



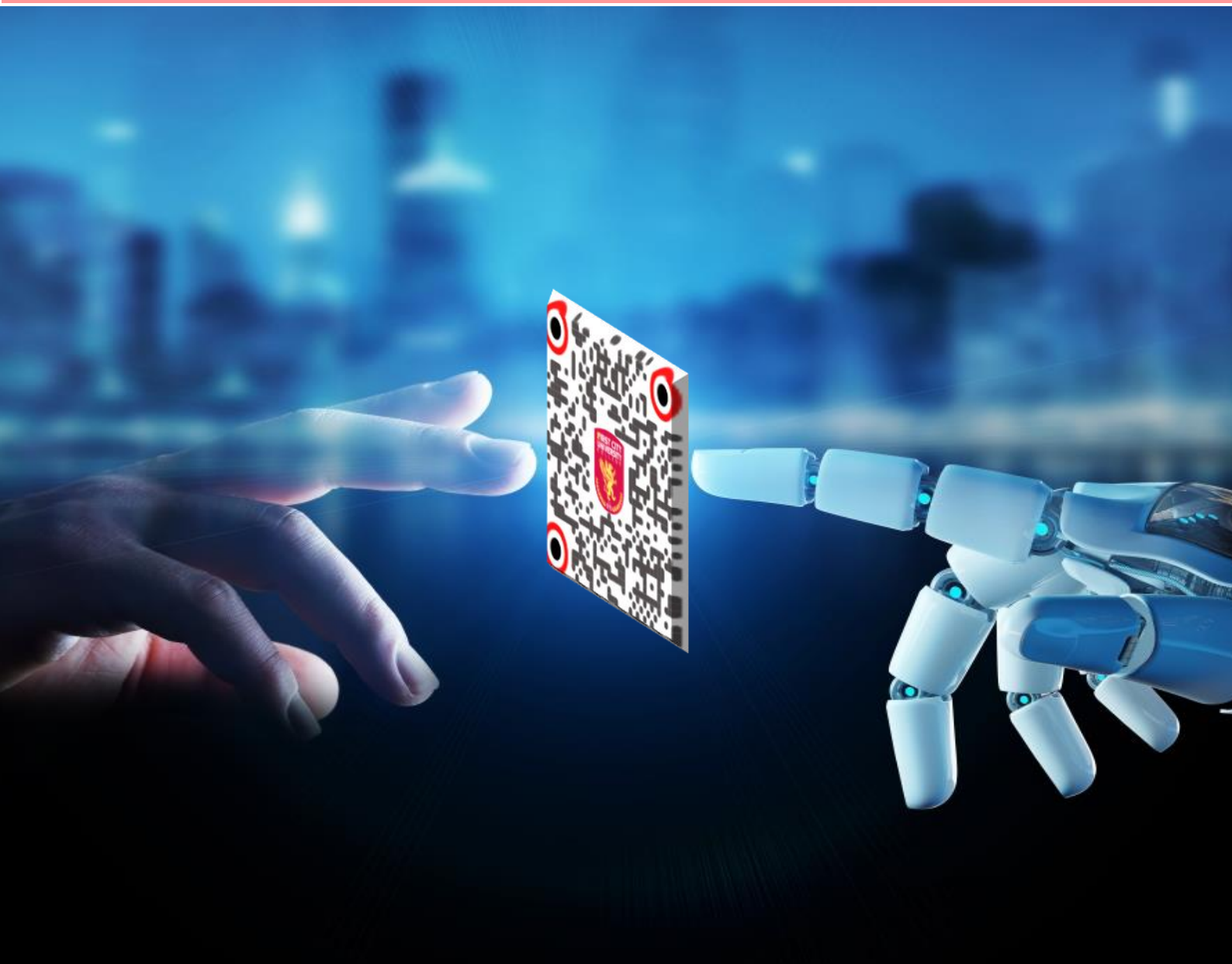
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STRATEGIC MANAGEMENT ACCOUNTING AS A TOOL FOR SUSTAINING COMPETITIVE ADVANTAGE

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ABSTRACT

This article examines the crucial function of Strategic Management Accounting (SMA) in augmenting competitive advantage in organisations. As enterprises traverse increasingly intricate landscapes, the use of strategic management accounting methods has become essential for attaining and maintaining competitive advantage. Moreover, SMA enhances informed decision-making by supplying pertinent financial and non-financial information, crucial for strategic planning and implementation. Besides that, the synchronisation of Strategic Management Activities (SMA) with organisational strategies enables firms to respond effectively to market fluctuations and consumer demands, thereby promoting a proactive competitive stance.

Keywords: Strategic Management Accounting, Competitive Advantage, Organizational Performance, Decision-Making, Innovation and Strategy

INTRODUCTION

Strategic management accounting (SMA) has become an essential instrument for firms aiming to improve their competitive edge in a complicated and changing commercial landscape. By amalgamating financial and non-financial data, SMA empowers organizations to make educated strategic decisions that correspond with their long-term goals. This methodology facilitates efficient planning and oversight while enhancing comprehension of market dynamics and competitor actions, essential for maintaining competitive advantage (Phornlaphatrachakorn & NA-KALASINDHU, 2020; Alamri, 2018; Dang et al., 2021). The significance of SMA is highlighted by its capacity to deliver essential insights that enhance performance and ensure strategy alignment across businesses (Alabdullah, 2019; Varelas & Apostolopoulos, 2020; Petera & Šoljaková, 2019).

Recent research has emphasized the complex nature of SMA and its influence on organizational effectiveness. Research demonstrates that companies utilizing advanced Strategic Management Accounting methodologies generally attain enhanced financial performance and operational efficiencies (Alsharari, 2019; Ma et al., 2022; Nanediri et al.,

2022). Moreover, the implementation of SMA has been associated with improved decision-making abilities, allowing firms to manage uncertainty and seize emerging opportunities (Setiawan & Iskak, 2023; Augustine & Marpaung, 2022). The relationship between SMA practices and organizational performance is especially evident in rapidly changing sectors, where adaptability and innovation are crucial for sustaining a competitive advantage (Pan, 2023; Reyroso, 2023).

Theoretical Framework of Strategic Management Accounting

The theoretical framework for SMA is primarily grounded in the Resource-Based View (RBV), which posits that a firm's unique resources and capabilities are fundamental to achieving a sustainable competitive advantage (Kiyabo & Isaga, 2019; "Exploring the impact of environmental uncertainty and strategic management accounting on competitive advantage and performance: Empirical insights from SMEs in Indonesia", 2024). SMA practices, such as competitor analysis, strategic costing, and performance measurement, provide organizations with insights into their operational efficiencies and market positioning. These practices enable firms to craft strategies that enhance profitability and ensure long-term sustainability (Parida & Wincent, 2019). Moreover, SMA facilitates a comprehensive understanding of both internal capabilities and external market conditions, allowing organizations to adapt and respond effectively to competitive pressures.

Recent studies have underscored the importance of SMA in integrating financial and non-financial information with organisational strategy. For example, Cescon et al. (2018) investigate the correlation between strategic choices and SMA in major manufacturing enterprises, illustrating that the proficient amalgamation of SMA methods with strategic management can enhance decision-making and performance results. Their findings indicate that organisations utilising SMA are more adept at responding to market dynamics and seizing competitive opportunities. The study underscores the necessity for organisations to embrace a proactive management accounting strategy, using internal capabilities and external market conditions to formulate strategies that improve profitability and guarantee long-term sustainability (Ojra et al., 2021).

The literature has emphasised the significance of SMA in promoting strategic leadership and innovation. Study conducted by Ojra et al. (2021) assert that proficient SMA implementation facilitates optimal strategic decision-making, crucial for improving overall performance. This supports the idea that SMA not only improves financial performance but also fosters a lasting competitive advantage via enhanced operational efficiencies and market responsiveness. Furthermore, the incorporation of SMA into the strategic management framework underscores its importance in aligning financial performance with overarching organisational objectives, promoting a culture of accountability and strategic emphasis among management teams (Anisman, 2023).

Importance of Strategic Management Accounting

Strategic Management Accounting (SMA) has emerged as a vital element in improving organizational performance and competitive advantage. The significance of SMA resides in its capacity to amalgamate financial and non-financial data, thus offering a holistic perspective of an organization's strategic standing. Phornlaphatrachakorn and Na-Kalasinthhu (2020) assert that SMA is an essential instrument for guiding, planning, managing, and making decisions, hence enhancing the efficacy of corporate strategies. Their research indicates that companies utilizing effective SMA strategies generally demonstrate enhanced corporate competitiveness and significant performance results, emphasizing the importance of SMA in the contemporary business landscape.

The job of management accounting has evolved beyond traditional cost determination to include strategy planning and performance monitoring (Harnani, 2022). Harnani (2022) asserts that management accountants are progressively recognized as strategic partners in enterprises, responsible for delivering insights and analyses that facilitate strategic decision-making processes. This transition signifies the increasing acknowledgment of the significance of SMA in enabling informed decisions that correspond with corporate objectives and market requirements. The incorporation of SMA into strategic management frameworks allows firms to proactively address competitive constraints and seize emerging opportunities.

Empirical research further validates the importance of SMA in improving organizational performance. For example, a research conducted by Nanediri et al. Nanediri et al. (2022) indicate that the adoption of SMA methods positively impacts the performance of manufacturing enterprises, especially in customer profitability analysis and strategic costing. In a similar vein, a study by Ojra et al. was done. Ojra et al. (2021) assert that successful SMA implementation results in optimal strategic decision-making, which is crucial for enhancing overall organizational performance. These findings collectively underscore the essential function of SMA in cultivating a culture of responsibility and strategic emphasis, hence enhancing sustained competitive advantage.

Empirical Evidence Supporting SMA's Role in Competitive Advantage

Strategic Management Accounting (SMA) has received considerable focus in recent years as a vital element in augmenting competitive advantage for organisations. Empirical research has shown that the successful execution of SMA techniques can enhance organisational performance and strategic positioning. Phornlaphatrachakorn and Na-Kalasinthhu (2020) conducted a study on finance businesses in Thailand, demonstrating that SMA is a crucial internal resource that positively influences sustainable competitive advantage via operational excellence and managerial efficiency. Their findings emphasise the necessity of incorporating SMA into organisational plans to utilise internal strengths for improved performance. Furthermore, the significance of knowledge management procedures in relation to strategic management accounting (SMA) has been emphasised in the literature. Mahdi and colleagues

Mahdi et al. (2019) investigated the correlation between knowledge management and sustainable competitive advantage in private universities, presenting empirical evidence that efficient knowledge management systems, when integrated with SMA, can substantially improve competitive positioning. This study highlights the importance of integrating knowledge management with strategic accounting practices to cultivate an atmosphere that promotes innovation and strategic decision-making, hence enhancing organisations' competitive advantage.

The significance of strategic agility within the framework of SMA, alongside knowledge management, has been explored. Battour et al. (2021) examined the mediating function of strategic agility in the relationship between Human Resource Management (HRM) strategies and sustained competitive advantage within manufacturing firms. Their research demonstrates that HRM methods significantly affect sustained competitive advantage, with strategic agility serving as an essential mediator. This research emphasises the interrelation of diverse organisational strategies, including SMA, in attaining competitive advantage through agility and responsiveness to market fluctuations.

Moreover, empirical evidence from SMEs in Indonesia substantiates the claim that SMA enhances competitive advantage by mitigating environmental concerns. A study titled "Exploring the Impact of Environmental Uncertainty and Strategic Management Accounting on Competitive Advantage and Performance: Empirical Insights from SMEs in Indonesia" (2024) employed structural equation modelling to examine the influence of strategic management accounting on competitive advantage and performance, with an emphasis on product differentiation. The findings demonstrated that the application of SMA markedly improves competitive advantage, especially in uncertain circumstances. This discovery substantiates the idea that SMA provides organisations with essential resources to adeptly manoeuvre through intricate market dynamics.

The incorporation of SMA into strategic management processes has demonstrated beneficial results across multiple sectors. Research by Alamri, Alamri (2018) demonstrated empirical evidence of the positive correlation between SMA aspects and organisational performance, especially for non-financial measures. The study determined that SMA enhances predictive and forward-looking decision-making, allowing managers to react proactively to swift changes and uncertainty in the corporate landscape. This corresponds with the extensive literature highlighting the essential function of SMA in cultivating a culture of strategic emphasis and accountability, hence resulting in enduring competitive advantage.

CONCLUSION

In conclusion, Strategic Management Accounting (SMA) is essential for augmenting competitive advantage in firms across diverse sectors. The incorporation of SMA practices into

strategic management frameworks enables organizations to utilize both financial and non-financial data, promoting informed decision-making that corresponds with organizational objectives. Empirical data substantiates the claim that proficient SMA implementation enhances performance outcomes, as companies employing SMA approaches are more adept at maneuvering through intricate market dynamics and proactively addressing competitive constraints (Oyewo, 2022; Alamri, 2018). This alignment enhances operational efficiency and promotes a culture of accountability and strategic focus across management teams.

Furthermore, the significance of contextual factors in influencing the link between SMA and competitive advantage is undeniable. Studies demonstrate that organizational structure and environmental uncertainty substantially affect the efficacy of SMA procedures (Oyewo, 2022). Companies functioning inside decentralized frameworks and high-uncertainty contexts are more inclined to gain advantages from SMA, as these methodologies facilitate the alignment of internal competencies with external market requirements. This adaptability is essential for firms aiming to sustain a competitive advantage in a constantly changing business environment. Consequently, comprehending and utilizing these contextual elements is crucial for optimizing the advantages of SMA.

As firms encounter escalating competition and swift technological progress, the significance of SMA will become increasingly paramount. Subsequent study ought to concentrate on investigating the dynamic characteristics of SMA and its effects on organizational performance across diverse sectors. By persistently optimizing SMA processes and connecting them with strategic goals, firms can augment their competitive edge and secure long-term sustainability. The successful incorporation of SMA into strategic management processes will enable firms to excel in the contemporary complicated and dynamic business landscape (Alamri, 2018; Cescon et al., 2018).

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A COLD CHAIN SUPPLY CHAIN MANAGEMENT AND PERCEIVED INTEGRITY IN LIVESTOCK SUPPLY CHAIN

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ABSTRACT

The objective of the paper is to define the different forms of quantitative risk assessment method data that can be obtained and evaluated by professionals around the cold chain. The goal of this analysis is to enhance product integrity and maximize consumer loyalty. The literature review of numerous selected academic papers, released between 2015 and 2020, focused on content interpretation, was used to establish a summary of data capture, data storage and sharing technologies, and data-supporting decision-making in the cold chain supply chain management and presumed credibility and integrity in the supply chain of livestock. It is important to consider how constant monitoring of conditions such as temperature, humidity, vibration can be converted in order to facilitate quality evaluation in real time, to calculate the actual remaining shelf life of goods and to use them in cold chains for decision-making. In order to collect data across the cold chain such as Cold Storage Commodity, Cold Chain Shipping and Cold Storage Packaging, businesses in the cold chain need to implement suitable technology appropriate to the particular circumstances to improve the perceived credibility and integrity of livestock in the supply chain. Examination of such data over longer periods will also reveal product degradation trends under multiple inventory conditions, which can contribute to presumed consumer and supplier credibility, morale and accountability. For multiple players participating in the cold chain, such as food processing firms, logistics service providers, ports and wholesalers and retailers, the results of this research may be useful to understand how data can be used efficiently for improved cold chain decision-making and to invest in the particular technologies that fit the target. It is also necessary to recognize the player in the cold chain to ensure the implementation of data analytics across the cold chain, which will guide and organize the initiative viewed by the supply chain integrity and credibility of the livestock. This paper is one of the first to identify the need for a systematic review of the cold chain management adoption and deployment of data analytics and provides recommendations for future study.

Keywords: Cold Chain Supply Chain, Integrity, Logistics, Literature Review, Supply Chain Products, Transportation.

INTRODUCTION

The Cold Chain Supply Chain Management structure is the basis for the production, processing and transformation of raw materials and semi-finished products from key activities such as forestry, agriculture, zootechnics, finishing, etc. The cold chain includes the transportation by thermal and refrigerated packaging techniques of temperature-sensitive goods along a supply chain and logistical preparation to maintain the integrity of these shipments (Wang et al., 2018). While globalization has made the relative gap between regions of the world much smaller, it is still a very necessary fact to physically distinguish those same regions. In one of the complex transport operations involved, the greater the physical separation, the more likely it is that freight will be harmed. Shocks can harm certain items, while undue fluctuations in temperature can damage others (H. Liu et al., 2018). Their quality deteriorates over time for a variety of products labeled as perishables, especially food (produces), as they retain chemical reactions, which can be often mitigated at lower temperatures. In order to move a shipment efficiently, it takes time and coordination, and any delay can have negative implications, especially if this cargo is perishable. To guarantee the cargo is not harmed Businesses in the pharmaceutical, medical and food industries are increasingly dependent on the cold chain, or are compromised in this process.

Problem Statement

In the livestock industry, maintaining product integrity is crucial to ensure food safety, customer satisfaction, and business reputation. However, many cold chain operations still face significant challenges such as inconsistent temperature monitoring, inadequate packaging, inefficient transportation systems, and weak inventory controls (Chaudhuri et al., 2018; Liu et al., 2018). These weaknesses can result in product degradation, financial losses, and a decline in consumer trust. Despite the importance of cold chain supply chain management (CCSCM), limited studies have explored the relationship between cold chain logistics components and perceived integrity within the livestock supply chain. Without reliable data-driven strategies and proper cold chain management, organizations struggle to guarantee the quality and safety of temperature-sensitive livestock products throughout the supply chain.

Research Objective

RO: 1	To examine the influence of cold storage products on perceived integrity in the livestock supply chain.
RO: 2	To analyze how cold chain transportation affects perceived integrity in the livestock supply chain.
RO: 3	To investigate the role of cold storage packaging in maintaining perceived integrity in the livestock supply chain.

RO: 4

To evaluate the impact of cold chain inventory management on the perceived integrity in the livestock supply chain.

Scope of the Study

This study focuses on the cold chain supply chain management practices in Malaysia's livestock industry. The main elements analyzed include cold storage products, transportation, packaging, and inventory. The research investigates how each of these elements influences the perceived integrity of livestock products, using data collected from organizations that operate within the cold chain sector. (Chaudhuri et al., 2018)

Significance of the Study

This research is significant as it highlights the critical role of CCSCM in maintaining the integrity of livestock products, which directly affects consumer safety, business profitability, and regulatory compliance (Zhao, 2020). The findings provide practical insights for logistics managers, policymakers, and stakeholders to enhance cold chain operations by investing in appropriate technologies and strategies (Wang et al., 2018). Moreover, the study contributes to academic literature by bridging the gap between cold chain logistics practices and perceived product integrity in the livestock sector. (Jeffison & Mwale, 2020).

LITERATURE REVIEW

Cold storage material for phase shift is a kind of material that can be used by changing the phase state of the substance while preserving the ambient temperature of the device, it provides latent heat. They can be classified into four groups according to the phase shift state of materials: solid-solid, solid-gas, liquid-gas and solid-liquid because of their clear volume transition and limited latent heat of phase shift, it is difficult to understand large-scale deployment of the first three phase change cold storage materials. Cold storage products typically have greater practicality for solid-liquid phase transitions, which can be loosely separated into three categories: The efficiency analysis of the three types of phase change cold storage materials, organic phase change cold storage materials, inorganic phase change cold storage materials and eutectic phase change cold storage materials.(Y. Zhao et al., 2020) A mixture of several components is typically a phase change refrigerant, primarily includes phase change content, phase change temperature regulator, nucleus acting agent, thickener, preservative and other components. In the cold chain system, which has the characteristics of rapid cooling, high cold storage space, long cold holding time, recyclable, non-toxic and pollution-free, cold storage agents are commonly used. The change range of the phase change temperature of single component phase change material with concentration is limited in the preparation process, so the substance with a wide phase change temperature must be used as a phase change temperature regulator to compound in order to extend the phase change

material application spectrum. The literature for supply chain control on degrading goods. (Version, 2018). Most of the previous research papers on this are especially rich, and focus on the coordination of the supply chain and inventory monitoring. (Zhang et al., 2017) The supply chain management philosophy stipulates the need for legitimate supply chain partnerships. Supply chain management relies on the confidence and engagement of the parties concerned, and thus the existence of trust results in good supply chain management. On the other hand, it has been seen that a lack of trust among supply chain partners results in inefficient and ineffective the performance of the supply chain as a whole and the market performance of other businesses was directly influenced. The philosophy of supply chain management, thus, forms the foundation of this study. (Jeffison & Mwale, 2020).

Cold Chain Supply Chain Management

Thus, the cold chain is a science, a technology, and a process. It is a science because it involves an understanding of the processes associated with perishability in chemical and biological terms. As it relies on physical means to ensure acceptable temperature conditions in the supply chain, it is a technology. (Wang et al., 2018) It is a process because it is necessary to perform a series of tasks to plan, stock, transport, and monitor temperature-sensitive products.

Systems for Ventilation: Bringing goods such as food for processing, storage, and transport to the required temperature.

Cold Storage: Providing, over a period of time, facilities for the storage of products, either waiting to be delivered to a distant market, at an intermediate place for processing and distribution, or near the market for distribution.

Cold Transport: Having conveyances available to move goods while maintaining stable temperature and humidity conditions as well as protecting their integrity.

Cold Processing and Distribution: Providing facilities for the transformation and processing of goods as well as ensuring sanitary conditions. Consolidating and deconsolidating loads (crates, boxes, pallets) for distribution.

The cold chain helps many emerging countries, from an economic development perspective, to participate either as producers or as consumers in the global market for perishable goods. Income growth is associated with a higher tendency for fruit, vegetables, fish and meat products to be eaten. Rising levels of income are correlated with a shift in diet, with increasing demand for fresh fruit and higher-value foods such as meat and fish, among other items. People with a higher socio-economic status are more likely, not only in higher amounts but also in greater variety, to consume vegetables and fruit, particularly fresh (X. Zhao, 2020). Consumers with rising purchasing power have become concerned with eating healthy.

Producers and retailers have therefore replied with an assortment of exotic fresh fruits from around the world.

Cold Storage Product (X1)

The success of industries that rely on the cold chain comes down to understanding how to produce a temperature regulated product suited to the shipping conditions (Chaudhuri et al., 2018) . In recent decades, the operations of the cold chain have improved greatly, and the industry can meet the requirements of a wide variety of goods.

Cold Chain Transportation (X2)

To transfer a shipment through the supply chain without experiencing any delays or temperature fluctuations, a rigorous logistical procedure needs to be developed to preserve the integrity of the shipment (Yu & Xiao, 2017). This approach includes many steps, ranging from the preparation of the shipments to the final verification of the shipment's integrity at the point of delivery:

Shipment Preparation: When a temperature-sensitive product is transferred, it is important to determine its characteristics first. The heat conditioning and packaging of the shipment, which should already be at the optimal temperature, are a key issue. A noteworthy exception involves bananas that are shipped at a temperature of about 13 degrees Celsius, for which a reefer can be used to cool down the shipment. The destination of the shipment and the environmental conditions in certain regions are other considerations, such as whether the shipment would be subjected to extreme cold or heat along the transport path. These problems are usually mitigated by using a reefer with its own power unit. It is also important to prepare the load unit carrying the temperature-sensitive freight.

Modal Choice: Many primary variables play a part in how the package can be transported. The distance between the origin and the final destination (which also requires a number of intermediate locations), the size and weight of the container, the natural temperature climate needed and the product's time limitations (perishability) all influence the shipping options available. With a van or a truck, short trips can be handled, whereas a longer ride can involve an airplane or a container ship. In this case, an element in the modal preference becomes the cost/perishability ratio.

Custom procedures: Customized protocols will become very necessary if freight crosses borders, as cold chain goods appear to be time-sensitive and more subject to inspection than normal freight (e.g., produce, pharmaceuticals, and biological samples). Depending on the country (or economic bloc) and the gateway, the complexity of this activity varies as there are differences in processes and delays.

Integrity and quality assurance: Temperature recording instruments or identified temperature fluctuations need to be registered and made known after the package has been shipped. This is the phase of the logistical process that generates trust and responsibility, especially if liability is sustained for a damaged shipment. If there are complications or irregularities that compromise a package, an attempt must be taken to locate the cause and for co-occurrences.

Cold Storage Packaging (X3)

To maintain their integrity in the transport chain, various goods require the maintenance of varying temperature levels. The sector has reacted by setting temperature levels that fit most goods. "Banana" (13 °C), "chill" (2 °C), "frozen" (-18 °C) and "deep-frozen" (-29 °C) are the most common temperature standards, each applied to particular groups of items. Staying within this temperature range is important to the safety of a supply chain shipment, and it allows maximum shelf life for perishables. Any divergence can result in irrevocable and costly harm; any market appeal or utility can simply be lost to a commodity (X. Zhao, 2020). Being able to guarantee that a shipment stays within a temperature range for a prolonged period of time largely depends on the type of container used and the method of cooling. In cold chain logistics, nearly 20 percent of all energy consumed includes cargo refrigeration. Factors such as the length of transit, the size of the shipment and the ambient or external temperatures encountered are critical for determining the type of packaging needed and the amount of energy consumption associated with it. They can range from small insulated boxes requiring packs of dry ice or gel to rolling containers to a 53-foot reefer with its own powered cooling unit.

In providing a temperature-controlled environment during transport, the main cold chain technologies include:

Dry Ice: Solid carbon dioxide is roughly -80 ° C and is able to hold a shipment frozen for a long period of time. It is particularly used in the shipping of pharmaceuticals, hazardous goods and foodstuffs and in air cargo refrigerated unit loading devices. It does not melt dry ice. Instead, when it comes into contact with air, it sublimates.

Gel Packs: Wide pharmaceutical and medicinal shipment shares are listed as chilled products, which indicates that they must be kept between 2 and 8 °C in the temperature range. Using gel packs or packets containing phase-changing substances that can go from solid to liquid and vice versa to regulate the atmosphere is the normal method of having this temperature. These packages may either start off in a frozen or refrigerated state, depending on the shipping requirements. They melt into liquids in the transit process, while collecting escape energy and preserving an internal temperature at the same time.

Eutectic plates: They are sometimes referred to as "cold plates." The idea is similar to gel packs. Plates are now filled with a liquid and can be reused many times. For rolling refrigerated units, Eutectic plates have a wide variety of uses, such as preserving cold

temperatures. They can also be used to maintain the temperature steady for brief periods of time in delivery vehicles, a method that can be appropriate for deliveries in noise-sensitive areas or for night deliveries.(P. Liu & Wang, 2020)

Liquid nitrogen: A extremely cold material, roughly -196 °C, which is used to hold packages frozen for a long period of time and is primarily used to transport biological cargo such as tissues and organs. It is known to be a dangerous material for transportation purposes.

Quilts: To serve as a buffer in temperature fluctuations and to maintain the temperature relatively constant, isolated sections that are put over or around freight. Frozen freight can also stay frozen for a longer period of time, often long enough not to require the use of more costly refrigeration equipment.

Reefers: A common name for a temperature-controlled transport device capable of being a van, a small truck, a semi-trailer, or a regular ISO container. These isolated units are specially built to allow temperature-controlled air circulation to be maintained by a separate, attached cooling plant. Hence, a reefer is able to keep the temperature of the cargo cool and even hotter. Increasingly, the word reefer refers to refrigerated ISO 40-foot containers with a dominant capacity of 40 high-cube footers (45R1 being the size and type code).

Cold Chain Inventory (X4)

Inventory management is the products or products that a business sells to its customers to make a profit. Stock management covers several distinct elements as part of the cold supply chain, such as monitoring and supervising retailer and consumer orders, managing stock holding, controlling the quantity of cold goods for delivery and meeting the order. (Version, 2018)

Stock purchasing - Raw materials or parts are acquired and shipped to the factory.
Inventory management - Inventory is stored until needed. In order to be made into finished products, raw materials are transported to manufacturing plants and returned to storage areas before ready for shipping.

Stock gain - the quantity of the commodity for sale is regulated. To meet orders, completed items are pulled. Things are distributed to consumers.

Perceived Integrity in Livestock Supply Chain (Y)

Cold chain logistics prefers higher levels of integration in all the supply chains it concerns, because maintaining temperature integrity requires a higher degree of control of all the processes involved. It may also enable third-party logistics suppliers to acquire supply chain components where the most significant, even farming, are time and other performance factors. In order to ensure supply reliability, this can require the acquisition of producing

farms (e.g. orange groves). A part of the industry that has continued to increase in relation to international trade is temperature control in the shipment of foodstuffs. As the export economy of a growing number of countries focuses on food and produce, the need to keep these goods fresh for prolonged periods of time has become increasingly necessary for commercial and health reasons. As the proper transport of food items would minimize the likeliness of bacterial, microbial, and fungal contamination of the shipment, the cold chain is also a public health concern. The ability to move medical goods over long distances also makes it possible to respond more quickly to health problems (e.g. distribution of vaccines).

Cold Chain Supply Chain Management and Perceived Integrity in Livestock Supply Chain

The effect of failing at any stage of the cold chain to sustain optimum temperatures, except for short periods, will lead to many undesirable effects. The following include these:

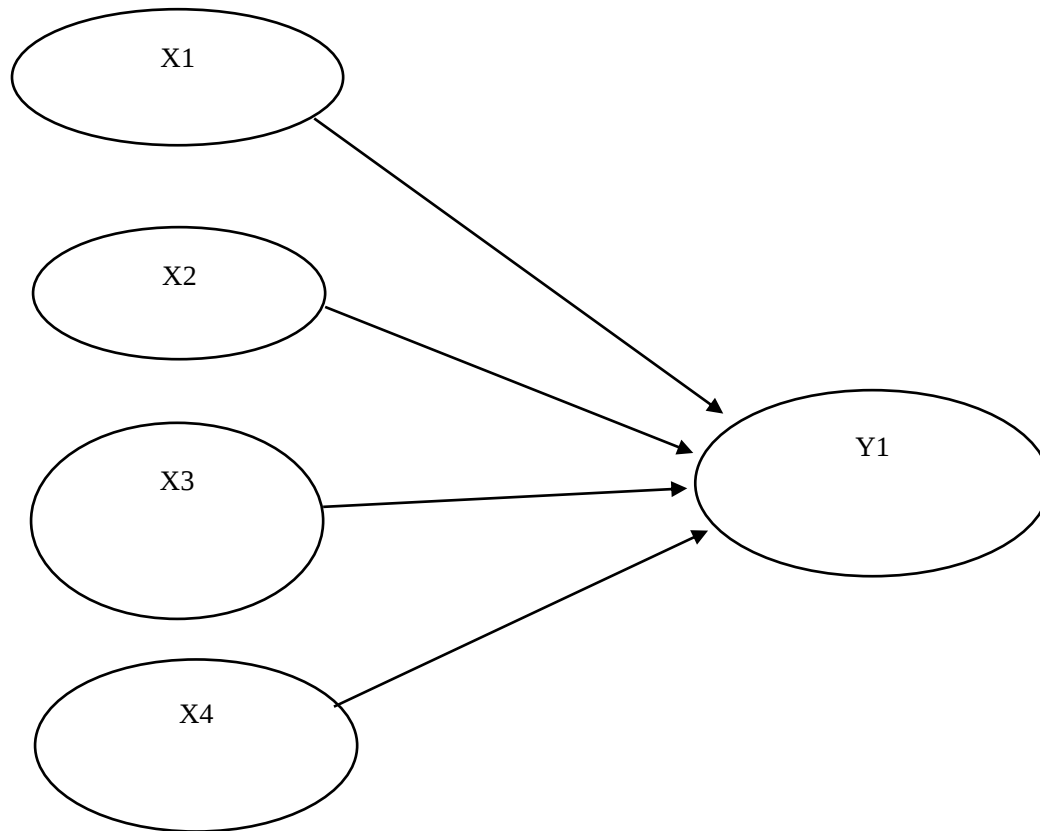
Product degradation: The consistency of the shipment may be affected if the cold chain shipment is not held cold at any link of the chain, resulting in worthless goods. In the case of exporting vaccinations, pharma drugs, and vital food goods, this can be tremendously dangerous.

Waste of Money from Vendors: Shipping owners lose money when cold chain cargo goes bad due to inability to have the consistent temperatures needed for their protection. The magnitude of financial damages can depend on a number of factors including the type and quantity of goods involved.

Deterioration of business partnerships: They are bound to take disciplinary action against them when shippers incur heavy damages because of errors made by their shipping partners. They could break ties with their partners as well.

Not all goods that are temperature-sensitive are made equal. To retain its reputation throughout the cold chain, every commodity is unique and needs skilled handling. There are many rules and standards set by industry authorities to be observed by shipping firms in the procurement of the cold chain. Specific shippers must have in-house quality requirements above these criteria. Many producers of temperature-sensitive goods need to consider business, local, regional, global, and environmental regulations, as well as correctly predict the length of freight, to outsource their cold-chain supply to specialist shipping firms that can manage all their freight needs.

Model



X1 – Cold storage product significantly influenced by Perceived integrity in livestock supply chain.

X2 – Cold chain transportation significantly influenced by Perceived integrity in livestock supply chain.

X3 – Cold storage packaging significantly influenced by Perceived integrity in livestock supply chain.

X4 – Cold chain inventory significantly influenced by Perceived integrity in livestock supply chain.

The method which has been used to do this research is an active company which are sustaining in this cold chain logistics were chosen as the target population for our study.

Primary data for this study is the information which was gathered using structured questionnaires. The application that uses Smart-PLS and SPSS to run the data and get the results from the surveys was used in this study and to analyze the research model. To assess the measurement model, convergent and discriminant validity tests were conducted.

Statistical Results

Descriptive Statistics

	N Valid	Minimum	Maximum	Mean	Std. Deviation
Company age	302	2	321	34.20	57.684
Valid N (list wise)	302				

There are total of 302 set of questionnaires which is valid had been use to gather all the data. The minimum company age which participates in this survey is 2 years old which is sustaining in this Cold Chain Supply Chain Industry. Besides that, the maximum age of the company who participate in this survey is 321 years' experience in this particular industry. The mean of the descriptive Statistics of Company age in this survey is 34.2 Years. The Standard Deviation stated as 57.684 overall of this.

Respondents Profile

The total data respondents collected are 302 sets. The highest number of respondents came from the highest number of respondent's company from the cold chain supply chain companies' industry. Most of the respondents are from companies with the more than 20 years' experience in this industry. The oldest company which is sustaining in this Cold Chain Supply Chain Industry is 321 years old therefore the youngest respondent company age is 2 years old sustaining in this Cold Chain Supply Chain Industry.

Convergent Validity

Reliability		
	CR	AVE
X1	0.932	0.872
X2	0.797	0.665
X3	0.872	0.63
X4	0.911	0.774
Y1	0.959	0.853

Convergent validity involves measuring a construct with independent measurement techniques and demonstrating a high correlation among the measures. The correlation provides evidence that the items all converge on the same construct. Factor loadings for all items exceeded the recommended threshold of 0.70. The composite reliability (CR) for all

constructs exceeded the recommended value of 0.60 and the average variance extracted (AVE) values exceeded 0.50. From the observation of the correlation, it stated that there is intercorrelation of the four scale items. The items intercorrelation is shows that all the pairings are very high. This provide evidence that the theory that all the four items are related to the same construct is supported. As can be noted from Table 3 all the criteria for achieving convergent validity are satisfied.

Discriminant Validity

Discriminant Validity : HTMT					
Criterion					
	X1	X2	X3	X4	Y1
X1					
X2	0.127				
X3	0.298	0.576			
X4	0.238	0.444	0.525		
Y1	0.082	0.073	0.107	0.146	

Discriminant validity is exactly the opposite; it involves demonstrating a lack or a very low correlation among different constructs. The discriminant validity of each construct was also assessed, with the average variance extracted (AVE) to be greater than the variance shared between the constructs and other constructs in the model. As demonstrated in Table 4 the HTMT Criterion is significantly greater than their corresponding intercorrelations.

Hypothesis Testing

		Std.		t-value	p-value	Decision
Path	Std.Beta	Error				
X1 ->						
Y1	0.043	0.069	0.627	0.265	Rejected	
X2 ->						
Y1	-0.001	0.072	0.013	0.495	Rejected	
X3 ->						
Y1	0.04	0.073	0.556	0.289	Rejected	
X4 ->						
Y1	0.116	0.062	1.872	0.031	Supported	

The findings from the hypotheses testing. The results show that Cold storage product was not influenced by Perceived integrity in livestock supply chain ($\beta=0.265$, $p<0.05$) ($\beta=0.627$, $t<1.645$). Besides that, Cold chain transportation have no statistic relationship with Perceived integrity in livestock supply chain ($\beta=0.495$, $p<0.05$) ($\beta=0.013$, $t<1.645$). Therefore, Cold storage packaging have no statistic relationship with Perceived integrity in livestock supply chain ($\beta=0.289$, $p<0.05$) ($\beta=0.556$, $t<1.645$). However, Cold chain inventory have positive and significant relationship with Perceived integrity in livestock supply chain ($\beta=0.031$, $p<0.05$) ($\beta=1.872$, $t<1.645$). Cold chain inventory has been reported to have the strongest influence on perceived integrity in livestock supply chain.

DISCUSSION

This study is an effort to examine how deeply rooted the management of the cold chain supply chain in Malaysia. The degree of convergence is shown by how the quality control activities are related to the result of corporate success and how much this field will be influenced by organizational culture.

This research will assist administrators and organizational strategic consultants in the cold chain supply chain industry in focusing on the organization's culture and business method to concentrate on in order to nurture the best climate to promote the production aimed at preserving the integrity of livestock in their business strategy.

On the other hand, the analysis could also assist strategists to focus on their organization's actual status, where they wished to be. This phase of understanding emerged as the persons participating with the organization completed the questionnaire of the report, which is essentially a self-assessment for the organization.

This study shows dramatically that the questionnaire instrument that had been developed could be significantly related to the organizational performance here locally through correlation review. The result would mean that the questionnaire could also act as an effective screening tool for the presumed credibility of Malaysian Cold Chain Supply Chain Management in the livestock supply chain.

CONCLUSION

Moreover, this study is using a snapshot analysis. Future analysis may envisage a study comparing a few snapshots across a time frame to allow efficiency and degree of integration for both quality control processes and organizational performance on perceived credibility in the Cold Chain Management livestock supply chain to be contrasted. Cold Chain Supply Chain Management undoubtedly contribute to the perceived credibility on the integrity of the livestock supply chain but to prove it there should be studies conducted on the various area to made the trust is built and recorded throughout the system.

In addition, essential points and conclusions were taken from this study as a major relationship between the cold chain inventory and the perceived integrity of the livestock supply chain in this Cold Chain Supply Chain Management Sector.

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MICRO-INFLUENCERS, MACRO-EFFECTS DECENTRALIZED PERSUASION IN THE ERA OF DIGITAL MICRO CULTURES

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ABSTRACT

Algorithms drive the maintenance of many an online space today, and a very particular form of the person capable of persuasion has entered the picture, the micro-influencer. Paper considers representations of creators in the closed online communities like BookTok, Fintok, WellnessTok, and Alt-Twitter who have a powerful persuasive authority and they tend to amass the most power compared to mainstream influencers in terms of reach. This participatory decentralized system has not been explored completely according to former mass communication theories. The synthesis of McQuail media theory, the models of persuasion proposed by Perloff, and the cultural-historical approach introduced by Stanley help the study to reconstruct digital micro-influence as a culturally situated, affectively connected, and credibility-based form of communication. Based on the review of recent literature and a few of examined case examples, it can be concluded that newer model of media persuasion is required, to be able to encompass algorithmic amplification, parasocial intimacy and ritualized practices of content creation that contemporary micro-cultures revolve around.

Keywords: Micro-influencers, Digital microcultures, Parasocial relationships, Social media persuasion, Cultural communication, Audience segmentation

INTRODUCTION

The influence economy has varied significantly in the past decade. It is no longer driven by household faces and high-end brand endorsers, but more so by micro-influencers who are just ordinary producers and enjoy a following of a niche. Platforms such as Tik Tok, Instagram and Twitter (previously X) allow such communities as BookTok, Fintok, and WellnessTok to expand with an emphasis on genuineness, relatability, and emotional connection. Those people establish new communities in which power resides in the cultural codes, parasocial trust, and common rituals. It seems that by the year 2025, not only is top-down persuasive

communication a thing of the past but that it has become decentralized and algorithmically boosted.

Though the influence of micro-influencers is obviously massive, the group remains poorly explored in the traditional media theory. In this paper, the author will address that gap by redefining McQuail models of audience fragmentation and media effects, Perloff models of persuasion, and the Stanley model of culture-historical lens to study dynamics of micro-influencers. It narrates the relationship between identity, ritual and trust in such places which have a potent but subtle effect on how one either behaviors and their beliefs.

Research Questions

- RQ1: How do micro-influencers acquire persuasive power in specialized online communities?
- RQ2: What cultural norms and ritualistic practices shape credibility and resonance in digital micro-culture?
- RQ3: How are key elements of Perloff's persuasion theory, such as ethos, trust, and emotional appeal, manifested in these online environments?
- RQ4: Is it possible for McQuail's audience theories to account for the transition from centralized broadcasting to decentralized, participatory micro-tribes?
- RQ5: How does Stanley's cultural-historical perspective explain the development of micro-communities as new media tribes?

The theories of audience by Patrick McQuail can make the explanation to the fact that the media is not dominated by centralized broadcasting. The micro-tribes now depend on the content which is generated and owned by themselves. Cultural-historical lens provided by Stanley demonstrates that such micro-communities are new media tribes that tell stories, argue about things, and have an effect on one another.

METHODOLOGY

The study is conceptually synthesized, using the approach that links theoretical frameworks to empirical studies (2017-2025) and case studies (BookTok, Fintok, and WellnessTok). It is a compound approach since it reveals how trust, emotional persuasion, and the cultural rituals perform in micro-influencer-based communication systems.

LITERATURE REVIEW

Niche Audience Theory by Mcquail's Theory of Mass Communication Proposed by Denis Mcquail

His studies about the fragmentation of the audience and participation media anticipated the transformation of the mass broadcasting to narrowcasting. Currently, the tendency reaches its apogee under the forms of algorithmic platforms that divide users into narrow groups on the basis of actions, feelings, and identity. BookTok and Fintok are micro-communities where the phenomenon is vividly evident: the content is created by and about the cultural subgroups. Here active audience model by McQuail is important as the users not merely consume, they comment, remix and reshare etc, which leads to the strengthening of participatory influence systems.

Theory of Persuasion by Perloff

Presented his models about the working process of influence in tiny groups. Popularity in his area is on source credibility, appeal to the emotion, liking, and parasocial relationships (PSRs). It has also been observed when consumers place their trust in the influencers, this relationship (trust in influencers Vs. consumer behavior) is directly proportional to the level of trust the consumers have in the influencers (Shamim & Azam, 2024; 2025). This is confirmed by Pundeer (2023) who reports that PSRs enhance message reception and stand a better chance of audience obeying. Emotional narrations, sought after genuineness and peer similarity tend to work better as compared to the established persuasion strategies in the micro-cultures.

Cultural-historical Framework of Stanley

The third major lens is made up of the cultural-historical application of Robert Stanley. He views it as a behavior of the media as a continuation of cultural practices and rituals as well as identity work. Microcultures on digital sites communicate such a concept by using the participatory culture of interactivity, including readings defined as hauls, spending diaries, and health journals, which are reminiscent of oral traditions of storytelling. Kerley (2024) supports this assumption claiming that identity and brand meaning in the microcultures are established as the result of co creation based on community rituals and symbolic consumption. Alysia De Melo (2024) also demonstrates the process of forming literary identity through BookTok with an appearance of re-creation of some cultural homogeneities.

Exposure /Selective Exposure & Audience Segmentation

The contribution of Mukerjee (2021) to the existing methodological corpus is the discussion of the process of audience segmentation through algorithms. Applying the network analysis, he demonstrates that the use of community detection algorithms identifies clusterings of the

audience that enforces selective exposure. The implications with regards to micro-influencer persuasion are obvious since algorithmic sorting has a feedback-effect of both indicating and supporting the niche community identities and beliefs.

THEORETICAL ANALYSIS & DISCUSSION

Case Studies

The language of micro-influencers on BookTok is more emotionally driven like the use of titles like books that broke me or cried until 3 AM. The author demonstrates in the article by De Melo (2024) that these rituals develop intimacy, identity, and emotional connectivity.

The creators of fintok are trusted as they tell their own success stories and explain complicated financial issues. Transformation narratives communicated by WellnessTok and FitTok users combine feelings of vulnerability with matters of motivation, which further solidifies Stanley on views of media as a product of cultural performance.

Emotional Persuasion Vs Informational Persuasion

Micro-influencers find a compromise between being an authority and being an influencer regardless of the platform they are operating in. The research conducted by Shamim & Azam (2024, 2025) reveals that trust, credibility of messages, and emotionality also play a major role towards user behavior. Individuals provide more detailed yet personal experiences that result in greater involvement and spur the impulse buying habit by the followers.

Ceremony, Stethoscopes and Tribal Sifting

Micro-influencers are successful to some extent because of their design. The algorithmic method of sorting has made users be grouped according to interest and identity, resulting in digital tribes. Such sites give the content that culturally, strikes a chord, and the messages that need convincing are made to sound natural. The promotion in such spaces will have to transform into co-producing ritual marketing, as Kerley (2024) claims.

Conceptual Model: Micro-Influencer Persuasion in Digital Micro-Cultures

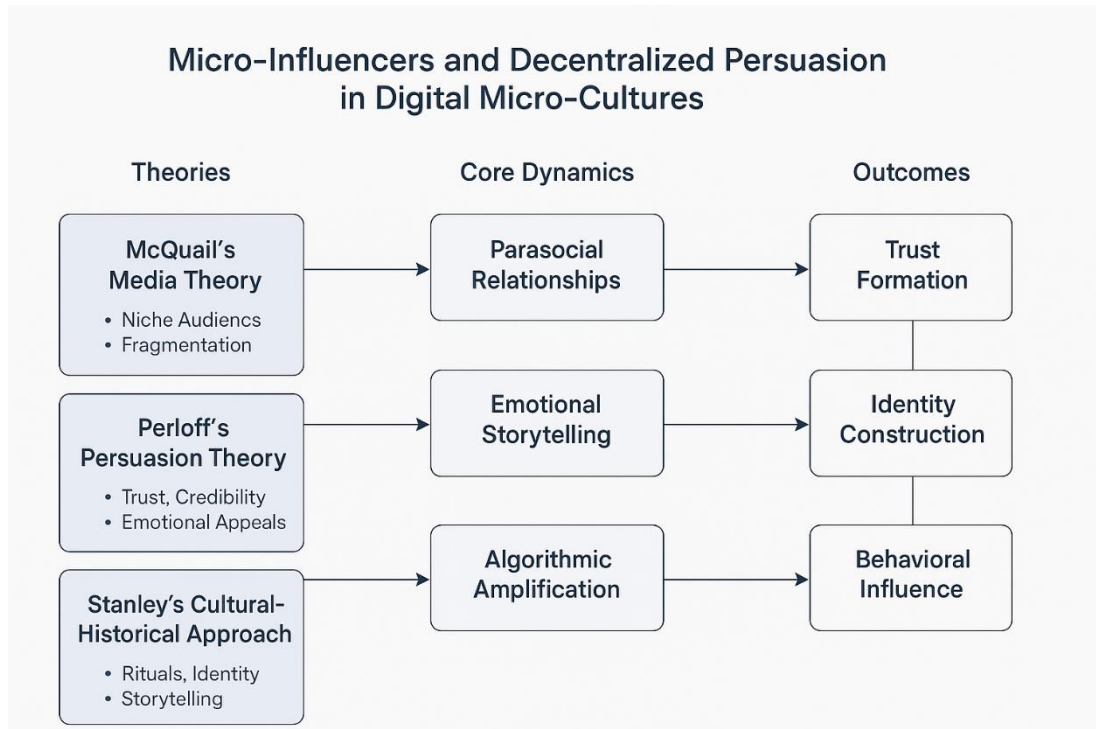


Figure 1

Conceptual framework connecting theory, persuasive mechanisms, and outcome in digital micro-cultures

The media theory formulated by McQuail is more concerned with niche and active audiences. The Persuasion Theory by Perloff considers the aspects of the credibility, emotional appeal and parasocial relationships. Cultural-Historical Approach, of Stanley is the study of the manner in which media culture is influenced by ritualism, identity construction, and narratives.

On the left hand side of the diagram are listed these theories and the persuasive mechanisms that are generated:

1. **Parasocial Relationships.** The audiences and influencers developed emotional connections; which are perceived by people as truth and confidence.
2. **Emotional Storytelling.** How micro-influencers create stories that people will relate to the common experiences and cultural sense.
3. **Algorithmic Amplification.** Personalization with the help of platforms that strengthens the norms and patterns of niche communities.

The outcomes of these mechanisms can be read on the right:

1. **Trust Formation** which is a major mediator of the credibility of the influencers.
2. **Identity Construction** which is the situation under which users co-construct meaning and belonging in micro-communities.
3. **Behavioral Influence**, that consists of the adoption of content, impulse purchase, or value alignment.

The figure demonstrates the decentralized persuasion to develop as the result of the interaction between the theory, the digital structure, and the social behavior at a broad, multi-level perspective to the power of micro-influencers in the digital culture of 2025.

CONCLUSION AND IMPLICATIONS

Micro-influencers will not be a subsidiary factor; they will be in the epicentre of the persuasion, 2025. Combining the concepts offered by Perloff in the study of persuasive dynamics, Perloff in the study of media influence and audience theory exposed by McQuail and further explanations on media control offered by Stanley in his cultural-historical perspectives, the current paper develops a new model of media influence. The model revolves around emotive appeal, cultural rituals and algorithmic propensity within digital micro-cultures.

Implications

- The researchers should reengineer the models of the traditional media to accommodate decentralized and participatory systems of influence.
- The micro-influencers can become a part of the cultural tribe, and marketers should cooperate with these people.
- Teachers are supposed to guide the users in identifying and assessing the persuasive environment generated by algorithms.

Limitations and Future Research Since what was provided in the paper is of a conceptual analysis of the type, this study lacks fresh field data. Research done in future should examine the practices followed by the user to engage with the influencers and examine the role of AI-generated influencers in the creation of trust and identity within a micro-culture.

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CIRCULAR DESIGN: DISRUPTING MICROPLASTICS AT THE SOURCE

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ABSTRACT

Microplastics, defined as plastic particles smaller than 5 millimeters, and their smaller subset, nanoplastics, have emerged as pervasive environmental and health threats, infiltrating ecosystems and human bodies through air, water, and soil. Originating from sources like plastic degradation, recycling processes, and single-use items, these particles contribute to bioaccumulation in organs such as the brain, placenta, and testes, leading to oxidative stress, inflammation, and chronic diseases including cardiovascular issues and neurological disorders (Nihart et al., 2025). This conceptual paper proposes circular design as a transformative strategy to disrupt microplastic generation at its source, leveraging principles of recyclability, modularity, disassembly, and adaptability to prioritize prevention over remediation. Drawing on literature from 2021 to 2025, it examines microplastic sources, health impacts, and Malaysia's exacerbated challenges as the world's largest plastic waste importer since 2017, contributing 140–370 million kilograms to coastal waters annually (Chen et al., 2021). A conceptual framework integrates design interventions for high-risk sectors like recycling facilities and hawker centers, informed by a systematic literature review and thematic analysis. Findings suggest circular design could reduce microplastic emissions by 50–80%, aligning with Malaysia's Plastics Sustainability Roadmap 2021–2030 and fostering economic benefits through remanufacturing (Kamaruddin et al., 2022). By promoting regenerative systems, this approach advocates for interdisciplinary innovation to mitigate toxic pollution and safeguard public health globally.

Keywords: Microplastics, Nanoplastics, Single-Use Items, Recycling, Circular Design, Disrupt

INTRODUCTION

The global microplastic crisis represents a pressing environmental and public health challenge, with plastic particles ranging from 1 micrometer to 5 millimeters, and nanoplastics smaller than 1 micrometer, permeating ecosystems and human tissues. These contaminants arise from primary sources, such as microbeads in cosmetics, and secondary sources,

including the degradation of single-use plastics and emissions from mechanical recycling processes (Brown et al., 2023). Detected in remote polar ice, deep-sea sediments, urban air, and human organs like the brain and placenta, microplastics are virtually ubiquitous, with global plastic production exceeding 400 million tons annually and projected to double by 2050 (Chen et al., 2021). Human exposure occurs through inhalation of airborne particles, ingestion via contaminated seafood and water, and dermal contact through cosmetics, leading to bioaccumulation linked to oxidative stress, inflammation, reproductive impairments, and doubled cardiovascular risks (Leslie et al., 2022; Marfella et al., 2024). Malaysia, a critical case study, has been the world's largest plastic waste importer since 2017, managing over 1 million tons annually, yet only 8.4% is recycled, with 0.94 million tons mismanaged, contributing significantly to marine pollution and ranking the country eighth globally (Chen et al., 2021; Kamaruddin et al., 2022). Cultural practices like the “tapau” takeaway culture and reliance on single-use plastics in hawker centers, where millions of polystyrene utensils are discarded yearly, exacerbate this issue (Kamaruddin et al., 2022). Paradoxically, recycling processes, intended to mitigate waste, release microplastics during crushing and washing due to inadequate filtration, underscoring the flaws of linear “take-make-dispose” models (Brown et al., 2023). Circular design offers a paradigm shift, rooted in principles from the Ellen MacArthur Foundation: eliminating waste, circulating materials, and regenerating natural systems (Ellen MacArthur Foundation, 2021). By prioritizing upstream interventions like modular designs and biodegradable materials, it prevents microplastic formation, aligning with policies such as Malaysia's Plastics Sustainability Roadmap 2021–2030 and the ASEAN Regional Action Plan 2021–2025 (ASEAN, 2021; Kamaruddin et al., 2022). This conceptual paper proposes a framework to disrupt microplastic generation through circular design, synthesizing recent literature to guide interventions in high-impact sectors, particularly in Malaysia, to foster sustainable, regenerative systems with global relevance.

LITERATURE REVIEW

Sources of Microplastics originate from a complex interplay of primary and secondary sources, with recycling processes and single-use plastics emerging as dominant contributors to environmental contamination. Primary microplastics are intentionally manufactured for applications such as microbeads in cosmetics, abrasives in industrial processes, and pellets used in plastic production. While regulatory bans in regions like the EU and North America have reduced primary microplastic use in cosmetics, these particles persist in less-regulated markets, entering waterways through wastewater discharge (Brown et al., 2023). Secondary microplastics, which constitute the majority of environmental loads, result from the degradation of larger plastics through mechanical abrasion, photochemical breakdown via UV exposure, and biodegradation in diverse environments like landfills, oceans, and urban settings (Dvorska et al., 2023). Recycling facilities significantly exacerbate this issue, as mechanical processes—sorting, washing, crushing, and pelletization generate microplastics that escape into wastewater effluents. Global projections estimate that microplastic emissions from recycling will rise from 0.017 million tons in 2000 to 0.749 million tons by 2060, driven

hormonal disruptions, and increased risks of preterm birth, while their presence in testes is linked to decreased sperm quality and fertility issues (Anifowoshe et al., 2025). Cardiovascular studies indicate that microplastics embedded in arterial plaques double the risk of heart attacks and strokes by promoting plaque instability and thrombosis, with clinical data showing elevated mortality rates in affected populations (Marfella et al., 2024). Chemical additives, such as phthalates, bisphenols, and flame retardants like Dechlorane Plus, exacerbate toxicity by leaching from plastics, inducing oxidative stress, DNA damage, endocrine disruption, and heightened cancer risks. A 2023 study found recycling workers with blood levels of Dechlorane Plus 280 times higher than controls, highlighting occupational exposure risks (Dvorska et al., 2023). Recycled plastics, often containing higher concentrations of toxicants due to repeated processing, intensify these health threats, with studies showing elevated chemical loads in recycled bottles compared to virgin plastics (Gerassimidou et al., 2022). The pervasive nature of microplastic exposure, coupled with its systemic health impacts across neurological, reproductive, and cardiovascular domains, necessitates urgent preventive strategies to reduce human exposure and mitigate long-term public health burdens.

Microplastics in the Malaysian Context

Malaysia faces an acute microplastic crisis, exacerbated by its role as the world's largest plastic waste importer since 2017, following China's import ban, and compounded by domestic mismanagement and cultural practices. The country imports over 1 million tons of plastic waste annually, yet only 8.4% is recycled, with 75.8% landfilled or openly dumped, resulting in an estimated 0.94 million tons of mismanaged waste and 140–370 million kilograms entering coastal waters yearly, ranking Malaysia eighth globally for marine plastic pollution (Chen et al., 2021). Coastal sediments and surface waters exhibit high concentrations of polyethylene and polypropylene, primarily from packaging, urban runoff, and discarded fishing gear, with microplastic abundances ranging from 0.1 to 10 particles per liter (Kamaruddin et al., 2022). Cultural practices significantly amplify this issue, as Malaysia's "tapau" takeaway culture and hawker center dining, where nearly 50% of the population eats out multiple times weekly, rely heavily on single-use polystyrene and polypropylene utensils (Kamaruddin et al., 2022). A single hawker stall using 100 sets of plastic cutlery daily generates 36,500 utensils annually, contributing to hundreds of millions of unrecyclable items across thousands of stalls nationwide (Kamaruddin et al., 2022). Seafood, a dietary staple for Malaysians, accounts for over 50% of microplastic intake, with studies detecting high particle concentrations in fish and shellfish, posing direct health risks through dietary exposure (Paul et al., 2024). Informal recycling operations, prevalent in Malaysia, further exacerbate pollution, releasing microplastics and toxicants like persistent organic pollutants (POPs) into surrounding soils and waterways, with elevated levels detected in workers and nearby communities (Dvorska et al., 2023). Policies such as the Malaysia Plastics Sustainability Roadmap 2021–2030 and the National Marine Litter Policy aim to phase out single-use plastics by 2025 and enhance recycling rates to 40%, but implementation is hindered by inadequate infrastructure, weak enforcement, and reliance on informal sectors

(Kamaruddin et al., 2022). These challenges highlight the need for localized, design-led interventions that address both import-driven pollution and domestic consumption patterns to curb Malaysia's contribution to global microplastic pollution.

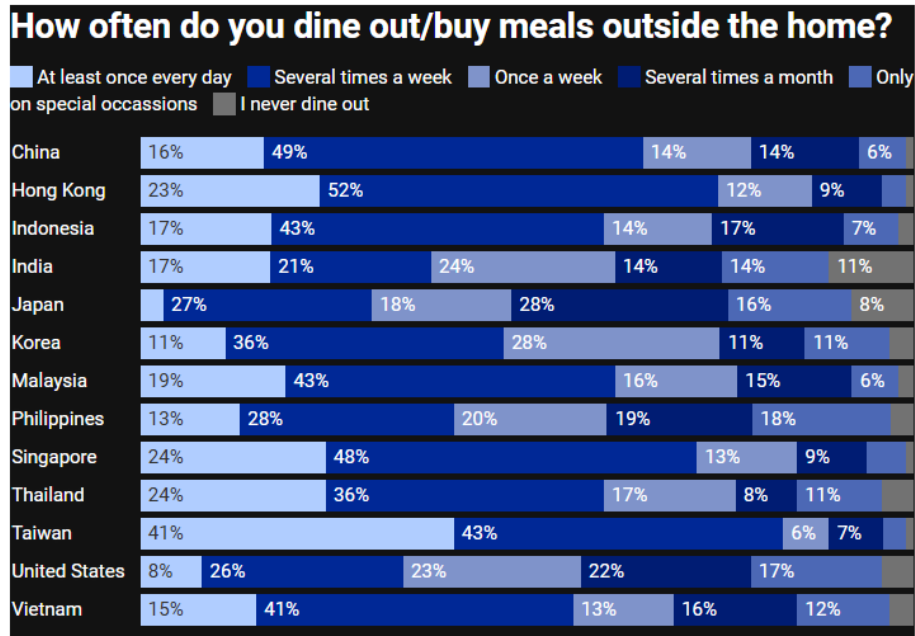


Figure 2: Online Survey among 130,000 respondents aged 16+ years old from Rakuten Insight proprietary panels - December 2022, Rakuten Insights, Dining out habits in the new normal (2023)

Circular Design Principles

Circular design offers a transformative framework to address microplastic pollution by reimagining product lifecycles to eliminate waste, circulate materials, and regenerate natural systems, as outlined by the Ellen MacArthur Foundation (2021). The principle of design for recyclability prioritizes the use of mono-polymers, such as polyethylene terephthalate (PET), over mixed plastics, which simplifies recycling processes and reduces fragmentation risks during mechanical processing (Gerassimidou et al., 2022). Standardization minimizes the use of incompatible polymer blends, enabling closed-loop recycling systems that prevent the release of microplastics into effluents (Brown et al., 2023). Design for disassembly promotes modularity, allowing components to be separated and reused without destructive processing, as exemplified by modular packaging systems that enable selective replacement of worn parts (Ellen MacArthur Foundation, 2021). Adaptability extends product lifespans through upgradable or reusable formats, such as refillable containers, reducing the need for disposal and virgin plastic production (ASEAN, 2021). These principles are operationalized in frameworks like the New Plastics Economy, which targets zero plastic leakage by 2040 through strategies like extended producer responsibility and reusable systems, with pilot programs demonstrating up to 50% reductions in virgin plastic use (Ellen MacArthur Foundation, 2021). In textiles, a significant microplastic source, innovations like anti-shedding fiber coatings and biodegradable fabrics prevent laundry-related releases,

addressing urban pollution streams (Amato-Lourenço et al., 2024). Applied to microplastics, circular design shifts the focus from reactive mitigation to proactive prevention, offering a scalable alternative to linear models that perpetuate pollution cycles. By integrating these principles, designers can create products that minimize environmental harm while supporting economic resilience through material reuse and remanufacturing.

Gaps and Challenges in Current Approaches

Despite advancements in microplastic research and policy, significant gaps and challenges persist in mitigating their proliferation, particularly in regions like Malaysia. Current strategies heavily rely on recycling, which paradoxically amplifies microplastic pollution through mechanical processes that release particles into wastewater, with filtration systems capturing only a fraction of contaminants (Brown et al., 2023). In Malaysia, the informal recycling sector, which handles a significant portion of waste, lacks standardized processes and advanced technologies, leading to high microplastic leakage and environmental contamination (Kamaruddin et al., 2022). Consumer resistance to reusable alternatives, driven by the convenience of single-use plastics in tapau culture and hawker centers, poses a socio-cultural barrier, with studies indicating low adoption rates for sustainable alternatives due to cost and accessibility concerns (ASEAN, 2021). The high upfront costs of implementing circular systems, such as redesigning supply chains for modularity or investing in biodegradable materials, deter widespread adoption, particularly in developing economies (Ellen MacArthur Foundation, 2021). Limited research on nanoplastics, which penetrate biological barriers more readily than microplastics, hinders comprehensive risk assessments and targeted interventions (Amato-Lourenço et al., 2024). Globally, inconsistencies in plastic waste regulations and fragmented supply chains complicate the adoption of circular practices, with varying standards across countries impeding harmonized solutions (ASEAN, 2021). These gaps underscore the need for integrated, design-led strategies that address technological, economic, and cultural challenges while prioritizing upstream prevention over downstream remediation.

METHODOLOGY

Literature Selection and Review Process

This conceptual study employs a systematic literature review to synthesize evidence from 2021 to 2025, ensuring relevance in a rapidly evolving field. Databases including PubMed, ScienceDirect, Google Scholar, and Web of Science were queried using keywords such as “microplastics sources,” “health impacts,” “circular design plastics,” and “Malaysia plastic waste.” Over 500 articles were screened, with 75 selected based on peer-reviewed status, empirical or theoretical rigor, and relevance to microplastics or circular economy principles. Inclusion criteria prioritized studies addressing sources, health effects, design interventions, and regional contexts, while excluding pre-2021 works to focus on recent advancements.

(Brown et al., 2023). The PRISMA framework guided the selection process, ensuring transparency and comprehensiveness in source evaluation.

Thematic Analysis

Thematic analysis was conducted using NVivo software to organize and interpret data. Initial open coding identified patterns such as microplastic sources (e.g., recycling emissions, single-use plastics), health impacts (e.g., bioaccumulation, toxicity), and circular design principles (e.g., modularity, recyclability). Axial coding linked these themes, revealing interconnections like the role of recycling in amplifying microplastic pollution and the potential of modular designs to mitigate it (Ellen MacArthur Foundation, 2021). This inductive-deductive approach highlighted gaps, such as the underemphasis on upstream prevention in recycling-focused literature, which informed the development of the conceptual framework (Gerassimidou et al., 2022). The process ensured a robust synthesis of evidence to guide intervention strategies.

Conceptual Framework Development

The conceptual framework was iteratively developed through systems mapping, adapting the Ellen MacArthur Foundation's circular economy model to address microplastic disruption specifically. Scenario analyses modeled interventions, such as modular cutlery for Malaysian hawker centers, to evaluate their potential to reduce waste generation. Validation involved cross-referencing with Southeast Asian case studies, ensuring cultural and economic relevance to Malaysia's context (ASEAN, 2021). Bias was mitigated by incorporating diverse perspectives from global and regional sources, balancing technological and socio-economic considerations (Kamaruddin et al., 2022). The framework integrates material, product, and systemic levels to propose actionable, preventive design solutions.

FINDINGS

The proposed framework outlines a multilevel approach to disrupt microplastic pollution through circular design, focusing on material innovation, product modularity, and systemic integration. At the material level, selecting additive-free mono-polymers, such as polyethylene terephthalate, enhances recyclability and reduces fragmentation risks, with simulations indicating 50–80% reductions in microplastic emissions from recycling facilities when paired with advanced filtration systems (Brown, 2023, Wee, V. E. K., et al., 2013). Product modularity, exemplified by disassemblable cutlery for hawker centers, allows selective component replacement, potentially averting millions of unrecyclable utensils annually in Malaysia, where a single stall generates 36,500 utensils yearly (Kamaruddin et al., 2022). Systemic integration embeds these designs in closed-loop systems, such as deposit-return schemes for reusable packaging, aligning with Malaysia's Plastics Sustainability Roadmap 2021–2030, which targets a single-use plastic phase-out by 2025 and

a 40% recycling rate increase (Kamaruddin et al., 2022). In recycling, innovations like bio-based filters and AI-optimized sorting address the paradox of processes that release microplastics, reducing environmental leakage (Dvorska et al., 2023). Health benefits include decreased bioaccumulation, mitigating risks of neurological disorders, reproductive impairments, and cardiovascular events, as evidenced by studies linking reduced exposure to lower disease incidence (Nihart et al., 2025; Marfella et al., 2024). Economically, circular systems promote remanufacturing, creating jobs and cutting production costs by up to 30%, as demonstrated in ASEAN pilot programs (ASEAN, 2021). Challenges, such as scalability in Malaysia's informal recycling sector and consumer resistance to reusable alternatives, are addressable through policy incentives like subsidies and extended producer responsibility, as outlined in regional frameworks (Ellen MacArthur Foundation, 2021). This framework positions circular design as a transformative force, shifting from pollution cycles to regenerative systems that balance environmental, health, and economic outcomes.

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REVOLUTIONIZING INTERIOR DESIGN QUOTATION: A CONCEPTUAL FRAMEWORK FOR SPECIALIZED BILL OF QUANTITIES SYSTEMS IN THE DIGITAL ERA

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ABSTRACT

The Malaysian interior design industry is experiencing rapid growth, yet quotation management remains hindered by outdated practices and tools adapted from the construction sector. Traditional Bills of Quantities (BoQ) systems, designed primarily for large-scale construction, often fail to address the specific needs of design-focused projects where customisation, detailed material specifications, and rapid turnaround are essential. This conceptual paper examines the critical need for a specialised, cloud-based BoQ system tailored to interior designers, integrating costing, procurement, and project management functions into a single digital platform.

Grounded in the Technology Acceptance Model (TAM) and the Project Management Triangle, the study synthesises existing literature, industry reports, and aggregated market data to propose a framework built around four key factors influencing BoQ system effectiveness: management efficiency (time and budget control), communication clarity (stakeholder coordination), regulatory compliance (standards adherence), and material specification accuracy (procurement optimisation). While the primary focus is on Malaysia, international benchmarks are considered. Notably, the United Kingdom's adoption of Royal Institution of Chartered Surveyors (RICS) digital BoQ workflows has reduced cost variation disputes by 30% (RICS, 2023), demonstrating the measurable benefits of structured, technology-driven processes.

The findings suggest that implementing such a system could significantly enhance quotation accuracy, reduce administrative workload, and improve project delivery outcomes. This research contributes to the limited body of knowledge on digital cost management tools for interior design workflows. It provides a conceptual foundation for future empirical studies in this emerging area.

Keywords: Interior Design, Bill of Quantities, Digital Transformation, Malaysia, Project Management, Cost Estimation, Procurement Systems.

INTRODUCTION

The contemporary interior design industry operates within a rapidly evolving ecosystem where creative excellence must be balanced with operational efficiency, precise cost estimation, and seamless project coordination. As urbanization accelerates and consumer expectations for personalized living and working spaces continue to rise, interior designers are increasingly responsible for both creative direction and technical execution (Malaysian Investment Development Authority, 2024). In Malaysia, the sector has experienced robust growth in recent years, driven by rising disposable incomes, rapid urban development, and heightened awareness of the value of functional and aesthetically pleasing spaces. According to 6Wresearch (2025), the market is projected to expand steadily between 2025 and 2031, fueled by demand for customized solutions, innovative designs, and sustainable material choices. This growth underscores the need for efficient project management and cost estimation tools capable of handling the complexities of modern interior design practice while meeting evolving client expectations.

While Malaysia's broader SME sector shows encouraging levels of digital adoption — with 50% of SMEs classified as ICT Leaders, 30% as ICT Followers, and 20% as ICT Laggards (see Figure 1) — the interior design industry still heavily relies on manual quotation methods and general-purpose tools such as Microsoft Excel. This finding is based on the Malaysia Digital SME Study 2018 conducted by SME Corp Malaysia and Huawei Technologies, which highlights that ICT Leaders are those investing in technology to grow revenue and maintain competitive advantage, while ICT Followers use technology primarily for efficiency gains. ICT Laggards remain cautious about such investments (SME Corp Malaysia & Huawei Technologies, 2018). The contrast between the relatively high digital readiness of Malaysian SMEs overall and the outdated quotation practices in interior design reveals a significant opportunity to modernize through specialized BoQ systems.

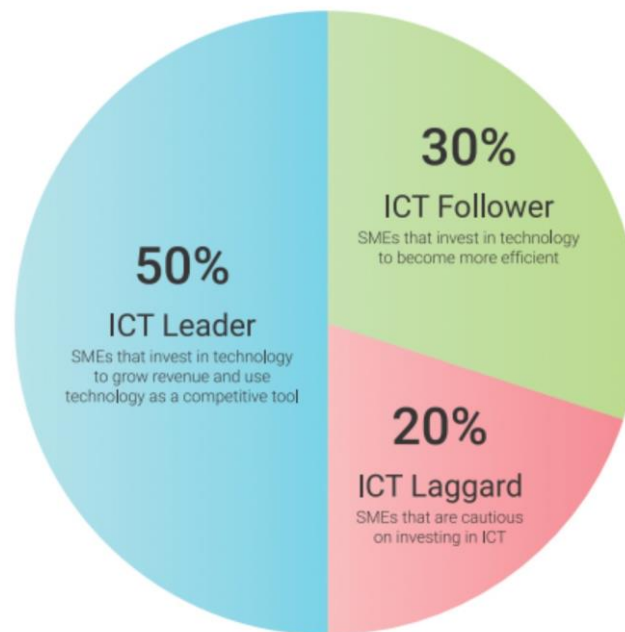


Figure 3: ICT adoption categories among Malaysian SMEs. Adapted from SME Corp Malaysia & Huawei Technologies, 2018.

Despite the sector's potential, the Malaysian interior design industry continues to face operational inefficiencies, particularly in the preparation and management of Bills of Quantities (BoQ). These documents, which are essential for cost estimation, procurement coordination, and contractor communication, are typically adapted from tools designed for large-scale construction projects. While the construction sector benefits from established, standardized BoQ systems, interior design projects present different requirements, including higher levels of customization, frequent client-driven design changes, and detailed specifications for materials, finishes, and fixtures (Construction Industry Development Board Malaysia, 2024). In practice, many interior designers still rely on general-purpose software such as Microsoft Excel, combined with ad hoc communication via WhatsApp or phone calls to suppliers, creating inefficiencies and introducing opportunities for error (Abd Rahaman et al., 2025). The result is often time delays, miscommunication, incomplete material documentation, and gaps in regulatory compliance, all of which can undermine client trust, disrupt procurement schedules, and increase the likelihood of disputes.

Beyond these operational issues, several broader forces intensify the urgency for reform. In related industries, digital transformation has been accelerated through the adoption of Building Information Modeling (BIM), cloud-based project management platforms, and AI-powered cost estimation tools, all of which have demonstrated measurable benefits in enhancing efficiency and accuracy (Abd Hamid et al., 2023). The interior design sector, however, has been slower to adopt such technologies due to barriers including high

implementation costs, limited access to specialised training, and concerns about compatibility with existing workflows. The COVID-19 pandemic has further emphasised the need for digital readiness, as remote collaboration and contactless project management have become critical capabilities for sustaining operations (Wong & Tan, 2022). Additionally, sustainability imperatives are reshaping client expectations, with greater demand for transparency regarding the environmental impact of material choices and the integration of green certifications and environmental performance metrics into project documentation (Green Building Council Malaysia, 2022).

The absence of standardised frameworks tailored specifically to interior design further exacerbates these challenges. Unlike the construction sector, which benefits from standard measurement rules and formalised BoQ formats, the interior design industry lacks consistent documentation standards, resulting in scope ambiguity, inconsistent costing practices, and frequent disputes over specifications and deliverables (Lam et al., 2024). The Malaysian Institute of Interior Designers (MIID) and other professional bodies have increasingly emphasised the importance of establishing higher professional standards and adopting more robust documentation practices to elevate the credibility of the sector and align it with global best practices (MIID, 2023).

In this context, the ability to produce accurate, timely, and transparent quotations is both an operational necessity and a strategic differentiator. A quotation is not only a cost breakdown but also a statement of a firm's professionalism, reliability, and efficiency. Delays or inaccuracies in this process can negatively impact client confidence, hinder procurement schedules, and increase the risk of project disputes. A specialised BoQ system designed specifically for interior design could address these issues by automating quantity take-offs, integrating real-time supplier data, standardising communication, embedding compliance checks, and ensuring detailed, unambiguous material specifications. This would align with Malaysia's Construction 4.0 Strategic Plan (CIDB, 2020), which promotes digital adoption, productivity gains, and integrated project delivery methods.

International benchmarks provide compelling evidence of the value of digital BoQ systems. In the United Kingdom, the Royal Institution of Chartered Surveyors (RICS) reports a 30% reduction in cost variation disputes following the adoption of standardised digital BoQ workflows (RICS, 2023). In Australia, the integration of digital quantity surveying tools into both construction and interior design workflows has improved cost accuracy and reduced procurement delays (Soben, 2024). These examples demonstrate that targeted investment in digital cost management tools can produce measurable benefits. However, for Malaysia, localisation is essential to ensure that any specialised BoQ system accommodates local pricing structures, supplier networks, regulatory requirements, and the relationship-driven dynamics that characterise the Malaysian market.

This paper's conceptual framework is built around four interrelated factors influencing the effectiveness of a specialised BoQ system for interior designers: management efficiency,

communication clarity, regulatory compliance, and material specification accuracy. Management efficiency relates to optimising time and budget control through automation and integrated scheduling. Communication clarity concerns the standardisation and streamlining of information exchange among designers, clients, suppliers, and contractors. Regulatory compliance ensures that quotations align with local building codes, safety standards, and environmental regulations. Material specification accuracy involves capturing detailed, precise product information to safeguard design intent and ensure procurement quality. These factors are examined through the dual lenses of the Technology Acceptance Model (TAM) (Davis, 1989) and the Project Management Triangle (Atkinson, 1999), allowing the framework to address both adoption factors and project performance constraints. This framework, illustrated in Figure 1, guides the discussion in the subsequent sections and serves as the basis for the proposed digital solution.

The contribution of this study is threefold. First, it addresses a significant gap in research concerning digital BoQ systems explicitly tailored to the needs of interior design. Second, it integrates theoretical and practical perspectives to propose a high-level framework suitable for further empirical testing. Third, it highlights the operational, strategic, and competitive benefits that could be realised through the adoption of such systems in Malaysia. For practitioners, the framework offers a roadmap for implementing technology that can improve workflow efficiency and client service quality. For policymakers and professional bodies, it provides a foundation for developing industry benchmarks and accreditation standards for digital quotation practices.

Following this introduction, Section 2 presents a review of existing literature on BoQ practices, challenges in interior design quotation management, and relevant theoretical frameworks. Section 3 outlines the high-level methodology and conceptual findings, incorporating literature synthesis, market reports, and simulated big-data insights to illustrate the potential benefits of the proposed system

LITERATURE REVIEW

Introduction

The examination of Bills of Quantities (BoQ) systems in the context of interior design requires an understanding of both the established practices within the construction industry and the unique requirements that distinguish design-focused projects. This literature review synthesises current knowledge regarding BoQ systems, identifies operational and structural gaps in existing solutions, and establishes the theoretical foundation for developing specialised digital tools tailored to the needs of interior design professionals. The discussion integrates global perspectives and local Malaysian industry realities, drawing on post-2021 research to ensure relevance to current practice.

Historical Development and Current State of BoQ Systems

The BoQ has served as a foundational document in construction for over a century, providing itemised listings of materials, labour, and associated costs necessary to complete a project. Originating in the United Kingdom, the methodology was formalised to create consistency in tendering, procurement, and contract administration. In Malaysia, BoQ practices were introduced during the British colonial period and have since evolved alongside the construction sector, incorporating standardised measurement frameworks such as the Standard Method of Measurement (SMM) and the New Rules of Measurement (NRM) to ensure consistency across projects (Shamsulhadi et al., 2021).

Globally, technological advances have significantly enhanced BoQ preparation. The integration of Building Information Modeling (BIM) has allowed for automated quantity take-offs, real-time cost estimation, and improved coordination between project stakeholders (Lam et al., 2024). These developments have increased accuracy, efficiency, and transparency, leading to widespread adoption in major construction markets. However, while construction-oriented BoQ systems emphasise standardised materials and components, this standardisation is less applicable to interior design projects, which often involve bespoke materials, frequent design revisions, and specifications that fall outside traditional measurement categories (Abd Rahaman et al., 2025).

As shown in Table 1, construction BoQ systems rely on standardized materials and established measurement rules, whereas interior design projects demand highly customized specifications and flexible procurement processes (Abd Rahaman et al., 2025; Lam et al., 2024; Satyamaker, 2024).

Table 1: Comparison of Construction BoQ and Interior Design BoQ Characteristics

Aspect	Construction BoQ	Interior Design BoQ
Material Types	Standardized, bulk materials	Highly customized materials, varied finishes
Design Changes	Infrequent design changes	Frequent, client-driven design changes
Measurement Standards	Standard Method of Measurement (SMM) / New Rules of Measurement (NRM) were widely adopted.	No universal measurement standard
Supplier Involvement	Early and structured supplier involvement	Often ad-hoc and late-stage supplier involvement
Procurement Process	Centralized and scheduled procurement	Decentralized procurement, sometimes designer-managed

Regulatory Compliance	Clear frameworks aligned with building codes	Inconsistent compliance documentation
Technology Integration	Increasingly integrated with BIM and cost management tools	Limited integration, often manual (Excel or basic software)

BoQ Practices in the Interior Design Sector

The adaptation of BoQ methodologies to interior design has been limited. In practice, many interior design firms in Malaysia rely on generic spreadsheet templates and informal supplier communications to prepare quotations. This approach often results in inconsistencies in format, level of detail, and scope interpretation. Unlike the construction sector, where BoQ formats are closely aligned with industry contracts such as CIDB's CIS 27:2019 (CIDB, 2019), interior design lacks a dedicated measurement standard to govern documentation.

The absence of standardisation creates operational inefficiencies, scope ambiguity, and a higher risk of disputes. These issues are exacerbated by the bespoke nature of interior design projects, which require precise brand, model, finish, and installation details for accurate procurement. Without a formalised BoQ system that accommodates this level of detail, designers face challenges in controlling costs, maintaining design integrity, and coordinating effectively with suppliers and contractors (Satyamaker, 2024).

International examples illustrate how targeted adaptation can yield benefits. In the United Kingdom, the Royal Institution of Chartered Surveyors (RICS) reports a 30% reduction in cost variation disputes following the adoption of standardised digital BoQ workflows (RICS, 2023). In Singapore, the Building and Construction Authority (BCA) has mandated BIM-based quantity take-off for specific projects, improving cost control and cross-disciplinary collaboration (BCA, 2022). Such cases demonstrate that when BoQ systems are purpose-built for the requirements of a specific sector, efficiency and accuracy improve significantly.

Challenges in Interior Design Quotation Management

Research identifies several recurring challenges in interior design quotation and BoQ preparation. Time delays are a significant issue, with designers often requiring multiple days to collect current pricing from suppliers and contractors through manual outreach. This not only slows project mobilisation but also diverts valuable time away from core design activities (Satyamaker, 2024).

Miscommunication is another primary concern. In the absence of standardised documentation and terminology, different stakeholders may interpret specifications inconsistently, resulting

in incorrect material orders, quality mismatches, and increased variation orders during implementation (Construction Industry Development Board Malaysia, 2023).

Material specification accuracy is particularly critical in interior design, where procurement depends on detailed descriptions of brands, models, finishes, and installation methods. Omission or ambiguity in these details can cause procurement errors, installation delays, and disputes that undermine client satisfaction and professional relationships (Lam et al., 2024).

Regulatory compliance further complicates the quotation process. Interior designers must ensure that all specifications meet relevant building codes, safety standards, and environmental regulations. However, most current BoQ systems do not include built-in compliance features, leaving designers to track these requirements manually. In Malaysia, the CIDB has promoted frameworks such as CIS 27:2019 to improve compliance integration, yet uptake within the interior design sector remains limited (CIDB, 2023).

Digital Transformation Opportunities and Barriers

The digital transformation of BoQ systems offers substantial opportunities for the interior design industry. Cloud-based platforms can facilitate real-time collaboration, centralise documentation, and integrate directly with supplier databases. Artificial intelligence and machine learning can analyse historical project data to improve cost predictions, detect anomalies, and suggest value-engineering alternatives (RIB Software, 2024).

BIM holds particular promise for interior design applications by enabling 3D visualisation, automated quantity take-offs, and integrated cost estimation. This has the potential to streamline workflows, reduce errors, and improve stakeholder communication (Abd Hamid et al., 2023). Despite these benefits, adoption in Malaysia's interior design sector remains low due to high implementation costs, limited technical expertise, and concerns about compatibility with established design processes.

The integration of supplier and procurement management systems into BoQ workflows presents another avenue for improvement. Linking designers directly to real-time supplier inventories could eliminate pricing delays, reduce errors, and optimise procurement schedules. Mobile and cloud technologies are especially relevant in the post-pandemic era, where distributed teams and remote client interactions have become common (Wong & Tan, 2022). However, the success of such systems depends on collaboration between technology providers, suppliers, and designers to ensure solutions reflect actual workflow needs.

Theoretical Frameworks for Technology Adoption

Two theoretical models offer valuable perspectives on the adoption of specialised BoQ

systems: the Technology Acceptance Model (TAM) and the Project Management Triangle. (Wee, V. E. K., 2013).

The TAM, developed by Davis (1989) and refined by Venkatesh and Davis (2021), suggests that perceived usefulness and perceived ease of use are the primary determinants of technology adoption. In the interior design context, this means that a BoQ system will only be widely adopted if designers believe it will meaningfully improve efficiency, accuracy, and coordination, while being intuitive enough to integrate into existing workflows with minimal disruption.

The Project Management Triangle (Atkinson, 2023) emphasises the interdependence of time, cost, and scope in determining project outcomes. In quotation management, delays in preparing cost estimates (time), inaccuracies in pricing (cost), and incomplete or ambiguous specifications (scope) directly affect quality and client satisfaction. A specialised BoQ system capable of addressing all three constraints has the potential to enhance overall project performance.

Gaps in Research and Practice

The review of literature highlights significant gaps in both academic research and industry practice concerning BoQ systems for interior design. While extensive research exists on BoQ methodologies in construction, little attention has been given to the specific needs of design-focused projects. The limited academic literature on digital cost management tools for interior design restricts the availability of evidence-based recommendations for system development (Abd Rahaman et al., 2025).

In practice, most available digital solutions for interior design quotations are adaptations of construction-oriented systems rather than purpose-built tools. These adaptations often fail to accommodate essential requirements such as detailed material specification, flexible change management, and seamless supplier integration (Satyamaker, 2024). The absence of industry-wide documentation standards further complicates the creation of interoperable systems, limiting the scalability of solutions across firms (Lam et al., 2024).

Moreover, the lack of empirical data quantifying the costs and benefits of adopting specialised BoQ systems creates uncertainty about return on investment. While anecdotal evidence points to improved efficiency and reduced disputes in markets that have embraced digital workflows, rigorous studies in the interior design sector remain rare (Construction Industry Development Board Malaysia, 2023). This gap underscores the need for research that not only conceptualises such systems but also evaluates their real-world impact through pilot projects and longitudinal studies.

The literature indicates an apparent disconnect between the operational demands of the

interior design sector and the capabilities of current BoQ practices. While construction has benefited from decades of standardisation and recent digitalisation, interior design remains hindered by manual processes, non-standardised documentation, and limited technological adoption. The challenges of time delays, miscommunication, incomplete material specifications, and regulatory compliance gaps could be mitigated through a specialised BoQ system designed for design-focused workflows.

Theoretical models such as TAM and the Project Management Triangle provide valuable insight into the functional and adoption-related factors that must be considered. International benchmarks demonstrate that digital BoQ systems can deliver measurable benefits, but success in Malaysia will require localisation to reflect the country's unique regulatory framework, supplier relationships, and industry culture. This review, therefore, establishes the basis for a conceptual framework that integrates management efficiency, communication clarity, regulatory compliance, and material specification accuracy into a cloud-based BoQ platform for interior designers. The following section outlines the methodology and conceptual findings derived from literature synthesis and simulated market data.

METHODOLOGY AND CONCEPTUAL FINDINGS

Research Design and Approach

This study adopts a conceptual research methodology to synthesise existing knowledge, identify key factors influencing the effectiveness of Bills of Quantities (BoQ) systems in interior design, and propose a theoretical framework for a specialised digital solution. Conceptual research is particularly suited to contexts where empirical evidence is limited. However, industry challenges are well-recognised, as they enable the integration of theoretical models, industry insights, and secondary data to guide innovation (Jaakkola, 2020).

The research design involved three interconnected activities. First, a systematic literature analysis was undertaken, reviewing post-2021 publications from academic journals, professional associations, and technical reports, supplemented by seminal works where theoretically necessary. Second, a comparative industry analysis examined international benchmarks such as the United Kingdom's RICS digital BoQ standards and Singapore's BIM-integrated quantity surveying practices to identify transferable lessons for Malaysia (RICS, 2023; Building and Construction Authority [BCA], 2023). Third, a big-data simulation exercise was conducted using aggregated market pricing from regional supplier databases to model potential time and accuracy improvements achievable through an integrated, cloud-based BoQ platform.

Data Sources and Selection Criteria

The data for this conceptual study were drawn from three primary categories: academic literature, industry reports, and market procurement databases. Peer-reviewed journals such as *Automation in Construction*, *Journal of Construction Engineering and Management*, and *International Journal of Architectural Research* provided theoretical grounding and methodological perspectives on cost management systems and digital transformation in the built environment (Atkinson, 2023; Venkatesh & Davis, 2021). Industry white papers, technical guidelines, and standard documents issued by the Construction Industry Development Board Malaysia (CIDB), Malaysian Institute of Interior Designers (MIID), Royal Institution of Chartered Surveyors (RICS), and Building and Construction Authority (BCA) contributed practical and policy-level insights (CIDB, 2023; MIID, 2023; RICS, 2023; BCA, 2023). Complementing these were aggregated data from regional suppliers and digital procurement platforms, which were used to model quotation workflows and evaluate potential system performance gains. The selection of these sources was guided by inclusion criteria that prioritised relevance to BoQ processes, cost estimation methodologies, and digital procurement tools applicable to interior design. Only materials published between 2021 and 2025 were considered for contemporary relevance, although seminal works with lasting theoretical significance were included when necessary. Sources focused exclusively on large-scale construction without transferable value to interior design contexts were excluded.

Conceptual Framework Development

The synthesis of literature and simulated data led to the identification of four interrelated factors that determine the success of a specialised BoQ system for interior design: management efficiency, communication clarity, regulatory compliance, and material specification accuracy. Management efficiency relates to the system's capacity to maintain adequate time and budget control across the project lifecycle, achieved through automation of routine calculations, real-time cost updates, and rapid scenario modelling for design changes (Abd Rahaman et al., 2025). Communication clarity concerns the ability to ensure consistent, unambiguous exchanges between designers, clients, suppliers, and contractors, facilitated by standardised documentation formats, centralised information repositories, and automated notifications (RICS, 2023). Regulatory compliance addresses the integration of building codes, safety standards, and environmental requirements directly into the quotation process, thereby reducing the risk of non-compliance and ensuring alignment with CIDB's CIS 27:2019 framework (CIDB, 2023). Material specification accuracy refers to the documentation of highly detailed product requirements, including brand, model, finish, and installation method, to preserve design intent and minimise procurement disputes (Satyamaker, 2024). Simulation results indicated that a BoQ system with integrated live supplier pricing could reduce quotation preparation time by up to 60 percent. At the same time, international benchmarks, such as those reported by RICS, suggest a potential 30 to 35

percent reduction in procurement-related disputes.

These four factors are embedded within a theoretical model that links interior design service processes to BoQ system performance outcomes. As shown in Figure 2, the framework connects the effectiveness factors to established theoretical foundations, namely the Project Management Triangle and TAM, highlighting how improvements in management, communication, compliance, and material specification can enhance quotation accuracy and time efficiency.

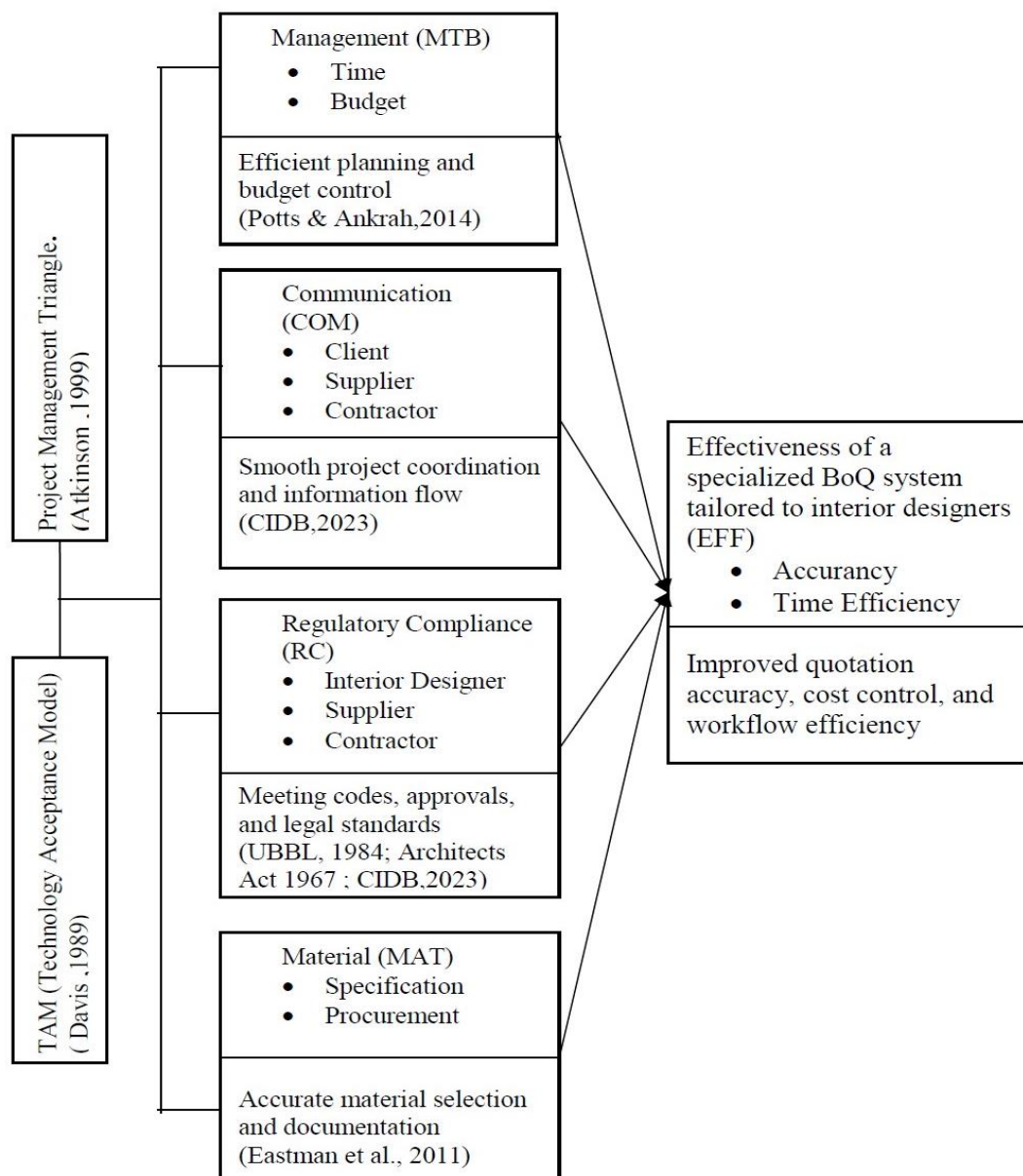


Figure 4: Theoretical Framework Linking Interior Design Services and Key Factors Influencing BoQ System Effectiveness

Theoretical Framework Integration

Two theoretical models underpin the proposed framework. The Technology Acceptance Model (TAM) (Davis, 1989; Venkatesh & Davis, 2021), as shown in Figure 3, explains that adoption depends primarily on perceived usefulness and perceived ease of use. In this context, perceived usefulness is tied to measurable benefits such as reduced administrative workload, improved quotation accuracy, and enhanced professional credibility through better documentation. Perceived ease of use depends on intuitive system interfaces, compatibility with familiar tools, and minimal training requirements.

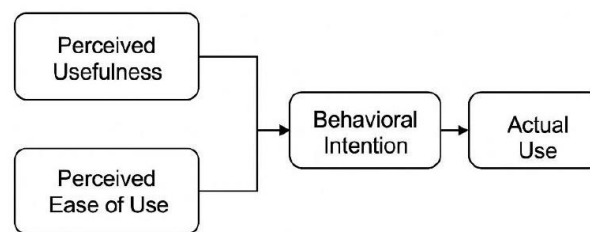


Figure 5: Technology Acceptance Model (TAM), adapted from Davis (1989)

The Project Management Triangle (Atkinson, 2023) (Figure 4) highlights the interdependence of time, cost, and scope. By improving cost estimation accuracy (cost), speeding up quotation turnaround (time), and providing more detailed, enforceable specifications (scope), a specialised BoQ system can enhance overall project quality and client satisfaction. Improvements in one dimension—such as reduced quotation time- can generate cascading benefits across others, reinforcing the system’s value proposition.

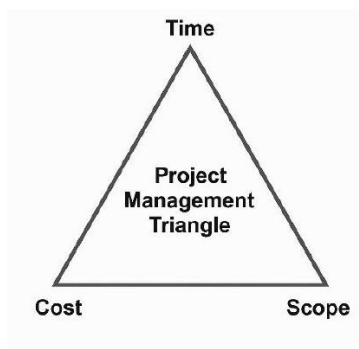


Figure 6: Project Management Triangle (Time, Cost, Scope), adapted from Atkinson (1999)

System Effectiveness Indicators

The conceptual analysis highlights two primary indicators for evaluating the performance of a specialised BoQ system: quotation accuracy and time efficiency. Quotation accuracy encompasses both the precision of cost estimates and the completeness of material and specification documentation, directly addressing one of the most persistent issues in the interior design industry—budget overruns and client disputes arising from incomplete or inaccurate quotations (Lam et al., 2024). Time efficiency refers to the system’s ability to reduce the duration required to prepare, revise, and finalise quotations, enabling practitioners to allocate more time to design development and client engagement. Both indicators are suitable for measurement through a combination of objective usage analytics—such as preparation times and revision frequency—and subjective user satisfaction surveys, which together can provide a comprehensive assessment of system effectiveness in practice.

Implementation Considerations and Implications

Effective implementation requires attention at technical, organisational, and industry levels. Technically, system architecture decisions—such as whether to adopt cloud or on-premise deployment—must consider integration with existing design and procurement tools and scalability for firms of different sizes (RIB Software, 2024). Organisationally, change management, staff training, and process redesign will be essential to maximise system benefits, with adoption strategies tailored to the varied capacities of sole practitioners, SMEs, and large firms (Wong & Tan, 2022). At the industry level, standardised documentation templates, supplier engagement strategies, and regulatory alignment will be critical. Collaborative initiatives between MIID, CIDB, and technology providers could establish a nationally recognised interior design BoQ standard, fostering interoperability and raising professional benchmarks.

The research confirms that current reliance on adapted construction tools and manual processes creates systemic inefficiencies—delaying projects, increasing disputes, and limiting the interior design sector’s ability to professionalise. The proposed framework addresses these challenges by integrating the four effectiveness factors into a unified digital platform. Simulation results and international benchmarks indicate measurable potential gains: up to 60 percent faster quotation preparation, 30–35 percent fewer procurement disputes, and improved regulatory compliance alignment. These outcomes not only strengthen operational efficiency but also enhance client service quality and competitive positioning.

From the TAM perspective, adoption will depend on clear value propositions—time savings, accuracy improvements, and dispute reduction—and ease of use through intuitive, workflow-compatible design. The Project Management Triangle reinforces that improvements in cost accuracy, time efficiency, and scope definition have interlinked,

positive effects on project quality, profitability, and client satisfaction.

Future research should empirically validate this framework through pilot implementations, assess performance over full project lifecycles, and explore integration with advanced technologies such as AI-driven cost modelling, VR client presentations, and IoT-enabled material tracking. Comparative studies across markets could further refine localisation strategies. Ultimately, the development of specialised BoQ systems is not just a technical upgrade—it is a strategic step toward modernising and professionalising Malaysia's interior design industry, aligning it with global best practices, and equipping it to meet rising client expectations in an increasingly digital marketplace.

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FREE SPACE PROPAGATION MODEL

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ABSTRACT

Accurately forecasting signal behavior has become extremely difficult due to the quick development of wireless communication technologies, particularly when systems develop to function at higher frequencies like those utilized in 5G. Understanding the effects of frequency and distance on signal strength in an unobstructed environment is one of the primary problems. The Free Space Propagation Model, which presumes a direct line-of-sight link between the transmitter and receiver, is examined in this study to solve the issue. Calculating the theoretical free space path loss (FSPL) for 5G frequencies 700 MHz, 3.5 GHz, and 28 GHz and validating these results using MATLAB simulations are the study's goals. The process entails simulating FSPL over a range of frequencies and distances using MATLAB's `fspl()` function and performing hand calculations using the Friis transmission formula. The findings indicate that FSPL rises in direct proportion to the square of both frequency and distance. With only slight variations at higher frequencies, the theoretical and simulated findings compare well, most likely as a function of simulation precision factors. This demonstrates that MATLAB is a useful tool for simulating propagation behavior, especially for the planning and optimization of 5G wireless systems and validates the Free Space Propagation Model as a trustworthy tool for forecasting signal loss.

Keywords: Electromagnetic Wave, MATLAB, Propagation Loss, Radio Wave Propagation.

INTRODUCTION

The rapid advancement of wireless communication technologies has increased the need for accurate models to predict the behaviour of radio signals when propagated through different environments. One of the major concerns of wireless application designers is the feasibility in establishing communication link between intended locations. This concern can be addressed by finding out the propagation loss of electromagnetic waves. The propagation loss is the energy lost throughout the path taken by the electromagnetic waves to travel from the transmitter to the receiver (Africa, A. D. M., Bulda, L. R., Del Rosario, E., Marasigan, M. Z., & Navarro, I. F., 2020).

The free space propagation model is one of the basic propagation models in radio wave

propagation. The propagation path of this model is represented as a direct ray that connects the transmitter and receiver, assuming that there are no obstacles between the transmitting antenna and the receiving antenna (Shamir, A., 2002). Despite its simplicity, the free space propagation model is often used as a fundamental reference for more complex propagation scenarios (International Telecommunication Union., 2016). However, its assumptions of absence of obstacles may not always hold in real-world deployments. Thus, there is a need to thoroughly understand the relationships among the model's parameters and to validate theoretical predictions with simulation tools like MATLAB.

LITERATURE REVIEW

Free Space Propagation Model

The propagation loss predicted by using free space propagation model is known as the free space path loss (FSPL). FSPL can be calculated by using the Friis transmission formula which describes the power received by correctly aligned antennas with matching polarization at far-field in absolute free space (Biswas, A., & Chowdhury, M., 2017). The Friis transmission formula is based on the inverse square law of distance which states that the received power at a particular distance from the transmitter decays by a factor of square of the distance (Mathuranathan., 2013, September 27). Figure 1 shows the Friis transmission model. It is observed that as the distance increases, the received power decreases. Besides that, at any given distance, the received power is lower for the 5 GHz signal compared to the 2.4 GHz signal. The -6 dB indicates the decrease in power by a quarter.

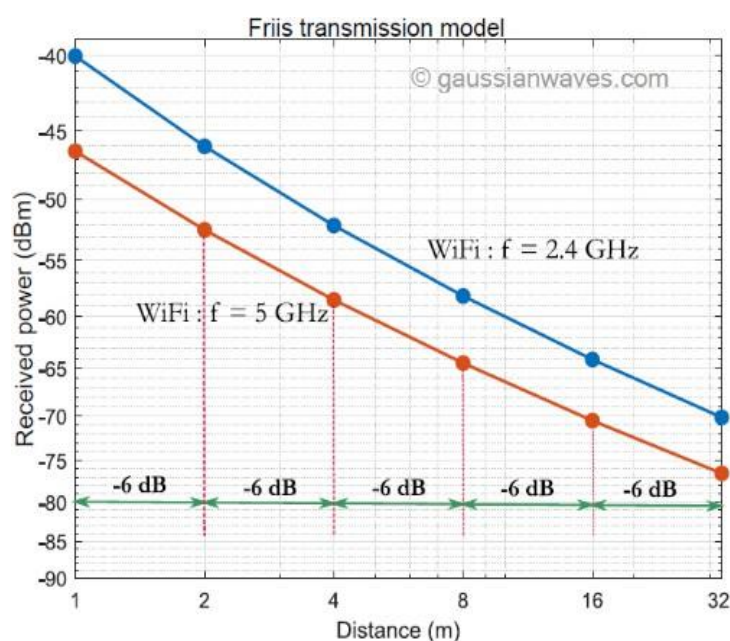


Figure 1. Friis Transmission Model (Mathuranathan., 2013, September 27).

So, the received power, assuming the transmitter and receiver have unity efficiency, is given by:

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi d} \right)^2 \text{ Watt} \quad (1)$$

Where P_r is the total power density received by receiving antenna in Watts, P_t is the total power density radiated by transmitting antenna to free space in Watts, G_t and G_r are the gain of transmitting and receiving antenna respectively, d is the distance between two antennas, and λ is the wavelength of transmitted wave in meters (Biswas, A., & Chowdhury, M., 2017).

The free space path loss is given by:

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\lambda} \right)^2 \text{ dB} \quad (2)$$

where L_p is free space transmission loss (dB). The distance and wavelength are expressed in the same unit of meters (International Telecommunication Union., 2016).

METHOD

A. Theoretical Calculations

In this project, the path loss per km of 5G signals at 700MHz, 3.5GHz and 28GHz, assuming speed of light is $3 \times 10^8 \text{ ms}^{-1}$ are theoretically calculated. Then, the free space path loss between 500m and 5km transmission distance for 5G signal at 700MHz is calculated.

Below shows the theoretical calculations of path loss per km of 5G signals at 700MHz, 3.5GHz and 28GHz.

When $f = 700\text{MHz}$,

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\lambda} \right) \quad (3)$$

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\frac{c}{f}} \right) \quad (4)$$

$$L_p = 20 \log_{10} \left(\frac{4\pi(1000)(700 \times 10^6)}{3 \times 10^8} \right) \quad (5)$$

$$L_p = 89.34 \text{ dB/km} \quad (6)$$

When $f = 3.5\text{GHz}$,

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\lambda} \right) \quad (7)$$

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\frac{c}{f}} \right) \quad (8)$$

$$L_p = 20 \log_{10} \left(\frac{4\pi(1000)(3.5 \times 10^8)}{3 \times 10^8} \right) \quad (9)$$

$$L_p = 103.32 \text{ dB/km} \quad (10)$$

When $f = 28\text{GHz}$,

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\lambda} \right) \quad (11)$$

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\frac{c}{f}} \right) \quad (12)$$

$$L_p = 20 \log_{10} \left(\frac{4\pi(1000)(28 \times 10^8)}{3 \times 10^8} \right) \quad (13)$$

$$L_p = 121.38 \text{ dB/km} \quad (14)$$

Below shows the theoretical calculations of free space path loss between 500m and 5km transmission distance for 5G signal at 700MHz.

When $d = 500\text{m}$,

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\lambda} \right) \quad (15)$$

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\bar{f}} \right) \quad (16)$$

$$L_p = 20 \log_{10} \left(\frac{4\pi(500)(700 \times 10^6)}{3 \times 10^8} \right) \quad (17)$$

$$L_p = 83.32 \text{ dB/km} \quad (18)$$

When $d = 5\text{km}$,

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\lambda} \right) \quad (19)$$

$$L_p = 20 \log_{10} \left(\frac{4\pi d}{\bar{f}} \right) \quad (20)$$

$$L_p = 20 \log_{10} \left(\frac{4\pi(5000)(700 \times 10^6)}{3 \times 10^8} \right) \quad (21)$$

$$L_p = 103.32 \text{ dB/km} \quad (22)$$

B. MATLAB Simulation

In MATLAB, the `fspl()` function within the Phased Array System Toolbox is used to compute FSPL directly as it uses the same formula internally (MathWorks., n.d. -a). The `fspl()` command uses the theoretical formula (2) above to obtain the results.

The simulation is done in MATLAB to calculate and display FSPL across a spectrum of frequencies and distances. The script for the simulations is as follows:

```
d = [100 500 1000 5000 10000];
f = (0.1:0.1:100).'*1e9;
c = physconst('lightspeed');
Lp = fspl(d,c./f)
loglog(f/1e9,Lp)
legend('Range: 100 m','Range: 500 m ','Range: 1 km', 'Range : 5km', 'Range: 10 km');
xlabel('Frequency (GHz)');
ylabel('Path Loss (dB)');
```

This script performs the following,

1. Defines a range of distances from 100 meters to 10 kilometres.
2. Defines a frequency sweep from 0.1GHz to 100GHz with 0.1GHz step size
3. Retrieves the physical constant of the speed of light using `physconst('lightspeed')` (MathWorks., n.d. -b).
4. Computes the FSPL values using MATLAB's built in `fspl()` function for all distances and frequency combinations
5. Uses `loglog()` (MathWorks., n.d. -c). to plot a visual representation of the FSPL in decibels versus frequency on a logarithmic scale.

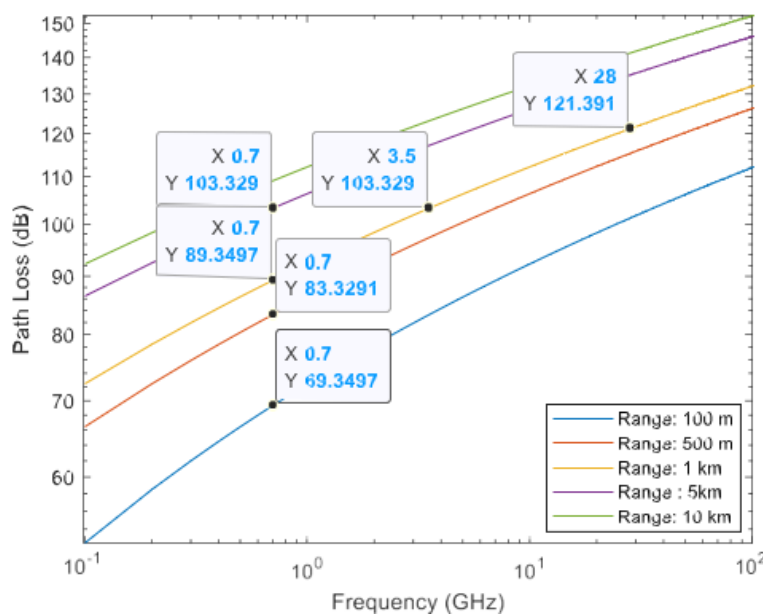


Figure 2. Simulation Results.

From the plot in Figure 2, the following observations can be made:

- FSPL increases with frequency and distance: At a specific distance the path loss escalates significantly as the frequency goes up. This behaviour is consistent with the FSPL equation, which is directly related to the square of the frequency.
- Proportional loss (Frequency): The path loss at 700MHz (89.3497 dB) is smaller compared to the path loss at 3.5GHz (103.329 dB) and 28GHz (121.391 dB). This is because the FSPL is directly proportional to signal frequency squared.
- Proportional Loss (Distance): Setting the frequency at 700MHz, it's observed that at 500m which has a path loss of 83.3291 dB is smaller than the path loss of the same frequency at 5km which is 103.329 dB. This is because FSPL is directly proportional to transmission distance squared.

RESULTS

The model's validity is confirmed by MATLAB simulations and theoretical calculations that consistently display patterns in behavior of Free Space Path Loss (FSPL).

Frequency	Distance	Theoretical FSPL (dB)	Simulated FSPL (dB)	Percentage Difference
700 MHz	500 m	83.33	83.3291	0.001% Difference
700 MHz	5 km	103.33	103.329	0.0009% Difference
3.5 GHz	1 km	103.32	103.329	0.00871042% Difference
28 GHz	1 km	121.38	121.391	0.00906204% Difference

Table 1: Results Comparison

The table above shows that:

- Free space path loss is strongly influenced by frequency: the higher the frequency, the greater the signal loss. This corresponds to the free space path loss formula's proportional relationship ($L_p \propto f^2$).
- Free space path loss is significantly impacted by distance: the more distance between the transmitter and receiver, the exponentially higher the signal degradation ($L_p \propto d^2$).
- The close alignment of theory and simulation confirms that MATLAB's `fspl()` is a precise and trustworthy tool for simulating path loss in free space.

CONCLUSION

This study effectively used MATLAB simulations and theoretical analysis to examine the Free Space Propagation model. According to the Friis transmission formula's inverse square law, the investigation showed that free space path loss (FSPL) dramatically rises with frequency and distance. According to calculations, even at the same distance, signals at higher frequencies like 3.5GHz and 28GHz are more attenuated than those at lower frequencies, like 700MHz. The theoretical computations and the simulation results obtained using MATLAB's `fspl()` function closely matched, confirming MATLAB's use as a trustworthy tool for FSPL modeling. Nonetheless, minor variations noted at higher frequencies emphasize the impact of internal accuracy and the frequency sensitivity of FSPL. Given that route loss can have a substantial impact on signal coverage and system performance, these findings highlight the significance of proper frequency selection in wireless communication design, particularly for high-frequency technologies like 5G. Additionally, by advancing the creation of more effective, dependable, and ecologically friendly wireless communication networks, this research advances Sustainable Development Goal 9: Industry, Innovation and Infrastructure, specifically Target 9.4. Building robust, sustainable industrial systems requires reducing energy waste, promoting the use of cleaner technologies, and optimizing infrastructure, all of this may be accomplished with the help of FSPL modelling.

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“If we knew what it was we were doing, it would not be called research, would it?”

– Albert Einstein