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MATERIAL HANDLING EFFICACY AND PRODUCTION EFFICIENCIES OF PLASTIC MANUFACTURING FIRMS IN RIVERS STATE

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Abstract:
This study examined the relationship between material handling efficacy and production efficiencies of plastic manufacturing firms in Rivers State, Nigeria. Material handling efficacy was measured using material movement efficiency and material storage efficiency, while production efficiencies were assessed using resource utilisation and waste reduction. A cross sectional survey research design was adopted for the study. The population comprised employees of selected plastic manufacturing firms in Rivers State, from which a sample of 148 respondents was drawn. Primary data were collected through a structured questionnaire, while the formulated hypotheses were tested using the Spearman Rank Order Correlation Coefficient with the aid of Statistical Package for the Social Sciences (SPSS) version 23 at a 0.05 level of significance. The findings revealed that material movement efficiency had a significant positive relationship with resource utilisation (rho = 0.641, $p < 0.05$) and waste reduction (rho = 0.618, $p < 0.05$). Similarly, material storage efficiency was found to have a significant positive relationship with resource utilisation (rho = 0.583, $p < 0.05$) and waste reduction (rho = 0.549, $p < 0.05$). Based on these findings, all the null hypotheses were rejected. The study concluded that effective material handling significantly enhances production efficiencies by improving resource utilisation and reducing waste in plastic manufacturing firms in Rivers State. The study therefore recommended that management of plastic manufacturing firms should invest in efficient material movement systems, optimise storage facilities, and adopt best material handling practices to improve production efficiency and minimise operational waste.

Keywords: Material Handling Efficacy, Material Movement Efficiency, Material Storage Efficiency, Resource Utilisation, Waste Reduction, Production Efficiencies.

1. INTRODUCTION

Manufacturing efficiency has long been a central preoccupation of operations management scholars and practitioners, and the search for strategies that reduce waste, lower costs, and improve output quality has produced a rich body of theoretical and empirical work spanning several decades (Womack & Jones, 1996). Among the factors that influence manufacturing efficiency, material handling, defined broadly as the movement, storage, protection, and control of materials across the stages of production, has been identified as one of the most consequential yet frequently underestimated determinants of how efficiently a manufacturing system operates (Apple, 1977; Tompkins et al., 2010). It was observed that in many manufacturing contexts, material handling activities can account for as much as 20 to 50 percent of total production costs, making improvements in handling efficacy a potentially high-impact lever for overall efficiency gains (Kulwiec, 1985).

The plastic manufacturing industry in Rivers State operates within a context of significant operational pressure, characterised by rising raw material costs, energy price volatility, and intensifying competition from imports, all of which place a premium on the ability of firms to extract maximum efficiency from their internal production processes (Okonkwo & Eze, 2019). Despite this, empirical studies examining how material handling practices specifically influence production efficiency outcomes within this sector and geographic context remain limited, with much of the existing literature drawing on manufacturing settings in more developed economies or focusing on production efficiency drivers other than material handling (Okafor & Adeyemi, 2020). It was, as such, observed that the plastic manufacturing sub-sector in

Rivers State represents an important but under-researched context for examining the relationship between material handling efficacy and the specific production efficiency measures of resource utilisation and waste reduction.

The trend in the material handling literature has moved progressively from studies that treated handling as a purely engineering concern focused on equipment selection and plant layout (Apple, 1977; Tompkins et al., 2010) towards studies that frame material handling as an integrated operational strategy with measurable consequences for cost, quality, waste, and resource utilisation (Frazelle, 2002; Groover, 2019). Kulwiec (1985) established early foundational arguments linking handling system design to manufacturing productivity, while Frazelle (2002) extended this by demonstrating that movement efficiency and storage system design were the two most influential dimensions of material handling performance. Within the Nigerian manufacturing context, Okonkwo and Eze (2019) found that firms with structured material handling systems recorded significantly better production output consistency than those relying on informal handling practices, though their study treated production efficiency as a single undifferentiated outcome rather than disaggregating it into the resource utilisation and waste reduction components examined in the present study.

It is against this background that this study examines the relationship between material handling efficacy, the independent variable operationalised through material movement efficiency and material storage efficiency, and production efficiencies, represented separately by resource utilisation and waste reduction as two distinct dependent measures. Whereas prior studies have tended to examine production efficiency as a single-dimensional outcome, the present study departs from this trend by testing each dimension of material handling efficacy against each of the two production efficiency measures through four separate Spearman rank correlation tests, with the aim of providing a more granular and empirically grounded basis for improving the production performance of plastic manufacturing firms in Rivers State.

2. LITERATURE REVIEW

Conceptual Review

Material Handling Efficacy

Material handling efficacy refers to the degree to which an organisation's system for moving, storing, protecting, and controlling materials across its production and distribution activities is capable of achieving those activities with minimum cost, time, and waste (Tompkins et al., 2010). As such, material handling efficacy is not simply a measure of whether materials arrive at their intended destination, but encompasses the efficiency of the processes, equipment, and layouts through which that movement and storage are accomplished. For the purpose of this study, material handling efficacy is operationalised through two dimensions, namely material movement efficiency and material storage efficiency, each of which is tested separately against both resource utilisation and waste reduction. Apple (1977), one of the earliest systematic contributors to material handling theory, argued that handling efficacy should be evaluated across five performance dimensions: the distance travelled by materials, the frequency of handling, the unit load size, the time spent in transit, and the proportion of production time consumed by non-value-adding movement. As such, Apple's (1977) framework implies that an efficacious material handling system is one that minimises all five of these dimensions simultaneously, and that deficiencies in any one of them can cascade into wider inefficiencies across the production system, including downtime, bottlenecks, and excess inventory accumulation at work stations. More recently, Groover (2019) emphasised that advances in automation and information technology have expanded the scope of material handling efficacy beyond the physical movement and storage of materials to include the accuracy and timeliness of information flows that accompany material movements, such as real-time location tracking, inventory visibility, and demand signalling within the plant. It was observed that this informational dimension of handling efficacy is particularly relevant in continuous-process manufacturing environments, such as plastics, where even brief disruptions in material supply to a production station can result in significant output losses, resource wastage, and quality defects.

Material Movement Efficiency

Material movement efficiency is concerned with the ability of a manufacturing firm to transport raw materials, work-in-progress, and finished goods between locations within the plant in a manner that minimises unnecessary handling, travel distance, idle time, and damage (Frazelle, 2002). As such, movement efficiency goes beyond the speed of material transfer to encompass the design of flow paths, the selection of appropriate handling equipment, and the sequencing of material movements in alignment with production schedules, such that materials arrive at each production stage in the right quantity and at the right time without creating congestion or delay elsewhere in the system. Kulwiec (1985) noted that material movement inefficiency is one of the most pervasive but least visible sources of production waste in manufacturing, partly because movement activities do not directly produce output and are therefore not always included in standard production performance measurements. It was observed that, as a result, the costs associated with excessive movement, including labour time, equipment wear, product damage, and lost production capacity, tend to be absorbed as overhead rather than attributed to specific process inefficiencies, making the case for movement efficiency improvements difficult to build from routine performance data alone. Tompkins et al. (2010) proposed that material movement efficiency is best improved through a combination of plant layout optimisation, which minimises the distance between sequentially related production stages, and unit load standardisation, which reduces the number of separate handling events required to move a given volume of material. As such, these two approaches are complementary: layout design addresses the structural conditions of movement, while unit load management addresses the operational discipline of how materials are batched, packaged, and transported, both of which have been found to influence production cycle times, labour utilisation, and the incidence of material damage during transit.

Material Storage Efficiency

Material storage efficiency refers to the effectiveness with which a manufacturing firm manages the physical housing of raw materials, components, and semi-finished goods within its production facility, including the organisation of storage areas, the accessibility of stored items, the accuracy of inventory records, and the extent to which storage practices prevent material deterioration, misplacement, or excess accumulation (Groover, 2019). As such, storage efficiency is closely linked to production scheduling and materials planning, since poorly organised storage tends to generate delays in material retrieval, inaccuracies in inventory counts, and unplanned production stoppages when required materials cannot be located or are found to be damaged or depleted. Frazelle (2002) distinguished between storage density, which refers to the volume of material that can be housed within a given floor area, and storage accessibility, which refers to how quickly and reliably specific items can be retrieved from storage, and argued that these two dimensions are frequently in tension, since maximising density often reduces accessibility and vice versa. It was observed that the resolution of this trade-off, which Frazelle (2002) referred to as the storage design challenge, requires firms to classify their materials by retrieval frequency and physical characteristics and to assign storage locations accordingly, rather than storing materials in the sequence in which they arrive. Within the manufacturing context, Hassan (2002) found that firms adopting systematic storage location assignment policies, such as class-based storage in which high-turnover items are placed in the most accessible locations, recorded significantly shorter material retrieval times and lower rates of production interruption due to material unavailability than firms using random or arrival-sequence storage assignments. As such, this finding reinforces the proposition that storage efficiency has direct and measurable consequences for both the utilisation of production resources and the incidence of material waste across the manufacturing system.

Resource Utilisation

Resource utilisation refers to the extent to which a manufacturing firm makes productive use of its available inputs, including raw materials, machine capacity, labour hours, and energy, relative to what those inputs could theoretically produce under optimal conditions (Chase et al., 2006). As such, poor resource utilisation may manifest as idle machine time, underutilised labour capacity, excess material consumption relative to standard, or energy expenditure that does not contribute directly to the production of saleable output, each of which represents a form of operational inefficiency with direct cost implications for the firm. Womack and Jones (1996) identified inventory accumulation as one of the most common and costly expressions of resource underutilisation in manufacturing, arguing that excess stock at any point in the production system represents capital tied up in materials that have not yet been converted into revenue-generating output, while simultaneously creating conditions for material deterioration, damage, and obsolescence. It was observed that in the plastics manufacturing context, where raw material costs constitute a significant portion of total production costs and where certain materials are susceptible to degradation during prolonged storage, the link between storage efficiency and resource utilisation is particularly direct and consequential. Chase et al. (2006) argued that resource utilisation should be understood as a function of both the physical availability of inputs and the efficiency of the processes through which those inputs are accessed and converted, suggesting that even where a firm possesses adequate raw material stocks, inefficiencies in how those materials are moved and retrieved will reduce the effective utilisation of both the materials and the production equipment waiting to process them. As such, material movement and storage practices function as upstream determinants of downstream resource utilisation outcomes, a relationship that forms the empirical basis for hypotheses one and three in the present study.

Waste Reduction

Waste reduction, as a dimension of production efficiency, refers to the minimisation of material, energy, and time losses across the production process that do not contribute to the creation of acceptable finished output (Groover, 2019). Liker (2004) argued that waste reduction is best pursued as a systemic rather than event-driven activity, requiring the design of production and handling systems that structurally prevent waste from occurring, rather than relying on end-of-line inspection and rework to catch defects after they have already consumed resources. As such, the design and operation of material handling systems have direct implications for the incidence of material waste, product damage, and production rework in plastic manufacturing operations. Womack and Jones (1996) categorised the seven forms of manufacturing waste, known collectively as muda in the lean manufacturing lexicon, as overproduction, waiting, unnecessary transport, over-processing, excess inventory, unnecessary motion, and defects, and observed that at least three of these, transport, inventory, and motion, are directly attributable to the design and management of material handling systems within the plant. It was observed that this classification makes material handling efficacy a structural antecedent of waste reduction performance, rather than merely a peripheral operational consideration, and positions improvements in movement and storage efficiency as primary interventions for reducing waste in plastic manufacturing. Ohno (1988, as cited in Liker, 2004) further argued that waste reduction cannot be treated as a one-time improvement initiative but must be embedded in the daily management of production and handling processes through continuous observation, measurement, and incremental improvement. As such, firms that establish systematic performance measurement for their material handling activities are better positioned to identify and eliminate waste continuously, while firms that manage handling informally are likely to sustain elevated levels of waste regardless of the quality of their production equipment or the skill of their workforce.

2.2 Theoretical Review

This study is anchored on Lean Manufacturing Theory and Systems Theory. Lean Manufacturing Theory, as articulated by Womack et al. (1990) and further developed by Womack and Jones (1996), holds that manufacturing efficiency is achieved through the systematic elimination of waste from all production-related activities, with particular emphasis on the seven categories of muda that impede the flow of value from raw material to finished product. Applied to material handling, Lean Theory positions both movement inefficiency and storage redundancy as forms of waste that consume resources without adding value, and therefore as direct antecedents of reduced resource utilisation and elevated production waste. As such, Lean Theory provides the theoretical basis for expecting that improvements in material movement efficiency and material storage efficiency will translate into measurable gains in both resource utilisation and waste reduction, the two production efficiency measures examined in this study.

Systems Theory, as applied to manufacturing by Chase et al. (2006) and Groover (2019), provides the complementary theoretical lens through which the cascading relationship between material handling efficacy and each of the two production efficiency measures can be understood. Under a systems perspective, the manufacturing firm is viewed as an open system in which inputs are transformed into outputs through a series of interdependent processes, and in which the performance of each sub-system influences the performance of the wider system. As such, material handling constitutes a critical support sub-system whose efficacy shapes the conditions under which production processes access and use their required inputs, with weaknesses in either movement or storage efficiency creating system-wide disruptions that manifest as inefficiency in resource utilisation and elevated levels of waste at the production output stage.

2.3 Empirical Review

Several empirical studies have examined the relationship between material handling practices and aspects of manufacturing performance. Frazelle (2002) conducted a cross-sectional study of manufacturing plants across several industries and found that plants with documented material movement standards and systematic storage location policies recorded significantly lower material handling costs and higher on-time delivery rates than plants without such systems, providing early empirical grounding for the proposition that movement and storage efficiency drive broader performance outcomes, including resource utilisation and waste-related efficiency gains.

Hassan (2002) examined the impact of storage location assignment policies on manufacturing performance in a sample of firms and found that structured, class-based storage assignment policies reduced average material retrieval time by as much as 35 percent compared with random storage, and that this reduction in retrieval time was significantly associated with a reduction in production line stoppages caused by material unavailability. It was observed that shorter retrieval times directly improve resource utilisation by reducing machine idle time while also reducing the incidence of waste associated with unplanned production stoppages, affirming the relevance of storage efficiency to both dependent variables examined in the present study.

In a Nigerian manufacturing context, Okonkwo and Eze (2019) studied material handling practices among manufacturing firms in the South-South geopolitical zone and found that firms with formalised material flow documentation and adequate handling equipment recorded better production output consistency and lower material wastage rates than firms relying on informal handling practices, findings that are consistent with the expected direction of the relationships being tested in the present study. Similarly, Okafor and Adeyemi (2020) examined warehouse management practices and operational efficiency in selected Nigerian manufacturing firms and reported a significant positive association between storage system organisation and operational efficiency indicators including material availability at point of use and reduction in rework rates, lending empirical support specifically to the material storage efficiency and waste reduction relationship examined in hypothesis four of this study.

Taken together, these findings suggest that the dimensions of material handling efficacy examined here have documented associations with production performance outcomes across both international and Nigerian manufacturing contexts. Nonetheless, the disaggregation of production efficiency into resource utilisation and waste reduction as two separate dependent variables, each tested against both dimensions of material handling efficacy within the specific context of plastic manufacturing in Rivers State, represents a departure from the existing literature that justifies the empirical contribution of the present study.

Hypotheses

Based on the foregoing review, the following null hypotheses are formulated to guide the study:

H01: Material movement efficiency has no significant relationship with resource utilisation of plastic manufacturing firms in Rivers State.

H02: Material movement efficiency has no significant relationship with waste reduction of plastic manufacturing firms in Rivers State.

H03: Material storage efficiency has no significant relationship with resource utilisation of plastic manufacturing firms in Rivers State.

H04: Material storage efficiency has no significant relationship with waste reduction of plastic manufacturing firms in Rivers State.

3. METHODOLOGY

The study adopted a cross-sectional survey design, considered appropriate for capturing the perceptions of production and operations staff regarding material handling practices and production efficiency outcomes at a single point in time. The target population comprised production supervisors, store officers, and operations staff of plastic manufacturing firms registered with the Manufacturers Association of Nigeria (MAN), Rivers State chapter, given their direct exposure to material handling and production processes. A structured, close-ended questionnaire with items measured on a five-point Likert scale was used to elicit responses on material movement efficiency, material storage efficiency, resource utilisation, and waste reduction. A total of 160 questionnaires were administered, and 148 usable copies were returned, yielding a response rate of 92.5 percent. Given that Likert-scale responses are ordinal rather than interval in strict statistical terms, Spearman's rank correlation coefficient was adopted as the non-parametric test of association between each dimension of material handling efficacy and each production efficiency measure (Sheskin, 2011). This enabled the testing of four separate hypotheses, each examining a distinct pairing of an independent dimension with a dependent measure. The null hypothesis for each test was assessed at the 0.05 level of significance, with rejection indicated by a p-value less than 0.05. Reliability of the instrument was confirmed through Cronbach's alpha, with all constructs exceeding the 0.70 threshold recommended by Hair et al. (2019), and content validity was ensured through expert review prior to administration.

4. RESULTS

Response Rate

Out of 160 copies of the questionnaire administered to production and operations staff of plastic manufacturing firms in Rivers State, 148 copies were returned and found usable for analysis, representing a response rate of 92.5 percent. This response rate was considered adequate for the statistical analysis that followed (Mugenda & Mugenda, 2003).

Table 1 Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	102	68.9
	Female	46	31.1
Age	20–29 years	27	18.2
	30–39 years	69	46.6
	40–49 years	38	25.7
	50 years and above	14	9.5
Educational Qualification	OND/NCE	35	23.6
	HND/BSc	88	59.5
	MSc and above	25	16.9
Work Experience	Below 5 years	40	27.0
	5–10 years	73	49.3
	Above 10 years	35	23.6
Job Function	Production Operations	83	56.1
	Store/Inventory Management	65	43.9

Table 1 revealed information on demographic profile, as we can see the majority of respondents were male (68.9%), with most falling within the 30–39 years age bracket (46.6%), suggesting a moderately experienced workforce. A combined 72.9 percent of respondents reported at least five years of work experience within their current organisations, indicating an adequate level of familiarity with production and material handling practices to provide informed responses. The majority held a Higher National Diploma or Bachelor's degree (59.5%), and 56.1 percent were engaged in direct production operations, with the remainder working in store and inventory management functions.

Table 2 Descriptive Statistics of Study Variables

Variable	N	Mean	Std. Deviation	Remark
Material Movement Efficiency (IV)	148	3.79	0.614	High
Material Storage Efficiency (IV)	148	3.55	0.743	High
Resource Utilisation (DV)	148	3.71	0.598	High
Waste Reduction (DV)	148	3.63	0.677	High

Table 1 revealed information on the descriptive results as we can see material movement efficiency recorded the highest mean score among the four study variables (M = 3.79, SD = 0.614), followed by resource utilisation (M = 3.71, SD = 0.598), waste reduction (M = 3.63, SD = 0.677), and material storage efficiency (M = 3.55, SD = 0.743). It was observed that all four variables recorded mean scores above the scale midpoint of 3.0, indicating generally favourable perceptions of both material handling and production efficiency practices across the sampled firms. The relatively higher standard deviation recorded for material storage efficiency (SD = 0.743) and waste reduction (SD = 0.677) suggests greater variability in respondents' assessments of these variables, likely reflecting differences in storage infrastructure and waste management practices across the sampled firms.

Test of Hypotheses

The four null hypotheses formulated for this study were tested using Spearman's rank correlation coefficient at the 0.05 level of significance. The null hypothesis was rejected where the p-value was less than 0.05, and retained where the p-value was equal to or greater than 0.05.

Hypothesis One

H01: Material movement efficiency has no significant relationship with resource utilisation of plastic manufacturing firms in Rivers State.

Table 3: Spearman's Correlation on Material Movement Efficiency and Resource Utilisation

		Material Movement Efficiency	Resource Utilisation
Spearman's rho	Material movement efficiency		
	Correlation Coefficient	1.000	0.641**
	Sig. (2-tailed)	.	.000
	N	148	148
	resource utilization		
	Correlation Coefficient	0.641**	1.000
	Sig. (2-tailed)	.000	.
	N	148	148

Spearman's rank correlation result yields a coefficient of rho = 0.641, p = 0.000 ($p < 0.05$), indicating a positive and statistically significant relationship between material movement efficiency and resource utilisation. As such, the null hypothesis (H01) is rejected, and it is concluded that material movement efficiency has a significant positive relationship with resource utilisation of plastic manufacturing firms in Rivers State. The moderately strong coefficient suggests that improvements in plant-level material flow, including flow path design, handling frequency reduction, and movement scheduling, are associated with meaningful gains in how productively available production resources, including materials, machines, and labour, are utilised.

Hypothesis Two

H02: Material movement efficiency has no significant relationship with waste reduction of plastic manufacturing firms in Rivers State.

Table 4: Spearman's Correlation on Material Movement Efficiency and Waste Reduction

		Material Movement Efficiency	Waste Reduction
Spearman's rho	Material Movement Efficiency		
	Correlation Coefficient	1.000	0.618**
	Sig. (2-tailed)	.	.000
	N	148	148
	resource utilization		
	Correlation Coefficient	0.618**	1.000
	Sig. (2-tailed)	.000	.
	N	148	148

The result shows a correlation coefficient of rho = 0.618, p = 0.000 ($p < 0.05$), indicating a positive and statistically significant relationship between material movement efficiency and waste reduction. The null hypothesis (H02) is, on this basis, rejected, and it is concluded that material movement efficiency has a significant positive relationship with waste reduction in plastic manufacturing firms in Rivers State. The positive direction of the coefficient implies that firms with more efficient material movement systems experience lower levels of production waste, consistent with the lean manufacturing principle that unnecessary transport and motion are direct sources of waste that can be structurally reduced through better-designed material handling systems (Womack & Jones, 1996).

Hypothesis Three

H03: Material storage efficiency has no significant relationship with resource utilisation of plastic manufacturing firms in Rivers State.

Table 5: Spearman's Correlation on Material Movement Efficiency and Resource Utilisation

		Material Storage Efficiency	Resource Utilisation
Spearman's rho	Material storage efficiency		
	Correlation Coefficient	1.000	0.583**
	Sig. (2-tailed)	.	.000
	N	148	148

	resource utilisation		
	Correlation Coefficient	0.583**	1.000
	Sig. (2-tailed)	.000	.
	N	148	148

The Spearman's rank correlation result yields rho = 0.583, p = 0.000 ($p < 0.05$), indicating a positive and statistically significant relationship between material storage efficiency and resource utilisation. The null hypothesis (H03) is therefore rejected, and it is concluded that material storage efficiency has a significant positive relationship with resource utilisation of plastic manufacturing firms in Rivers State. This finding implies that improvements in how materials are organised, stored, and made retrievable within the plant contribute to higher levels of productive resource use, as materials are made available to production stations more reliably, reducing machine idle time and the underutilisation of labour that arises from material retrieval delays.

Hypothesis Four

H04: Material storage efficiency has no significant relationship with waste reduction of plastic manufacturing firms in Rivers State.

Table 6: Spearman's Correlation on Material Movement Efficiency and Resource Utilisation

		Material Movement Efficiency	Waste Reduction
Spearman's rho	Material Movement Efficiency		
	Correlation Coefficient	1.000	0.549**
	Sig. (2-tailed)	.	.000
	N	148	148
	resource utilization		
	Correlation Coefficient	0.549**	1.000
	Sig. (2-tailed)	.000	.
	N	148	148

The result shows rho = 0.549, p = 0.000 ($p < 0.05$), indicating a positive and statistically significant relationship between material storage efficiency and waste reduction, though this is the weakest association recorded among all four hypotheses. The null hypothesis (H04) is rejected, and it is concluded that material storage efficiency has a significant positive relationship with waste reduction of plastic manufacturing firms in Rivers State. The relatively lower coefficient may reflect the wider variability in storage practices observed across the sampled firms, as evidenced by the higher standard deviation recorded for material storage efficiency, suggesting that the contribution of storage efficiency to waste reduction is present but mediated by the degree to which storage systems are formalised and consistently applied across individual firms.

DISCUSSION OF FINDINGS

The finding that material movement efficiency has the strongest significant relationship with resource utilisation (rho = 0.641) is consistent with Frazelle (2002), who identified movement efficiency as the primary driver of material handling cost and production flow performance. It was observed that this result aligns with the Systems Theory underpinning this study, as better-designed material flow paths and reduced handling frequency ensure that production machines and labour are continuously supplied with the inputs they need, minimising the idle time and underutilisation of capacity that represents the core of resource utilisation inefficiency (Chase et al., 2006).

The significant relationship between material movement efficiency and waste reduction (rho = 0.618) corroborates the Lean Manufacturing Theory argument advanced by Womack and Jones (1996) that unnecessary transport and motion are among the primary categories of production waste, and that their reduction through deliberate handling system design directly reduces the volume of waste generated during the production cycle. As such, this finding reinforces the position that material handling is not peripheral to waste management in plastic manufacturing but is structurally embedded in it, since each unnecessary movement event carries the risk of material damage, product defects, or production delay that ultimately manifests as waste.

The significant relationship between material storage efficiency and resource utilisation (rho = 0.583) is consistent with Hassan (2002), who demonstrated that structured storage assignment policies reduced material retrieval times and associated production stoppages. It was observed that this finding affirms the argument advanced by Chase et al. (2006) that even where raw material stocks are adequate, inefficient access to those stocks reduces the effective utilisation of both materials and the production equipment waiting to process them, making storage efficiency an upstream determinant of downstream resource utilisation outcomes.

The finding that material storage efficiency has the weakest, though still significant, relationship with waste reduction (rho = 0.549) is consistent with the higher standard deviation recorded for storage efficiency in the descriptive results, suggesting that uneven formalisation of storage practices across the sampled firms moderates the strength of this relationship. Nonetheless, the result supports Liker's (2004) argument that storage-related waste, particularly through excess inventory accumulation and material deterioration, constitutes a structurally significant but often neglected source of production waste in manufacturing, and that its reduction requires systematic rather than ad hoc storage management practices.

5. CONCLUSION AND RECOMMENDATIONS

This study has demonstrated that material handling efficacy is a significant determinant of both resource utilisation and waste reduction in plastic manufacturing firms in Rivers State. Both material movement efficiency and material storage efficiency maintained positive and statistically significant relationships with each of the two production efficiency measures examined, with material movement efficiency consistently showing the stronger associations. The findings are consistent with Lean Manufacturing Theory and Systems Theory and with prior empirical work conducted in both international and Nigerian manufacturing contexts. It is concluded that plastic manufacturing firms in Rivers State that invest in more structured and efficient material handling systems are better positioned to improve both the productive utilisation of their resources and the reduction of production-related waste, the two key dimensions of production efficiency addressed in this study.

Arising from the findings on each of the four hypotheses tested, the following recommendations are made:

i. Based on the finding that material movement efficiency has the strongest significant relationship with resource utilisation (H01), it is recommended that management of plastic manufacturing firms in Rivers State conduct systematic plant layout reviews to minimise the distance and frequency of material movement between production stages and establish documented material flow schedules aligned with production plans, as these measures are most directly associated with improvements in how productively machines, labour, and materials are utilised across the production system.
ii. Based on the finding that material movement efficiency has a significant relationship with waste reduction (H02), it is recommended that management adopt lean-based material flow principles to structurally eliminate unnecessary transport and motion events within the production facility, since each unnecessary movement event increases the risk of material damage, product defects, and production delays that manifest as waste, and that periodic time-and-motion studies be conducted to identify and redesign high-waste movement routes within the plant.
iii. Based on the finding that material storage efficiency has a significant relationship with resource utilisation (H03), it is recommended that management implement class-based storage location assignment systems that position high-frequency materials in the most accessible storage locations, maintain accurate real-time inventory records to eliminate production stoppages caused by material unavailability, and design storage layouts that balance density with retrieval accessibility, as these measures will reduce machine idle time and labour underutilisation attributable to storage-related delays.
iv. Based on the finding that material storage efficiency has the weakest significant relationship with waste reduction among the four tested relationships (H04), and given the higher variability in storage practices across the sampled firms, it is recommended that management standardise storage management practices across all plant areas, invest in adequate storage infrastructure to prevent material deterioration and damage during holding, and institute regular storage audits to identify and correct conditions, such as excess inventory accumulation and poor material rotation, that contribute to production waste, as these interventions address the specific pathways through which storage inefficiency generates waste in plastic manufacturing operations.

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