Decarbonizing Industrial Logistics

—PHILIPP MIKLAUTSCH
Chair of Industrial Logistics, Montanuniversität
Leoben, 8700 Leoben, Austria

—MANUEL WOSCJANK
Chair of Industrial Logistics, Montanuniversität
Leoben, 8700 Leoben, Austria

(Corresponding author: Philipp Miklautsch.)

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Abstract—Transport decarbonization is a major climate change mitigation challenge. Transportation is an industry that takes significant effort to change. It is the basis of every person’s daily life. People’s mobility and freedom are central to their quality of life. Global goods transport also ensures that the supply chains can source raw materials, intermediate, and end products. Freight transport is a complex interaction between multiple actors and stakeholders. Using interviewed expert insights, we provide insights for managers and organizations on factors influencing the decarbonization of transportation and industrial logistic. We map the interrelationships of those factors and create factors and enabler interrelationships visualizing the complex dependencies among them. We identify two major propositions on how to decarbonize industrial logistics on a broad scale—with the goal of future proofing this decarbonization.

Key words: Climate change, decarbonization, logistics, technology

1. INTRODUCTION

Industrial logistics is concerned with the planning, implementation, controlling, and continuous optimization of material flows and associated information flows [1]. Logistics’ primary role is to align customer requirements with social and regulatory pressures. Central to this evolving pressure is the alignment of logistics to climate protection targets. Global freight transportation is central to managing greenhouse gases (GHG)—the scientific consensus of the major contributor to climate change [2].

Industrial shippers require transportation activities to move raw materials, by-products, and finished goods in their in- and outbound logistics. These industrial transportation and logistics activities are central to manmade consumption-based responsibility for GHG emissions. Initiatives to reduce these emissions are frequently marketed by companies, but these GHG emissions from the freight transport sector continue to grow as if no crisis exists.

Current evidence shows that logistics industry decarbonization practices have yet to reach their potential [3]. Some pioneers in low-carbon industrial logistics do exist. We explore the underlying mechanisms to understand what distinguishes these exemplary organizations from less aggressive organizations. We briefly introduce a broader background in Section 2 followed by some insight into how we captured the information. Our results are then presented in Section 3. We then provide interrelationships and what they mean to managers and organizations in Sections 4 and 5. Finally, Section 6 concludes this article.

2. BACKGROUND

According to institutional theory, greening industrial firms can occur from external pressures and from various stakeholder groups. Powerful stakeholders put coercive pressures on organizations, such as when the government sets carbon taxes. Customers may put on competitive and normative pressures when they demand certain green actions through conscious buying behavior. Organizations may also face mimetic competitive pressures from other
organizations [4], [5]. Thus, a variety of pressures and responses are likely to occur.

In order to understand industrial logistics decarbonization, we conducted a series of semistructured interviews with logistics experts from exemplar organizations in the automotive, metal, food, and materials sector. These exemplar organizations have implemented low-carbon practices in their logistics processes. We also interviewed consultants and academics to provide a broader view of the industry decarbonization.

The semistructured interview guideline was developed in collaboration with researchers and practitioners. Ten interviews were conducted with experts. We transcribed interviews and then analyzed them using content structuring content analysis [6]. Within this approach, a categorization is derived from the interview guideline followed by coding and text passage inclusion to help maintain the quality and validity of our findings [7].

3. RESULTS OF THE STUDY

The content structuring content analysis resulted in two sets of factors. The first set describes the positive and negative factors that affect willingness to adopt low-carbon industrial logistics practices. Those factors are further grouped into external and internal factors. The factors can also be viewed as barriers or motivators and are dependent on the industry sector, the company size, and the organizational culture.

These factors are fairly consistent with various institutional theoretic pressures [5]. This outcome highlights the validity of the results. Our discussion will focus on the enablers. Enablers are success factors that facilitate the broad adoption of low-carbon industrial logistics practices. The identified external and internal factors, as well as the enablers, are summarized in Table 1.

3.1. Factors Affecting the Willingness to Adopt Industrial Logistics Decarbonization Practices  

A broad variety of factors were provided by our experts—each falling within the institutional pressure dimensions. We now provide some insights into the most predominant linkages to industrial logistics companies’ willingness to adopt industrial logistics decarbonization practices from the broader set in Table 1. The most often mentioned factor is that the costs of transportation will rise significantly when adopting low-carbon practices in logistics (COSTS). The prospect of rising costs is a barrier because the transport sector is a highly competitive cost-driven industry; charging premiums for offsetting the costs is not feasible.

The manufacturing industry—the shippers of the goods to be transported—is not willing to pay the carriers more for green transport services. This situation does not mean that the shippers are not ready to implement low-carbon practices, but they resist decarbonization initiatives that will result in higher transportation costs. Shippers are ready to implement practices when they are at cost neutral—one way of achieving cost neutrality is by reducing through a strategic reconfiguration of supply chain nodes.

Two other dominant factors closely connected with costs are based on regulatory forces. First, the existing internalization of external cost approaches, such as carbon emissions’ taxes or requiring participation in an emission trading scheme (INTER), is too low to incentivize low-carbon technologies

| Table 1. Factors and Enablers of Decarbonization in Industrial Logistics. |
|---------------------------------------------------------------|
| Factors influencing the willingness to adopt practices | Internal enablers |
| Shareholder value | SHARE | Strategic positioning regarding the investment in future technologies | STRAT |
| Internealization of external costs and incentives to reduce GHG emissions | INTER | Key figures with appropriate responsibility and self-motivation | FIGURES |
| Development of the energy market | ENERGY | Exchange and communication with stakeholders | COMM |
| Market participants | PARTI | Use of software | DIGI |
| Clear requirements for reporting and calculating GHG emissions | REQ_GHG | Transparency and knowledge of emissions and operational processes | TRANSP |
| Legislation, permits, and subsidies | LEG | Pilot projects as test runners with low risk | PILOT |
| Availability of necessary infrastructure and technology | INFRA | Logistics organizational structure | ORGA |
| Citizens and regional policy | CITI | Awareness, motivation, and competence of employees | EMPL |
| Commitment of the owner or board of directors | MGMT | Level of control of transportation processes | CONTROL |
| Marketing, image, and reputation | IMAGE | Definition and operationalization of goals | GOALS |
| Costs and possibility of passing them on to customers | COSTS | Tendering and long-term contracts with service providers | LSP |
| Operational efficiency and service level | EFF | Use of services and consulting as well as outsourcing | SERV |
| Corporate culture and policy | CULTURE | Other | OTHER_SUC |
and practices adoption. Second, uncertainty in regulations, as well as subsidies (LEG), discourages organizations from investing. New decarbonization supporting technologies may require significant investments in vehicles and infrastructure. Companies are not prepared to make these investments without the support of subsidies to lower potential technology risk. This risk arises from skepticism about regulatory strategies that may shift in the future. Another risk source is the volatile energy markets (ENERGY), which make cost estimates difficult and subject to significant uncertainty.

Managerial attitude and perception are crucial for any organizational investment. Therefore, management commitment is an important influencing factor for industrial logistics decarbonization (MGMT). This commitment has been found to be positively correlated to the size of the company. This issue may arise due to the larger visibility of and more resources available in larger companies.

We found that investments, costs, and management commitment are closely related to other factors, namely marketing, image, and reputation (IMAGE). The more a company is the focus of media attention, the more it is willing to invest in green measures—as long as the communication of the measures attracts customers or reassures shareholders.

Eventually, respondents made clear that further investments in green practices and their communication do not result in enough marketing and reputation-building value to be justified. Many initiatives are, thus, not pursued. This phenomenon—mentioned many times by experts—can be observed in many companies that started implementing battery electric vehicles (BEVs) or natural gas trucks in creating media attention for their green logistics initiatives. Many times these initiatives stopped prematurely after one or two vehicles were in operation and were never truly institutionalized into the company.

Lack of customer consciousness and marketing impact is not solely to blame for the lack of logistics decarbonization implementation. Another factor that arose from our interviews is a lack of infrastructure (INFRA). Infrastructure is needed to change logistics systems and start with the widespread availability of alternative energy vehicles, new charging and refueling infrastructure, as well as intermodal terminals and rail lines that are suitable for freight transport.

3.2. Enablers Affecting the Success of Industrial Logistics Decarbonization Practices

The other set of identified factors comprise factors determining the success of industrial logistics low-carbon practices—it is for this reason, we identify these factors as enablers and go beyond just the willingness to adopt the practices. The full set of enablers appears in Table 1. In this section, we focus on specific enablers that were mentioned numerous times in different contexts throughout the interviews. Due to the frequency of mentions, we initially view these as the most important enabling factors.

The most frequently mentioned enabler is anchoring logistics decarbonization in the business strategy (STRAT). These strategies—when they exist in organizations—need to be sufficiently operationalized. The exemplar organizations identified two major reasons for the strategic importance of logistics decarbonization. The first reason is that fossil-free logistics is an unavoidable future scenario. By building on this strategic perspective, a strategic tradeoff between the logistics emissions and the short-term cost is completed. Much of this scenario is replete with uncertainty since many times the organizations are unlikely to be familiar with new technologies and practices to support this endeavor.

By investing in these decarbonization technologies, the organizations wanted to prepare now for the ultimate long-term scenario. They also felt that they could build competitive advantage when fossil-free logistics become mandatory or unavoidable. Currently, costs for those technologies are higher than costs for traditional technologies. Companies justify these higher costs for transportation by reducing risks of unacceptable future costs of transportation or even the unavailability of transportation services.

The second reason to accept an industrial logistics decarbonization strategy is to create security. Investments in green logistics and transportation solutions can reduce the dependency on volatile energy and carbon emission markets. Uncertainty in these markets is great. Decoupling from these uncertainties and contingencies creates security for the organization itself, as well as its customers and supply chain partners.

To integrate and execute the organizational strategy, human resources input and supporting values are necessary. A part of this is building a culture that supports these values, fosters awareness of climate risk, and creates innovative ideas on how to minimize those risks. The presence of key figures and champions with these perspectives is of utmost importance (FIGURES). Those supportive figures can exist at all employee levels. They need to be motivated to mitigate climate impacts and also need to be able to influence decisions made in the company—
either by being the decision makers themselves or by being recognized and consulted by the decision makers.

Many times these champions require stamina and persistence, the decision-making process for investments that will only pay off in the future is perceived as quite lengthy and may be fully discounted. Many of the respondents were key figures and mentioned that significant personal interest and spare time were invested in the development of ideas and knowledge on decarbonization topics.

Building knowledge includes reading specialist magazines, listening to pertinent podcasts, or participating in different advocacy groups or industry clusters. The importance of working and communicating with advocacy groups and industry associations was so frequently discussed that we categorized it as a separate enabler (COMM).

These groups of stakeholders can be industrial partners, logistics service providers (LSP), representatives of the authorities or regulators, or customers. Information and knowledge exchange on low-carbon technological or process innovations, funding opportunities, or the state of adoption across the industry were each seen as crucial for the success of logistics decarbonization solutions. These issues are, especially, pertinent as many parties are involved in transportation activities by nature.

Communication with LSP was important because the experts perceive smaller LSPs to have little knowledge about low-carbon measures and practices. Therefore, shipper experience gained in pilot projects conducted with larger LSP can be a valuable facilitator in driving the adoption of measures. This characteristic is seen as another important enabler to reduce manager, employee, and partner concerns with changes to old proven systems (PILOT).

Before any changes can be made to established systems, they must first be known and made transparent (TRANS). The importance and difficulty in achieving holistic transparency in logistics systems exist because many parties are involved across multiple processes—many times the companies do not even have control of these processes. This situation highlights the difficulty to calculate carbon emissions in inbound and outbound transportation activities, hindering comparable and meaningful emission reporting. This lack of meaningful reporting and transparency lowers the managerial relevance of reducing emissions.

Holistic software systems implemented on a supply chain level for processing information from all partners (DIGI) is a dimension that can overcome transparency concerns. Digital systems cannot only provide transparency but also aid in calculating emissions and providing decision support for specific decarbonization implementation measures. But, it has also been observed that current software and digitization solutions are limited in how holistic they are; also observed is lagging disruptive innovations in this area.

4. INTERRELATIONSHIPS AND IMPLICATIONS OF IDENTIFIED FACTORS

In our discussions and analysis, we found that the factors and enablers are strongly connected and influence each other in multiple ways. We started documenting various interrelationships between the factors and enablers—the threads of a spiderweb of relationships—graphically summarizing them in Figure 1.

In this figure, the color of the link provides insight into the characteristic of the node and its influence. Blue nodes and links represent external
factors, green ones are internal factors, and yellow ones are enablers. Note that no links have external factors as end nodes; in these cases, it is unlikely that these external nodes will be influenced from within a single organization.

The identifier terms used in Figure 1 are the same as the factor and enabler identifiers from Table 1. These interrelationships provide a systemic and deeper understanding of the underlying mechanisms for industrial logistics decarbonization.

When investigating the spiderweb, the first major observation is the many blue links that are connected to the enabler STRAT. This observation indicates a strong alignment of strategic positioning to external pressure, for example, from legislation or shareholders. Besides the strategic aspects, transparency and digitalization seem to be significantly influenced by the government and the communication to other stakeholders due to regulatory or mimetic pressure.

In general, many black arrows are directed toward the strategic factor, showing the vast amount of other factors and enablers that exert pressure on decision makers and influence far-reaching strategic decisions. Another prominent factor includes costs, which are found to be at the center of all decisions related to decarbonization. What is further eye-catching is the yellow connections among the yellow nodes. This within the group observation highlights the strong mutual dependence of the enablers. A reason for this observation is that institutionalizing some enablers results in the institutionalization of other enablers. An example of this interrelationship is the link between organizational structure and key figures’ enablers. These factors are complementary as the existence of an appropriate organizational structure can establish the existence of motivated and influential key figures and vice versa.

From these links, we are able to draw two main propositions on a decarbonized and future-proof industrial logistics system for organizations and managers, which we will now discuss with an allusion to Figure 1. The first major proposition is that holistic systemic decisions are needed; the second major proposition is that energy management will be a central fundamental for decarbonization. We delve further into these general perspectives.

4.1. Importance of Holistic Decision Making in Industrial Logistics

Logistics decisions can be made in a hierarchical structure across four levels where decisions at the upper levels determine the decision space of the lower levels. The levels comprise structural decisions that set the basic supply chain structure, commercial decisions that define the customer, supplier, and service provider base, operational decisions that determine which activities are carried out on a daily basis, as well as functional decisions that specify technical details on how those activities are carried out [8]. Rising costs of logistics activities that accompany new technologies and energy carriers are the most important factor facing companies seeking to be greener or decarbonized.

Technical details for manufacturers and customers of logistics and transportation usually occur at the lower levels of decision making in logistics—namely, the functional or operational level. These levels are usually outsourced to LSPs. LSPs can only operate within the agreed contractual provisions, which are determined by decision makers on the commercial level. This situation provides a first indication that organizations should make logistics-related decisions consistent across hierarchical decision-making levels and carefully consider changes in lower level decisions that are potentially outsourced.

Identifying and pursuing “win–win” outcomes through the mitigation of emissions and cost reductions are important goals. One common approach to achieve win–win outcomes that arise from a reduction of transportation demand and activities. Practices to operationalize this approach must be decided at the upper hierarchical level of decision makers because this approach necessitates structural or commercial decisions. Examples include changing the location of suppliers, warehouses, plants, or customers. These decisions are strategic, far-reaching, and affect more than just logistics functions. But minimizing transportation demand at the same time minimizes fuel demand and is an example, which is directly related to costs and emissions.

To exploit these potentials, one respondent recommends that a single “Supply Chain Department” of the organization, made up of multiple functions and levels, manages this process. The strategic decision maker is responsible for structural decisions, including facility location decisions, and commercial decisions, such as supplier selection, in addition to functional and operational decisions, such as scheduling of trucks for deliveries and dispatches. Establishing this type of cross-cutting function can ensure end-to-end responsibility for material flows—as well as associated emissions—throughout the entire company.

Holistic material flows control also means commensurate information flows—a crucial resource in establishing a broad-based assessment of emissions from logistics. Combining these decisions in one department means the need for a single source of truth and information—enabling higher transparency inside the organization.
Decisions on supplier selection can be linked to existing or new long-term contracts with LSP, fostering deeper collaboration and trust, which can be used to test new and innovative solutions to reduce emissions and costs.

The holistic perspective is understood on two levels. First, the consideration of all decision-making levels of logistics, even if these are outsourced to LSP; and second, material flow integration beginning with upstream suppliers, passing through the company, and ending at the customer. Allocating these perspectives to a cross-functional department can result in meaningful measures for industrial logistics decarbonization.

4.2. Introducing the Energy Management Perspective in Industrial Logistics Discussions into the decarbonization of logistics quickly boil down to alternative energy sources and associated drive systems that will pave the way toward a decarbonized transport system. These technologies are yet to be fully used competitively.

Logistics experts tend to criticize or promote technological solutions depending on their perception and experience with a specific technology. For example, classical arguments against BEVs are the availability of renewable energy and charging infrastructure, short ranges of trucks, and questionable resource consumption in battery production. Alternatively, logistics managers who have adopted BEVs are enthusiastic about the vehicles.

The discussion on fuel-cell electric vehicles powered with hydrogen currently has similar issues, especially on the production and distribution of green hydrogen. Logistics experts are curious about the technology because of the potential long-range operations of these vehicles. High gas prices and new studies, showing smaller emission reduction potentials than expected, have caused interest in natural gas-powered trucks to level off. Most interest in this technology remains with companies that can produce biogas as fuel.

These examples highlight a phenomenon found in exemplar logistics decarbonizing companies—the technology used in the vehicles will likely be determined by the competitive availability of the appropriate form of renewable energy than by the operational characteristics of the vehicles themselves. This availability, in turn, will depend on how well logistics is integrated into the organizational energy management system and how well primary or secondary excess energy will be used for logistics.

With rising transportation costs—for example, because of rising carbon taxes or fossil fuel prices—the use of excess energy for logistics that are currently sold or used somewhere else can become economically beneficial relatively quickly. An illustrative example of this situation was described by an interviewee from a brewery: the organic waste from the brewing process is no longer sold as fertilizer but is fed to a biogas plant, the energy from which is used to fuel gas-powered trucks, reducing emissions as well as costs of transportation.

5. Concerns and Implications

We have observed a number of factors and enablers that are needed for industrial logistics decarbonization. There are many dimensions to this problem. There are also a variety of planning, design, and implementation concerns that cover the broader organization, partners, and multiple stakeholders. We mention some of these concerns and directions.

For companies relying on transportation, the question will be which of the new technologies to use and where and how to counteract potential additional costs. For example, introducing the energy management perspective in industrial logistics highlights the new potential to simultaneously reduce emissions and costs and ensure the future competitiveness and greenness of industrial logistics. To exploit any available potential, organizational structures, management systems, and employee motivation need to be established to provide a holistic picture of industrial logistics and its related emissions.

Win–win is difficult to find. Working with a multiplicity of stakeholders is required to get an effective holistic solution. Who to involve becomes a major concern—each stakeholder has a different motivation and pressure to address. We did not interview a broader set to determine whether behavior and personal individual values play a role and these may be just as critical as strategic and operational decisions.

The holistic perspective is also shifting. We only took a snapshot. The relationships are quite extensive among the various factors. Which practice or concern will have priority is something that will also evolve. Careful evaluation and evolution, including technological forecasting and scenario planning, will be needed. Organizations and their partners must lead or be involved in this strategic scenario planning.

Essentially, there will be internal and external initiatives and organizations and managers in industrial logistics need to be aware and proactive in these developments. Hiding from the inevitable will make society but also organizations unsustainable.
6. CONCLUSION

Decarbonization of industrial logistics and transportation is a complex issue. Even though we know the concerns, the environment remains dynamic, including organizational, technological, and external forces playing a multiplicity of roles. Central to the issues is that renewable energies and the associated drive technologies associated with mobility and transportation will shape the image of logistics in the future. In this regard, there will not be just one dominant technology but a mix of different ones.

Using expert interviews, we examined how exemplar organizations have already advanced decarbonization of industrial logistics practices in recent years. We found at least a couple of major conclusions that can be drawn from the insights offered. There is a spiderweb of interrelationships among factors affecting the willingness to and enablers fostering the success of the adoption of low-carbon logistics practices for industrial firms.

Before fully blowing away the cobwebs, it is necessary to spin them, which is why we see this article as one major step toward more empirical and quantitative studies to deepen the understanding of factor and enabler relevance and the strength of the observed interrelationships.

In addition to these questions, further research is also required to validate and quantify the propositions and implications drawn. We seek to help foster the understanding of why decarbonization practices are adopted in leading companies and, at the same time, provide a basis for logistics managers that aim at designing future-proof industrial logistics systems.

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Philipp Miklautsch is currently working toward the Ph.D. degree with the Chair of Industrial Logistics, Montanuniversität Leoben, Leoben, Austria. He is a Junior Researcher with the Chair of Industrial Logistics, Montanuniversität Leoben. He is primarily dealing with the greening of industrial logistics systems. By doing interdisciplinary research with scientists of different fields and countries, he augments his industry experience with theoretical concepts and considerations to understand the underlying mechanisms and develop new tools to decarbonize the industry. In 2021, he was a Guest Researcher and a Lecturer with the University of Chiang Mai, Chiang Mai, Thailand.

Manuel Woschank received the Ph.D. degree in management sciences (summa cum laude) from the University of Latvia, Riga, Latvia, and the Habilitation degree in industrial management from Montanuniversität Leoben, Leoben, Austria. He is currently the Deputy Head of the Chair of Industrial Logistics, Montanuniversität Leoben, and an Adjunct Associate Professor with the Faculty of Business, Management, and Economics, University of Latvia. He was a Visiting Scholar with the Technical University of Kosice and Chiang Mai University. His research interests include the areas of production planning and control, logistics 4.0 concepts and technologies, behavioral decision-making, and engineering education.