مجلة البحوث المالية والتجارية
المجلد (26) – العدد الرابع – أكتوبر 2025

The Effect of Agile Supply Chain Management on Supply Chain Wastes: A Case Study on Natural Gas Vehicles Company

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تاريخ الإرسال	2025-07-30
تاريخ القبول	2025-09-09
رابط المجلة: https://jsst.journals.ekb.eg/	

Abstract:

This study aims to examine the effect of Agile Supply Chain Management on Supply Chain Wastes as a case study on Natural Gas Vehicles company, one of the subsidiaries of the Egyptian petroleum sector. Agile Supply Chain Management is the independent variable, while Supply Chain Wastes is the dependent variable. To achieve the study's objectives, quantitative statistical methods were applied, supported by a questionnaire as the primary data collection tool. Data was collected from a sample of 228 individuals, including 98 top management and 130 managers, and analyzed using SPSS software. The results showed a negative and statistically significant relationship at the level of ($\alpha \leq 0.05$) between agile supply chain management and supply chain wastes, with a correlation coefficient of -0.600. Furthermore, the analysis revealed that agile supply chain management has a substantial impact of -0.645 on supply chain wastes. The study concluded with a set of recommendations in light of the results presented.

Keywords: Agile supply chain management, Supply chain wastes, Wastes, Agility, Supply chain, Natural gas vehicles companies, Natural Gas for vehicles.

1. Introduction:

In today's fast-paced and changeable business environment, companies are increasingly adopting Agile Supply Chain Management as a strategic solution to address market volatility, intense competition, and shifting customer needs (Gangaraju et al., 2025). This modern supply chain approach focuses on being highly adaptable and responsive, allowing organizations to effectively manage uncertainty, improve operational efficiency, and enhance overall performance. Agile supply chain management supports businesses in staying competitive by enabling them to quickly adjust to rapid changes in market conditions and consumer expectations (Istimaroh, 2023).

Yet, it is imperative to note that like most organizations in the region of natural gas vehicles industry has a number of core challenges that affect the efficient functioning of its supply chain management system in this case, disposal of waste (Mostafa & EL Sakty, 2023). Wastes are any activity or resource in the supply chain that does not add value to the final product or service to be delivered. These wastes, if recognized and cut down, will help enhance overall supply chain performance and the costs associated with it (Vegter et al., 2020). Even though there are certain beneficial outcomes of the agile supply chain management in form of improving the processes, most firms in Egypt including that in the natural gas vehicle industry have not embraced this strategy to the optimum (Mostafa & EL Sakty, 2023).

2. Literature Review

Research on supply chain agility and waste reduction has evolved progressively over the past years, with contributions that build the foundation for this study. The following review summarizes prior studies in chronological order to highlight the cumulative nature of knowledge.

In 2022, several studies addressed waste and agility in different contexts. Mulyana et al. (2022) identified eight key types of waste in higher education, including overproduction, defects, and underutilized talents, recommending that the top three be prioritized for elimination. Similarly, Gull et al. (2022) explored corporate sustainability practices and found that waste generation negatively affects financial performance, whereas recycling has a positive effect. In the same year, Escuder et al. (2022) demonstrated that Lean methodologies in urban logistics improved efficiency by up to 25% in serviced stores, proving the value of structured waste reduction strategies.

In 2023, research attention expanded to supply chain agility and its broader impacts. Amini (2023) confirmed that strategic agility enhances competitive capabilities in the banking sector, with clarity of vision being the most influential factor. During the COVID-19 pandemic, Çetindaş et al. (2023) analyzed supply chain agility and revealed that it positively affects demand stability and firm performance, with demand stability acting as a mediator. Gomes et al. (2023) compared Lean and Agile strategies in vaccine distribution, concluding that agility reduces lead time and enables faster rollouts, though at higher costs.
Within manufacturing and industrial contexts, Gangaraju et al. (2023) established that agile practices in Industry 4.0 environments improve financial outcomes through faster response to demand and enhanced customer satisfaction. Korucuk et al. (2023) identified critical success factors for agile supply chain management and emphasized that integration with risk reduction strategies improves flexibility, customer satisfaction, and competitiveness. Mukhsin (2023) examined supply agility in the broiler industry and found that it significantly influences both supply chain and firm performance, with supply chain performance acting as a mediating variable. Additionally, Da Motta et al. (2023) reduced waste in automotive component testing through Lean manufacturing approaches, while De Jesus et al. (2023) validated a multi-method framework to identify and minimize operational waste in distribution warehouses, achieving significant reductions in lead time and non-value-adding activities.
Taken together, these studies demonstrate that both agility and Lean approaches contribute significantly to performance improvement and waste reduction across industries. However, it is important to note that the majority of reviewed studies are concentrated in 2022 and 2023, with no relevant studies from 2024 or 2025 found at the time of writing. This indicates a research gap in more recent literature, particularly in emerging economies and in the context of natural gas vehicles in Egypt. This cumulative body of research underscores the importance of agile supply chain management for reducing waste, enhancing flexibility, and improving performance. It also provides the theoretical foundation upon which the current study builds its hypotheses and conceptual model.

3. Theoretical Framework of the Study:

The literature review seeks to provide a rich review of literature from other scholars with regards to agile supply chain management and supply chain wastes. When analyzing these studies collectively, one may

create more comprehensive profiles of how these particular factors affect the performance of supply chain. This synthesis will not only give theoretical support to the current study but also identifies the research gap which needs to be covered for the development of better practices of supply chain management.

3.1 Agile Supply Chain Management

3.1.1 Definition and Importance of Agility

According to Singh et al. (2024), agility describes the ability of such a firm to implement swift adjustments when it comes to business undertakings in view of the internal and external environment. This capability is strategic in current complex and ever-growing supply chain function due to technology advancement, unpredictable hence volatile customer behavior, and unpredictable global business climate. Flexibility in supply chain management has evolved into a significant concept over the last few years due to the pressure experienced by organizations to be astute and deal with changes within their market and its customers.

It is quite evident that the issue of agility plays a crucial role in supply chain management. Supply chain agility gives organizations more ability to deal with disruption, create value from new opportunities and have the competitive advantage they need in the market. This is in agreement with (Alzoubi et al., 2022) their study affirmed that agile supply chain can improve the ability to respond quickly to demand, reduce lead time, eliminate wastes and hence improve customer satisfaction. In addition, agility can help organization to minimize costs such as holding cost in inventory and make better decision on resources utilization.

3.1.2 Dimensions of Agility:

Theses dimensions are the most widely recognized, according to a usage frequency of 78.69% in literature. These four characteristics are essential for an enterprise's agility, which helps counter sudden changes in an instable volatile marketplace (Patel and Sambasivan, 2022).

3.1.2.1 Responsiveness:

Responsiveness as applied to agility is defined as the capability of the organization in responding to its environment's changes. Some of them are based on the changes in market conditions, customers' needs and wants, technologies, or regulatory standards. A responsive

organization is able to quickly adapt its line of action according to current information or events on the ground, and therefore will be better placed to seize opportunities and avoid risks than its counterparts in an organization that is not very responsive (Kazancoglu et al., 2022).

Responsiveness therefore relies on an organization's ability to detect changes requiring fast action and respond to them effectively and cohesively. This often calls for lean bureaucratic structures, employee self-organization and good information flow. In general, organizations come up with methodologies for gauging their environment with mechanisms for responding quickly and efficiently to changes (Richey et al., 2022).

3.1.2.2 Speed:

Speed is one of the components of agility in supply chain, meaning the capacity of an organization to swiftly respond to emerging markets situation, or customers' needs. The capacity to respond quickly to changes, which has been presented in the article as one of the main sources of competitive advantage in rapidly evolving fast business environment. In regard to agility in supply chains, it is therefore necessary to look at speed in regards to product development, order cycles, and the speed of new process, and technology introduction (Gölgeci and Gligor, 2022).

Ravindran et al. (2023), show that the concept of speed in supply chains does not only apply on products or inventories, but on decisions and information as well. An agile supply chain therefore relies on up-to-date information processed through intelligent analytics to respond to change in the market. In addition, velocity is correlated with the notion of time, triangulated competition in which organizations work to cut down lead-time, time held in inventory, and increase the total momentum of material and information flow throughout the supply chain. This emphasis on speed helps organizations to be more customer-focused, help reduce costs related to holding inventory and obsolesce, and establish the organization as the first in new and fast-growing markets.

3.1.2.3 Flexibility:

According to Jafari et al. (2023), they examined a possibility that flexibility includes one or more of the activities that are involved in the supply chain, such as the processes of production and marketing, management, as well as storage, sales, and distribution. It has the

capacity to bring about changes in the supply chain that lead to shifts in volume, changes in direction of line of production and product portfolio changes that meet the current scenario. Flexibility reflects the concept of agility in supply chain management. Flexibility refers to the ability of an organization and its supply chain processes and assets to adapt to changing requirements.

In addition, Gölgeci and Gligor, (2022), focused on gathering about flexibility in the supply chains, come to learn that flexibility is not only the kind that entails change, but it is also the kind that entails purposeful change. Being able to identify changes in the market conditions and, as a result, be able to make earlier adjustments that would be suitable for the new supply chain strategies is made possible by organizations that have a high degree of flexibility. By taking this approach, companies are able to maintain a competitive advantage and, as a result, avoid the negative effects that are associated with market instability. The adaptability of the supply chain, on the other hand, is not only a matter of the partners involved, but also of the purchasing and supply partnerships that have the potential to improve the supply chain network.

3.1.2.4 Competency:

In this context, agility competency means the disposal of an individual or an organization to respond efficiently and effectively to change related dynamics. It includes the ability to change one's thinking constantly, make decisions quickly and adapt plans if necessary. Employees, therefore, with high agility competency can operate well in volatile contexts, because their mental and practical contexts adapt effectively and efficiently to new knowledge or conditions. This skill involves acceptance of feedback, willingness to learn and ability to constantly find ways to effect change. Speed has become so desirable in the current business environment as it helps organizations and persons to adapt easily and faster to the ever-changing business environment and market volatility to meet their buyer needs effectively and efficiently (Kumkale, 2022).

3.1.3 Measuring Agility in Supply Chains

It is self – evident that the definition and quantification of agility in supply chains are necessary steps for evaluating organizational performance. But what is more difficult, especially because of the multi-dimensional nature of agility, is to measure it. Researchers have put

forward numerous frameworks and methodologies for assessing supply chain agility. For example, (Kazancoglu et al., 2022) have proposed an extensive model, the agility index that includes the flexibility, response, and adaptability factors. This index helps organizations to know their current agility position relative to other organizations, and also to measure their agility progress in the future.

A second way to assess agility is in the form of Key Performance Indicators – similar to how one tracks performance in a game – to help understand how agile an organization is in different ways. Le, (2020), put forward the following KPIs: - Order fulfilment cycle time- Perfect order fulfilment rate- Supply chain flexibility index, these suggest clear-cut indexes of an organization's capacity to mobilize fast and adequately to alterations in the market. However, some researchers propose including the qualitative measurements together with the quotas to reflect more about the value which is difficult to measure, including the company's culture and its workers' adaptability.

3.1.4 Benefits and Challenges of Agile Supply Chain Management

There are high numbers of perks of applying agile supply chains which may lean towards affect the competitive advantage of an organization. This is according to Waqas et al. (2022) who noted that organizations with agile supply chains deal with demand volatility; optimize instead of maximizing inventory holding costs; deliver higher levels of customer satisfaction; and create new markets. A supply chain that operates on the agile model are also more prepared for such disruptions as they range from natural disasters, geopolitical instabilities to shift in consumer trends. This resilience can be reflected in better financial performance and sustainable business stories of organizations.

However, harnessing and sustaining agile supply chains is not without some degree of problem. A major challenge that arises is major capital investments in technology and the infrastructure especially with regards to human capital. According to Waglé and Wignaraja (2022), organizations suffer from the unbudgeted expenses of migrating away from outdated tool suites and reorienting their employees properly. Furthermore, cultural resistance also poses a challenge to organisations embracing agility because there are normally strings attached by traditional supply chain management archetypes. To surmount these challenges, it is necessary to adopt strategic management, effective leadership support and commitment and learning organization culture.

3.2 Wastes in Supply Chain

3.2.1 Understanding Wastes in Supply Chains

Waste within the supply chain management involves work processes and material that do not in any way benefit the ultimate end product or service hence, adding disorganization and cost to the supply chain (Morseletto, 2020). While the idea of waste has been borrowed from the lean manufacturing tradition, the authors have expanded the more traditional notion of waste within the supply chain management concept to embrace the entire supply chain network. Knowing and recognizing these wastes is significantly essential for many organizations intending to improve supply chain activities and functioning.

Mulyana et al. (2022), identify seven types of waste in lean thinking: overproduction, waiting, transportation, overprocessing, inventory, motion, and defects. In SCM, these wastes can be categorized in many types and include extra inventory, movement, activities, and defects. All of the identified wastes are a crucial aspect that, when managed effectively, will enable organizations to reduce their supply chain costs while at the same time enhancing its supply chain services to customers. Furthermore, identification of wastes unveils ideas for improvement and innovation that are sustainable sources of competitive advantage.

3.2.2 Wastes and Supply Chain Performance

Understanding the different types of wastes prevalent in the supply chain is beneficial to most organizations because the presence of wastes in supply chains is normally negative to the optimal performance of the supply chain (Wijewickrama et al., 2021). Beullens and Ghiam (2022), indicated that waste hampers the supply chain, and can result in high operation cost, low returns, and unsatisfied consumers. In particular, wastes are longer lead times and inventory costs, and decreased ability to satisfy market demands. These inefficiencies undermine an organization competitive edge and limit their capacity to deliver according to customer needs in terms of cost, quality and delivery performance.

In addition, the economic consequences of wastes do not end at the values affecting financial performance. In the same line of thought (Fernando et al., 2022) posit that supply chain sources of throw away wastes give rise to environmental degradation due to over utilization of resources and high emissions. In fact, it is not only a factor that decreases the performance of sustainability aspects in an organization

but also harm its image and impact its engagement with stakeholders. Secondly, they discourage organization improvement and innovation indicating that wastes hinder change programmes resulting to organizations not being in a position to adopt to changing market environment.

Understanding wastes in the capacity of a multi-variable entity, therefore helps to design comprehensive plans fitting for improvements of supply chain and sustainability performance. The physical form and distribution of wastes and their complex cascading effect on the entire supply chain dictated by the availability of the wastes means that a multi-variable approach is most suitable when designing plans for the improvement of supply chain and sustainability performance (Duman et al., 2020).

3.2.3 Strategies for Waste Reduction in Supply Chains

Waste management is critical in supply chain enhancement since organizational leaders ought to put sound practices in place to address the problem. The most common strategy identified is the implementation of lean supply chain management. Lean thinking essentially requires the definition of value by customers and elimination of all unnecessary steps. This entails mapping of the value streams, establishing the pull production systems and sustaining improvement. Lean solutions can assist an organization in controlling the production wastes by cutting down on overproduction, and lowering the inventory stocks along with the crafting of efficient workflows in the supply chain network (Payaro, 2023).

One of the major approaches of waste management with reference to the business is exploration of higher technologies and data analytics. According to Hrouga et al. (2022), the application of IoT sensors, AI and Blockchain technologies increase visibility and control in supply chain systems to make appropriate resource allocations and process improvements. For instance, predictive analytics can lead to enhanced demand forecasting, the aim of which is minimising over-buffeting and subsequent, excess inventory. Moreover, automated tools will also help to avoid common mistakes and accelerate the process, which addresses wastes including things being done incorrectly and delay. Such technological solutions should therefore be integrated with other technologies in the society through proper planning and designing so that the required impact can be achieved concerning waste management.

3.3 Relationship between Agility and Supply Chain Waste Reduction

Various scholars indicate that supply chain agility is positively correlated to the performance of supply chain activities, including the identification and eradication of different kinds of wastes. A study by Srinivasan et al. (2020) revealed that there is more responsiveness in the agile supply chains to the prevailing market conditions, which has an overall effect of minimizing on over production, a major issue affecting the conventional supply chains, leading to excess inventories. The characteristic of the decrease in underutilization and overprocessing is more semblable in the structures that can organize resources more flexibly within the fiscal cycle and promptly adapt to the changes in demand.

Nevertheless, the link between agility and waste reduction is not always positive one. Agility, as mentioned by Mishra et al. (2024), can potentially enhance numerous aspects of supply chain, but there will also be new problems. For example, while using agile systems there might be more addressable transportation costs or the need to keep buffer inventories in the supply chain. These trade-offs are interrelated and mitigating them and finding the right balance requires comprehension of each organization's environment and the overall supply chain network. Moreover, the ability of the agility in minimizing waste might be realized upon the organizational agility and compliance with the whole established objectives.

4. Study Problems

Supply chain management in the natural gas vehicles industry in Egypt faces persistent challenges, particularly regarding the wastes generated during different stages of the supply chain. These wastes include excess inventory, defects, inefficient processes, and missed opportunities caused by shortages, all of which undermine efficiency and increase costs (Mostafa & El Sakty, 2023). Despite the potential of agile supply chain management to address such challenges—through better inventory control, effective use of technology, smoother workflows, and improved supplier collaboration—its adoption in this sector remains limited.

The core problem lies in the scarcity of empirical studies that examine the role of agile supply chain management in reducing supply chain wastes within developing countries, and specifically in Egypt's natural gas vehicles industry. Although this industry is strategically significant as part of Egypt's energy diversification plan and contributes

directly to sustainability goals, little is known about how agility practices influence waste reduction in this context.

Accordingly, the present study seeks to bridge this research gap by empirically investigating the impact of agile supply chain management on supply chain wastes in the Egyptian natural gas vehicles industry. This will provide insights into how agility can be leveraged to enhance operational efficiency, reduce waste, and improve competitiveness in emerging economies.

The study focuses on two main questions:

1. **Primary relationship: Whether there's a connection between Agile supply chain management and supply chain waste**
2. **Effect analysis: How Agile supply chain management specifically impacts supply chain waste**

The research further breaks this down into four sub-dimensions of Agile methodology:

- **Responsiveness - How quickly the supply chain can adapt to changes**
- **Speed - The velocity of operations and decision-making**
- **Flexibility - The ability to modify processes and structures**
- **Competency - The skills and capabilities within the supply chain**

5. Study Significance

The research importance is well-articulated across five key areas:

5.1 Academic Contribution: The study aims to enhance understanding of how Agile dimensions affect waste reduction, addressing a gap in current literature.

5.2 Practical Application: The findings could benefit the natural gas vehicle industry specifically, and provide actionable insights for organizational decision-makers.

5.3 Competitive Advantage: Agile supply chain management can help companies remain flexible and responsive to market fluctuations, ultimately reducing waste and improving sustainability.

5.4 Research Gap: The authors note a significant lack of research on this topic, particularly in local, Arab, and international contexts.

5.5 Managerial Value: The study could provide practical guidance for managers and decision-makers on implementing Agile principles to reduce waste, improve performance, and decrease costs.

6. Study Objectives Analysis

This section outlines six specific objectives that provide a comprehensive framework for investigating Agile supply chain management and its impact on waste reduction in the natural gas vehicles industry.

6.1 Primary Objectives

Objective 1: Current State Assessment The study begins by examining the existing implementation of Agile supply chain management within the Natural gas vehicles company. This baseline assessment is crucial for understanding the starting point and identifying areas for improvement.

Objective 2: Dimensional Impact Analysis This core objective investigates how the four key Agile dimensions (Responsiveness, Speed, Flexibility, and Competency) specifically affect supply chain waste. This represents the heart of the research question and will likely involve quantitative analysis to measure these relationships.

6.2 Secondary Objectives

Objective 3: Waste Investigation A focused examination of supply chain waste patterns within the natural gas vehicles company, which will provide the dependent variable data for the study.

Objective 4: Comparative Analysis The study aims to highlight what makes this research distinctive compared to previous studies in the field, positioning it within the existing body of knowledge while emphasizing its unique contributions.

Objective 5: Effect Identification This objective specifically targets identifying and measuring the effect of Agile supply chain management on waste reduction, which directly addresses the main research question.

Objective 6: Practical Recommendations The study concludes with actionable outcomes - providing practical suggestions and recommendations for developing Agile supply chain management practices that can effectively reduce waste in natural gas vehicle companies.

7. Study variables (hypothesis study plan)

In light of the study problem and its objectives, testing the nature of the relationship between the main and sub-variables requires the formulation of a hypothetical framework. This framework explains the nature and scope of the relationships among variables. The study model was designed based on the frameworks for the study variables, which are agile supply chain management and supply chain wastes. Figure No. (1) shows the hypothesis of the current research.

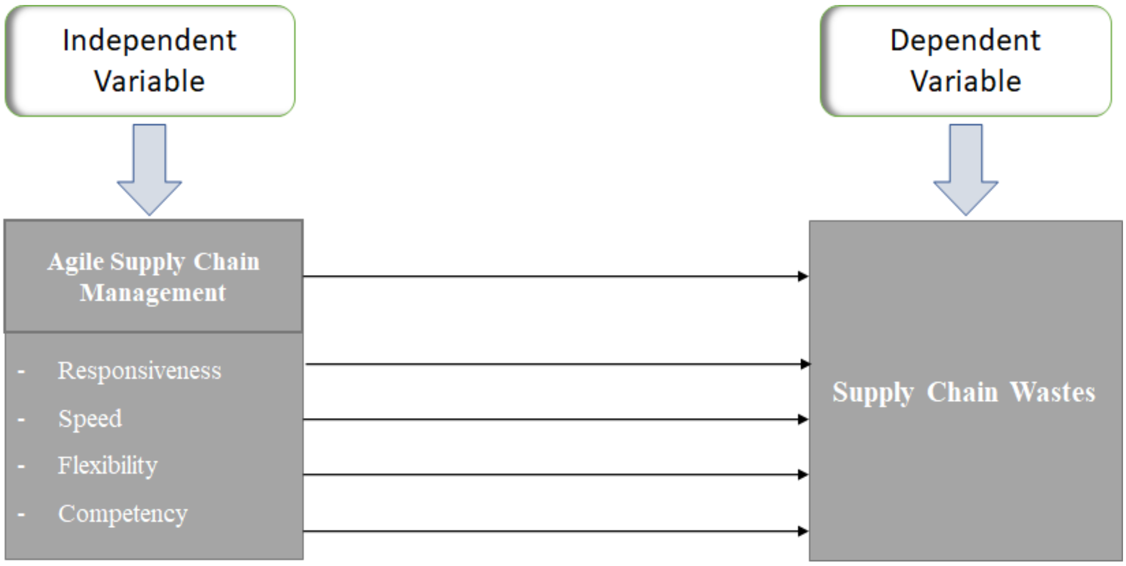

Figure No. (1) Conceptual framework
Source: Developed by the authors

7.1 Dual Hypothesis Structure

The study employs a comprehensive two-tier hypothesis framework that examines both relationships and effects between Agile supply chain management and supply chain waste:

7.1.1 Main Hypothesis 1: Relationship Analysis

Primary Hypothesis: There is a significant negative relationship between Agile supply chain management and supply chain wastes.

Sub-hypotheses (Relationship-based):

1. **Significant negative relationship between Responsiveness and supply chain wastes**
2. **Significant negative relationship between Speed and supply chain wastes**

3. **Significant negative relationship between Flexibility and supply chain wastes**
4. **Significant negative relationship between Competency and supply chain wastes**

7.1.2 Main Hypothesis 2: Effect Analysis

Primary Hypothesis: Agile supply chain management has a significant negative effect on supply chain wastes.

Sub-hypotheses (Effect-based):

1. **Responsiveness has a significant negative effect on supply chain wastes**
2. **Speed has a significant negative effect on supply chain wastes**
3. **Flexibility has a significant negative effect on supply chain wastes**
4. **Competency has a significant negative effect on supply chain wastes**

8. Research Methodology

This study adopts a quantitative approach, to examine the effect of agile supply chain management on supply chain wastes.

8.1 Data Collection

8.1.1 Primary Data: The data for this study was collected using a stratified sampling method, where the population was divided into separate levels based on top management and management level. Data collection was conducted through questionnaires distributed by the researcher at Natural Gas Vehicles Company, affiliated with the Egyptian petroleum sector.

Table 7: Number of items used for each variable in the questionnaire and their sources

Variable	Number of Items	Reference
Agile supply chain management - Responsiveness	5	Hosseini et al. (2013)
Agile supply chain management- Speed	5	Lin et al. (2006); Ismail and Sharifi (2006)
Agile supply chain management- Flexibility	5	Hosseini et al. (2013)

Variable	Number of Items	Reference
Agile supply chain management-Competency	6	Hosseini et al. (2013)
Supply Chain Wastes	15	El-Namrouty & Abushaaban (2013); Klein et al. (2023)

8.1.2 Secondary Data: Data was collected from several sources including websites, libraries, journals, articles and research papers, all focusing on topics related to the research problem.

8.2 Target Population:

Policy makers, top management and managers who work at different managerial levels as well as logistics and supply chain managers located within greater Cairo in Natural gas vehicles company that has been incorporated in 1995 as the first company in Egypt to commercialize the vehicular natural gas as an alternative fuel for vehicles. (Shaarawi et al., 2024).

8.3 Research Sample

8.3.1. Type: Data gathered through questionnaire using a five-point Likert scale ranging from "strongly agree" (1) to "strongly disagree" (5) to assess each item.

8.3.2. Size: The study conducted a quantitative approach, utilizing a questionnaire as the primary data collection tool. Data was gathered from 228 participants (98 Top management and 130 manager) using a stratified sampling method, with a 95% confidence level and a 5% margin of error.

$$n = \frac{z^2 . p(1-p)}{e^2}$$

Equation 1: Infinite sample size calculation

$$n = \frac{n}{1 + \frac{n-1}{479}}$$

Equation 2: Finite sample size calculation

(Cochran, 1977)

Where:

n: Sample size

Z: Z-value (e.g., 1.96 for a 95% confidence level).

p: Population proportion (e.g., 0.5 if unknown).

e: Margin of error (in decimal, e.g., 0.05 for 5%).

Population = 479

9. Measurement of Relationships and Effects Between Study Variables:

9.1 Variable Measurement Framework

This study employs a comprehensive dual measurement approach to examine both the relationships and effects between the independent and dependent variables. The research framework distinguishes between correlation analysis to identify associations and structural equation modeling to determine causal effects, providing a robust foundation for understanding how Agile Supply Chain Management Influences Supply Chain Wastes in the natural gas vehicles industry.

9.1.1 Independent Variable Measurement

The independent variable, Agile Supply Chain Management, is conceptualized as a multidimensional construct measured through four key dimensions that collectively represent organizational agility capabilities. Responsiveness is measured using five items based on Hosseini et al. (2013), focusing on the organization's ability to detect and react to environmental changes, including IT system capabilities, competitive analysis support, customer service quality, relationship maintenance, and market demand prediction. Speed is assessed through five items derived from Lin et al. (2006) and Ismail & Sharifi (2006), examining the organization's capacity for rapid execution including information access throughout the supply chain, virtual communication effectiveness, new market exploration velocity, outsourcing emphasis, and web-based application utilization.

Flexibility is evaluated using five items from Hosseini et al. (2013), measuring the organization's adaptability in operations including delivery policy modifications, supplier diversification capabilities, customer demand responsiveness, staff adaptability to sudden changes,

and storage capacity adjustments. Competency is measured through six items also based on Hosseini et al. (2013), assessing organizational skills and capabilities including decentralized decision-making, vertical integration, team-oriented goals and measures, innovation infrastructure creation, trust-based partner relationships, and appropriate technology implementation. All dimensions utilize a 5-point Likert scale ranging from "strongly agree" to "strongly disagree," ensuring consistent measurement across the construct.

9.1.2 Dependent Variable Measurement

Supply Chain Wastes, the dependent variable, is measured using fifteen comprehensive items derived from established frameworks by El-Namrouty & Abushaaban (2013) and Klein et al. (2023). This measurement approach captures various forms of waste prevalent in supply chain operations, including transportation inefficiencies, energy consumption waste, defect-related losses, motion waste, waiting time inefficiencies, inventory excess, and underutilized human capabilities. The measurement scale is designed to assess waste reduction outcomes, where lower scores indicate better waste control and higher operational efficiency. Three items were ultimately excluded during the analysis due to insufficient factor loadings, resulting in a refined measurement model that maintains content validity while ensuring statistical rigor.

9.2 Relationship Measurement Approach

The study employs Pearson correlation analysis to examine the strength and direction of linear relationships between Agile Supply Chain Management and Supply Chain Wastes. This analytical approach tests the primary hypothesis that a significant negative relationship exists between agile supply chain management and supply chain wastes, along with four sub-hypotheses examining individual relationships for each agility dimension. Correlation coefficients provide insights into the degree of association, with values interpreted according to established guidelines where coefficients between 0.3 and 0.7 indicate moderate relationships, and values between 0.7 and 1.0 represent strong relationships. The analysis revealed statistically significant negative correlations across all relationships, with the overall correlation between Agile Supply Chain Management and Supply Chain Wastes reaching -0.600, indicating a strong negative association.

Among the individual dimensions, Flexibility demonstrated the strongest relationship with Supply Chain Wastes (r = -0.627), followed by Speed (r = -0.612), Competency (r = -0.545), and Responsiveness (r = -0.470). These findings provide empirical evidence that higher levels of agility in supply chain management are consistently associated with lower levels of waste across all measured dimensions, supporting the theoretical foundation of the study.

9.3 Effect Measurement Approach

The study utilizes Structural Equation Modeling with Partial Least Squares (PLS-SEM) to examine causal effects and determine the magnitude of influence that Agile Supply Chain Management exerts on Supply Chain Wastes. This advanced analytical technique enables the examination of direct effects through path coefficients, providing insights into the causal relationships postulated in the research hypotheses. The analysis tests the primary hypothesis that Agile Supply Chain Management has a significant negative effect on Supply Chain Wastes, along with corresponding sub-hypotheses for each agility dimension.

Path coefficient analysis revealed substantial negative effects across all examined relationships, with the overall effect of Agile Supply Chain Management on Supply Chain Wastes reaching $\beta = -0.645$, indicating a strong negative causal influence. The coefficient of determination (R^2) demonstrates that Agile Supply Chain Management explains 41.7% of the variance in Supply Chain Wastes, representing a moderate to strong explanatory power in organizational research contexts. Among individual dimensions, Flexibility exhibited the strongest effect ($\beta = -0.664$, $R^2 = 44.1\%$), followed by Speed ($\beta = -0.645$, $R^2 = 41.6\%$), Competency ($\beta = -0.604$, $R^2 = 36.5\%$), and Responsiveness ($\beta = -0.553$, $R^2 = 30.6\%$).

9.4 Measurement Quality and Validation

The study implements rigorous measurement validation procedures to ensure the reliability and validity of findings. Convergent validity is established through indicator loadings exceeding 0.70 for most items and Average Variance Extracted values above recommended thresholds for all constructs except Supply Chain Wastes, which achieved an acceptable AVE of 0.4 reflecting the inherent complexity of waste measurement. Discriminant validity is confirmed through Heterotrait-

Monotrait (HTMT) ratios below 1.0 for all construct pairs, ensuring that each construct captures unique phenomena not represented by others.

Reliability assessment demonstrates excellent internal consistency across all constructs, with Cronbach's Alpha values ranging from 0.851 to 0.969, substantially exceeding the recommended threshold of 0.70. Composite reliability values similarly exceed acceptable standards, though some values above 0.95 suggest potential opportunities for measurement streamlining in future research. The study also addresses common method bias through Harman's single-factor test, confirming that no single factor accounts for more than 50% of the variance, thereby validating the distinctiveness of measured constructs.

10. Statistical Rigor and Analytical Depth

The measurement framework incorporates multiple layers of statistical analysis to ensure comprehensive understanding of variable relationships and effects. Effect size calculations (f^2) provide insights into practical significance, with values ranging from 0.441 for Responsiveness to 0.790 for Flexibility, all indicating moderate to large effects according to established guidelines. Predictive relevance assessment through Q^2 values demonstrates the model's capability to predict future observations, with values ranging from 0.094 to 0.154 indicating satisfactory predictive accuracy.

The dual analytical approach of examining both relationships and effects provides complementary insights into how Agile Supply Chain Management Influences Supply Chain Wastes. While correlation analysis reveals the strength of associations, path analysis uncovers the magnitude of causal influences and explanatory power. This comprehensive measurement strategy ensures that the study's conclusions are grounded in robust empirical evidence, supporting both theoretical advancement and practical applications in supply chain management within the natural gas vehicles industry context.

Table 8: Sample distribution

Job position	N	%
Top Manager	98	42.98%
Manager	130	57.02%
Total	228	100.00%

Source: Developed by the author

Hence, tools are as follows:

10.1 Analytical Statistical Tools: This initial phase of analysis ensures that the dataset meets the necessary quality requirements before proceeding to more complex modelling procedures, it includes:

- **Outlier Detection**
  Outliers represent extreme data points that deviate significantly from other observations in the dataset.
- **Missing Data Evaluation**
  The evaluation of missing data is particularly important, as the presence of substantial missing values can compromise the estimation of path relationships and the overall model fit.
- **Data Normality Assessment**
  The assessment of normality focuses on examining the distribution characteristics of the data, primarily through measures of skewness and kurtosis.
- **Common Method Bias Investigation**
  A type of measurement of errors that occurs in survey-based research. Harman's single-factor test was conducted to assess the potential presence of common method bias, with the results presented in Table 1:

Table 1 Results of Harman's single-factor test

Total Variance Explained						
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% Of Variance	Cumulative %	Total	% Of Variance	Cumulative %
1	15.443	42.897	42.897	15.443	42.897	42.897
2	3.343	9.286	52.182			
3	2.287	6.354	58.536			
4	1.526	4.238	62.774			
5	1.188	3.299	66.074			
6	1.092	3.032	69.106			
7	0.913	2.537	71.643			
***Note*: Other components were trimmed for simplicity**						
***Extraction Method:* Principal Component Analysis.**						
***Remark*: No problem exists**						
***Source:* SPSS V. 29 Software**						

As shown in the table, the principal component analysis extracted seven factors with eigenvalues greater than 0.95, with the first factor accounting for 42.897% of the total variance. The remaining factors cumulatively explained an additional 28.747% of the variance, bringing the total explained variance to 71.643%. According to established guidelines in methodological literature, common method bias is considered problematic if a single factor emerges from the unrotated factor solution or if one general factor accounts for more than 50% of the covariance among measures (Podsakoff et al., 2003; Fuller et al., 2016). Therefore, no significant common method bias as evidenced by Harman's single-factor test.

10.2 Measurement Model Assessment

The measurement model assessment in PLS-SEM follows established criteria for evaluating reflective measurement models, focusing on three key aspects: convergent validity, discriminant validity, and reliability assessment, as outlined in Table 2.

Table 2: Measurement Model Assessment Rules

Evaluation Items	Measurement Items	Fitting Criteria	
		Cut off	*Preferable*
Convergent Validity	Indicator Loadings	> 0.40	> 0.70
	Average Variance Extracted	> 0.40	> 0.50
Discriminant Validity	HTMT	< 1.00	< 0.90
Reliability Assessment	Cronbach's Alpha, Composite Reliability rho_A coefficient	> 0.60	> 0.70
Source: Researcher's Development			

Convergent validity examines the extent to which measurement items correlate positively with other measures of the same construct, assessed through indicator loadings and Average Variance Extracted (AVE). According to the fitting criteria presented in Table 2, indicator loadings should exceed 0.40 at a minimum, with values above 0.70 being preferable, while AVE should be greater than 0.40 with a preferable threshold of 0.50 (Hair et al., 2017). These thresholds ensure that the construct explains a substantial portion of the variance in its indicators,

confirming that the indicators effectively represent the construct they are intended to measure.

A- Indicator Loadings:

Table 3: Item Loading with Associated Significance and CI

Item <- Construct	Loading	t-value	P-value	95% CI for Loading	
				LL	UL
Q1 <- Responsiveness	0.815	31.295	<.001	0.759	0.861
Q2 <- Responsiveness	0.842	43.729	<.001	0.802	0.877
Q3 <- Responsiveness	0.803	27.389	<.001	0.736	0.852
Q4 <- Responsiveness	0.761	19.706	<.001	0.678	0.825
Q5 <- Responsiveness	0.813	32.276	<.001	0.757	0.857
Q6 <- Speed	0.875	45.124	<.001	0.835	0.908
Q7 <- Speed	0.86	40.736	<.001	0.815	0.898
Q8 <- Speed	0.884	52.269	<.001	0.847	0.913
Q9 <- Speed	0.63	11.555	<.001	0.515	0.726
Q10 <- Speed	0.809	26.782	<.001	0.745	0.863
Q11 <- Flexibility	0.913	68.285	<.001	0.886	0.937
Q12 <- Flexibility	0.893	53.777	<.001	0.857	0.923
Q13 <- Flexibility	0.916	75.067	<.001	0.888	0.937
Q14 <- Flexibility	0.92	89.325	<.001	0.898	0.939
Q15 <- Flexibility	0.918	72.679	<.001	0.889	0.94
Q16 <- Competency	0.831	33.771	<.001	0.779	0.876
Q17 <- Competency	0.854	42.612	<.001	0.807	0.888
Q18 <- Competency	0.737	22.45	<.001	0.663	0.793
Q19 <- Competency	0.871	48.708	<.001	0.832	0.902
Q20 <- Competency	0.754	21.344	<.001	0.677	0.818
Q21 <- Competency	0.84	36.774	<.001	0.791	0.88
Q22 <- Supply Chain Wastes	0.666	11.697	<.001	0.534	0.758
Q23 <- Supply Chain Wastes	0.67	11.071	<.001	0.54	0.771
Q24 <- Supply Chain Wastes	0.71	13.841	<.001	0.592	0.796

Item <- Construct	Loading	t-value	P-value	95% CI for Loading	
				LL	UL
Q25 <- Supply Chain Wastes	0.433	6.783	<.001	0.306	0.552
Q26 <- Supply Chain Wastes	Neglected				
Q27 <- Supply Chain Wastes	Neglected				
Q28 <- Supply Chain Wastes	0.625	10.627	<.001	0.489	0.722
Q29<- Supply Chain Wastes	0.666	10.774	<.001	0.522	0.766
Q30 <- Supply Chain Wastes	0.57	8.992	<.001	0.436	0.677
Q31 <- Supply Chain Wastes	0.443	6.361	<.001	0.289	0.561
Q32 <- Supply Chain Wastes	Neglected				
Q33 <- Supply Chain Wastes	0.663	13.053	<.001	0.558	0.758
Q34 <- Supply Chain Wastes	0.651	10.546	<.001	0.521	0.758
Q35 <- Supply Chain Wastes	0.653	10.366	<.001	0.517	0.759
Q36 <- Supply Chain Wastes	0.575	7.303	<.001	0.406	0.716
Remark: **Convergent validity attained through item loadings**					
Source: **SmartPLS 3 Software**					
CI= Confidence Interval; LL= lower limit; UL= upper limit.					

- **The results demonstrate predominantly strong loadings across most indicators, with values well above the preferable threshold of 0.7, indicating robust item reliability.**
- **Three indicators (Q37, Q38, and Q43) being neglected due to loadings below the minimum acceptable threshold of 0.4.**

B- Average Variance Extracted:

Table 4: Average Variance Extracted

Construct	Average Variance Extracted (AVE)
Responsiveness	**0.652**
Speed	**0.668**
Flexibility	**0.832**
Competency	**0.666**
Agile Supply Chain Management	**0.628**
Supply Chain Wastes	**0.4**
Remark: **Convergent validity attained through item loadings**	
Source: **SmartPLS 3 Software**	

AVE values for all the constructs, except for the supply chain wastes, are well above the preferred threshold of 0.5. The relatively lower AVE for Supply Chain Wastes aligns with the more varied indicator loadings observed for this construct, reflecting the inherent complexity of measuring waste in supply chain contexts. Supply chain wastes may manifest in diverse forms across different organizational contexts, potentially explaining the greater measurement variance observed. Despite this limitation, the AVE value of 0.4 is still in the accepted range, combined with strong composite reliability, provides sufficient evidence of convergent validity.

Discriminant validity, assesses the extent to which a construct is empirically distinct from other constructs in the model, ensuring that each construct captures unique phenomena not represented by other constructs (Franke & Sarstedt, 2019). This is evaluated through the Heterotrait-Monotrait ratio of correlations (HTMT), with values below 1.00 considered acceptable and values below 0.90 preferred, indicating sufficient distinctiveness between constructs (Henseler et al., 2015).

Table 5: Discriminant validity (HTMT)

Construct <-> Construct	HTMT	95% CI for HTMT	
		LL	UL
Flexibility -> Competency	**0.953**	**0.919**	**0.984**

Construct <-> Construct	HTMT	95% CI for HTMT	
		LL	UL
Responsiveness -> Competency	0.951	0.911	0.987
Responsiveness -> Flexibility	0.922	0.886	0.955
Speed -> Competency	0.947	0.909	0.98
Speed -> Flexibility	0.965	0.933	0.993
Speed -> Responsiveness	0.956	0.911	0.998
Supply Chain Wastes -> Agile Supply Chain Management	0.657	0.583	0.738
Supply Chain Wastes -> Competency	0.62	0.538	0.712
Supply Chain Wastes -> Flexibility	0.695	0.615	0.771
Supply Chain Wastes -> Responsiveness	0.552	0.468	0.654
Supply Chain Wastes -> Speed	0.702	0.614	0.789
Remark: **Discriminant validity through HTMT attained**			
Source: **SmartPLS 3 Software**			

The HTMT analysis shows that constructs in the model have acceptable discriminant validity, with values below 1.0. The high correlations among Agile Supply Chain Management dimensions (e.g., Speed, Flexibility, Responsiveness, Competency) are expected because they are closely related parts of the same higher-order construct (Hair et al., 2018).

Reliability assessment evaluates the consistency and stability of the measurement items. This is typically assessed through Cronbach's Alpha, rho_A coefficient and Composite Reliability.

A- Cronbach's alpha values above 0.70 indicate satisfactory reliability for established constructs, with values between 0.60 and 0.70 considered acceptable for exploratory research (Hair et al., 2019).

B- The rho_A coefficient, introduced by Dijkstra and Henseler (2015), represents a more recent advancement in reliability assessment that provides a reliability estimate between Cronbach's alpha (lower bound) and composite reliability. This measure offers a more exact reliability coefficient for PLS path models and has gained increasing attention as a valuable complement to traditional reliability measures (Henseler et al., 2016). Similar to

other reliability measures, rho_A values above 0.70 generally indicate satisfactory reliability.

C- Composite reliability values range from 0 to 1, with higher values indicating greater reliability. Values between 0.70 and 0.90 are generally considered satisfactory, while values above 0.90 may suggest redundancy among indicators, and values above 0.95 may indicate potential problems with indicator specificity (Hair et al., 2019). While such high values confirm strong reliability, they may also suggest opportunities to streamline measurement in future research by potentially removing redundant indicators without sacrificing content validity.

Table 6: Reliability of measurement model analysis

	Cronbach's Alpha	rho_A	Composite Reliability
Responsiveness	0.866	0.868	0.903
Speed	0.872	0.891	0.908
Flexibility	0.949	0.95	0.961
Competency	0.899	0.905	0.923
Agile Supply Chain Management	0.969	0.973	0.972
Supply Chain Wastes	0.851	0.866	0.878
Remark: **Internal Reliability consistency attained**			
Source: **SmartPLS 3 Software**			

These values substantially exceed the recommended threshold of 0.70, indicating strong internal consistency. However, some composite reliability values exceeding 0.95, which some methodological guidelines suggest may indicate potential redundancy among indicators (Hair et al., 2019). So, may suggest in future research removing redundant indicators without sacrificing content validity.

10.3 Descriptive Statistics

Descriptive statistics provide a fundamental framework for understanding the basic features of research data, offering concise summaries of the central tendencies, dispersions, and distributions of

measured variables. This includes (mean - standard deviation - coefficient of variation).

10.4 Pearson Correlation

Correlation analysis represents a fundamental statistical approach for examining the strength and direction of linear relationships between pairs of variables, providing essential insights into how constructs covary within a research model (Cohen et al., 2013). According to established guidelines, correlation values between 0 and 0.3 (absolute value) indicate weak relationships, values between 0.3 and 0.7 suggest moderate relationships, and values between 0.7 and 1.0 represent strong relationships (Akoglu, 2018; Ratner, 2009).

10.5 Structural Equation Modelling with PLS-SEM

To examine the effects and associations among variables in the study, Path coefficient, coefficient of determination R^2, effect size F^2, predictive relevance Q^2.

10.5.1 Statistical Analysis and Hypothesis Testing, to answer the Hypotheses question

Hypothesis 1

- **Is there a relationship between Agile supply chain management and supply chain wastes?**
  To test this hypothesis, Pearson correlation was used, table 9 illustrates this: -

Table 9: illustrates the Pearson correlation between agile supply chain management and its dimensions and supply chain wastes.

Hypothesis	Pearson Correlation	Significance
There is a significant negative relationship between Agile supply chain management and supply chain wastes.	-0.600	0.000
There is a significant negative relationship responsiveness and supply chain wastes.	-0.470	0.000
There is a significant negative relationship between speed and supply chain wastes.	-0.612	0.000
There is a significant negative relationship between flexibility and supply chain wastes.	-0.627	0.000
There is a significant negative relationship between competency and supply chain wastes.	-0.545	0.000

This statistical significance across all relationships provides strong evidence against the null hypothesis of no association between the constructs, suggesting that meaningful relationships exist within the research model.

Hypothesis 2

- **Is there an effect of Agile supply chain management on supply chain wastes?**

  To test this hypothesis, path coefficient was used. Table 10, illustrates the analysis of path coefficient, this analysis provides evidence regarding the direct effects postulated in the research hypotheses, determining whether the data support the theoretical propositions linking Agile Supply Chain Management and its dimensions (responsiveness, speed, flexibility, and competency) to Supply Chain Wastes.

Table 10: Path Coefficient

H	Path	B	t-value	P-value	95% CI for B		Remark
					LL	UL	
H2	Agile Supply Chain Management -> Supply Chain Wastes	-0.645	17.828	0	-0.705	-0.562	Supported
H2-1	Responsiveness -> Supply Chain Wastes	-0.553	12.819	0	-0.625	-0.456	Supported
H2-2	Speed -> Supply Chain Wastes	-0.645	19.188	0	-0.699	-0.57	Supported
H2-3	Flexibility -> Supply Chain Wastes	-0.664	19.504	0	-0.719	-0.584	Supported
H2-4	Competency -> Supply Chain Wastes	-0.604	16.578	0	-0.663	-0.515	Supported
Remark: All hypotheses were accepted							

Source: Based on SmartPLS V.3 Software

The analysis of direct effects presented in Table 10, provides comprehensive evidence regarding the influence of Agile Supply Chain Management and its dimensions on Supply Chain Wastes, offering strong support for the research hypotheses postulating these relationships.

The primary hypothesis (H2) proposing a significant effect of Agile Supply Chain Management on Supply Chain Wastes is strongly supported by the data (β = -0.645, t = 17.828, p = 0.000). The substantial negative path coefficient indicates that higher levels of agile supply chain management are associated with lower levels of supply chain wastes, confirming the theoretically expected inverse relationship.

The sub-hypotheses examining the effects of individual agility dimensions on Supply Chain Wastes reveal varying magnitudes of impact, though all demonstrate statistically significant negative relationships. Flexibility (H2.3) demonstrates the strongest effect on Supply Chain Wastes (β = -0.664, t = 19.504, p = 0.000), with a confidence interval ranging from -0.719 to -0.584. This finding suggests that the ability to adapt operations to accommodate changing requirements and diverse customer needs represents the most impactful dimension of agility for waste reduction. The strong negative effect indicates that organizations with greater supply chain flexibility experience substantially lower levels of waste, highlighting the critical importance of adaptability in minimizing inefficiencies.
Speed (H2.2) exhibits the second strongest effect on Supply Chain Wastes (β = -0.645, t = 19.188, p = 0), with a confidence interval ranging from -0.699 to -0.57.

This result highlights the significance of rapid response capabilities in minimizing waste, suggesting that organizations able to quickly execute operations and implement changes experience lower levels of inefficiency in their supply chains.

Competency (H2.4) demonstrates a similarly strong effect on Supply Chain Wastes (β = -0.604, t = 16.578, p = 0), with a confidence interval ranging from -0.663 to -0.515. This finding underscores the importance of organizational knowledge, skills, and expertise in reducing supply chain wastes. The substantial negative coefficient suggests that enhancing competencies related to agile supply chain management represents a valuable strategic approach for waste reduction.

Responsiveness (H2.1) exhibits the weakest effect among the agility dimensions, though it maintains a significant negative

relationship with Supply Chain Wastes (β = -0.553, t = 12.819, p = 0), with a confidence interval ranging from -0.625 to -0.456. The comparatively smaller magnitude of this effect suggests that while the ability to recognize and respond to changes contributes to waste reduction, its impact is less substantial than other dimensions of agility. This finding provides nuanced insights into the relative importance of different agility aspects, suggesting that organizations might prioritize flexibility, speed, competency and responsiveness when seeking to optimize waste reduction outcomes.

These capabilities support leaner operations and lead to significant improvements in overall efficiency and customer satisfaction. These findings are consistent with the studies by Gangaraju et al. (2023), which declared that supply chain agility enables organizations to respond quickly to changes in customer demand, decrease lead times, enhance product quality and boost customer satisfaction, which accordingly contribute to higher revenue, better profitability and sustainable growth.

The researcher attributes this relationship to the core principles of agility responsiveness, flexibility, adaptability, and rapid decision-making which enable organizations to identify and minimise various forms of waste, such as overproduction, delays, excess inventory, inefficient processes or processes that does not add value to the final product or service.

<u>The coefficient of determination (R^2)</u> quantifies the model's explanatory power which is illustrated in table 11, indicating the explanatory power across examining the effects of Agile Supply Chain Management and its dimensions on Supply Chain Wastes.

Table 11: coefficient of determination (R^2)

Independent	Dependent	R Square
Agile Supply Chain Management	Supply Chain Wastes	0.417
Responsiveness	Supply Chain Wastes	0.306
Speed	Supply Chain Wastes	0.416
Flexibility	Supply Chain Wastes	0.441
Competency	Supply Chain Wastes	0.365

In the beginning, all R^2 values fall within the acceptable range for social science research, where coefficients between 0.25-0.50 are

generally considered moderate to strong relationships in organizational and management studies (Strzelecki, 2024).

Agile supply chain management construct demonstrates an R^2 value of 0.417, indicating that approximately 41.7% of the variance in supply chain wastes is explained by agile supply chain management. Among the agility dimensions, Flexibility demonstrates the highest explanatory power with an R^2 value of 0.441, indicating that approximately 44.1% of the variance in supply chain wastes is explained by Flexibility. The Speed dimension similarly demonstrates robust explanatory power with an R^2 value of 0.416, indicating that approximately 41.6% of the variance in supply chain wastes is explained by Speed.

The Competency dimension shows moderate explanatory power with an R^2 value of 0.365, indicating that approximately 36.5% of the variance in supply chain wastes is explained by competency. Responsiveness dimension demonstrates the lowest explanatory power among the agility dimensions, though it still shows moderate predictive accuracy with an R^2 value of 0.306 indicating that approximately 30.6% of the variance in supply chain wastes is explained by responsiveness.

Moreover, the effect size F^2 is presented in table 12 providing insights into the substantive significance of the relationships between Agile Supply Chain Management dimensions and supply chain wastes, revealing varying levels of practical importance across different predictors.

Table 12: f^2 Effect Size

	f-square
Agile Supply Chain Management	**0.714**
Responsiveness	**0.441**
Speed	**0.711**
Flexibility	**0.790**
Competency	**0.574**

Examining the direct effect of overall agile supply chain management on supply chain wastes, the analysis reveals a large effect size with an f^2 value of 0.714, among the individual agility dimensions, Flexibility demonstrates the largest effect size with an f^2 value of 0.790, speed similarly demonstrates the second large effect size with an f^2 value

of 0.711, followed by competency with f^2 value of 0.574 and the least f^2 size is the responsiveness with value of 0.441.

<u>Predictive relevance</u>, is measured through Q^2 value, represents a critical assessment that evaluates the model's capability to accurately predict data for the future.

Table 13: Q^2 Predictive Relevance

Independent	Dependent	SSO	SSE	Q^2 (=1-SSE/SSO)
Agile Supply Chain Management	Supply Chain Wastes	2736	2348.704	0.142
Responsiveness	Supply Chain Wastes	2736	2477.536	0.094
Speed	Supply Chain Wastes	2736	2340.854	0.144
Flexibility	Supply Chain Wastes	2736	2314.995	0.154
Competency	Supply Chain Wastes	2736	2401.944	0.122

The overall Agile Supply Chain Management model exhibits a Q^2 value of 0.142, indicating medium predictive suggesting that the model not only explains variance in Supply Chain Wastes but also demonstrates reasonable capability to predict new observations of this construct. Among the individual agility dimensions, Flexibility demonstrates the highest predictive relevance with a Q^2 value of 0.154, followed by speed with 0.144, then competency with 0.122 while Responsiveness exhibits the lowest predictive relevance among the agility dimensions with 0.094.

Collectively, these results provide strong empirical support for the theoretical framework proposing that Agile Supply Chain Management and its dimensions significantly influence Supply Chain Wastes. All hypothesized direct effects are supported by the data, with statistically significant negative relationships observed across all paths. The varying scales of these effects offer valuable insights into the differential impacts of agility dimensions, with flexibility emerging as the most influential aspect for waste reduction, followed by speed, competency, and responsiveness. These outcomes suggest that while an integrated approach to agility yields substantial benefits for waste reduction, organizations might strategically emphasize particular dimensions

based on their relative impacts when resource constraints necessitate prioritization.

Moreover, the outcomes align with the earlier studies indicating that agile supply chain management plays a vital role in reducing lead times and improving both operational efficiency and cost-effectiveness. Additionally, agile supply chain management is considered a strategic approach for improving overall supply chain performance and optimizing inventory management as well as enhances the ability to respond more effectively to market variations. So, it likely to contributes in minimizing inefficiencies within the supply chain as a main element in waste reduction. Therefore, the results not only validate the estimated hypotheses but also support the objective of indicating how agile supply chain management serves as a practical and strategic tool for eliminating numerous forms of wastes in the supply chain.

11. Results and Recommendations:

- **Agile Supply Chain Management recorded a moderate average (Mean = 3.270, SD = 0.761), indicating that the organization holds moderate to good agility capabilities with a moderate consistency of responses (CV = 23.27%).**
- **Competency is the most positively rated agility dimension (Mean = 3.464, SD = 0.796), reflecting the respondents' belief that their organization owns strong capabilities, skills, and proficiency essential for agile processes.**
- **Speed ranks second among the agility dimensions with a mean of 3.278 (SD = 0.799), followed closely by Flexibility (M = 3.226, SD = 0.900). The relatively high mean values for these dimensions suggest that respondents generally perceive their organizations as possessing moderate to good capabilities in rapidly responding to changes (Speed) and adapting operations to accommodate varying requirements (Flexibility). However, Flexibility demonstrates the highest coefficient of variation among the agility dimensions (CV = 27.88%), indicating greater variability in perceptions of organizational flexibility compared to other agility dimensions. This variability may reflect significant differences in how organizations have developed and implemented flexible supply chain practices.**
- **Responsiveness recorded the lowest average rating among the agility dimensions (Mean = 3.111, SD = 0.725), indicating that the ability to swiftly detect and react to changes is seen as a weaker area. Though, its score still suggests moderate ability, with a coefficient of variation**

(CV = 23.31%) suggesting a fair level of consistency in respondents' observations.

- **Supply Chain Wastes exhibit the lowest mean score of all constructs (Mean = 1.625, SD = 0.462), which is good, as lower scores reflects better waste control. Respondents generally perceive their organization as efficiently minimizing and controlling supply chain wastes.**
- **The study results revealed a strong negative statistically significant relationship at level of of ($\alpha \leq 0.05$) between agile supply chain management and supply chain wastes with a correlation coefficient of -0.600. The most statistically significant dimension of the agile supply chain management is flexibility with a correlation coefficient of -0.627 followed by speed with a correlation coefficient of -0.612 then competency with a correlation coefficient of -0.545 then the least significant dimension was responsiveness with correlation coefficient of -0.470.**
- **Results showed that agile supply chain management affects supply chain wastes with -0.645, with a coefficient of determination of 41.7% of the variance in the dependent variable (supply chain wastes) with the remaining variation may be attributed to other factors. Moreover, the study showed that the most influential dimension is flexibility, followed by speed, competency and lastly responsiveness with B value of (-0.664, -0.645, -0.604, -0.553) respectively.**

12. Study Recommendations

This section presents five practical recommendations for implementing Agile supply chain management to reduce waste in natural gas vehicle companies. The recommendations are grounded in both scientific literature and field study findings from the organizational context.

12.1 Technology-Driven Recommendations

Recommendation 1: Enterprise Resource Planning (ERP) Implementation The study advocates for adopting cloud-based ERP systems to enhance data sharing across the supply chain network. This technological foundation enables faster, more accurate responses while building trust and transparency between suppliers, manufacturers, and logistics partners. Cloud-based platforms are particularly valuable for real-time visibility and coordination.

Recommendation 2: Agile Project Management Tools The research recommends implementing specialized Agile tools like Jira, Trello, or Asana to enhance the four key Agile dimensions: transparency, planning, flexibility, and speed. These tools also provide crucial tracking capabilities for supply chain operations, enabling better monitoring and continuous improvement.

12.2 Organizational and Strategic Recommendations

Recommendation 3: Cross-Functional Collaboration The study emphasizes fostering cross-functional teamwork for decision-making and problem-solving. Additionally, it recommends leveraging AI for demand forecasting and data analysis to reduce uncertainty - a critical factor in waste reduction.

Recommendation 4: Supplier Diversification A straightforward but essential recommendation to avoid single-vendor dependency, which can create vulnerabilities and increase waste when disruptions occur.

Recommendation 5: Business Continuity Planning The study recommends developing comprehensive backup plans to handle sudden disruptions, ensuring business continuity and minimizing waste during unexpected events.

12.3 Implementation Insights

These recommendations reflect a holistic approach that combines:

- **Technological infrastructure (ERP systems, project management tools)**
- **Organizational capabilities (cross-functional teams, AI integration)**
- **Risk management (supplier diversification, contingency planning)**

The recommendations appear to directly address the Agile dimensions studied (Responsiveness, Speed, Flexibility, Competency) while providing concrete, actionable steps that natural gas vehicle companies can implement to reduce supply chain waste. The emphasis on technology integration and collaborative approaches aligns with modern Agile principles and digital transformation trends in supply chain management.

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Appendix 1:

Questionnaire:

A: The demographic questions presented to participants as part of the research instrument:

What is your Job Position?

☐ **Manager** ☐ **Top Manager**

B: Variables

1. **Independent Variable: Agile Supply Chain Management**

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Responsiveness					
• **Ability of IT system to meet the expectations of users.**	○	○	○	○	○
• **IT-support methods for the analysis of competitive environment.**	○	○	○	○	○
• **Pre- and post-sales services.**	○	○	○	○	○
• **Maintaining and enhancing relationships with customers.**	○	○	○	○	○
• **The ability to predict market demand.**	○	○	○	○	○
Speed					
• **Access to information throughout the chain.**	○	○	○	○	○

• **Virtual Communication.**	○	○	○	○	○
• **Speed of exploring new markets.**	○	○	○	○	○
• **Emphasis on outsourcing.**	○	○	○	○	○
• **The use of web-based applications.**	○	○	○	○	○
Flexibility					
• **Ability to change delivery policies.**	○	○	○	○	○
• **Ability to purchase from different sources (different providers).**	○	○	○	○	○
• **Ability of being responsive to diverse demands of customers.**	○	○	○	○	○
• **Ability of supply chain staff to deal with sudden changes.**	○	○	○	○	○
• **Ability to change storage capacity.**	○	○	○	○	○
Competency					
• **Decentralized decision making.**	○	○	○	○	○
• **Vertical integration.**	○	○	○	○	○
• **Team-oriented goals and measures.**	○	○	○	○	○
• **Creation of infrastructure to**	○	○	○	○	○

encourage innovation					
• Relationships based on trust with partners.	○	○	○	○	○
• Appropriate Technology.	○	○	○	○	○

2. Dependent Variable: Supply Chain Wastes

	Totally Agree	Agree	Neutral	Disagree	Totally Disagree
• By the nature of your work, materials and products transportation minimization facilitates the control of materials and human resources.	○	○	○	○	○
• Materials and products transportation minimization reduces the necessary energy, such as, number of workers and electricity.	○	○	○	○	○
• Materials and products transportation minimization in your company reduces the risk of damaged units or defects.	○	○	○	○	○

• **Defects minimization leads to better reputation with customers and increasing the marketing of the product.**	○	○	○	○	○
• **Defects minimization reduces the excess movement of workers.**	○	○	○	○	○
• **Workers and machines waiting minimization facilitate the monitoring of product quality.**	○	○	○	○	○
• **By the nature of your work, workers and machines waiting minimization reduces the materials transport between work stations and machines.**	○	○	○	○	○
• **When you minimize the excess inventory through working, your production defective units are less.**	○	○	○	○	○
• **When you minimize the excess inventory through working, you are better exploiting areas of the workplace.**	○	○	○	○	○
• **Excess inventory minimization**	○	○	○	○	○

reduces the number of workers needed in your production.					
• **There is a lot of tacit knowledge that ends up being lost due to the lack of adequate knowledge management.**	○	○	○	○	○
• **There are employees working in positions that require skills much lower than their training or education levels.**	○	○	○	○	○
• **Employee experiences are not fully explored.**	○	○	○	○	○
• **Employee capabilities are not fully utilized.**	○	○	○	○	○
• **Employee skills are not fully utilized.**	○	○	○	○	○