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# Adoption of Cloud Computing in Logistics: Insights from Expert Survey in the Context of Industry 4.0*

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## Abstract

Cloud computing is shaping the digital transformation of logistics by offering scalability, real-time visibility, and predictive decision-making. Adoption varies across organizations, and challenges such as vendor lock-in, regulatory compliance, and workforce readiness continue to influence progress. This study considers the perspectives of 25 logistics professionals to provide an initial picture of current practices, expected benefits, and persistent barriers. The findings show that large organizations in manufacturing and distribution are further along in adoption, while smaller firms remain at earlier stages. Respondents highlighted predictive analytics, operational scalability, and environmentally sustainable logistics as the most consistent benefits. They also recommended phased migration strategies, targeted training programs, and integration with technologies such as artificial intelligence, the Internet of Things, blockchain, and robotics. To ensure that the survey questions were reliable, a Cronbach's alpha test was conducted for each group of Likert-scale items. All groups showed good internal consistency (α between 0.81 and 0.91), meaning that respondents answered the related questions in a consistent way. This confirms that the survey instrument was statistically reliable and suitable for analysis. These insights contribute to ongoing discussions on digital transformation in logistics and provide a foundation for future empirical research.

**Keywords:** Cloud Computing, Logistics, Industry 4.0, Digital Transformation

## Introduction

Cloud computing has become one of the key forces behind the digital transformation of logistics. Many companies now face growing pressure to gain better visibility across their operations, reduce costs, react more quickly to changing customer demands, and meet ambitious sustainability goals. As defined by Mell and Grance (2011), cloud computing provides scalable and on-demand access to shared computing resources, a principle that still captures the essence of how technology is applied in both research and everyday business practice.

Within logistics, cloud solutions are often described as enablers of innovation and operational flexibility. As Marston et al. (2011) observed, the main advantage of the cloud lies in its ability to replace capital-intensive IT systems with more adaptable, service-based infrastructures. This flexibility is particularly valuable in logistics, where workloads constantly fluctuate and coordination across the supply chain must happen in real time.

Adoption, however, is far from uniform. Gupta et al. (2013) show that smaller companies often struggle with limited budgets, a shortage of technical expertise, and ongoing worries about data security, while larger organizations tend to have the means to test and deploy advanced logistics platforms. Vial et al. (2019) also highlights that technology adoption depends not only on technical readiness but also on cultural and managerial willingness to embrace new ways of working.

Recent research places cloud computing within the broader Industry 4.0 ecosystem. Buyukozkan and Gocer (2018) identify cloud computing, IoT, big data analytics, and artificial intelligence as core technologies driving

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digital supply chains. Similarly, Enache (2023) argues that the growing adoption of cloud-based systems and IoT in logistics significantly increases cybersecurity risks that must be actively managed. Bajdor (2024) further highlights that cloud computing can support sustainable supply-chain management and organizational sustainability, although barriers such as implementation costs and digital competency gaps remain.

Even with this growing body of work, little is known about how logistics professionals themselves view the opportunities and challenges of adopting cloud technologies. Much of the existing literature remains conceptual or based on single case studies. Broader, survey-based research remains rare, yet it is essential for understanding how adoption trends vary across organizations and how they fit into larger Industry 4.0 strategies.

This study aims to fill that gap by examining the current state of cloud adoption in logistics and by capturing professionals' views on its benefits, barriers, and enabling technologies. It is guided by two main questions:

1. How do logistics professionals perceive the key benefits and challenges influencing the adoption of cloud computing within Industry 4.0 environments?
2. How can best practices and complementary technologies encourage more effective adoption of cloud solutions in logistics?

By exploring these questions, the paper contributes to ongoing discussions about digital transformation in logistics. It highlights both the potential of cloud computing, and the practical barriers organizations still face, offering insights into how these technologies can be more effectively integrated with Industry 4.0 tools to improve logistics performance.

## Materials and Methods

2.1. Research workflow

The research followed a structured workflow designed to ensure clarity and reproducibility.

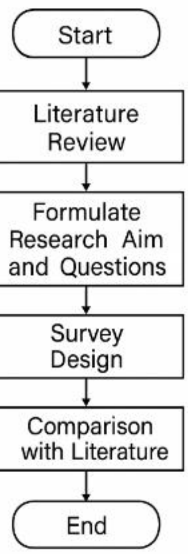


**Figure 1. Research workflow.**

Figure 1 presents the research workflow followed in this study. The process began with a structured literature review on cloud computing in logistics and Industry 4.0 to identify existing research gaps and define the conceptual foundation of the study. On this basis, the overall research aim and guiding questions were formulated.

The second stage involved the design of a survey questionnaire structured around five main themes: (i) demographics and organizational context, (ii) extent of cloud adoption, (iii) barriers and challenges, (iv) anticipated benefits, and (v) best practices and complementary technologies.

In the third stage, the survey was distributed to logistics professionals through academic and professional networks. Data were collected over a four-week period. Quantitative items were analyzed using descriptive statistics, while open-ended responses were coded thematically. The results were then compared with insights from the literature to identify areas of alignment and divergence.

## Data collection

Data were gathered through a structured online survey conducted between April and May 2025. The target group consisted of professionals working in logistics, supply chain management, information technology, and related areas. Invitations were shared through university contacts, professional associations, and LinkedIn groups focused on logistics and digital transformation to reach a diverse audience.

The questionnaire included both closed and open-ended questions. Closed-ended items captured demographic details such as professional role, years of experience, company size, and industry sector, while open-ended items invited participants to elaborate on barriers, benefits, and best practices.

**Table 1. Description of participating experts.**

| Category | Description |
|---|---|
| Number of respondents | 25 |
| Average professional experience | 10–15 years |
| Primary fields | Logistics (40%), Supply Chain (28%), IT/Systems (20%), Other (12%) |
| Company size | Small (24%), Medium (36%), Large (40%) |
| Industry sectors | Manufacturing, Retail, Transportation, Logistics services |
| Positions | Managers, Analysts, Engineers, Consultants |

A total of 25 complete responses were received. Although the sample size is modest, it provides meaningful insights from experienced professionals, aligning with the exploratory nature of this research.

## Results

### *Adoption levels*

Figure 2 illustrates the distribution of cloud adoption levels among the 25 professionals surveyed. The results show that cloud technologies are already widely integrated in logistics and related sectors.

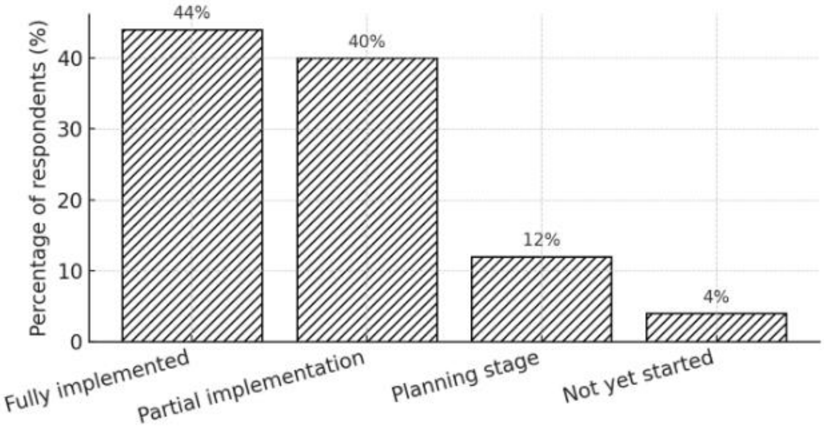


**Figure 2. Cloud adoption levels among surveyed professionals (n = 25).**

Nearly half of the respondents (44%) reported full implementation of cloud solutions within their organizations, while 40% indicated partial deployment. A smaller group (12%) stated that adoption was still in the planning phase, and only one respondent (4%) reported that implementation had not yet started. Overall, the figure suggests that most organizations represented in the sample are already engaging with cloud technologies to some extent, reflecting the growing role of digital transformation and Industry 4.0 practices in logistics operations.

Figure 3 presents the overall distribution of barriers to cloud adoption. The answer options were developed based on findings from the literature review, which identified common technical and organizational obstacles discussed by scholars such as Marston et al. (2011), Vial et al. (2022), Ben-Daya et al. (2019), and Ivanov et al. (2019).

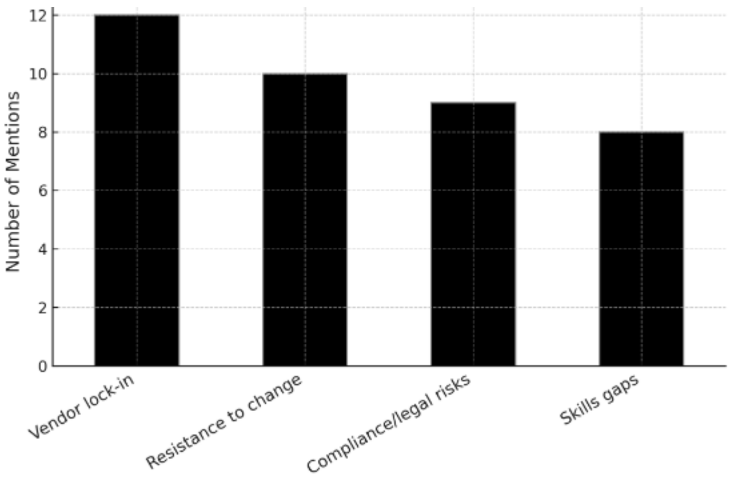


**Figure 3. Barriers to cloud adoption.**

Respondents confirmed several of these challenges as continuing to limit the adoption of cloud computing in logistics. Vendor lock-in was the most frequently mentioned barrier, cited by 12 respondents (46%). Resistance to change followed with 10 mentions (38%), while compliance and legal risks were noted by 9 participants (35%). Skills gaps were reported by 8 respondents (31%). These findings indicate that both technical dependencies and organizational readiness continue to influence cloud adoption decisions. To assess the relative importance of these challenges, respondents also rated each barrier on a five-point scale (1 = not a barrier, 5 = major barrier). The resulting mean severity scores reflect the perceived significance of each factor across organizations of varying sizes and digital maturity.

**Table 2. Mean Barrier Ratings by Organization size.**

| Organization size | Vendor lock-in | Change resistance | Staff skills/training |
|---|---|---|---|
| Small (1–50) | 3.50 | 4.67 | 3.67 |
| Medium (51–250) | 3.67 | 3.67 | 3.75 |
| Large (251–1000) | 2.40 | 4.00 | 4.00 |
| Very Large (1000+) | 3.30 | 3.90 | 4.00 |

Table 2 presents the mean barrier ratings by organization size. Small firms gave the highest rating for resistance to change (4.67), suggesting cultural and managerial barriers are more pressing in resource-constrained settings. Medium-sized firms emphasized vendor lock-in (3.67) and skills shortages (3.75). Very large organizations highlighted staff training needs (4.00) while also rating vendor lock-in as a persistent concern (3.30).

**Table 3. Mean Barrier Ratings by Industry Sector.**

| Industry sector | Vendor lock-in | Change resistance | Staff skills/training |
|---|---|---|---|
| Distribution | 3.43 | 4.14 | 4.50 |
| Manufacturing | 3.33 | 4.00 | 3.67 |
| IT | 3.00 | 3.25 | 3.60 |
| Transportation | 2.33 | 4.00 | 4.00 |

Table 3 represents mean barrier ratings for the industry sector. Distribution companies reported the greatest need for staff training (4.50), while manufacturing respondents also stressed resistance to change (4.00) and vendor lock-in (3.33). IT firms rated vendor lock-in (3.00) and resistance (3.25) lower, although staff skills remained a concern (3.60). Transportation respondents indicated high training needs (4.00) and resistance (4.00) but rated vendor lock-in lower (2.33).

**Table 4. Mean Barrier Ratings by Stage of Adoption.**

| Stage of adoption | Vendor lock-in | Change resistance | Staff skills/training |
|---|---|---|---|
| Planning stage | 3.00 | 3.00 | 3.00 |
| Partial implementation | 2.78 | 4.10 | 3.78 |
| Fully implemented/operational | 3.62 | 4.00 | 4.40 |

Table 4 presents the mean barrier ratings by stage of adoption. Organizations in the planning stage reported moderate scores across barriers (around 3.00). Firms in partial implementation stressed resistance to change (4.10) and staff training (3.78). Fully implemented organizations reported the highest training needs (4.40) and vendor lock-in (3.62), showing that challenges persist even at advanced stages of adoption.

**Table 5. Anticipated Benefits.**

| Benefit | Respondents (n) | % of sample |
|---|---|---|
| Real-time dashboards | 18 | 69.2% |
| Predictive analytics | 17 | 65.4% |
| Adaptive & intelligent systems | 16 | 61.5% |
| Green logistics | 11 | 42.3% |
| Global scalability | 11 | 42.3% |

Table 5 presents the distribution of anticipated benefits. Respondents identified several benefits from adopting cloud technologies in logistics. The most frequently mentioned were real-time dashboards (18 respondents, 69.2%), predictive analytics (17, 65.4%), and adaptive and intelligent systems (16, 61.5%). Green logistics and global scalability were each noted by 11 respondents (42.3%). These findings suggest that professionals view cloud adoption not only as a tool for operational efficiency but also as a pathway toward greater sustainability and decision-making intelligence.

**Table 6. Best practices.**

| Best Practice | Respondents (n) | % of sample |
|---|---|---|
| Staff training | 20 | 76.9% |
| Change management planning | 17 | 65.4% |
| Phased migration | 16 | 61.5% |
| Strong data security strategy | 15 | 57.7% |
| Use of expert consultants | 10 | 38.5% |

Table 6 summarizes the responses on best practices. Respondents highlighted several best practices to support successful cloud adoption in logistics. The most frequently cited recommendation was staff training (20 respondents, 76.9%), reflecting the importance of workforce preparation and digital skills. Change management planning was mentioned by 17 respondents (65.4%), underlining the need for structured organizational support during transition. Phased migration was advised by 16 participants (61.5%) to reduce implementation risks, while data security strategies were cited by 15 (57.7%) as essential to maintaining trust and compliance. Finally, 10 respondents (38.5%) suggested the use of expert consultants to guide the adoption process.

**Table 7. Complementary technologies.**

| Technology | Respondents (n) | % of sample |
|---|---|---|
| Artificial Intelligence (AI + variants) | 4 | 15.4% |
| IoT integration | 1 | 3.8% |
| ERP systems | 1 | 3.8% |
| Connectivity improvements (e.g., internet) | 1 | 3.8% |
| Other isolated mentions (1 each) | 5 | 3.8% each |
| "No idea" | 1 | 3.8% |

When asked about technologies that could complement cloud adoption, respondents most often pointed to artificial intelligence (AI), mentioned in several forms including AI agents and deep learning (4 respondents, 15.4%). IoT integration was suggested by one respondent (3.8%), reflecting interest in real-time data connectivity. Other mentions included ERP systems (3.8%), improved internet connectivity (3.8%), and delivery optimization tools (3.8%).

While responses were fragmented, the emphasis on AI indicates that logistics professionals increasingly view intelligence-driven applications as central to realizing the value of cloud computing. The references to IoT, ERP, and connectivity also highlight the importance of interoperability and system integration.

## *Results validation*

Before analyzing the results, the reliability of the survey questions was checked to make sure that people answered similar questions in a consistent way. This was done using a method called Cronbach's alpha (α), which shows whether a group of questions measures the same general idea. If people answer all the questions in a group in a similar way, the alpha value will be high. If their answers vary a lot, the alpha will be low.

The reliability test was done in Python using an automated calculation. For each topic group (Barriers and Challenges, Anticipated Benefits, and Best Practices), the program compared how strongly the answers to the questions were related. To make the results more reliable, a method called bootstrapping was used. This means the computer repeatedly mixed and re-tested the same data (1000 times) to see how much the result could change if the study were repeated.

The small range shown as 95% confidence interval (CI95) gives the limits where the true alpha value is most likely to fall. Cronbach's alpha tells how consistent the answers are. CI95 tells how confident we are in that consistency score.

**Table 8. Results validation through Cronbach's alpha analysis.**

| Topic | Cronbach's α | 95 % CI | Interpretation |
|---|---|---|---|
| Barriers and Challenges | 0.81 | [0.73 – 0.87] | Good consistency |
| Anticipated Benefits | 0.84 | [0.76 – 0.89] | Good consistency |
| Best Practices | 0.91 | [0.86 – 0.94] | Very high consistency |

The results show that all three groups of questions were consistent. The Barriers and Challenges group ($\alpha = 0.81$) measured the main obstacles in a reliable way. The Anticipated Benefits group ($\alpha = 0.84$) also showed good agreement, meaning respondents understood the benefit items similarly. The Best Practices group had a very high score ($\alpha = 0.91$). This means the questions were strongly related, but it may also suggest that a few items repeated the same idea (for example, staff training and change management planning). In future surveys, these could be merged or rephrased.

Although the results are reliable, two limitations should be mentioned. First, the survey sample was small (25 participants), which can slightly affect how stable the alpha scores are. Second, Cronbach's alpha only shows that the answers are consistent; it does not prove that the questions measure the right concept. Future studies with more respondents could also use factor analysis to confirm how the questions group together.

## Discussion

### *Findings*

The survey results provided insight into how logistics professionals perceive cloud adoption within Industry 4.0 environments. The findings reaffirm several patterns reported in previous studies, yet they also offer contextual nuances and practitioner-based perspectives that extend existing knowledge.

Vendor lock-in, resistance to change, and workforce skills were consistently identified as key challenges (Marston et al., 2011; Buyukozkan et al., 2021; Vial et al., 2019). However, the data show that these barriers are perceived differently depending on the organization's maturity and size. Smaller firms emphasized cultural and financial constraints, while larger organizations were more concerned with dependency on external providers and the integration of legacy systems. This suggests that the nature of the barrier evolves with the stage of digital maturity, adding a layer of understanding that goes beyond earlier conceptual models.

The results also reveal that logistics professionals do not view cloud adoption as a purely technical process. Instead, they describe it as a strategic and human-centered transformation, where success depends on leadership commitment, continuous training, and internal communication. This practitioner insight complements existing research that has mainly focused on technical or infrastructural determinants.

In terms of benefits, predictive analytics, scalability, and green logistics emerged as the most valued outcomes. While these align with prior literature (Ben-Daya et al., 2019; Sun et al., 2022), respondents particularly emphasized real-time dashboards and adaptive systems as tools that improve daily decision-making and operational visibility. This points to a shift from strategic aspirations to practical, data-driven implementation, indicating that logistics companies are moving from experimentation toward operational integration.

Another contribution of this research lies in identifying the balance between optimism and caution among practitioners. Respondents acknowledged the transformative potential of cloud solutions but also expressed concern about long-term dependency, data governance, and maintaining human oversight in increasingly automated systems. This balanced view adds empirical depth to theoretical debates on digital transformation readiness and resilience (Ivanov et al., 2019).

Overall, the findings extend previous literature by bringing forward the voice of logistics professionals illustrating how adoption decisions are interpreted and experienced in practice, rather than only theorized. They highlight that the true challenge in cloud-based logistics transformation lies not in technology availability but in the organizational ability to align people, processes, and strategy to fully realize digital value.

### *Research limitations and further steps*

Several limitations should be acknowledged when interpreting the results.

First, the sample size was small (n = 25), which limits the statistical generalization of the findings to the broader logistics sector. The survey relied on voluntary participation, introducing a potential self-selection bias, as individuals with a strong interest in digital transformation may have been more likely to respond. The cross-sectional design captured opinions at a single point in time, preventing the observation of changes in attitudes or adoption maturity as organizations progress in their digital transformation journeys.

Second, some sections of the survey, particularly those related to benefit ratings and compliance-related barriers, had incomplete or uneven coding, which restricted the depth of quantitative comparison possible at this pilot stage. These data limitations highlight the need for a larger and more balanced sample to achieve stronger statistical validity.

Despite these constraints, the study serves as an important foundation for ongoing PhD research. The next phase aims to extend the survey to approximately 385 logistics professionals across various regions and firm sizes. This expanded dataset will allow for more advanced quantitative analysis, including hypothesis testing, correlation modeling, and segmentation by firm size, sector, and digital maturity. Such an approach will improve reliability, enhance the external validity of findings, and enable meaningful comparisons across European and global logistics contexts.

While this pilot phase validates the research framework and reveals preliminary patterns, the forthcoming large-scale study will provide the depth and statistical power needed to draw stronger conclusions and develop practical guidelines for cloud-enabled logistics transformation.

## Conclusions

Cloud computing is an essential driver of digital transformation in logistics. This study explored how industry professionals perceive its benefits, barriers, and best practices. The findings show that adoption is advancing across organizations but remains influenced by provider dependency, workforce readiness, and organizational culture. The most anticipated benefits, predictive analytics, scalability, and sustainability reflect a growing strategic alignment between digitalization and environmental performance.

The study reinforces that cloud adoption in logistics is both a technological and organizational process. Effective implementation requires not only infrastructure investment but also strong leadership, continuous staff training, and careful management of vendor relationships.

Future work within the PhD research will extend these findings using a larger dataset to validate the observed patterns. This next phase will provide a comprehensive view of how cloud computing contributes to agility, efficiency, and sustainability in logistics under Industry 4.0.

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