's AGV market. Singh (2023) AGVs can be incorporated into other conventional warehouse automation technologies that may already be present in brownfield projects, such as warehouse management software or conveyors, in order to create a completely automated and optimised warehouse environment. It is clear that AGVs give facilities with the necessary adaptability to perform under all conditions. Such operational versatility and personalisation result in simpler processes, faster order processing, and lower operating expenses, all of which are desirable benefits for any sensible company owner.

The second hypothesis for the study is as follows:

"H02: There is no significant impact of where AGV is implemented (in terms of old and existing warehouses, New Warehouses Coming Up, Brownfield Projects and Green Field Projects) on the Prospects of AGV in India.

H12: There is a significant impact of where AGV is implemented (in terms of old and existing warehouses, New Warehouses Coming Up, Brownfield Projects and Green Field Projects) on the Prospects of AGV in India".

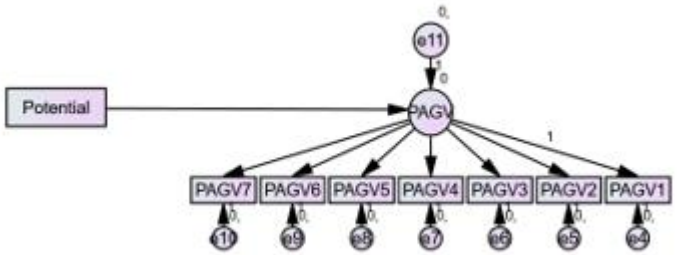

Figure 2: SEM Analysis

To test the hypothesis first model fit is checked. Chi-Square (CMIN) = 49.036; df = 20, p <.000. The Chi-Square value shows that the model fits the data.

"Regression Weights: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
PAGV	<---	Potential	-.089	.085	-1.050	.294	par_7
PAGV1	<---	PAGV	1.000				
PAGV2	<---	PAGV	1.042	.069	15.062	***	par_1
PAGV3	<---	PAGV	1.127	.069	16.372	***	par_2
PAGV4	<---	PAGV	1.092	.071	15.305	***	par_3
PAGV5	<---	PAGV	.939	.079	11.956	***	par_4
PAGV6	<---	PAGV	.845	.086	9.784	***	par_5
PAGV7	<---	PAGV	.924	.082	11.287	***	par_6"

Table 3: Regression weight for the second hypothesis

The regression weight for the path from Potential "(location for AGV implementation) to PAGV (AGV prospects)" is not statistically significant (p =.294). This implies that the individual implementation locations ("old and current warehouses, new warehouses coming up, brownfield projects, greenfield projects") have no major direct impact on the prospects of AGVs in India. Overall, the model's fit indices indicate that the model is generally well-fitted, with certain indices showing a moderate fit. Yet, the major finding is that the deployment location of AGVs ("old and existing warehouses, new warehouses coming up, brownfield projects, and greenfield projects") has no significant impact on AGV prospects in India, as evidenced by the insignificant regression weight (p =.294). Therefore, the study fails to reject the null hypothesis indicating there is no significant impact of where AGV is implemented (in terms of old and existing warehouses, New Warehouses Coming Up,

Brownfield Projects and Green Field Projects) on the Prospects of AGV in India. This implies that where the AGVs are implemented does not affect the prospects of AGVs in India.

A report from Alvarez and Marshal (2023) indicated that warehouse automation is driven by a variety of causes, including rising demand, operational complexity, and the need for modernisation. The increasing usage of automated technology and procedures in warehouse operations demonstrates the maturation of warehouse automation. The research defines automation maturity as Levels 0 through 4, with Level 0 indicating purely manual operations and Level 4 indicating end-to-end automation. At present, warehouses in the country have varied automation maturity levels, ranging from 0 to 2. Level 3, characterised by island automation, is still uncommon, highlighting the possibility for increased automation adoption in India. The survey projects that by 2030, nearly 80% of Indian warehouses will have some level of automation. According to the paper, India's journey towards warehouse automation will be unique, emphasising the significance of finding a precise balance between human involvement and technology.

6. Conclusion:

The primary aim of this research is to investigate the trends in MHEs in India, especially in the context of warehouses. To this end, a descriptive study was conducted that collected and analysed quantitative data from stakeholders in Indian warehouses. A total of 168 responses were taken and the demographic profiles of the respondents were analysed. The study has found that major barriers to the adoption of AGV in Indian warehouses include cost, lack of awareness, complex technology, cheap labour reliability and infrastructure concerns. The study also found that the Indian warehouses are seeking to integrate AI, priortising sustainability and are focusing on modular and scalable MHEs. Novel technologies such as augmented reality, predictive maintenance and data analytics are also used. The study also revealed that the demand for AGVs is rising, AGVs are considered cost-effective, AGVs help inaccurate inventory management and help in effective order fulfilment. Lastly, the MHEs integrate seamlessly with WMS, is considered safe and respondents had a good understanding of the basic principles behind AGVs.

The hypothesis testing of the study revealed that awareness and understanding of AGVs do have a significant impact on the prospects of AGVs in India. This implies that to increase the adoption of AGVs in India, the stakeholders should focus on creating awareness regarding the AGVs among the employees of warehouses. The outcome of the second research hypothesis implies that the place of AGV implementation does not have a significant impact on the prospects of AGV in India. Hence AGV can be implemented in any kind of project and it has a huge potential application in Indian warehouses. The practitioners in the country should take advantage of AGVs and make investments in MHEs and AGVs despite the challenges due to future benefits and cost advantages. The practitioners should also focus on how they can integrate MHEs and AGVs in existing WMS. Considering cost is an issue, companies should focus on making significant investments in AGVs to enjoy operational efficiency.

As for future studies, this field is barely explored especially in the Indian context. Hence further studies can be conducted to investigate the efficiency of AGVs and MHEs and their cost-benefit analysis. Case studies can be done where the efficiency of AGVs can be compared with that of manual workers. Future studies can also compare the efficiency of AGVs in greenfield and brownfield projects.

All authors declare that they have no conflicts of interest". Research does not involve any human participant. Consent has been given by all authors for the paper.

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Appendix:

"Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
The primary reason for the limited adoption of AGVs in India is their cost.	168	1	5	3.41	1.215
Limited awareness about AGVs and operatorless machines is a major cause of the limited adoption of AGVs in India.	168	1	5	3.44	1.270
The complexity of the technology is a major concern as to why warehouses in India are not integrating AGVs.	168	1	5	3.28	1.262
The availability of cheap labour is a key reason why AGVs are not adopted in warehouses across India.	168	1	5	3.63	1.303
The reliability of AGVs is a major cause of their limited utilisation in warehouses across the country.	168	1	5	3.21	1.303
The adoption of AGVs is negatively affected by resistance from the workforce	168	1	5	3.00	1.281
The adoption of AGVs and operatorless machines is also limited due to infrastructural constraints in Indian warehouses.	168	1	5	3.79	1.252
The usage of robotics and automation is rapidly emerging in the Indian warehouse sector.	168	1	5	3.53	1.198
Indian warehouses are actively seeking opportunities to integrate artificial intelligence (AI) in their operations.	168	1	5	3.41	1.278
Warehouses in India are prioritising sustainability and eco-friendly MHE solutions in their operations.	168	1	5	3.63	1.270
The warehouses in the country are actively seeking modular and scalable MHE solutions in their operations.	168	1	5	3.76	1.113

Warehouses in the country are actively exploring and implementing augmented reality (AR) technologies for MHE training and operations.	168	1	5	3.33	1.217
In Indian warehouses, predictive maintenance technologies are being implemented for MHEs	168	1	5	3.45	1.203
The Indian warehouses are investing in data analytics and real-time monitoring systems for MHEs.	168	1	5	3.38	1.217
I expect rapid growth in the implementation of AGV technologies in India."	168	1	5	3.58	1.176
The Indian government is actively supporting AGV initiatives, and policies are favourable for their adoption.	168	1	5	3.30	1.197
The demand for AGVs in India is continuously rising and industries across sectors are implementing this technology.	168	1	5	3.48	1.238
The infrastructure in Indian warehouses is prepared to support the adoption of AGVs.	168	1	5	3.08	1.243
The workforce in Indian warehouses is enthusiastic about AGVs, embracing them as tools to enhance efficiency and productivity.	168	1	5	3.07	1.236
In my opinion, AGVs are more cost-efficient and their return on investment potential is excellent.	168	1	5	3.49	1.276
India has a strong pool of skilled talent readily available for AGV-related tasks, facilitating adoption.	168	1	5	3.24	1.263
MHE operations are highly accurate in inventory management, minimizing stockouts and overstock of goods.	168	1	5	3.51	1.121
MHEs are quite effective in fulfilling orders and rarely cause delays.	168	1	5	3.59	1.052
MHEs are quite flexible and they seamlessly adapt to changing demands with minimal manual interventions.	168	1	5	3.43	1.087
MHEs are highly reliable, rarely experience downtime, and efficiently minimise any disruptions in regular operations.	168	1	5	3.51	1.111
MHE operations are very cost-effective.	168	1	5	3.55	1.048
MHEs can be seamlessly integrated with Warehouse Management Systems (WMS), enhancing overall efficiency and accuracy in operations.	168	1	5	3.63	1.036
MHEs are very safe in the warehouse environments of the country and accidents are very rare.	168	1	5	3.46	1.071
I have an understanding of the basic principles of AGVs.	168	1	5	3.45	1.136
I am aware of the different types of AGVs available in the market.	168	1	5	3.12	1.237
I have a basic understanding of various applications of AGV in Industrial operations.	168	1	5	3.55	1.232
Valid N (listwise)	168”				