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Zero-Distance Mobility and the Transformation of Transport Through Teleportation

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ABSTRACT

For two centuries, developments in transportation systems have been shaped by trade-offs between mass, speed, and infrastructure. Teleportation, the hypothetical instantaneous transfer of physical matter, has received limited attention in research despite its potential to transform this paradigm. This article reconceptualizes teleportation as a structured future scenario through the combined use of morphological scenario analysis (inspired by GMA) and Causal Layered Analysis. Within this framework, a Zero-Distance Mobility Framework comprising six dimensions, four impact mechanisms, and eight theoretical propositions has been developed. Four archetypal scenarios have been created based on technological maturity, governance models, energy infrastructure, scope of application, and social acceptance. Teleportation could transform urban land use, last-mile logistics, supply chains, modes of transportation, and labor markets; this transformation, in turn, would be shaped by regulatory, political, and social factors. The study provides early warning indicators and strategic triggers for decision-makers.
Keywords: teleportation; future of transport; zero-distance mobility framework; general morphological analysis
JEL Codes: R41, O33, L91

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Sıfır Mesafeli Hareketlilik ve Işınlanma Yoluyla Ulaşımın Dönüşümü

ÖZET

İki yüzyıldır ulaşım sistemlerindeki gelişmeler, kütle, hız ve altyapı arasındaki ödünleşmeler çerçevesinde şekillenmiştir. Fiziksel maddenin varsayımsal olarak anlık biçimde aktarılması olarak tanımlanan ışınlanma, ulaşım paradigmasını dönüştürme potansiyeline rağmen araştırmalarda sınırlı düzeyde ele alınmıştır. Bu makalede ışınlanma, Genel Morfolojik Analizden (GMA) esinlenen morfolojik senaryo analizi ile Nedensel Katmanlı Analizin birlikte kullanılmasıyla yapılandırılmış bir gelecek senaryosu olarak yeniden kavramsallaştırılmaktadır. Bu kapsamda altı boyut, dört etki mekanizması ve sekiz teorik önermeden oluşan Sıfır Mesafeli Hareketlilik Çerçevesi geliştirilmiştir. Teknolojik olgunluk, yönetişim modeli, enerji altyapısı, uygulama kapsamı ve toplumsal kabul temelinde dört arketipsel senaryo oluşturulmuştur. Işınlanmanın kentsel arazi kullanımı, son kilometre lojistiği, tedarik zincirleri, ulaşım modları ve iş gücü piyasalarını dönüştürebileceği; bu dönüşümün ise düzenleyici, siyasal ve toplumsal etkenler tarafından şekilleneceği öne sürülmektedir. Çalışma, karar vericiler için erken uyarı göstergeleri ve stratejik tetikleyiciler sunmaktadır.
Anahtar Kelimeler: ışınlanma; ulaşımın geleceği; sıfır mesafeli hareketlilik çerçevesi; genel morfolojik analiz
JEL Kodları: R41, O33, L91

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INTRODUCTION

The historical development of transportation systems has been shaped by the gradual reduction in the costs of overcoming the two fundamental constraints: distance and time. Railroads, automobiles, commercial aviation, and, most recently, high-speed trains, as well as electric and autonomous vehicle technologies, have not "eliminated" distance; they have merely reduced the unit cost of traveling that distance (Schafer & Victor, 2000). In this regard, a common feature of the dominant transportation paradigm is that it requires a physical entity (passenger, cargo, or vehicle) to move continuously along a specific route. Teleportation, on the other hand, refers to the ability to transfer matter or information from one point to another without physically traversing the intervening distance (Bennett et al., 1993; Pirandola et al., 2015); in this respect, it is considered one of the rare technological possibilities that have the potential to eliminate this common denominator and invalidate one of the fundamental assumptions of transportation science. Quantum teleportation was first proposed theoretically by Bennett and colleagues in 1993 and, over the subsequent thirty years, has been experimentally demonstrated at the photon and ion levels in laboratory settings (Bennett et al., 1993; Ren et al., 2017). However, these developments are limited to the transfer of the quantum state of a single quantum bit (qubit). The teleportation of a macroscopic object, such as a passenger or a cargo container, remains a theoretical assumption that has no experimental counterpart within the current framework of physics and involves significant conceptual difficulties (Pirandola et al., 2015). The aim of this study is not to predict when teleportation will become physically possible. Within a structured futures studies approach, this study examines how transport and logistics networks might be reorganized if such a capability were to emerge.

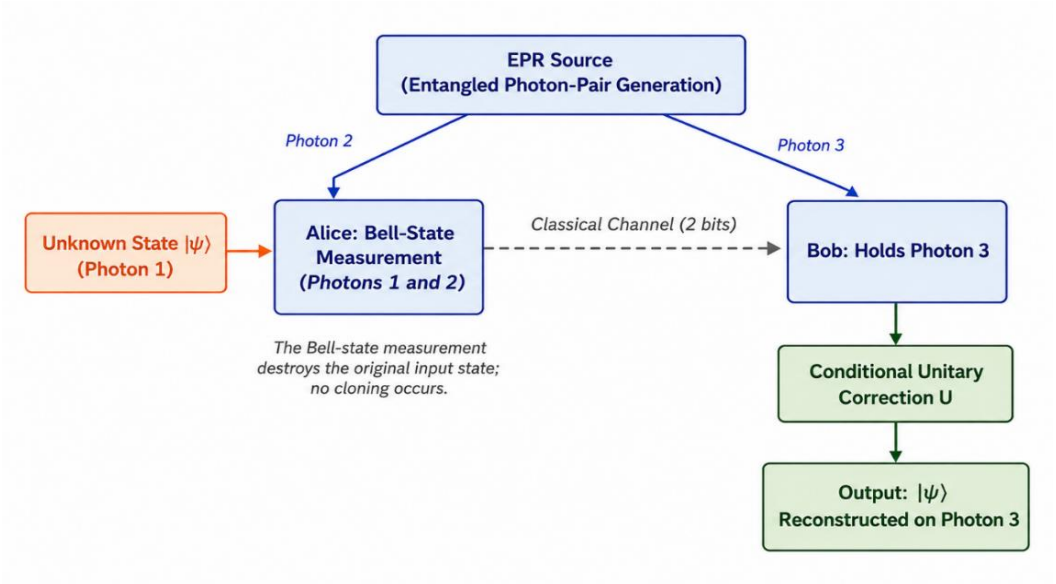

Figure 1. Schematic representation of the quantum teleportation protocol.

The figure was recreated by the author based on the protocol proposed by Bennett et al. (1993) and experimentally validated by Bouwmeester et al. (1997).

This article's contribution to the transportation literature can be summarized along three main axes. First, by introducing the concept of "zero distance" into the transportation literature, it extends the potential of teleportation for transportation systems beyond current discussions regarding autonomous vehicles, Mobility as a Service (MaaS), Hyperloop, and electric aircraft. Second, it presents an integrated methodological approach that combines scenario planning with Causal Layered Analysis to reveal not only "what might be possible" but also "the layers upon which this future is built." Finally, it translates the alternative future scenarios into policy and strategic implications in terms of urban transportation, logistics and supply chains,

modes of transportation (land, air, and sea), and labor markets; it also proposes early warning indicators that could enable the monitoring of these potential transformations starting today.

The article is organized as follows. In the first section, the scientific limits of teleportation are discussed, and the topic is contextualized within studies on the future of transportation. In the second section, "zero-distance mobility" is defined as a conceptual framework; the framework's fundamental dimensions and operational mechanisms are explained, and testable theoretical hypotheses are presented. The methodology used in the study, which includes a GMA-informed illustrative morphological scenario analysis and a Causal Layered Analysis, is detailed in Section 3. The implications and mechanisms of the "zero-distance" phenomenon in relation to the four key elements of the transport system are examined in Section 4. Section 5 presents four scenarios derived from the possibility space. The implications of the findings for policy and strategy are addressed in Section 6, whereas Section 7 addresses the limitations of the study and recommends further research.

1. CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

1.1. Teleportation: Scientific and Conceptual Boundaries

According to the body of literature in the physical sciences, two types of teleportation exist. These are: (a) quantum state teleportation where the quantum state of an object is transferred from one location to another using entangled states and classical communication (Bennett et al., 1993). In this process, the quantum state is transferred from the source to the destination; the original state at the source is destroyed upon measurement, and the state is not copied in a way that would allow the same quantum state to exist simultaneously in two different locations. (b) Matter teleportation, on the other hand, involves scanning and transmitting the entire atomic and molecular structure of an object and reconstructing it at a distant location; however, this scenario remains largely hypothetical at present. These two processes are based on different physical mechanisms and should not be considered the same phenomenon.

Indeed, the no-cloning theorem, a mathematical principle stemming from the linearity of quantum mechanics (Wootters & Zurek, 1982; Dieks, 1982), establishes that an unknown quantum state cannot be perfectly replicated. This principle should not be confused with a different physical process related to the measurement operation causing the collapse of quantum superposition, in other words, the collapse of the quantum state. It is not claimed that there is a direct technical relationship between experimentally demonstrated quantum state teleportation and theoretical matter teleportation, which envisions the reconstruction of an object at the atomic level by scanning it. Pirandola et al. (2015), while evaluating experimental progress in quantum teleportation, also discuss the field's unresolved problems and the potential limitations of future applications. This evaluation shows that current protocols are limited to the transmission of quantum information and states and do not establish an experimental foundation for the transmission of macroscopic matter.

The current research does not make any claims about the practicality of matter teleportation technology but, instead, adopts an approach commonly used in futures research across disciplines (Bell, 2003; Dator, 2009) for assessing technological possibilities in terms of possible, plausible, probable, and preferable futures. The development path of quantum teleportation through experiments helps in understanding the pace and limitations involved in its advancement. The first experimental demonstration of quantum teleportation was conducted by Bouwmeester et al. (1997) for photons, while continuous-variable quantum teleportation was demonstrated by Furusawa et al. (1998) and quantum teleportation between atomic qubits was demonstrated by Riebe et al. (2004). One of the long-term goals of this progress is the creation of a global communication infrastructure, as defined in the "quantum internet" vision of Wehner et al. (2018), aimed at connecting quantum processors. Progress toward this goal continues to depend on the development of quantum repeaters capable of transmitting entanglement over long distances. The current state of theoretical and experimental developments in this field has been comprehensively reviewed by Azuma et al. (2023). However, such an

infrastructure is also limited to the teleportation of quantum information and states and cannot be directly extended to the teleportation of macroscopic matter. To clearly establish this conceptual distinction, all references to the teleportation of goods, passengers, or cargo containers in the remaining sections of this article refer not to the quantum state teleportation described above and demonstrated experimentally, but to a hypothetical matter teleportation scenario. Therefore, when evaluating the scenarios and policy implications developed in the following sections, it is essential to maintain the distinction between these two types of teleportation.

1.2. Transport Futures Studies and the Zero-Distance Concept

The literature on the future of transportation has largely been shaped by the assumption that technological change will occur gradually. Autonomous driving (Litman, 2023), electrification, mobility as a service (MaaS), and very high-speed land transportation systems (Hyperloop) are among the primary areas of focus in this literature (Docherty et al., 2018). What these approaches have in common is that they are based on a vision of the future in which physical movement persists, albeit in a faster, cleaner, or more highly automated form. In this study, however, the concept of "zero distance" is proposed to describe a transportation scenario in which physical movement itself is partially or completely eliminated. This idea can be seen as an extension of the transformation brought about by the "death of distance" paradigm in communications technology (Cairncross, 1997) since this particular transformation has partly been achieved in the movement of information and services.

1.3. Methodological Approaches in Futures Studies

The domain of futures research involves the systematic identification of alternative futures and the analysis of such alternatives in a structured way, as opposed to generating a single "prediction" (Bell, 2003). One widely used technique in this field is scenario planning, as introduced by Schwartz (1991), which derives four scenarios from two key dimensions of uncertainty (Wilkinson & Kupers, 2013). However, this approach does not allow for the systematic modeling of more than two dimensions of uncertainty simultaneously. General Morphological Analysis (GMA), developed by Zwicky (1969) and adapted to contemporary futures studies applications by Ritchey (2011), enables the systematic mapping of multidimensional uncertainty fields, thereby overcoming this limitation (see Section 3.2). Inayatullah's (1998) Causal Layered Analysis (CLA), on the other hand, examines a future possibility not only at the level of superficial trends and visible problems (litany) but also at the levels of systemic causes, worldviews, discourses, myths, and metaphors, thereby enabling a deeper and more multilayered assessment of transformation. This study combines an exploratory morphological scenario analysis inspired by GMA with CLA, using an approach rarely encountered in the transportation literature, to examine both "what might happen" and "the mental models, assumptions, and forms of interpretation upon which this possibility is built."

1.4. Related Work: The "Teleportation Test" in Travel Behaviour Research

Regardless of the physical and technological feasibility discussed in this article, the concept of "teleportation" has long been used as an empirical measurement tool in the travel behavior literature. The concept of the "teleportation test" was coined by Mokhtarian and Salomon (2001) to test the assumption that travel is solely a derived demand. In this test, people are asked whether they would prefer to teleport to their destination point by simply snapping their fingers; their answers serve as a measure of the independent utility of travel. This approach has also been used in various studies in subsequent years. Russell and Mokhtarian (2015) evaluated findings from over a decade of teleportation tests to examine the apparent inconsistency arising from the fact that a significant portion of participants who reported an ideal travel time greater than zero nevertheless preferred teleportation. In a study conducted in Portland, Oregon, Humagain and Singleton (2020) found that a significant portion of participants, particularly those who walked or cycled to work, preferred their current daily commutes over teleportation, and that this preference was associated with sociodemographic characteristics, mode of transportation, and attitudes toward travel. In a more recent study, Acharya and Singleton (2024) conducted a comparative analysis of the preferences for autonomous driving and teleportation among individuals engaging in long-distance recreational travel. While this literature

complements the present study, it focuses on a different research question. The teleportation test developed by Mokhtarian and other researchers uses teleportation as a hypothetical counterfactual, one that is not expected to occur, to measure individuals' subjective attitudes toward travel. Unlike in previous research, in the present work, teleportation technology is viewed as a possible future technology and analyzed in terms of the likely consequences for transportation networks, logistics frameworks and competition in the industry. Another interesting aspect of the teleportation literature is the observation that some individuals derive intrinsic value from the travel experience itself and, therefore, do not necessarily prefer instantaneous travel. This is an important issue that needs to be taken into account in the framework of scenario analysis presented here. Thus, even if teleportation technology were to become feasible, its adoption rate would depend not only on technical and economic factors but also on individuals' attitudes toward travel itself.

2. THE ZERO-DISTANCE MOBILITY FRAMEWORK

2.1. Definition

In this research, the concept of zero-distance mobility is formulated as a mobility regime in which it becomes possible to transport a person, object, or cargo from one point to another, either partly or entirely, without physical movement across the intervening distance, while transportation costs become partially or fully decoupled from distance. This definition is conceptualized along a continuum rather than as a dichotomous condition. In this sense, zero-distance mobility may be understood as a phenomenon that can already be observed to some extent within existing transport systems, without requiring any assumption regarding teleportation. This situation is analogous to the partial erosion of distance described by Cairncross (1997) in relation to information and digital services. The present concept extends this tendency to the limiting case of physical goods and people.

2.2. Dimensions of the Framework

The concept of zero-distance mobility can be analyzed across six dimensions (see Figure 2). The first, the spatial-physical dimension, concerns the extent to which the physical route of movement is shortened or eliminated. The second, the temporal dimension, concerns the extent to which travel time approaches zero and the potential consequences of this shift for perceptions of time and space (Harvey, 1989). The third, the economic-cost dimension, concerns the extent to which transportation costs become decoupled from distance. The fourth, the institutional-regulatory dimension, addresses who governs this capability and under what regulatory framework. The fifth, matter-information convergence, applies specifically to the hypothetical matter-teleportation scenario. It is based on the assumption that the complete atomic and molecular structure of a physical object could be scanned, converted into information, and reconstructed elsewhere. This differs fundamentally from experimentally demonstrated quantum teleportation, which involves the transfer of an unknown quantum state rather than the conversion of a physical object into information (Bennett et al., 1993; Pirandola et al., 2015). The sixth dimension, social acceptance and experience, examines the extent to which the intrinsic value individuals attribute to travel itself may influence the level and speed of technology adoption (see Section 1.4). Table 1 summarizes these six dimensions, the fundamental impact mechanisms each dimension gives rise to, and their relationship to the theoretical propositions presented in Section 2.5.

Table 1. Dimensions of the Zero-Distance Mobility Framework

Dimension	Definition	Associated Effect Mechanism	Related Proposition(s)
Spatial-physical	The extent to which the physical route of movement is shortened or eliminated entirely	Infrastructure substitution	P3, P5
Temporal	The extent to which travel time approaches zero and the potential effects of this on perceptions of time and space	Time-space compression	P1, P4

Economic-cost	The extent to which the relationship between transportation cost and distance traveled weakens	Distance-cost decoupling	P1, P2
Institutional-regulatory	Who oversees this capability and under which governance model it is regulated	Node-centric respatialization	P6
Matter-information convergence	A dimension specific to the hypothetical matter teleportation scenario: the assumption that an object's atomic and molecular structure is scanned, converted into information, and reconstructed at a distant location. Experimentally demonstrated quantum state teleportation, on the other hand, does not convert a physical object into information but merely facilitates the transfer of a qubit's quantum state (see Section 1.1).	Infrastructure substitution	P2, P3
Social acceptance/experience	The potential impact of the intrinsic value individuals attribute to travel on the level and speed of technology adoption (see Section 1.4).	Time-space compression	P4, P8

2.3. Effect Mechanisms

The framework identifies four fundamental mechanisms through which zero-distance mobility affects the transportation system. The first mechanism, distance-cost decoupling, refers to the reduction or elimination of the dependence of transportation costs on the distance traveled. The second mechanism, time-space compression, is regarded as a further development of Harvey's (1989) thesis that communication and transportation technologies "compress" spatial and temporal distances in the process of capitalist modernization. The third mechanism, infrastructure substitution, refers to the replacement of existing linear and route-based transportation infrastructure (roads, railways, and air corridors) with node-based infrastructure. The fourth mechanism, node-centric respatialization, describes the reshaping of urban and regional spatial organization around transportation nodes. This final mechanism is closely related to the fundamental approach of Bertolini's (1999) node-place model, which treats public transit stations as the intersection of "node" and "place" functions. However, the node in question here constitutes the direct point of origin or destination of movement rather than merely a transfer station.

2.4. Conceptual Model

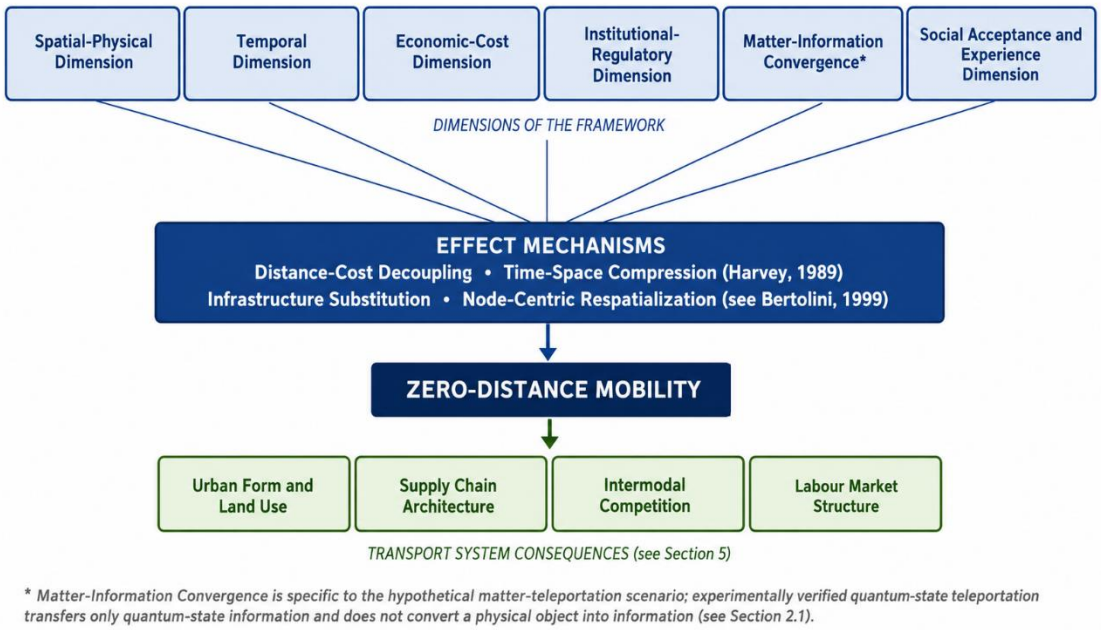

Figure 2. Conceptual model of the Zero-Distance Mobility Framework.

Source: developed by the author within the framework of Harvey (1989) and Bertolini (1999).

Figure 2 illustrates how the six dimensions of the framework contribute to the formation of a zero-distance mobility structure through four impact mechanisms, as well as the potential effects of this structure on the four subcomponents of the transportation system (see Section 4). The model should be viewed not as a linear causal chain, but as a holistic structure in which the dimensions activate different impact mechanisms simultaneously and in mutual interaction.

2.5. Theoretical Propositions

The eight theoretical propositions derived from the framework and guiding the scenario and impact analyses presented in the following sections are outlined below. These propositions have not been empirically tested within the scope of this study and have been formulated as hypotheses that can be tested in future research.

P1: As the level of technological maturity of zero-distance capacity increases, the explanatory power of distance-based transportation cost functions in explaining transportation costs decreases.

P2: The substitution relationship between zero-distance capacity and the market shares of traditional transportation modes varies depending on the economic value density of the cargo or passengers transported. The substitution effect is expected to be stronger in high-value, low-volume segments than in low-value, high-volume segments.

P3: As the level of geographic centralization of zero-distance infrastructure increases, that is, as the number of nodes decreases, the physical resilience and redundancy capacity of the transportation or supply chain system it serves decrease, while the risk that a failure at a single point will cause a system-wide disruption increases.

P4: As the intrinsic benefit individuals derive from travel itself, that is, the positive value they attribute to travel, increases, the rate of adoption of zero-distance technology in passenger transportation decreases.

P5: As the ability of zero-distance technology to substitute for the functions of geographic bottlenecks, such as ports, canals, and border crossings, increases, the factors determining the location of transportation infrastructure investments shift from geographic proximity to access to energy sources and regulatory conditions.

P6: As the governance model of zero-distance technology becomes more centralized, concerns regarding inequality in access to the technology and geopolitical control become more pronounced.

P7: As the density of zero-distance nodes in urban spaces increases, spatial organization shifts from a transit-oriented development (TOD) model toward a development model centered on zero-distance nodes.

P8: The impact of zero-distance capacity on the labor market varies depending on the combination of a contraction in occupations reliant on direct physical movement and potential expansion in occupations related to infrastructure, energy, and security. Regional inequalities may arise from the uneven spread of sectoral economic restructuring across regions.

3. METHOD: MORPHOLOGICAL SCENARIO ANALYSIS AND CAUSAL LAYERED ANALYSIS

3.1. The Literature Review Process: Scope and Limits

This study adopts a qualitative and exploratory design in the field of futures studies. However, it should be noted at the outset that the research was not conducted as a systematic review following the PRISMA protocol. An interpretive literature synthesis method based on the purposive selection of sources was used. For the sake of methodological transparency, the five main elements of this method are outlined below. The databases and access to the sources: The search was not conducted systematically in a single bibliographic database (such as Scopus or Web of Science). Topic-relevant academic searches were conducted in Google Scholar and the archives of relevant academic publishers and journals (Nature.com, Science.org, ScienceDirect, SpringerLink, Taylor & Francis Online, and Harvard Business Review) as well as the open-access preprint repository arXiv. The search terms: A complex Boolean search string or PICO/PECO search strategy was not used. Search strings were developed on the basis of individual keywords including "quantum teleportation experiment", "causal layered analysis", "general morphological analysis of the future", "bullwhip effect in the supply chain", "travel behavior teleportation test", "node-place model", "Schwartz scenario planning", and "supply chain resilience". The date range: This study did not use any particular or fixed publication date range (such as only 2015-2025). Foundational and seminal studies in the field (Bertolini, 1999; Harvey, 1989; Mokhtarian & Salomon, 2001; Schwartz, 1991; Zwicky, 1969) as well as more recent studies that cite or build on them (Acharya & Singleton, 2024; Georgescu, 2022) were considered. Source selection criteria: A source must: (a) have been published in a peer-reviewed journal or by a recognized academic publisher, (b) make a direct contribution to at least one of the following fields: physics and quantum information theory, futures studies methodology, transportation and urban planning, logistics and supply chain management, or travel behavior; and (c) directly support a specific claim, mechanism, or concept put forward in the article. Non-peer-reviewed blog posts and journalistic content were excluded. A limited number of arXiv preprints were considered solely to reflect current developments in the field of physics and were cross-checked against their published or accepted versions whenever possible. Thematic classification: No official coding manual was created for this study; no predefined, detailed coding categories were used; and no inter-coder reliability analysis was conducted. The selected sources were classified and evaluated within the framework of the five thematic areas mentioned above as part of a qualitative thematic synthesis conducted by a single researcher. Consequently, this process is based on a narrative and conceptual thematic grouping rather than a

numerical or statistical coding procedure. This approach aligns with one of the methodological approaches used in conceptual research and futures studies, which can be defined as purposeful literature selection and interpretive synthesis in qualitative research (Perlman et al., 2026; Skinner et al., 2022). The study's reference list consists of a total of sixty-one sources. However, this number does not represent a sample size obtained through a systematic search protocol but rather reflects the outcome of the purposeful selection and evaluation process described above. The fact that methodological elements specific to systematic reviews, such as independent source selection by two researchers, a pre-registered protocol, and a PRISMA flowchart, were not used is further discussed as a limitation of the study in Section 7.

3.2. Integrating Morphological Scenario Analysis and Causal Layered Analysis

Building on this literature, the study integrates two interrelated methods. The first method is a GMA-informed illustrative morphological scenario analysis that draws on the General Morphological Analysis (GMA) tradition, whose foundations were laid by Zwicky (1969) and adapted to contemporary futures studies applications by Ritchey (2011). However, the study does not apply a full-scale GMA based on an expert panel as defined by Ritchey. The cross-consistency assessment described below was conducted based on a single researcher's interpretive evaluation, without the use of an expert panel or computer-assisted GMA software (see Section 7). The fundamental element adopted from GMA in this study is the method's conceptual logic. Accordingly, a multidimensional morphological field is first systematically constructed, and then pairs of states that are logically incompatible with one another are eliminated. However, this approach should be regarded not as a full-scale, independently validated GMA application, but rather as an analysis in which the method's fundamental logic is applied in an illustrative manner. Recent studies also highlight the analytical value of this approach in structuring qualitative scenario fields and in subsequent evaluations (McIntosh, 2026). The classic two-axis scenario matrix (Schwartz, 1991) is based solely on two dimensions of uncertainty and positions four scenarios in four distinct areas defined by the two axes. In contrast, the scenarios developed in this study vary across five different dimensions: technological maturity, governance model, energy infrastructure, scope of implementation, and social acceptance. For this reason, the study adopts a multidimensional structure inspired by GMA rather than the classic two-axis scenario approach. These five parameters have been selected because each one represents an individual and mostly independent dimension of the expected results of the zero-distance mobility paradigm described above (Section 2). Technological maturity and energy infrastructure together define the limits of physical feasibility; governance structure defines who will control the capacities and who will have access to them; scope of implementation defines the segments of the transportation sector involved; and social acceptability affects the adoption rate of the technology in real-world settings. Variables like environmental impact, intensity of geopolitical competition, and the legal regime of liability have not been ignored but have been intentionally left out of the set of parameters. These variables are treated as secondary outcomes arising from interactions among the five primary parameters rather than as independent dimensions of the morphological space. For example, the level of geopolitical competition may be affected by the combined impact of governance structure and technological maturity. Including these variables in the set of parameters would dramatically increase the number of possible combinations in an exploratory analysis performed by a single researcher. In the morphological scenario analysis process, the parameters defining the system and the possible states associated with each parameter were first identified. Subsequently, logically incompatible state pairs, such as the combination of "low technological maturity" and "global-scale energy infrastructure," were eliminated through a cross-consistency assessment. In the final stage, four distinct archetypal configurations were selected from among the possible configurations found to be compatible under the applied evaluative criteria and developed into scenarios (see Section 5, Figure 4). The second method is Inayatullah's (1998) four-layered Causal Layered Analysis (CLA). This method conducts an in-depth examination of each scenario configuration derived from the GMA in terms of visible trends and issues (litany), systemic causes, discourse and worldview, and the layers of myth and metaphor. Thus, the analysis seeks to answer not only the question of "what might happen," but also the question of "on what assumptions, forms of interpretation, and mental models this possible future is built."

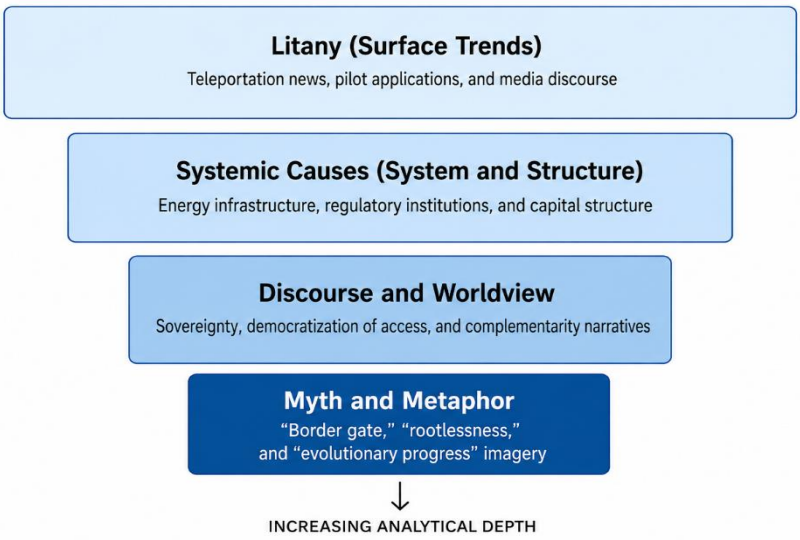

Figure 3. The four layers of Causal Layered Analysis (CLA).

Source: developed by the author based on Inayatullah (1998).

The fundamental criterion in evaluating the method is not to arrive at a single "correct future" prediction, but rather to consider a sufficient variety of possible futures and to ensure that the scenarios developed are internally consistent. In this regard, the study adopts an interpretive approach to futures studies rather than a positivist forecasting model (Inayatullah, 1998; Bell, 2003). The study sought to strengthen the internal consistency of the scenarios through GMA's cross-consistency assessment and by structuring the technological, economic, regulatory, and social dimensions of each scenario in a way that avoids contradictions. The alignment of the scenarios with the current body of knowledge was assessed through a comparative analysis with findings in the literature on transportation and energy economics (Schafer & Victor, 2000; Sovacool, 2017).

3.3. Cross-Consistency Assessment: An Illustrative Table for Transparency

To present the GMA-informed morphological analysis process in a transparent and traceable manner, six examples selected from the assessment of pairwise consistency among the five parameters are presented in Table 2. The complete cross-consistency matrix consists of a total of ten comparisons covering all pairwise combinations of the five parameters; each comparison, in turn, includes all possible matches of the states present in the relevant parameters. For clarity, only selected comparisons are presented below; these formed the basis for the four final archetypes. The complete configuration space, formed by selecting one state from each of the five parameters, consists of a total of 432 possible combinations. A detailed presentation of the 115 state-pair cells is provided in Appendix A. However, the study-defined illustrative consistency criteria were applied only to three parameter relationships. Therefore, the resulting configuration counts should be interpreted not as definitive outputs of a comprehensive GMA application based on an expert panel, but as approximate lower-bound values obtained within the scope of an exploratory analysis.

Table 2. Sample Cross-Consistency Assessment (Illustrative Selection)

Parameter A (State)	Parameter B (State)	Assessment	Rationale
Technological Maturity: Low	Energy Infrastructure: Global/Off-Grid	Incompatible (eliminated)	In the author's interpretive assessment, a global-scale infrastructure investment cannot be economically justified for a technology that remains at the laboratory or conceptual development stage, since large-scale infrastructure commitments typically follow, rather than precede, the achievement of sufficient technological maturity (Grübler, 1990).
Technological Maturity: High	Scope of Application: None/Experimental	Incompatible (eliminated)	By definition, high technological maturity implies at least a limited level of application or usage capacity; the absence of any application for a highly mature technology is therefore treated, for the purposes of this study-specific interpretive assessment, as an internal inconsistency.
Governance Model: Pre-Regulatory	Scope of Application: All Passenger and Cargo Segments	Incompatible (eliminated)	Full-scale implementation in passenger transportation, which is critical for public safety, is assessed in this study as requiring an institutionalized certification and oversight regime; consequently, such implementation in the absence of an established regulatory framework is treated as internally inconsistent (Mazur et al., 2022).
Governance Model: Centralized / State-Led	Energy Infrastructure: Global/Off-Grid	Compatible (retained)	Large-scale and strategic infrastructure investments, such as nuclear energy, space programs, and high-speed rail, have historically tended to follow state-led governance models (Grübler, 1990); this pattern is used here as an interpretive basis for the corresponding compatibility assessment.
Governance Model: Distributed / Platform-Led	Energy Infrastructure: Regional Scale	Compatible (retained)	In the author's interpretive assessment, platform-based deployment models generally begin at the regional or urban scale and expand gradually, whereas the financing and operation of infrastructure at a global scale by platform actors alone is treated as a comparatively less likely configuration (Rauch & Schleicher, 2015).
Governance Model: Hybrid / Multi-Stakeholder Consortium	Scope of Application: High-Value Cargo Only	Compatible (retained)	Sector-specific and multi-stakeholder consortium models, as seen in international coordination structures, particularly in aviation and maritime sectors, demonstrate a structure consistent with the development of standards first in more limited application areas with high economic value, followed by broader expansion (Abeyratne, 2024).

The first three rows of Table 2 show the state pairs eliminated from the configuration space because they are logically incompatible with one another; the last three rows show the consistent state pairs that were retained and served as the basis for the formation of the final four archetypes (S1–S4). A common feature of the eliminated combinations is the simultaneous occurrence of a state of early development or low maturity for one parameter alongside a state of advanced development or high institutionalization for another parameter. For example, the association between underdeveloped technology and global infrastructure or the pre-regulation situation in tandem with passenger transport operations was seen as inconsistent since it did not correspond to the expected pattern of development. Following an exploratory cross-consistency assessment applied to the three specified parameter relationships, four archetypes were selected from among the

configurations found to be consistent under the evaluation criteria, in accordance with the principle associated with the "maximum contrast" and "extreme configurations" approach in the GMA literature (Ritchey, 2011). To this end, four profiles were identified that differed from one another as much as possible in terms of technological maturity and governance model while maintaining internal parameter consistency; these profiles were designated S1–S4 (see Section 5, Table 5). This selection approach aims to highlight the four extreme profiles with the highest discriminative power in terms of policy and strategy for the transportation sector, rather than representing all of the configurations found to be consistent. Therefore, the four scenarios presented constitute a selected subset representing different boundaries of the configuration space with internal consistency, rather than the entire space itself.

4. DOMAINS OF IMPACT ON TRANSPORT SYSTEMS IN A ZERO-DISTANCE WORLD

In this section, drawing on the causal mechanisms identified in the existing literature, the potential impacts on the four core components of the transportation system are discussed in the event that the possibility of teleportation is realized on a partial or full scale. The assessment focuses specifically on freight transportation and logistics processes.

4.1. Urban Transport and City Planning

One of the key determinants of urban transportation demand is the spatial separation of residential, commercial, and service areas (Cervero, 2013). For example, the introduction of short-distance, high-frequency passenger transport via an intra-city network consisting of "node-based" transport stations could significantly weaken the relationship between accessibility and distance in the urban form. This situation could lead to the current transit-oriented development (TOD) model, which is concentrated around public transit corridors, evolving into a new spatial organization centered around teleportation nodes. However, the "last hundred meters" problem, that is, the need to reach the final destination from the teleportation station, which is expected to persist in a node-based system, indicates that traditional short-distance modes of transportation will not disappear entirely. The role of transportation options such as walking, micromobility, and small-scale autonomous vehicles may shift in this scenario, from facilitating the main journey to providing a connection between the final node and the ultimate destination.

4.2. Logistics and Supply Chain Management

One of the most significant effects of teleportation on the transportation economy is expected to manifest in freight transport and logistics rather than passenger transport. Within the hypothetical matter-teleportation scenario defined in Section 1.1, cargo transport would not be subject to the biological constraints associated with transporting living organisms. From a logistics perspective, this distinction could make freight applications particularly relevant for examining potential changes in supply-chain structure (Christopher, 2016). However, it must be emphasized that teleportation would not entirely eliminate physical transportation. Since a teleportation node would remain a fixed physical location, traditional transportation would still be necessary to provide the final link between the node and the final delivery point, similar to the "last hundred meters" problem observed in passenger teleportation (see Section 4.1). Therefore, the element that teleportation could essentially eliminate is the long-distance main transport stage, which currently accounts for a significant portion of logistics costs and delivery times (Christopher, 2016). Last-mile delivery is reported to account for a significant share of e-commerce logistics costs, although the proportion varies considerably by delivery conditions. Relevant studies indicate that this proportion can range from approximately 13% to 75%, depending on the source and delivery context, and in some cases can account for more than half of the total logistics cost (Gevaers et al., 2011; Olsson et al., 2019; García-Retuerta, 2023; see Table 3).

For high-value, low-volume shipments, such as pharmaceuticals, electronic components, spare parts, and e-commerce packages, the implementation of partial teleportation capabilities could transform warehousing and inventory strategies into a model based on very low stock levels that responds instantly to

demand. Such a transformation could significantly alter the structure of regional distribution center (RDC) networks. The approach to warehouse site selection based on geographic proximity may be replaced by a new site selection approach based on energy infrastructure and the capacity of teleportation nodes. In international supply chains, port capacity and vessel turnaround times, which are among the primary bottlenecks in container shipping (Notteboom & Rodrigue, 2008), could be partially replaced by teleportation capacity in high-value cargo segments. Conversely, maritime transport is expected to maintain its dominant position in the transport of bulk cargo and low-value, high-volume goods due to the balance between energy requirements and transportation costs (Stopford, 2009).

Possible Effects on Inventory Theory and the Bullwhip Effect

The following discussion is based on a theoretical and scenario-based inference rather than an empirical finding regarding teleportation. The reason for this is that there is currently no supply chain in which teleportation capacity is utilized and that can be empirically observed. Therefore, in this assessment, established inventory theory is adapted to the hypothetical capacity defined in Section 1.1; the aim is to identify the possible directions of the effect rather than to measure its magnitude. One of the well-established empirical findings in the supply chain management literature is that variability in demand information increases as it moves from the retailer to the manufacturer along the supply chain due to factors such as lead times, order consolidation, and the processing of demand signals. This phenomenon, referred to in the literature as the "bullwhip effect," can lead to excess inventory being held at different stages of the supply chain (Lee et al., 1997). One of the primary determinants of the bullwhip effect is the delay between order placement and delivery. As delivery time increases, so do the uncertainty surrounding demand forecasts and the resulting need for safety stock (Lee et al., 1997). Particularly in high-value, low-volume product categories, if teleportation were made available, delivery time could theoretically be reduced to near zero, thereby mitigating one of the key structural causes of the bullwhip effect. In this case, safety stocks could theoretically be reduced significantly across the whole supply chain, potentially reducing capital tied up in inventory. However, this is only a theoretical finding based on a hypothetical situation and not a proven one. The emergence of this effect depends on teleportation capacity being provided at a scale capable of meeting demand fluctuations seamlessly and with sufficient capacity. Otherwise, capacity constraints that may arise at teleportation nodes could create new bottlenecks rather than reducing the bullwhip effect, thereby adding an additional source of uncertainty to the supply chain.

The Agility-Resilience Trade-off: A Reading Through the Triple-A Framework

According to Lee (2004), competitive supply chains require three key attributes: agility, adaptability, and alignment, collectively referred to as the "Triple-A" framework. In a hypothetical teleportation-enabled supply chain, near-instantaneous responses to demand changes could substantially increase agility and reduce inventory requirements. Christopher and Peck (2004), however, emphasize that agility alone is insufficient and that resilience, defined as the capacity to maintain or rapidly restore functionality following disruption, is equally important. Drawing on the supply-chain resilience principles discussed by Ivanov and Dolgui (2021), a teleportation-based supply chain may become vulnerable if capacity is concentrated in a small number of nodes. Such concentration could allow technical failures, cyberattacks, or regulatory interventions affecting a single hub to generate more widespread disruptions than in geographically distributed networks.

International Trade, Customs Oversight, and Reshoring Trends

The convergence and divergence paths seen in global supply chains over the past two decades have led to the widespread adoption of nearshoring and reshoring practices. Nearshoring and reshoring refer to the relocation of manufacturing operations closer to end-user markets, driven by the uncertainties and lead time risks connected with geopolitical challenges (Bednarski et al., 2025). This trend is driven by the direct connection between distance and delivery time. The weakening of this relationship through teleportation, particularly for high-value shipments, could reduce the importance of geographical proximity in supply-chain design. However, international trade regulation issues like customs clearance, origin verification, health and safety certification, and taxation remain relevant regardless of transportation technology, even in the case of

teleportation (Karklina-Admine et al., 2024). The need to subject teleported shipments to customs and regulatory control would require the emergence of new inspection and certification procedures, distinct from traditional border checks. This area of policy-making would force countries to reconsider their border and sovereignty policies in the face of new technologies, especially in the centralized and state-managed context of Scenario 1.

Table 3. Cost Components in E-Commerce Logistics (Qualitative Categories)

Cost Component	Qualitative Category	Source / Rationale
Production/Warehouse Departure	**Low**	Although the source material does not give a figure for this stage, it is considered a stage that features a relatively low percentage of logistics costs in total.
Line-Haul Transport	**Medium**	The cost share of this stage is not specified as a separate percentage in the source. However, it is considered a transportation stage that occurs before the last-mile delivery within the logistics process and incurs moderate costs.
Regional Distribution Center	**Medium**	The source does not provide a direct cost ratio for this stage. Regional distribution center operations are considered a stage that incurs moderate costs, carried out prior to last-mile delivery and encompassing processes such as storage, handling, and preparation for distribution.
Last-Mile Delivery	**High (13%–75%)**	It is reported that the share of last-mile delivery in total logistics costs can range from approximately 13% to 75% and, in some cases, can exceed 50% of total costs.

Source: Gevaers et al. (2011).

4.3. The Strategic Position of Aviation, Maritime, and Land Transport

One of the fundamental functions of civil aviation is to enable the traversal of long distances in a short time. Given the possibility that this function could be directly replaced by teleportation, civil aviation is considered to be one of the modes of transportation that may be relatively more vulnerable to teleportation, particularly in medium- and long-haul passenger transport. In contrast, cargo aviation could serve as a complementary mode of transportation for time-sensitive shipments that the teleportation network cannot reach, particularly in regions with low demand density and those located outside teleportation hubs. Considering the economies of scale that provide unit cost advantages, maritime transportation is expected to maintain its strong position, especially in the transportation of low-value, high-volume cargo. Road transportation, on the other hand, can be crucial in connecting teleportation centers with destinations.

Table 4 classifies the relative energy intensity of traditional transport modes qualitatively as low, medium, or high, based on the literature (European Environment Agency, 2021; Krammer & Schäfer, 2025). For the hypothetical process of matter teleportation, there is no real-world equivalent under present-day physics. Therefore, no energy value is assigned to this process; instead, it is labeled as undetermined. This uncertainty is one of the study's significant methodological limitations and, at the same time, a key element that must be considered in scenario analysis. Within the framework of current knowledge, it is not possible to reliably predict in which cargo segments matter teleportation could become competitive in terms of energy requirements and economic costs. For this reason, the scenarios presented in Section 5 do not draw any definitive or quantitative conclusions regarding this aspect.

Table 4. Relative Energy Intensity Across Transport Modes (Qualitative Categories)

Transport Mode / Transfer Type	Relative Energy Intensity Category	Source / Rationale

Maritime (container)	Low	Due to economies of scale and relatively low energy consumption per unit of freight transported, it is considered one of the most energy-efficient modes of transportation for freight (European Environment Agency, 2021; Krammer & Schäfer, 2025).
Rail	Low-Medium	Thanks to economies of scale resulting from low rolling resistance and high transport capacity, it can achieve lower energy consumption per unit of cargo compared to road transport (European Environment Agency, 2021; Krammer & Schäfer, 2025).
Road (truck)	Medium	While it offers high flexibility in terms of routes and delivery, energy consumption per unit of cargo is generally higher than that of rail and maritime transport (European Environment Agency, 2021; Krammer & Schäfer, 2025).
Air (cargo)	High	Due to the high energy requirements of flight and the relatively high energy consumption per unit of cargo transported, it is considered one of the most energy-intensive options among traditional modes of freight transport (European Environment Agency, 2021).
Hypothetical Matter Teleportation	Undetermined	Since there is no experimentally demonstrated matter teleportation process at the macroscopic scale within the scope of current physical knowledge, it is not possible to make a reliable estimate of energy requirements. For this reason, no numerical value or relative energy intensity ranking has been assigned to hypothetical matter teleportation.

4.4. Labor Markets and Occupational Transformation

According to data from the International Labour Organization (n.d.), the transportation and warehousing sector accounts for a significant share of global employment. The sector's potential for transformation in terms of its employment structure in the face of automation and digitalization has been discussed in the existing literature (an expanded assessment based on Frey & Osborne, 2017). The widespread adoption of teleportation technology on a sector-wide scale could lead to a decline in employment in occupations directly tied to transportation activities, such as drivers, pilots, and maritime crew members. Conversely, the installation, maintenance, and energy management of teleportation systems, as well as other fields including quantum engineering, security, and regulation, may lead to the emergence of new jobs and specializations. Historically, major transitions in transport systems, such as the shift from steamships to diesel ships and from horse-drawn carriages to automobiles, have been described as processes of "creative destruction" in which certain professions were eliminated and new ones arose (Grübler, 1990). However, the transition to teleportation might be characterized by different dynamics. If the technology develops as a network that starts at certain nodes and expands quickly into new areas rather than through slow infrastructure investment, the period available for adjustments to take place in the labor market may be shorter than in previous eras of transport technology. This could cause greater job losses, especially in regions that rely on transport-based economic activity.

5. SCENARIO ANALYSIS: FOUR FUTURES DERIVED FROM THE MORPHOLOGICAL FIELD

As part of the morphological scenario analysis described in Section 3 and inspired by the GMA, a morphological space comprising five parameters (technological maturity, governance model, energy infrastructure, scope of application, and social acceptance) was established. Subsequently, logically incompatible combinations of conditions, such as the pairing of "low technological maturity" with "global-scale energy infrastructure," were eliminated through a cross-consistency assessment. From among the

configurations found to be compatible under the applied illustrative evaluation criteria, four distinct archetypes were selected (Figure 4, Table 5). As explained in Section 3.2, the key advantage of the GMA over the classical two-axis scenario matrix is that it allows for the simultaneous and multidimensional evaluation of all five parameters. Therefore, rather than being placed within an abstract space defined by two axes, each scenario represents a distinct state combination that is clearly defined in terms of all five parameters. It should be particularly emphasized that the S1–S4 scenarios are four representative future scenarios selected from the broader morphological space defined in Section 3.3 and Appendix A. These scenarios do not constitute a classification that encompasses all possible futures. The 150 configurations deemed compatible as a result of the applied illustrative evaluation criteria remain as candidates possessing internal consistency. S1–S4, on the other hand, were deliberately selected from among these configurations not to represent the full range of possibilities, but to highlight as clearly as possible the contrasts between key dimensions, primarily technological maturity and governance models (see Appendix A, Selection Criteria for the Four Archetypes). The four scenarios are not empirical proof of the eight theoretical propositions (P1-P8) mentioned in Section 2.5. Rather, these scenarios illustrate the possible operation of the propositions in various settings. S1–S4 were selected to represent variation across the full range of technological maturity and governance models. This approach allows the scenarios presented in Section 5 to be interpreted not as empirical proof of the propositions but rather as illustrations of their possible operation. Thus, the centralized governance model in S1 and decentralized governance model in S2 represent opposite poles with respect to P6. The single node in S1 and the distributed node network in S2 represent different levels of redundancy and fragility with respect to P3. The following subsections examine each of the scenarios in detail from the point of view of the four layers of the CLA (visible trends and issues [litany], systemic causes, discourse and worldview, and myths and metaphors) and evaluate the scenarios against the possible sector-specific consequences for transportation.

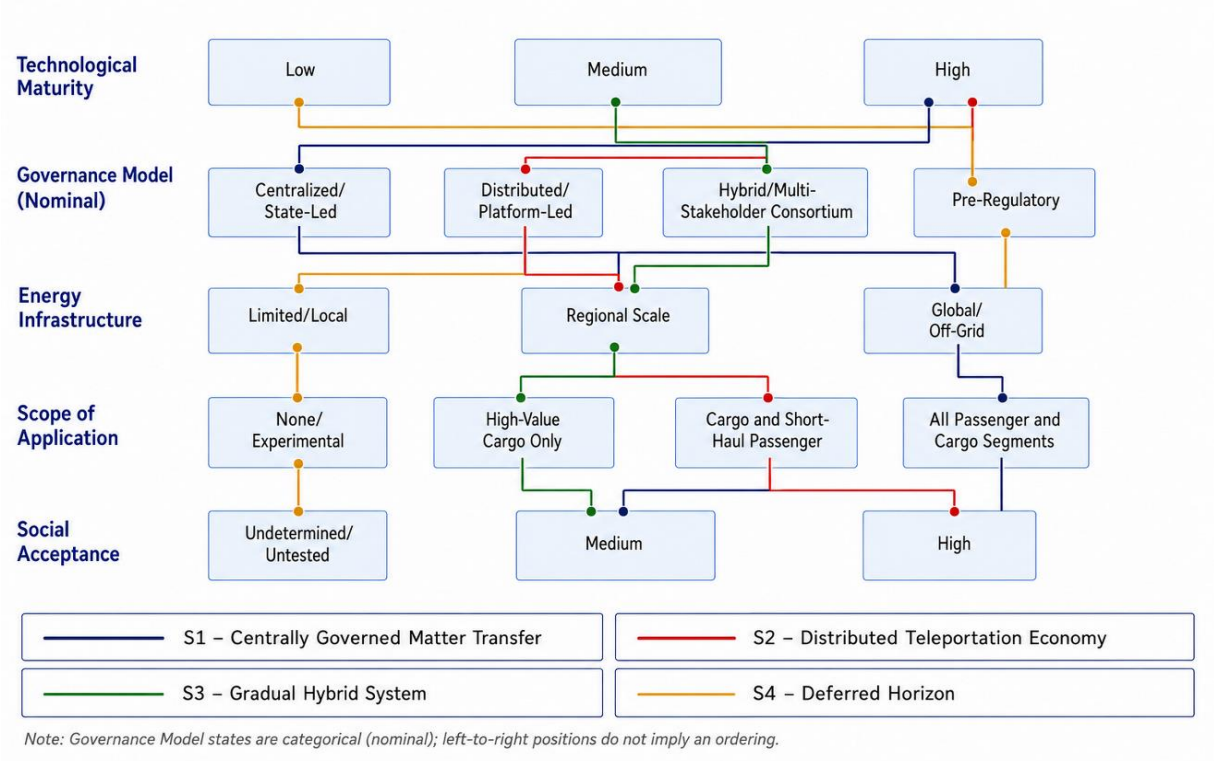

Figure 4. The morphological field: Configuration paths for the five parameters and four scenarios.

Source: Developed by the author, inspired by the General Morphological Analysis approach of Zwicky (1969) and Ritchey (2011).

Table 5. Comparative Summary of the Four Scenarios

Parameter	S1: Centrally Governed Matter Transfer	S2: Distributed Teleportation	S3: Gradual Hybrid	S4: Deferred Horizon
Technological Maturity	High	High	Medium	Low
Governance Model	Centralized / State-Led	Distributed / Platform-Led	Hybrid / Multi-Stakeholder Consortium	Pre-Regulatory
Energy Infrastructure	Global/Off-Grid	Regional Scale	Regional Scale	Limited/Local
Scope of Application	All Passenger and Cargo Segments	Cargo + Short-Haul Passenger	High-Value Cargo Only	None/Experimental
Social Acceptance	Medium	High	Medium	Undetermined/Untested

The measurement levels of the parameters require clarification. "Technological Maturity" can be considered an ordinal variable where Low < Medium < High; hence, it is possible to compare all four scenarios using this scale. By contrast, the "Governance Model" is treated as a nominal parameter, in line with typical applications of the GMA methodology (Ritchey, 2011). The four types of governance models, namely centralized/state-led, distributed/platform-led, hybrid/multi-stakeholder consortium, and pre-regulatory governance models, are not viewed as ordered levels on a single centralized-decentralized scale but rather as four distinct categories having different institutional properties.

As can be seen, the hybrid/multi-stakeholder consortium governance form mentioned in S3 is similar to the multi-party standard-setting structures characteristic of the aviation and maritime industries, namely ICAO and IMO (Abeyratne, 2024). The pre-regulatory state in S4, on the other hand, refers to a pre-institutionalization phase in which no governance regime has yet been institutionalized and relevant research remains limited to laboratory-scale quantum state experiments. For this reason, these two states should not be regarded as intermediate levels on the continuum between the centralized and decentralized forms of governance represented by S1 and S2. Both are conceptually distinct and internally consistent categories that lie outside this continuum. This nominal classification is a modeling choice consistent with the multi-parameter structure of morphological analysis and aligns with the fundamental logic of the GMA approach, which does not require states of different natures to be arranged along a single linear axis (see Section 3.2).

5.1. Scenario 1: Centrally Governed Matter Transfer

In this scenario, matter teleportation is commercialized in the long term and under specific conditions through large-scale, government-supported R&D programs. However, due to its high capital requirements and its strategic and security significance, the technology remains under the control of a limited number of governments and government-supported consortia. At the operational level, international air and maritime transportation must compete with state-controlled “teleportation corridors”. At the systemic level, the key drivers are state control of energy resources and the dual-use (civilian and military) potential of the technology. At the level of discourse and worldview, the concepts of “strategic autonomy” and “technological sovereignty” come to the fore. At the level of myth and metaphor, teleportation is conceived as a “border gate”; the question of who possesses the right to teleportation becomes a new dimension of sovereignty and citizenship. From the perspective of the transportation sector, the fundamental outcome of this scenario is the emergence of a two-tiered transportation structure. While strategically important and high-value flows take place via state-controlled teleportation networks, traditional transportation may recede into the role of a secondary transportation system serving lower-value-added flows, with its nature as a public service becoming increasingly pronounced.

5.2. Scenario 2: The Distributed Teleportation Economy: Platform Capitalism

In this scenario, the technology is maturing rapidly and is being widely adopted in the private sector. The regulatory framework, meanwhile, is following a development pattern similar to that of early-stage sharing economy platforms (Uber, Airbnb), which grew by exploiting gaps in the legislation (an assessment expanded

upon based on Rauch & Schleicher, 2015), and is characterized by relative flexibility and multi-stakeholder participation. At the litany level, dense teleportation node networks are being rapidly established, and competing platform companies are offering affordable, subscription-based teleportation services. At the systemic level, the primary drivers of this development are low barriers to entry and network effects. At the discourse and worldview level, the concepts of "the democratization of access" and "platform freedom" are coming to the fore. At the mythological/metaphorical level, the disappearance of distance is associated with the geographic untethering of capital and labor, giving rise to a new social narrative in which ties to place weaken. From the transportation industry perspective, the main consequence would be that traditional transport providers, such as freight carriers, taxis, and transportation network companies (TNCs), would have to transform into platform-based organizations or lose their competitive edge. Urban logistics might therefore become more dispersed and platform-focused. Yet, this transformation carries a risk of monopolization, as regulatory gaps, safety and liability issues, and network effects could allow a handful of platforms to dominate the market (Rauch & Schleicher, 2015).

5.3. Scenario 3: The Gradual Hybrid System: Multimodal Integration

Given that historical transformations in transportation technologies have emerged in a sector-specific and gradual manner, often first in niche applications, rather than through sudden substitution (Grübler, 1990), this scenario may be considered comparatively more plausible within the conceptual framework of this study. At the operational level, it is anticipated that teleportation will first be used for high-value, low-volume cargo, such as medical supplies, critical spare parts, and high-value e-commerce products, and later for short-distance, low-risk passenger transportation applications, such as connections between airports and city centers. At the systemic level, the governance model defined in Table 5 as a "hybrid/multi-stakeholder consortium" does not rely on the sole control of either a single government or private platform companies. Instead, similar to the multi-stakeholder sectoral standard-setting structures in aviation and maritime sectors (ICAO/IMO; Abeyratne, 2024), a governance structure is envisaged in which authority and responsibility are shared among government regulators, sectoral consortia, and technology providers. This structure provides the institutional foundation necessary for the gradual standardization and diffusion of the technology across different fields of application. At the level of discourse and worldview, the concepts of "complementarity" and "appropriate transport mode selection" gain prominence. Teleportation does not constitute a "revolution" that completely replaces existing transport modes; rather, it emerges as a complementary option within a multimodal transport system. Regarding the mythological and metaphorical levels, the scenario becomes a story of "evolutionary development" based on the idea of technological evolution and adaptation as opposed to radical breakthrough. For the transport sector, the main point of the scenario is that incumbents, such as logistics integrators, ports, and air carriers, are likely to retain their positions by incorporating teleportation into their offerings; however, they will face increased competition from new entrants and business models, especially in last-mile delivery and premium cargo services.

5.4. Scenario 4: The Deferred Horizon: An Evolving Conventional System

In this scenario, matter teleportation remains a purely hypothetical technology; experimental work is confined to laboratory-scale quantum state teleportation, and matter teleportation is not expected to move beyond this hypothetical stage in the near future. Properties of quantum state teleportation, such as quantum state collapse due to measurement and the impossibility of cloning quantum states (the no-cloning theorem), explain why it is limited to the transmission of information and quantum states. However, they cannot serve as a foundation for matter transmission since they are not applicable to macroscopic objects (Section 1.1). Existing teleportation experiments concern quantum states or matter qubits rather than the transfer or reconstruction of macroscopic objects (Hu et al., 2023; Olmschenk et al., 2009). Matter teleportation at the macroscopic scale therefore remains hypothetical under current knowledge, and its energy and computational requirements cannot presently be estimated reliably. At the litany level, the transportation sector continues evolving in line with current technological trends, such as electrification, automation, and MaaS (Docherty et al., 2018; Litman, 2023). At the systemic level, the key features of this scenario include the lack of experimental confirmation for matter teleportation as well as the absence of any physically proven mechanism

supporting the feasibility of this process. Since this technology has not reached the level of commercial readiness, no institutional framework regulating its use has yet been developed; it can be considered "pre-regulation" according to Table 5. This situation does not mean that this scenario is placed between S1 and S2 but denotes a phase of pre-institutionalization in which the distinction between centralized and decentralized governance is not yet meaningful. With respect to discourse and worldview, the dominant idea is "evidence-based planning rather than technological optimism." In myths and metaphors, matter teleportation is viewed as a dream of an uncertain technological future. For the transportation sector, the key implication of this scenario is that the dramatic transformation expected in the other three scenarios does not occur. Instead, current and upcoming transformations associated with automation, electrification, and MaaS, already discussed in transportation studies, continue evolving (Cruz & Sarmento, 2020; Miskolczi et al., 2021).

The relative positions of the four scenarios in terms of technological maturity are presented in Figure 5 using a qualitative scale of development stages that does not assume specific years. Since this study does not employ any Delphi panel, expert survey, or quantitative forecast methods, assigning years or decades to the scenarios would imply a degree of confidence in their occurrence that cannot be justified within this methodology. Therefore, the graph does not assign any dates to the scenarios; instead, it places them on a development scale comprising conceptual development, laboratory experiments, pilot/niche application, partial commercialization, and wide adoption. The main conclusion that can be drawn from this exercise is that differences in technological maturity between the scenarios stem from the states of parameters determined in the morphological scenario analysis (Table 5). This relative positioning is a theoretical assumption based on the morphological analysis and needs to be tested with further empirical research.

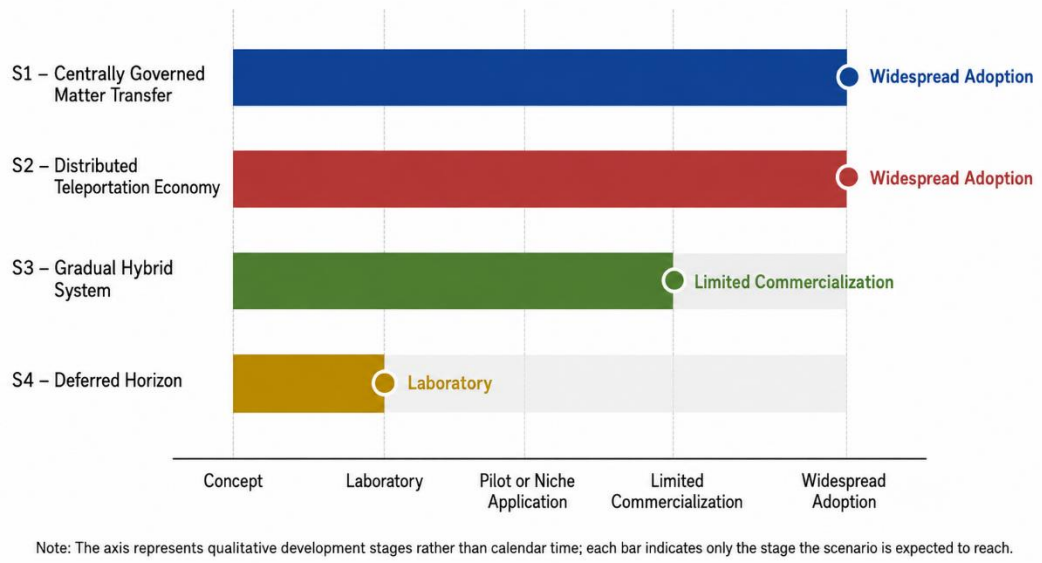

Figure 5. Qualitative development-stage roadmap by scenario (no calendar dates implied).

Source: conceptual/sequential representation developed by the author.

6. DISCUSSION: IMPLICATIONS FOR THE POLICIES AND STRATEGIES OF THE TRANSPORT AND LOGISTICS INDUSTRY

Although the four scenarios describe different configurations and conditions, comparing them helps identify policy and strategy options that would remain viable across several scenarios. In this regard, low-

regret policies, those which would be useful for transportation policymakers and logistics decision-makers under conditions of uncertainty, can be summarized according to the following headings:

- Flexibility of energy infrastructure: Whether or not teleportation becomes a reality, electrification, self-driving fleets, and future teleportation hubs imply greater reliance of transportation systems on energy infrastructure. Therefore, investments in flexible, resilient, and high-capacity energy infrastructure should prove to be valuable under various future scenarios (Sovacool, 2017).

- Phased and indicator-based development of regulatory frameworks: Developing phased regulatory policies corresponding to various stages of maturity of teleportation technology (laboratory stage, pilot projects, and commercial stage), triggered by specific early warning indicators, could help minimize the risks of excessive centralization envisaged in Scenario 1 and the lack of regulation in Scenario 2. Such an approach is in line with the OECD's (2024) approach to the proactive governance of emerging technologies.

- Modularity of logistics network setup: Developing regional distribution centers and port investments according to modular design principles could facilitate the integration of both existing transport modes and future transport innovations.

- Support policies for workforce transformation: Risks to transport-related occupations (drivers, pilots, maritime crew) can be mitigated with pre-established reskilling and career-transition policies. It is also worth noting that this need aligns with ongoing workforce transformation driven by automation and digitalization, regardless of how quickly teleportation is implemented (Frey & Osborne, 2017).

- Multilateral monitoring and standard-setting mechanisms: Given teleportation's potential for use in both civilian and military applications, establishing an early-stage multilateral monitoring, coordination, and standard-setting mechanism, modeled after international organizations such as ICAO and IMO (Abeyratne, 2024), could mitigate the risk of the technology becoming overly centralized under the control of a small number of actors.

The common thread among these recommendations is that, rather than adopting a passive approach of merely monitoring developments in the face of the possibility of teleportation in the transportation sector, the sector should focus on low-cost, reversible, and modular preparedness investments. This approach aligns with the understanding in the literature on futures studies of developing robust strategies that can maintain their functionality under conditions of high uncertainty and in the face of different future scenarios (Wilkinson & Kupers, 2013).

7. LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

The primary limitation of this study is that the technology under consideration, namely matter teleportation, is not an empirically observable phenomenon at present. Therefore, the scenarios presented should be evaluated not as predictions with verified probabilities of occurrence, but as structured possibility spaces designed to systematically examine alternative futures. A second limitation is that the five parameters used within the framework of General Morphological Analysis (GMA), technological maturity, governance model, energy infrastructure, scope of application, and social acceptance, do not encompass all possible variables. Environmental influences, the degree of geopolitical competition, and legal liability are not treated as independent variables in the current model. Furthermore, the cross-consistency analysis conducted in this research is based on the interpretive judgment of a single researcher, without an expert panel or computer-assisted GMA software (see Ritchey, 2011). Future studies could use structured expert panels to expand the number of variables and scenarios and to subject the cross-consistency matrix to a more comprehensive assessment. Another limitation is that the methodology of the research itself is mainly interpretive and qualitative in nature. The systematic collection of expert judgments through semi-quantitative approaches, such as Delphi panels or cross-impact analysis, could provide a more structured assessment of scenario relationships and relative plausibility (Schifano & Niederberger, 2025; Tori et al., 2023). Furthermore, as noted

in Section 3.1, the literature review is based on an interpretive literature synthesis rather than a systematic review protocol. Although this approach is consistent with the interdisciplinary and conceptual nature of the study, it may result in the omission of some relevant studies (Varpio et al., 2024).

Finally, this study focuses on the transportation and logistics sectors. The potential impacts that matter teleportation could have on health, defense, energy, and environmental policies are outside the scope of this study and require examination in separate research.

CONCLUSION

This study positions teleportation as a technological possibility that should be addressed more systematically in the literature on the future of transportation and examines the potential impacts of the "zero-distance" possibility, particularly on freight transport and logistics systems, within the framework of a structured scenario approach. The analysis suggests that, should teleportation become a reality, it could bring about significant transformations in urban spatial organization, supply chain structures, competition among modes of transportation, and labor markets within the transportation sector. However, it is anticipated that the nature and scope of this transformation will depend not only on the level of technological maturity but also on the governance model, energy infrastructure, scope of application, and societal preferences.

A combined assessment of the four scenarios highlights the importance of sector stakeholders adopting flexible, adaptable, modular, and, when necessary, reversible strategic preparedness approaches rather than making long-term, irreversible investment decisions in the face of such highly uncertain but potentially high-impact futures. Therefore, rather than attempting to predict when or on what scale teleportation will occur, it is crucial to incorporate such technologically uncertain possibilities into transportation and logistics planning at an early stage to develop the capacity to prepare for structural transformations that may emerge in the future.

Author Statement

Ethics Statement: *The author declares that ethical principles were adhered to during the preparation of this study. In the event that any violation is detected, all responsibility lies with the author. Furthermore, this study does not require an ethics committee report.*

Statement on the Use of Generative Artificial Intelligence (If Applicable): *The author declares that DeepL was used during the preparation of this article for the purposes of language verification. All generated outputs have been reviewed by the author and revised as necessary; the author is fully responsible for the final content of the published work.*

Author Contributions: *The author contributed to all sections of the study. The author's contribution is 100%.*

Conflict of Interest: *There is no conflict of interest. This study received no financial support.*

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Appendix A.

Illustrative Morphological Scenario Analysis Adapted from GMA: Complete Pairwise-Comparison Matrix

Methodological position: This appendix, which is explicitly referenced as the second limitation in Section 7 of the main text, describes research carried out based on the author's interpretation, without an expert panel or computer-assisted GMA software. Therefore, the analysis presented below is not a full expert-panel-based General Morphological Analysis (GMA) as understood in Ritchey (2011). Instead, it is an illustrative morphological scenario analysis, which is an adaptation of the GMA concept and builds on the six sample comparisons shown in Table 2 of the main text. The numerical results reported below should therefore be interpreted as outputs of the study-defined illustrative consistency procedure rather than as results of an expert-panel-based GMA. This appendix contains the complete formulation of the cross-consistency assessment described in Section 3.3 of the main text. While Table 2 in the main text presents only six example comparisons between parameters, this appendix (i) lists all ten pairwise comparisons between the five parameters along with their 115 state pairs, (ii) describes the entire configuration-space analysis resulting from the above-mentioned comparisons, and (iii) describes the criteria used to select the four archetypes (S1–S4) in that space.

Methodological Note

The study-defined illustrative consistency rule was applied only to the three relationships directly exemplified in Table 2 of the main text: (a) Technological Maturity × Energy Infrastructure, (b) Technological Maturity × Scope of Application, (c) Governance Model × Scope of Application. For these three relationships, a normalized rating (0–1) ranking each state between the poles "early/immature" and "advanced/institutionalized" was used; a combination was deemed "eliminated" (incompatible) when the difference between two states exceeded 0.5, a threshold defined by the author for the purposes of this illustrative analysis rather than one derived from an external source. This rule reproduces the four Table 2 examples that fall within these three relationships (the three eliminated pairs and the Hybrid/Multi-Stakeholder Consortium × High-Value Cargo Only pair). The two remaining examples (Governance Model × Energy Infrastructure) lie outside the scope of the rule and are marked as compatible*, which is consistent with their assessment in Table 2. The seven additional pairs of parameters (e.g., Technological Maturity × Governance Model, or Governance Model × Social Acceptance) were excluded from the rule because it was deemed methodologically inappropriate for those comparisons. Indeed, such a rule presupposes that both parameters of a pair allow a justified ordinal ordering from "early/immature" to "advanced/institutionalized." This condition is satisfied in the case of the three pairs mentioned above, where one parameter in each pair is either Scope of Application or Energy Infrastructure in combination with either Technological Maturity or Governance Model. In the case of the other seven pairs, one (or both) of the two parameters is more appropriately treated as a categorical or context-dependent variable rather than as a stage along a developmental continuum. Hence, application of an ordinal distance rule for them would be methodologically unjustified (see Section 5 on the treatment of Governance Model as a nominal parameter). Thus, in order not to extend the rule beyond its justified boundaries, a different strategy has been adopted. In the comparison cells corresponding to all the seven pairs under discussion, the compatibility is indicated by the tag "compatible*" (asterisk stands for the fact that no study-defined illustrative consistency rule was used). This approach biases the results conservatively: the elimination counts reported below represent a lower bound rather than an upper bound.

Summary Figures

For pairwise interactions (pairs of parameters):

Total state-pair cells (10 pairwise comparisons among 5 parameters)	**115**

Number of cells eliminated by the study-defined illustrative consistency rule	**12**
Remaining (compatible) cells	**103**

For the entire configuration space (all possible combinations formed by choosing one state from each of the five parameters):

Starting point: number of possible complete configurations (3×4×3×4×3)	**432**
Number of complete configurations excluded for containing at least one eliminated pair	**282**
Configurations retained under the applied illustrative rules	**150**

Check: *All four archetypes (S1–S4) identified in Table 5 of the main text are among the 150 configurations retained under these illustrative rules; that is, none of them is internally inconsistent.*

Selection Criteria for the Four Archetypes

The four archetypes were selected from the 150 configurations retained under the applied illustrative rules, following Ritchey's (2011) concepts of "maximum contrast" and "extreme configurations." Selection was based on three criteria.

- Maximum dispersion on the axis of Technological Maturity: the four configurations were selected to represent both extremes of the scale (Low: S4; High: S1 and S2) as well as one configuration representing the midpoint (Medium: S3). This ensures coverage of the entire maturity axis rather than a single point.

- Qualitative diversity on the axis of Governance Model: one of the four states of governance (centralized/state, distributed/platform, hybrid/multi-stakeholder, pre-regulatory) was assigned to each of the four archetypes. Because governance is treated as a nominal variable, this ensures that each of the four governance regimes is represented in one scenario (see the definitions in Section 5, Table 5).

- Distinctiveness of sectors: four configurations from the remaining 150 with the highest discriminating value for transport and logistics policy were selected. In other words, not only the difference in scale of parameter combinations but also the qualitative distinctness of policy/strategy implications was considered (see Section 6).

These three criteria are not an optimization algorithm reducing 150 configurations to the optimal set of one "solution." Consistent with the concept of "maximum contrast", which is common in GMA methodology, there can be several "reasonable solutions" and the final solution depends on the author's interpretation (see main text Section 7, second limitation). The parameter states of the four selected configurations are identical to the S1–S4 definitions in Table 5 of the main text (Ritchey, 2011).

The Complete Set of Ten Pairwise Comparisons (115 Cells)

Cells marked "Compatible" denote comparisons to which no study-defined illustrative rule was applied (see the Methodological Note). Green cells indicate compatibility under the study-defined illustrative rule, while orange cells indicate eliminated combinations.*

Compatible (study-defined illustrative rule)	Eliminated (study-defined illustrative rule)	Compatible* (rule not applied)

Comparison 1: Technological Maturity vs. Governance Model (study-defined rule not applied)

Technological Maturity \ Governance Model	Pre-Regulatory	Distributed/Platform-Led	Hybrid/Multi-Stakeholder Consortium	Centralized/State-Led
Low	Compatible*	Compatible*	Compatible*	Compatible*
Medium	Compatible*	Compatible*	Compatible*	Compatible*
High	Compatible*	Compatible*	Compatible*	Compatible*

Comparison 2: Technological Maturity vs. Energy Infrastructure

Technological Maturity \ Energy Infrastructure	Limited/Local	Regional Scale	Global/Off-Grid
Low	Compatible	Compatible	Eliminated
Medium	Compatible	Compatible	Compatible
High	Eliminated	Compatible	Compatible

Comparison 3: Technological Maturity vs. Scope of Application

Technological Maturity \ Scope of Application	None/Experimental	High-Value Cargo Only	Cargo + Short-Haul Passenger	All Passenger and Cargo Segments
Low	Compatible	Compatible	Eliminated	Eliminated
Medium	Compatible	Compatible	Compatible	Compatible
High	Eliminated	Eliminated	Compatible	Compatible

Comparison 4: Technological Maturity vs. Social Acceptance (study-defined rule not applied)

Technological Maturity \ Social Acceptance	Undetermined/Untested	Medium	High
Low	Compatible*	Compatible*	Compatible*
Medium	Compatible*	Compatible*	Compatible*
High	Compatible*	Compatible*	Compatible*

Comparison 5: Governance Model vs. Energy Infrastructure (study-defined rule not applied)

Governance Model \ Energy Infrastructure	Limited/Local	Regional Scale	Global/Off-Grid
Pre-Regulatory	Compatible*	Compatible*	Compatible*
Distributed/Platform-Led	Compatible*	Compatible*	Compatible*
Hybrid/Multi-Stakeholder Consortium	Compatible*	Compatible*	Compatible*
Centralized/State-Led	Compatible*	Compatible*	Compatible*

Comparison 6: Governance Model vs. Scope of Application

Governance Model \ Scope of Application	None/Experimental	High-Value Cargo Only	Cargo + Short-Haul Passenger	All Passenger and Cargo Segments
Pre-Regulatory	Compatible	Compatible	Eliminated	Eliminated
Distributed/Platform-Led	Compatible	Compatible	Compatible	Eliminated
Hybrid/Multi-Stakeholder Consortium	Eliminated	Compatible	Compatible	Compatible
Centralized/State-Led	Eliminated	Eliminated	Compatible	Compatible

Comparison 7: Governance Model vs. Social Acceptance (study-defined rule not applied)

Governance Model \ Social Acceptance	Undetermined/Untested	Medium	High
Pre-Regulatory	Compatible*	Compatible*	Compatible*
Distributed/Platform-Led	Compatible*	Compatible*	Compatible*
Hybrid/Multi-Stakeholder Consortium	Compatible*	Compatible*	Compatible*
Centralized/State-Led	Compatible*	Compatible*	Compatible*

Comparison 8: Energy Infrastructure vs. Scope of Application (study-defined rule not applied)

Energy Infrastructure \ Scope of Application	None/Experimental	High-Value Cargo Only	Cargo + Short-Haul Passenger	All Passenger and Cargo Segments
Limited/Local	Compatible*	Compatible*	Compatible*	Compatible*
Regional Scale	Compatible*	Compatible*	Compatible*	Compatible*
Global/Off-Grid	Compatible*	Compatible*	Compatible*	Compatible*

Comparison 9: Energy Infrastructure vs. Social Acceptance (study-defined rule not applied)

Energy Infrastructure \ Social Acceptance	Undetermined/Untested	Medium	High
Limited/Local	Compatible*	Compatible*	Compatible*
Regional Scale	Compatible*	Compatible*	Compatible*
Global/Off-Grid	Compatible*	Compatible*	Compatible*

Comparison 10: Scope of Application vs. Social Acceptance (study-defined rule not applied)

Scope of Application \ Social Acceptance	Undetermined/Untested	Medium	High
None/Experimental	Compatible*	Compatible*	Compatible*
High-Value Cargo Only	Compatible*	Compatible*	Compatible*

Scope of Application \ Social Acceptance	**Undetermined/Untested**	**Medium**	**High**
Cargo + Short-Haul Passenger	Compatible*	Compatible*	Compatible*
All Passenger and Cargo Segments	Compatible*	Compatible*	Compatible*