Hype Cycle for Transportation and Smart Mobility, 2023

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Initiatives: Manufacturing and Transportation Sector Dynamics in IT

Transportation technologies increase efficiency, improve safety, enhance user experience and support CIOs in achieving sustainability goals. This Hype Cycle identifies the risk and maturity of technologies that are needed to support the future of smart mobility and passenger transportation.

More on This Topic

This is part of an in-depth collection of research. See the collection:

- 2023 Hype Cycles: Deglobalization, AI at the Cusp and Operational Sustainability

Analysis

What You Need to Know

This Hype Cycle provides insights to underpin long-term technology planning in the areas of smart mobility and passenger transportation. It provides guidance for CIOs, CTOs and other digital leaders of transportation companies, in transit agencies and city governments that are planning efficient and future-oriented transportation systems.

The Hype Cycle outlines several technology-focused concepts and business models related to passenger transportation. The areas of coverage include:

- Urban transportation, including shared mobility and micromobility
- Rail transportation, such as battery electric trains, hyperloop and maglev trains
- Mass transit technologies like trackless tram, hands-free ticketing and digital twins
- Digital platforms such as mobility-as-a-service (MaaS)
- Maritime transportation technology like connected ships and electric ships
- Aviation, including ion-propelled vehicles (UAVs)
- Commercial space travel

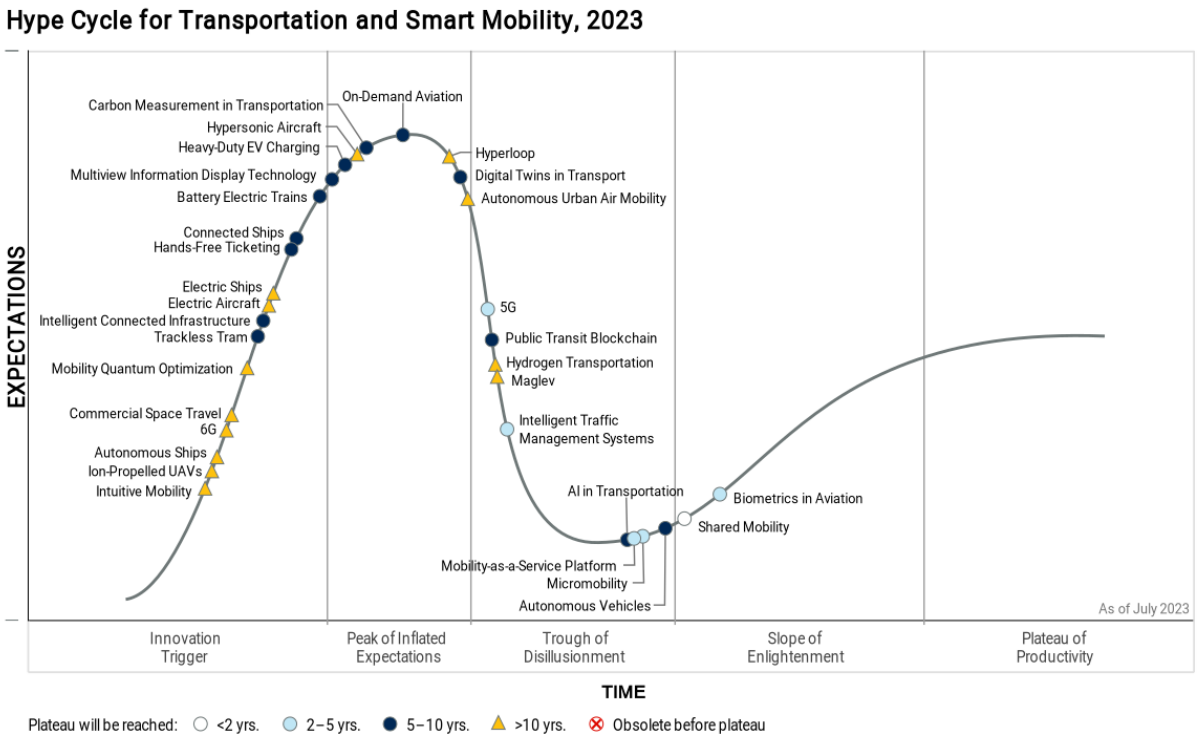
The Hype Cycle

The Hype Cycle for Transportation and Smart Mobility, 2023 helps the CIO visualize the hype and maturity of various technologies by assessing the potential of future technologies in this sector as well as the embedded challenge of implementing them. These technologies also reflect the key trends visible in this sector:

- **User experience** — The COVID-19 pandemic exposed foundational weaknesses of mass transport operators in terms of user centricity, exemplified by frequent service cancellations and delays, especially during busy seasons. Operators face increasing pressure to address shortcomings by investing in user-experience technology such as hands-free ticketing, advanced information displays and modern transportation systems, among other solutions.

- **New forms of mobility** — These same user centricity concerns are leading mass transit operators and transit agencies to look at new forms of mobility that increase the appeal of mass transit by offering a door-to-door service. MaaS platforms, shared mobility and micromobility are some of the most common approaches.
- **Cost optimization and efficiency** — The top priorities of CIOs in 2023 have focused on cost optimization and efficiency, with the implementation of technologies like artificial intelligence (AI), digital twin, and 5G/6G. (See Infographic: Top Priorities, Technologies and Challenges for CIOs in the United States for 2023).
- **Autonomous Vehicles** — Self-driving technology will continue to advance, leading to increased adoption across various areas, including ride-hailing and micromobility. This trend is motivated by the difficulty hiring and retaining drivers, as well as the need to reduce costs and improve safety.
- **Sustainability** — Regulation and public opinion are driving a greater emphasis on sustainable practices toward net-zero carbon transport. This trend is visible through the adoption of environmentally friendly transportation solutions such as micromobility, battery electric trains and hydrogen trains.

Figure 1: Hype Cycle for Transportation and Smart Mobility, 2023



Source: Gartner (2023)

The Priority Matrix

Many technologies have transformational or high impact on the transportation industry, but they will take longer to achieve their benefits. For instance, the use of AI in transportation or the adoption of autonomous vehicles has the potential to create a huge impact but mainstream adoption will take five to 10 years. CIOs involved in this space must strategize to implement these solutions over a longer period to generate the best outcome.

Innovations like 5G, biometrics in aviation or MaaS have moderate benefits, but CIOs need to prepare for the impact of such innovations as they are just two to five years away from reaching mainstream adoption. They need to act immediately if they want to leverage the potential benefits of these innovations.

Mainstream adoption of technologies like hyperloop, 6G or autonomous urban air mobility (UAV) will take more than 10 years; however, these innovations will have a transformational impact in the transportation industry and will set a new paradigm. CIOs interested in this space should strategize the R&D aspects of these innovations.

Table 1: Priority Matrix for Transportation and Smart Mobility, 2023

(Enlarged table in Appendix)

Benefit	Years to Mainstream Adoption			
↓	Less Than 2 Years ↓	2 - 5 Years ↓	5 - 10 Years ↓	More Than 10 Years ↓
Transformational			AI in Transportation Autonomous Vehicles	Autonomous Ships Commercial Space Travel Hyperloop Hypersonic Aircraft
High		5G Biometrics in Aviation Mobility-as-a-Service Platform	Battery Electric Trains Carbon Measurement in Transportation Connected Ships Heavy-Duty EV Charging Intelligent Connected Infrastructure	6G Electric Aircraft Electric Ships Mobility Quantum Optimization
Moderate	Shared Mobility	Intelligent Traffic Management Systems Micromobility	Digital Twins in Transport Hands-Free Ticketing Multiview Information Display Technology On-Demand Aviation Public Transit Blockchain Trackless Tram	Autonomous Urban Air Mobility Hydrogen Transportation Intuitive Mobility Ion-Propelled UAVs Maglev
Low				

Source: Gartner (July 2023)

On the Rise

Intuitive Mobility

Analysis By: Venecia Liu, Shivani Palepu, Dean Lacheca

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

Intuitive mobility is the ability to predict passenger movement through the use of pattern analysis, generative AI, advanced technologies and behavioral analytics.

Why This Is Important

Intuitive mobility is an opportunity for public transit and transport companies to anticipate a rider's needs and to provide relevant services. This makes predictive analytics more actionable by aligning travel behavior to opt-in consented data context for travel convenience. Intuitive mobility can also be applied with anonymized data to orchestrate transit for mass needs and better planning for the next best travel action and ensuring that relevant modes of transport are aligned.

Business Impact

Several transit authorities have tried on-demand transit with limited success given the cost to maintain and operate within an on-demand construct. Intuitive mobility abstracts data from various sources to look at passenger intent and behavior dynamics to increase rider satisfaction and facilitate better asset utilization as well as timely connections to other modes of transport.

Drivers

- Provides relevant modes of transport to increase ridership.
- Anticipates riders' needs to enhance passenger satisfaction and user centricity.
- Optimizes routes and services based on analytics to ensure timely transport services.
- Reduces carbon emission from private vehicles by providing more relevant public transport services.

Obstacles

- Technology investments in generative AI and data analytics.
- Limited skill sets and expertise to build AI algorithms, behavioral analytics and ridership data to build the predictive models.
- Data integration across various systems.
- Data privacy and data protection concerns.
- The cost to maintain and operate these systems is high.

User Recommendations

- Collaborate across multiple modes of transportation as well as the related infrastructure and ecosystem and context (time of day, weather, working hours and location type) to get a holistic view.
- Analyze various patterns not just ridership but also examine destination location to model out “intent” or “purpose” of transit as well as behavior into the analysis.
- Hire generative AI experts and predictive analytics experts or develop them in-house.
- Create a modular architecture with microservices to pull in data feeds from different sources.

Sample Vendors

INRIX; Otonomo (Neura); StreetLight Data

Gartner Recommended Reading

Quick Answer: How Can Transit CIOs Leverage Micromobility to Strengthen Public Transportation?

Ion-Propelled UAVs

Analysis By: Jonathan Davenport, Pedro Pacheco

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

Ion propulsion is a technique for creating thrust for unmanned aerial vehicles (UAVs). It works without moving parts and harnesses “ionic wind” power. When high voltage is applied, nitrogen and oxygen molecules in the air are ionized; these positively charged molecules are drawn toward a negatively charged electrode, banging into other air molecules to create an ionic wind. Ion engines have been used in spacecraft and satellites, but require a dedicated supply of nitrogen and oxygen to operate.

Why This Is Important

Ion propulsion has the potential to transform flight. UAVs will become airborne without the need for moving parts, such as propellers or turbine blades. As a result, flight will be almost silent, which is a major benefit in urban areas. Ion propulsion will also overcome possible entanglement issues, which impact current UAV safety.

Business Impact

Traditional drones are loud and, when deployed at scale, could be obnoxious, negatively impacting the ability for them to be deployed for use cases in urban areas. For example, NASA conducted a psychoacoustic test that found that the noise-related annoyance levels of traditional UAVs were higher compared to noise from road vehicle drive-bys in residential neighborhoods. The fact that ion-propelled UAVs are near-silent could be the solution to use within residential areas.

Drivers

- The high noise levels generated by propeller-operated drones and vertical takeoff and landing (VTOL) vehicles are prompting vehicle designers to look for solutions, particularly in urban applications. The acoustic footprint of traditional UAVs has been fairly high, in the region of 60 dB to 90 dB, but ion-propelled UAVs could significantly reduce the noise, making them well-suited to carry out activities in residential areas.
- Even if not yet considered as a major issue, propeller-based drones could impact wildlife when these become widespread, which would prompt a strong intervention from environmentalists. Ion-propelled UAVs may be seen as a way to mitigate this potential problem.
- The amount of thrust generated by ion propulsion has been a long-standing problem. Given these vehicles require electric power, this entails the usage of batteries. However, the big investments being made in the area of electric vehicles are enabling breakthroughs in terms of battery energy density. A lighter battery means less thrust is needed from ion propulsion to achieve sustained flight.
- Undefined Technologies showed its ion-propelled UAV technology in 2020, achieving a flight time of 25 seconds under lab conditions. This progressed to a real-world flight time of 4.5 minutes in 2022 and the company is working toward an objective of keeping the drone airborne for 15 minutes by the end of 2023 (see Undefined Claims 4.5-Min Flight for Its "Silent" Ion-Propulsion Drone, New Atlas).

Obstacles

- Traditionally, ion thrusters relied on the lack of friction in a vacuum, for example, to move satellites between orbits. Earth's gravity means that much larger amounts of thrust are required to lift an object. Ion thrusters have typically provided only 0.5 newtons of thrust, meaning each can support approximately 50 grams of weight.
- Battery energy density (kWh/kg) is still a major obstacle to the performance of ion propulsion. Each ion-propelled prototype created so far has been extremely lightweight. Due to their tiny batteries, current range is limited to short, cargoless flights.
- Navigation will be challenging in all but the calmest of wind conditions due to UAVs' lightweight design.
- Ion thrusters produce ozone, which in high concentrations can be harmful to the health of people.

User Recommendations

- Follow developments in academic research, such as those being undertaken by MIT and University of California, Berkeley, to see how the nascent technology matures.
- Follow the progress of early-stage companies like Undefined Technologies. Assess whether merger and acquisition investment or purchasing this technology is most appropriate at this stage, or if this technology can be replicated in-house.
- Track the most recent developments in battery technology because energy density will be a crucial factor for ion propulsion's success.
- Choose the most suitable use cases to allow for technology adoption growth, and consider that UAVs operating in urban environments are the most obvious choice. However, as technology evolves this may open opportunities for use cases entailing flights over nature reserves and military, with security services also possibly taking advantage of the ultralight and quiet nature of ion-propelled UAVs for surveillance.

Sample Vendors

Undefined Technologies

Gartner Recommended Reading

Forecast Analysis: IoT Enterprise Drones, Worldwide

Forecast: IoT Enterprise Drones by Use Case, Worldwide 2021-2031

Emerging Tech Impact Radar: Smart Robots and Drones

Emerging Tech: How to Overcome Hurdles to BVLOS Drones' Widespread Use

Autonomous Things: Technology Use Cases for R&D

Autonomous Ships

Analysis By: Jonathan Davenport

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

Autonomous ships — including container ships, harbor tugs and ferries — operate via an AI algorithm that perceives the ship's environment by fusing together data from onboard sensors such as video, lidar, radar, thermal imaging, sonar and ultrasonic sensors. The output from these sensors is classified and used, in combination with global navigation satellite system (GNSS) localization, HD maps, weather forecasts and destination data points, by the virtual captain to make piloting decisions.

Why This Is Important

Putting a virtual captain onboard a vessel can either complement human crew members or replace them entirely, which has the potential to increase operational safety and reduce vessel costs. Though the shipping industry has lagged behind others in the adoption of this technology, it is now beginning to make investments in proofs of concepts and trials, often with financial support from governments.

Business Impact

The majority of maritime accidents involve collisions or groundings. Automation can improve safety, and reduce costs through labor reduction and operational efficiency improvements. Lighter vessels can be designed because crew living space and associated welfare systems are not required. These new vessel designs will result in a reduction in operating costs — primarily fuel — and greenhouse gas emissions.

Drivers

- Autonomous ships will lead to fewer accidents. The European Maritime Safety Agency found that between 2011 through 2015, 50% of marine casualties occurred as a result of navigational errors, while 63% of accidental events were caused by human erroneous action.
- For new vessels, capital costs can be reduced when a vessel is designed without the need to support the human workforce. This eliminates the need for walkways, human-machine interfaces (HMIs), and heating and cooling systems.
- Competitive pressures are also encouraging companies to explore autonomous vessels. High-profile investments have been made by companies (such as IBM for its Mayflower vessel and Ocean Infinity for 23 autonomous vessels that it plans to launch as part of its Armada fleet).
- Governments are investing in these vessels. For example, Norway provided over half of the investment needed for Yara International to develop its autonomous electric Yara Birkeland vessel to help replace diesel trucks with cleaner alternatives.
- Ship crew members often work in very isolated environments and are away from their families for long periods of time. Autonomous ships can dramatically improve work-life balance for these individuals, provided they can be retained for shore-side activities.
- The International Maritime Organization's Maritime Safety Committee (MSC) is working on regulations for autonomous vessels. Current trials in international waters use the interim Maritime Autonomous Surface Ships (MASS) guidelines published in June 2019 and allow vessels to bypass current international shipping law, which states that ocean-going vessels must be properly crewed. This is complemented by the regulatory scoping exercise for the use of MASS, published in June 2021.

Obstacles

- Challenges relate to the virtual captain's ability to handle storms, lost loads, comms/sensor damage, harm to wildlife and piracy threats.
- Removing experienced crew from ships could mean that when accidents do occur, particularly involving fires, they might be more severe without a crew to intervene.
- To overcome risks related to maintaining uncrewed vessels, ship operators may start demanding higher levels of reliability from their equipment suppliers to ensure continued vessel operation.
- Autonomous ships face social acceptance barriers related to "stealing" jobs.
- For "nearshore" or shallow water maneuvers, the accuracy of sea charts presents challenges to navigation. The ability to create and maintain HD maps of the ocean floor will be vital, particularly if pilots who navigate vessels into ports are to be replaced by autonomous systems.

User Recommendations

- Create a strategic vision for business transformation by designing automated processes to complete operational tasks. Don't factor in human requirements at the start — this will constrain your thinking. Think about what you want to achieve, rather than how you can achieve it.
- Analyze how autonomous vessels might be maintained. Modularity will become a key requirement, enabled by a plug-and-play approach, so faulty equipment can be removed and replaced in port. Likewise, over-the-air updates to software and firmware will be vital. Electric propulsion technology might also be useful for certain use cases.
- Implement best practices by leveraging lessons from other industries, such as manufacturing or logistics, that have more mature implementations of other forms of autonomous things.
- Prepare to redeploy staff to higher-value jobs by actively communicating with individuals and trade unions, while putting in place specific training and support packages centered around shore-based tasks.

Sample Vendors

IBM; Massterly; Ocean Infinity; Orca AI; Saildrone; Yara International

Gartner Recommended Reading

Innovation Insight: Autonomous Ships Will Improve Operational Efficiency at Sea

Lessons From Mining: 4 Autonomous Thing Benefit Zones for Manufacturers

6G

Analysis By: Kosei Takiishi

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

6G is the generic name for the next-generation cellular wireless, also called Beyond 5G. In 2023, the features and timetable for 6G are not clearly defined, although it's expected to be commercialized in 2028 by some communications service provider (CSP) pioneers. 6G will enhance 5G capabilities and is intended to provide higher peak data rate (e.g., 100 Gbps to 1 Tbps), lower latency (e.g., 0.1 ms) and much more connection density and energy efficiency (e.g., 10 times more efficient).

Why This Is Important

The U.N.'s 2030 Agenda for Sustainable Development, including 17 goals, is heavily impacted by the mobile industry. Many of these social issues and ambitious goals will result in technologies that will become a part of 5G or future 6G cellular deployments. Design and research for 6G is already underway by many industrial associations and academic and commercial organizations. 5G can solve some of these challenges; however, 6G is indispensable for continuous growth and problem solving in the 2030s.

Business Impact

6G will enable end users, including consumers and enterprises, to transfer and process large volumes of data in real time, which enables true immersive experiences as well as more mission-critical human machine communications. Much richer and advanced connectivity of the physical world with the digital world — digital-physical fusion — is expected. There is no clear 6G definition, but 6G is aiming to improve 5G capabilities by adding one generation every 10 years (same as before).

Drivers

- Different from 4G and current 5G, 6G will become a sort of national network supported or impacted by countries and national policies. Some leading countries have started their initiatives, which will drive further research and discussions. In February 2023, the South Korean Minister for Science and ICT unveiled the K-Network 2030 plan, calling for South Korean tech firms to lead the way in developing world-class 6G technologies and software-based networks. The Chinese government has nominated 6G as one of its priority projects for 2023. In March 2023, the Beyond 5G Promotion Consortium in Japan published its B5G White Paper 2.0.
- Academics and commercial organizations want to be part of the 6G process, and active research has already begun. Working group one6G in Europe hosted a summit and held related open webinars in 2022. In February 2023, NTT DOCOMO hosted Open House'23, where 6G was one of the main topics. In November 2022, NTT DOCOMO published the 6G White Paper 5.0.
- Many commercial organizations and academic institutions have started their 6G research to be a part of the future 6G patent pool.

Obstacles

- The 5G journey is still in its early years, and its best practices and monetization are not clear. Success or failure of 5G to drive revenue and new business opportunities will have a major impact on 6G commercialization and business.
- The telecommunications industry has formulated its own specifications and standardization (such as 2G, 3G, 4G and 5G). It is unclear whether 6G will be able to incorporate external opinions, extending the start provided by some other industries' participation in developing 5G standards.
- Some 6G technologies, such as THz wireless, may not prove to be technically viable or cost-effective for most cellular users' needs.

User Recommendations

- Monitor discussion of the currently emerging 6G carefully.
- Prepare early trials and proofs of concept (POCs) in the late 2020s with vendors to learn more about the capabilities of 6G and early use cases, and begin building skill sets.
- Support your regulators and government to create their new national policy for 5G-Advanced and 6G. Technology innovation and strategy leaders should look at evolving 6G standards to get an early idea of future networking technologies.

Sample Vendors

Ericsson; Huawei; Nokia; NTT DOCOMO; Qualcomm; Samsung Electronics; SK Telecom

Gartner Recommended Reading

Emerging Tech Impact Radar: Communications

Commercial Space Travel

Analysis By: Mike Ramsey

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

Commercial space travel refers to commercial initiatives aimed at transporting people into space, outside of government-orchestrated research or military flights.

Why This Is Important

Citizen space travel represents a new market for advances in rocket technology and efforts by several private rocket companies to build new space-capable ships. There have been a handful of wealthy citizen space travelers, but space travel remains almost entirely the province of governments because of the cost and safety concerns. This is expected to change in the next decade, creating the potential for citizen space travel and exploration.

Business Impact

The near-term impact of citizen space travel is limited, but the long-term impact is vast. SpaceX provides commercial services to NASA to deliver astronauts to the International Space Station (ISS), and tourist flights into the Earth's orbit and to the ISS. Establishing a multiplanet society could create an entirely new transportation segment and massive investments in new technology, tourism and private research.

Drivers

- Regulatory approval for lightly trained, or untrained, passengers to travel on spacecraft will be critical in expanding space travel beyond astronauts, when in place.
- The cost-per-pound to launch may fall as low as $10 with the development of SpaceX's newest rockets.
- The use of autonomous flight controls reducing the need for qualified personnel, such as with the Inspiration4 flight, could lead to an expansion of space travel.
- The lure of an extremely exclusive type of travel could incentivize wealthy people to pay for the experience, not unlike attempting to scale Mount Everest.
- Reducing the operational cost of reusable rocket technology and multipassenger space crafts, as well as expanding the number of offerings in the market, will be vital to the growth of space travel.
- The publicity around early visits to space by citizen astronauts will be critical in allowing more such travels.
- Access to video of astronauts in the ISS has increased consumer interest in space travel and the opportunity to experience weightlessness.
- Government contracts for astronaut transportation, notably by NASA, have provided funding for early design and development of competitive commercial offerings.
- Systems which touch the edge of space, rather than reaching orbit, are being developed using balloons and airlaunch vehicles, reducing the cost of reaching space.

Obstacles

- There are very few options for traveling to space today, and those rockets are primarily used to transport astronauts to and from the ISS.
- While launch costs have fallen as low as $1,200 per pound aboard some SpaceX vessels, human cargo is more difficult and expensive to carry because of safety and life support functions.
- Getting safety and regulatory approval for new space-faring technology is challenging and takes a long time.
- Space travel is still inherently dangerous and requires special training of nearly every crew member because of the inability to send aid in case something goes wrong. Building a high level of safety for ordinary citizens will take several years.

User Recommendations

- Implement space tourism on long-term technology radar as a business opportunity for aerospace and hospitality companies.
- Determine whether your company can provide products or services that support the nascent space transport business.
- Examine technology being developed to support space travel, and check whether there are Earth-bound applications that could leverage the advances.

Sample Vendors

Axiom Space; Bigelow Aerospace; Blue Origin; Rocket Lab; SpaceX; Virgin Galactic; World View Enterprises; Zero 2 Infinity

Gartner Recommended Reading

Find Growth Opportunities on Earth Inspired by the Industrialization of Space

Maverick Research: It's High Time We Discuss the Ethics of Space Industrialization

Mobility Quantum Optimization

Analysis By: Pedro Pacheco

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Quantum computing (QC) is a type of nonclassical computing that operates on the quantum state of subatomic particles to address problems with vast combinatorial complexity. One of the many areas where quantum computing offers potential for polynomial improvement is optimization. In mobility, this capability can be used to optimize traffic, as well as highly complex operational ecosystems.

Why This Is Important

QC uses quantum mechanical principles, including superposition and entanglement, to effect extreme scale parallelism in computationally explosive problems. One of the early impact areas with potential for polynomial speedup is optimization where annealing algorithms have shown early promising results. Quantum systems designed to address optimization at scale have the potential to solve major transport optimization problems not addressed by classical computers.

Business Impact

The United Nations expects that 68% of the world's population will live in urban cities by 2050. Transit authorities have been looking to optimize urban mobility by improving routing and reducing commute times and traffic congestion while seeking a better quality of life for residents. Quantum systems designed to solve optimization problems at scale and specialized quantum-emulation classical technologies can potentially optimize the combined efficiency of transportation in a large ecosystem.

Drivers

Quantum computing has a strong potential in transportation as it allows companies to explore annealing-based solutions to problems that were previously seen as unsolvable or too time-consuming:

- QC's ability to model and forecast complex ecosystems, like traffic environment and urban planning, is a point of attraction for several organizations, as it could bring substantial improvements in increasing the efficiency with which people and goods are transported. Volkswagen has already started to test the technology in traffic optimization, using a QC from D-Wave. Ford is working with Microsoft on a use case that utilizes QC to optimize vehicle navigation route guidance. Besides making use of swarming effect information, the model uses QC to run frequent optimizations that take into consideration thousands of other vehicles on the road.
- Several transportation providers feature highly complex operations, like in the case of airlines or railway companies. Some of these companies see quantum annealing systems and classical quantum emulation alternatives as a tool that can unlock opportunities in terms of planning and running these operational processes, including running complex "what if" scenarios for better disruption preparedness. For instance, these are among the reasons why Delta Air Lines is partnering with IBM to explore quantum applications.
- Vehicle design also entails several processes of optimization, and some of them are already evaluating QC as a way to unlock significant additional improvements, be it in several parameters of vehicle performance or cost. As an example, Airbus launched the Quantum Computing Challenge back in 2019 as a way to accelerate cooperation with academia and startups in this area, with the aim of introducing QC for commercial applications.

Obstacles

The obstacles pertain to usage practicality and the complexity of using a computer in a totally different way for problem solving:

- **Decoherence.** QC is extremely sensitive to decoherence, a process where the surrounding environment (like magnetic and electric fields and heat sources) destabilizes qubits, leading to information loss and diverse results.
- **Shortage of QC programming skills.** QC programming languages are different from other existing languages, which entails the need to hire or train specific expertise.
- **Complexity of mapping business problems** and refactoring them into quantum applications. None of the existing classical applications and algorithms used in classical systems work in a quantum context.

- **Immaturity of the quantum ecosystems,** scale of systems and limited vendor maturity creates challenges in enterprise ability to develop sustainable optimization solution roadmaps.

User Recommendations

QC becomes more commercially accessible but is still in an early phase. Transportation CIOs must plan QC initiatives with a future mindset:

- Modernize optimization algorithms and leverage classical technologies, including accelerators and quantum emulation accelerators. Apply logical constraints to problems to optimize complexity.
- Identify inflection points where quantum alternatives become better than classical advantage. Most optimization problems may not need a quantum approach.
- Develop a long-term technology adoption plan focused on quantum ecosystem selection and choice. Roll out use cases in line with the evolution of QC technology. Focus on a five-year horizon to deploy real-time applications where calculation speed is essential.
- Set up a QC internal innovation and exploration team, with a strong executive sponsor, clear innovation processes and cross-functional support. Nurture QC expertise to achieve a major QC unit in the long run.
- Leverage QC-as-a-service providers as a start.

Sample Vendors

Alibaba Cloud; D-Wave; Fujitsu Group; Gurobi Optimization; IBM; Microsoft; NVIDIA; Rigetti Computing

Gartner Recommended Reading

Innovation Insight for Quantum Computing for the Automotive Industry

Quantum Computing Planning for Technology General Managers

Trackless Tram

Analysis By: Shivani Palepu, Pedro Pacheco

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

A trackless tram is a mode of mass transportation that doesn't require tracks like traditional trams or light rail. The vehicle runs on rubber tires using electric propulsion and is guided autonomously using optical, lidar, radar and GPS technology. Instead of using overhead power lines, these trams recharge their batteries at each station. They are considered as a catalyst for regenerating city suburbs and providing a cost-effective and sustainable mode of transportation.

Why This Is Important

Transit agencies that aim to prioritize cost-effectiveness and focus on sustainability may find trackless trams to be a viable mass transit alternative. They do not require costly track infrastructure and can be implemented quickly. Utilizing trackless technology, the trams can share road space with other vehicles, eliminating the need for dedicated tracks and enabling flexibility in terms of route planning and modifications.

Business Impact

Trackless trams are cost-effective as they do not require extensive track infrastructure installation or maintenance. They are much cheaper to build than the conventional light rail. Trackless trams also provide increased flexibility in terms of route planning and modifications as they do not have a fixed infrastructure to rely on. Being electrically powered, trackless trams emit zero tailpipe emissions, aiding organizations in achieving their carbon neutrality goals.

Drivers

- Trackless trams provide a cost-effective method for mass transit organizations due to improved flexibility and lack of required track infrastructure.
- From a sustainability perspective, trackless trams help in reducing pollution and traffic congestion in cities.
- Trackless trams feature modern designs that prioritize passenger comfort and experience, including “at level” onboarding. They improve the overall mobility experience of users and provide universal accessibility.
- Trackless trams could use autonomous technologies, such as computer vision, lidar, GPS technology and more, to guide the tram.
- It is easier for a trackless tram to share roads with other vehicles due to the absence of tracks. Rail tracks sometimes pose a risk for road vehicle drivers, and in some circumstances can cause accidents.
- Trackless trams allow a flexible approach to alter and redesign routes based on future demand.

Obstacles

- Some hype exists with trackless trams being viewed as “glorified” conjoined shuttle buses. There are not many suppliers for the market, which may lead to proprietary vendor lock-in.
- The reliability of trackless trams has raised some concerns, with regards to the weather impacts such as fog or snow conditions. An optically guided bus system was used in Las Vegas, which led to challenges with reliability due to oil spills and markings on the virtual track for the camera-based guidance system.
- The regulatory framework for trackless trams may not be well-established in some jurisdictions. Issues such as safety regulations, licensing and liabilities may need to be addressed to ensure compliance with existing laws.
- Trackless trams might have a short-lived hype with the innovations happening in autonomous vehicles, increasing demand for on-demand transportation and the adoption of micromobility modes.
- The fact that trackless trams operate autonomously may raise concerns.

User Recommendations

- Adopt a holistic perspective on the total cost of installing and operating a mass transit system. A trackless tram allows for a substantial cost reduction on infrastructure, as installation and maintenance of tracks is not required.
- Evaluate traffic patterns to identify traffic bottlenecks and plan for potential routes. Work with city planners to model additional infrastructure requirements where trackless trams could be a possible advantage to redesign tram lines and service passengers more easily.
- Follow developments from manufacturers of trackless trams as the technology will continue to evolve. It may also be useful to interact with technology companies in the area of autonomous driving. This could serve as a way to use their technology to help mitigate some of the limitations currently experienced by trackless trams in terms of autonomous operation.
- Stay informed about local regulations as they may vary depending on the location where the technology is being implemented.

Sample Vendors

CRRC Zhuzhou Locomotive; HÜBNER Group; Siemens

Gartner Recommended Reading

Technology Assessment of Transforming Trends in the Rail Industry for 2030

Electric Aircraft

Analysis By: Mike Ramsey

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Electric aircraft operate under electric propulsion for the purpose of transporting people or goods. These aircraft could include helicopters, planes and vertical takeoff and landing (VTOL) planes that use electricity rather than liquid fuels for propulsion.

Why This Is Important

Electric air transportation addresses the need for reducing greenhouse gas emissions and other pollution from fossil fuels. In the longer term, electric aircraft will have to transition to batteries to provide long-distance transportation when petroleum-based fuel becomes more expensive to extract from the Earth.

Business Impact

Electric aircraft already are making an impact on a small scale in the form of personal and commercial drones. Electric aircraft have the benefit of easy startup and repairability compared with combustion and jet engines. Numerous startups are making electric plasma jets and propeller-driven aircraft. Still, most of the new vehicles that have been produced to date are limited in size, range and speed. Electric aircraft may be ideally suited for short flights, where the cost of operation is high for liquid-fueled planes, especially jet planes.

Drivers

- Pollution regulation and the demand to reduce greenhouse gas emissions are the largest drivers for the adoption of this technology.
- The development of lighter, more powerful and less-expensive batteries is very likely to expand the use of electric aircraft, especially for short-distance vehicles.
- Most early efforts to develop autonomous urban aircraft use an electric powertrain because of the electric architecture and simplicity. If these vehicles begin to get market traction, it will help to increase the market penetration of electric aircraft.
- Some countries, such as France, have banned short-distance flights to reduce carbon dioxide emissions. Electric aircraft are seen as an alternative.

Obstacles

- The weight of batteries relative to the energy required to power planes, jets or helicopters limits the range of the vehicles.
- There have been some examples of long-distance electric aircraft, but they are mostly demo aircraft and travel at low speeds, and can carry only a small number of people.
- The lengthy period of certification for new aircraft is especially challenging for new technologies in aerospace. It can take a decade to get an airplane qualified as safe for passengers, which puts a strain on startups seeking revenue.
- Developing electric plasma jets that could come close to the range of liquid-fueled jets could take many years. Even then, the recharging time of a battery electric jet is likely to be substantial because of the size of the batteries.
- Airports will need to install fast-charging equipment to support electric aircraft. These chargers are expensive and will require electric infrastructure installation.

User Recommendations

- Investigate short-distance routes that could be replaced by electric aircraft as a first step in consideration of adding electric aircraft into a fleet.
- Watch whether experimental electric aircraft receive Federal Aviation Administration (FAA) and other regulatory body approval for passenger flights, because it likely will create an easier pathway for other companies to produce these aircraft.
- Check for signs that regulators will approve the use of electric drones over urban areas, as this will be a key first step toward allowing larger vehicles to operate in a similar theater.

Gartner Recommended Reading

Product Leader Insight: Composability and Ecosystem Solutions Form the Future of Aviation

Electric Ships

Analysis By: Jonathan Davenport

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Electric ships use battery packs to power an electric motor with no secondary source of propulsion. Investment in electric ships is motivated by the need to address fuel efficiency, sustainability and emission requirements, in addition to market demands for lower operational costs.

Why This Is Important

Electric propulsion can help the maritime sector attain net-zero emissions. Electric propulsion is limited by energy density and the prohibitive weight and cost of batteries when used in heavy-duty and long-range applications. At present, light-duty marine applications and small boats are most suited for electric propulsion, where the vessel can be charged at the end of its voyage. Key candidates for this technology include pleasure craft, ferries, inland waterway and coastal shipping and workboats.

Business Impact

Greenhouse gases emitted by maritime fleets can be reduced or completely eliminated by using electric vessels. For companies that want to reduce their carbon footprint, electric vessels can also be used as an alternative to transporting goods by road. There is also potential for reduced operational costs because electric motors require far less maintenance than combustion engines and are much more energy-efficient. Electric naval vessels are harder for submarines to detect because they are so quiet.

Drivers

- The maritime industry's carbon footprint is daunting. As a whole, the sector accounts for 2.5% of global greenhouse gas emissions. Shipping accounts for 13% of global sulfur dioxide emissions, along with emissions of other noxious pollutants. Most ships run on diesel or bunker fuel, which is inexpensive, but dirty, containing 3,500 times more sulfur than passenger vehicle diesel.
- Government incentives and political pressure may incentivize the maritime industry to switch to better energy sources. For example, government assistance has already been given to stimulate companies' participation in smart grid projects to enable the electricity power grid to respond to increased peak loads caused by electric ship charging.
- The cost of energy from renewable electricity can, in most European countries, compete with energy from fossil sources.
- Eliminating the internal combustion engine simplifies the ship's propulsion system, reducing the need for human intervention and making it easier to incorporate autonomous technology into vessels.

Obstacles

- Diesel technology is a reliable form of marine propulsion and auxiliary power generation. Even cruise ships, icebreakers and drilling vessels that use diesel-electric systems, don't source the electrical power from batteries, instead diesel generators provide power to the electric motors used to propel the ship forward.
- Batteries are heavy and occupy substantial space. Water currents also affect energy consumption, so electric ships have difficulty in traveling long distances without places to stop and charge.
- Thermal runaway is a risk for batteries and can lead to explosions.
- The initial capital investments in new battery and motor technology are significant (more than $1 million per ship). Also, as batteries are recharged, they degrade over time, meaning each battery will have a finite life span and will need replacing in the future if the vessel's range is to be maintained.
- Shore connection and charging infrastructure investments would also be required. Government support will be necessary to make electric vessels a reality.
- Regulations for low carbon emissions can be enforced only when the ships are within territorial waters. Out on the open ocean, no laws pertain.
- Experienced engineers, and an established repair and spare parts network are often lacking.

User Recommendations

Operators of maritime fleets should:

- Assess which (if any) vessel operations would be suitable for the utilization of an electric power train by looking at the distance that vessels travel, the water conditions and ability to recharge at destinations.

Operators of road vehicle fleets should:

- Calculate the greenhouse gas emissions and impact of utilizing trucks on road networks versus electric ships to move manufactured goods between locations. Study best-practice examples, such as those provided by the Yara Birkeland, which is using an electric ship to replace the 40,000 diesel-powered truck journeys a year.

CIOs working for government organizations, such as departments of transportation, should:

- Partner with electric utilities to build a long-term (20-year) electric ship business case. Assess the incentives and investments to install port-side charging infrastructure and what benefits, such as reduced greenhouse gas emissions, would be delivered.

Sample Vendors

ABB; Candela; Corvus Energy; Damen; Hitachi; Navier; PortLiner; Schneider Electric; Tyde; Wärtsilä

Intelligent Connected Infrastructure

Analysis By: Shivani Palepu, Ivar Berntz, Jonathan Davenport, Venecia Liu

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Definition:

Intelligent connected infrastructure (ICI) is a combination of technologies integrated in a mesh fabric to enable the infrastructure to do a data exchange with surrounding entities in an ecosystem, such as vehicles, technicians and equipment. The mesh is made up of elements such as AI, Internet of Things (IoT), cloud, analytics, edge computing, telecommunications and autonomous technologies. The transportation infrastructure can include ports, bridges, roadways, railways, airports and airways.

Why This Is Important

ICI can be used to orchestrate an operational environment that can link physical and digital assets with data to enhance communications. ICI can improve business operations to achieve better safety, less congestion, shorter wait times and better asset utilization. Stand-alone technologies, such as IoT or AI, have provided some benefit to the industry. However, a force multiplier can be achieved when technologies come together to communicate and exchange data to provide combined insights.

Business Impact

There are operational and service benefits to ICI. For example, ICI could improve port terminal operations whereby cranes, Automated Guided Vehicles (AGV), cargo, rail and trucks could exchange real-time data and status updates. Airports could benefit from an increased capacity and reduce the aircraft turnaround time through better orchestration, coordination and communication. Cities could move more vehicles through intersections with dynamic traffic light timing and reduce traffic congestion.

Drivers

- Transport entities are under pressure to alleviate supply chain bottlenecks. ICI can help developing more-efficient operations using a combination of technologies.
- There is a need for visibility and transparency of asset location and data to optimize operations. ICI combines diverse data sources to provide a more holistic view. ICI enables and empowers cross-ecosystem collaboration among transport assets.
- Ability to do remote maintenance and predictive maintenance of urban infrastructure and equipment before failures and accidents occur, such as the derailment of track from an overheated wheel bearing.
- Reduce operations cost and reduce turnaround times with efficient operations.
- Ability to monitor and notify drivers, passengers, operators of real-time situational data. Communicate relevant information utilizing data insights for timely action.
- The drive to build an intelligent urban ecosystem and enhance resident satisfaction.

Obstacles

- ICI requires digital mesh collaboration to be realized across the transportation infrastructure and across various technologies in the ecosystem.
- Technology standard alignment between infrastructure and vehicle. Challenges on technology integration, technologies standards, communication protocols as well as integrating data from various sources.
- The cost of integration of legacy systems is high.
- The investment to tie all the technologies together is challenging, and it requires coordination by various entities with different reporting structures and goals.
- The risk level is high. New technologies offer new possibilities but also come with unknown risks. For example, absence of standards and immature technologies can lead to unintended consequences and can facilitate hacking.
- Cybersecurity concerns for an integrated system, such as operational technology (OT) and IT technologies.
- There are privacy concerns on personal data use and thus, adoption of ICI might be challenging.

User Recommendations

- Identify stakeholders in your ecosystem who could benefit from better data insight, such as truck drivers waiting for unloaded cargo, pilots, tugboats, crane operators, rail cargo, shipyard equipment, shippers and emergency services.
- Assess existing data sources, and identify areas where data collection (such as maintenance, planning, forecasting, safety and traffic flow) can impact other business operations.
- Build a technology roadmap with this ICI vision to ensure edge computing or 5G implementations can be leveraged in multiple ways as a data exchange to multiple stakeholders.
- Consider adopting a composable business architecture for agility and tap into a data exchange platform to minimize the cost of building everything from scratch.

Sample Vendors

Alibaba Cloud; Bosch Group; Huawei; NTT Group (NTT DATA); Siemens Mobility

Gartner Recommended Reading

Tool: Connected Vehicle Use-Case Opportunity Assessment

Seize the Technology Advantage With Combinatorial Digital Innovation

Connected Ships

Analysis By: Jonathan Davenport

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Connected ships enable the collection of Internet of Things (IoT) data from a vessel while at sea, often over satellite connectivity. Data pulled from vessels is stored in cloud-based IoT middleware platforms to enable vessel data to be analyzed in near real time, providing a command and control platform. Analytics can be used to optimize operations, improve crew and cargo safety, maximize fuel efficiency, deliver predictive maintenance, and provide increased situational awareness.

Why This Is Important

At present, beyond location, ship operators have limited operational data about their fleets while they are at sea. By collecting data produced by multiple, previously siloed, ship systems, operational teams are afforded heightened levels of situational awareness which can be used to optimize operations.

Business Impact

Connected vessel initiatives will lay the groundwork for a fundamental shift in the marine sector, leading to increased efficiency, lower operational costs and cleaner vessel operations. The data that vessels generate is of interest to a range of stakeholders including ship operators, shipyards and equipment suppliers. The breadth of companies interested in the data creates opportunities for data monetization and the ability to create new digital services.

Drivers

- A range of data can be collected from radar, cameras, the Electronic Chart Display and Information System (ECDIS), telematic information from engines, the Automatic Identification System (AIS) and other systems.
- For ship builders, the incorporation of new IoT platforms, such as Damen's Triton, delivers the ability to share knowledge and collaborate with the wider maritime ecosystem, providing an opportunity to move from being shipbuilders to maritime services providers.
- Manufacturers of systems such as engines and generators increasingly want access to operational telematics data, to improve efficiency, as well as to support new business models such as engine-as-a-service.
- Insights about crew location aboard vessels combined with local real-time weather conditions will help ship operators to fulfill their duty of care to employees, alerting colleagues in the event of an accident and ensuring compliance with corporate policies.
- Cargo owners increasingly expect in-transit monitoring, including temperature and vibrational changes, and this can be routed through ship connectivity as a value-added service.
- With the rise of autonomous ships, having a mission planning system will become more important to deliver new missions/routes to the vessel remotely.
- Though the shipping industry has lagged others in its adoption of these new technologies, it is now beginning to make investments in proofs of concepts and trials.

Obstacles

- Delivering connected vessels requires a range of new software and hardware to be procured, including on-vessel sensors, networks and telematics, cybersecurity systems and connectivity contracts.
- To store the data, cloud storage and IoT platforms, which incorporate fleet management solutions are needed, which also need to be integrated into back-end enterprise and third party (data broker, etc.) systems. Incorporation of edge compute will also be important to enable the selection of relevant data to offload.
- Data sent via satellite communication is expensive, however connectivity costs are dropping fast and can be further reduced by compressing and batching data over cellular as the vessel approaches the shore.
- The true benefits to ship operators come when all their vessels are connected, but vessels have a long operational life. Retrofitting sensors and connecting these sensors to a central gateway onboard the vessel is not an insignificant task, both financially and technically.

User Recommendations

- Ensure the IoT data collected from vessels is useful by working with computing and sensor hardware developers to ensure that appropriate data can be collected from onboard assets.
- Build a compelling business case for investments in connected vessels by strategically assessing the items from which data should be collected and what the most appropriate collection frequency should be to deliver the necessary shore-based situational awareness.
- Minimize connectivity costs by investing in edge compute that can process and analyze data prior to sending it to the cloud. Store nontime critical data locally, to be offloaded over a cellular connection when the vessel nears shore.

Sample Vendors

ABB; Accenture; Damen Shipyards Group; JRCS; KONGSBERG; NEXSEAS; SeaOwl Technology Solutions; Siemens; Synectics; Tata Consultancy Services; Wärtsilä

Hands-Free Ticketing

Analysis By: Shivani Palepu

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

Hands-free ticketing is a next-generation contactless payment method that allows passengers to pay for their fare without touching a ticket or a ticket scanner. It relies on Near Field Communication (NFC), Bluetooth low energy (BLE) and other Internet of Things (IoT) sensors to detect and authenticate the passenger's presence. By integrating with mobile devices and wearables, such as smartphones or smartwatches, this technology reduces both transaction time and physical interactions.

Why This Is Important

Hands-free ticketing improves payment efficiency and speeds up entry and vehicle onboarding time. It reduces congestion at ticketing gates and machines, which improves passenger flows at the station. Hands-free ticketing also eases the journey of people traveling with children, carrying luggage, using wheelchairs or concerned about health risks.

Business Impact

Hands-free ticketing solutions require a minimal amount of hardware and reduce the need for physical ticketing infrastructure, thus saving costs. This technology would also allow operators to simplify ticket management, automate ticketing and improve operational efficiency. It would drastically reduce wait time at ticketing counters, improving the overall passenger experience.

Drivers

- Hands-free ticketing offers convenience to commuters where they can onboard the vehicle without physically interacting with ticketing machines or standing in queues at entry points, thus saving time and money.
- Contactless payment is important for health-conscious travelers, which makes hands-free ticketing a huge game changer for operators to promote safety.
- By reducing the need for physical tickets, ticketing machines or communication infrastructure, transportation agencies can save costs.

Obstacles

- Integration with existing ticketing systems and back-end systems might be challenging.
- User acceptance may be a challenge as some users might be hesitant to adopt this technology due to concerns over data privacy and security.
- Not everyone might have a smartphone or a smart device that will have the associated application.
- Ensuring hands-free ticketing is reliable and secure is a challenge, as it involves developing a system that can accurately and consistently read and verify tickets.
- Preventing fraudulent activities and illegal use of services is a major concern as hands-free ticketing doesn't require direct physical contact with ticketing gates or entry points.

User Recommendations

- Ensure that a successful account-based ticketing system is established before implementing hands-free ticketing technology. This will make its implementation much faster and easier.
- Address privacy concerns by providing transparent information on how user data is collected and ensure that the data is protected.
- Provide users with clear and concise instructions on how to use the system.
- Ensure hands-free ticketing is accessible to all users including those with disabilities.

Sample Vendors

Cubic; Thales Group

Gartner Recommended Reading

Market Guide for Digital Adoption Platforms

Battery Electric Trains

Analysis By: Pedro Pacheco, Shivani Palepu

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

Trains using 100% electric propulsion where electrical load is entirely stored in onboard batteries. When using 100% renewable energy, such trains provide a zero-emission alternative for operation in nonelectrified tracks, where the typical trains with pantographs are not usable.

Why This Is Important

Many countries are putting in practice ambitious decarbonization plans in order to achieve Paris Agreement targets. Rail is seen as one of the major solutions for carbon emission reduction in the area of transportation. It is estimated that more than 60% of rail tracks are not electrified which means they use carbon-heavy diesel-electric locomotives. Hence, a carbon-neutral solution train technology is needed for these situations.

Business Impact

Battery-electric trains (BETs) can provide carbon-neutral rail operation on nonelectrified tracks. This helps rail companies in achieving more ambitious carbon neutrality targets without incurring on the hefty investment of electrifying the entire track infrastructure.

Drivers

- Government pressure to achieve Paris Agreement targets puts pressure on several rail operators to phase out diesel locomotives in favor of zero-emission technologies.
- The fast progress of electrification for road vehicles is propelling a fast development of electric vehicle (EV) technology that, in turn, is being cascaded to other modes of transportation.
- It is common to have rail operators struggling with profitability. In this case, BETs can offer a lower operational cost than diesel locomotives due to lower maintenance needs and lower energy costs. Electric powertrains are also extremely simple and durable, something that will prolong their operational life in relation to complex diesel and diesel-hybrid powertrains.
- Air and noise pollution from diesel-electric trains are a concern in many areas cut across by nonelectrified tracks — like nature preserves or smaller towns. BETs can help reduce this environmental impact.
- Rail operators shy away from major track electrification projects because they entail a major capital expenditure and long downtime periods. In contrast, the transition to BETs can be done practically overnight once the electric locomotives and electric chargers are in place.

Obstacles

- Train manufacturers are not yet prioritizing alternatives to internal combustion or electric pantograph trains. This hampers BET technology development. EV technology is evolving extremely fast for road cars, but train OEMs are still using old technology and existing BETs are based on current electric pantograph trains, hence not fully optimized for BET specifics.
- Hydrogen trains can, at the moment, offer greater range than BETs. Even if EV technology has evolved greatly, hydrogen powertrain tech has, comparatively, evolved very little. Given that train OEMs use old technology both for hydrogen and electric, such, inherently, gives an advantage to hydrogen propulsion. For instance, the best EV passenger cars today already offer a clearly higher driving range than comparable hydrogen cars, but the same doesn't happen for trains.
- Rail operators start looking at biofuels or synthetic fuels as a carbon-neutral alternative. These fuels can be used with a conventional diesel-electric locomotive, which makes the change cost much lower than for BETs.

User Recommendations

For train makers:

- Accelerate the investment on BETs — don't be caught by surprise by rapidly-changing market demand. Partner with major automotive EV companies to acquire the best of EV tech currently used in road cars.
- Prioritize BETs over hydrogen trains. The automotive sector will remain as the engine for powertrain tech development and the overall combined investment in EVs is incomparably higher than that for hydrogen powertrains. The fast development of technology entails you must focus your efforts.
- Develop BETs with pantographs that can be used both on electrified and nonelectrified routes.

For rail operators:

- Keep monitoring the progress of BETs even if hydrogen trains are currently more competitive, as they are likely to overtake hydrogen train performance in the future.
- Track electrification may be a major investment but both BETs and hydrogen will offer limitations well into the next decade. For that matter, you should think long term in terms of decarbonization, something that often makes track electrification seem more attractive in relation to the existing alternatives.

Sample Vendors

Alstom; Hitachi; Stadler; Wabtec

Gartner Recommended Reading

Technology Assessment of Transforming Trends in the Rail Industry for 2030

Infographic: How to Start Building Dynamic Personas for Transportation

At the Peak

Multiview Information Display Technology

Analysis By: Shivani Palepu

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

Multiview information display technology in transportation (also known as parallel reality technology) enables multiple people to view personalized content on a single screen, simultaneously and without any specialized device or eyewear. It uses overhead sensors and multiview pixel technology in display screens that direct different-colored light, allowing viewers to look at personalized content based on their position. It is still at a very nascent stage of development.

Why This Is Important

The idea of multiview display technology in the transportation industry is to explore the potential of creating personalized, immersive experiences for individual passengers. It can revolutionize the way in which we interact with our physical world and thus improve the passenger experience. By having a personalized passenger information system, this technology can reduce queuing near information display boards and reduce the average travel time.

Business Impact

Multiview information display technology has a huge potential in enhancing customer satisfaction and experience. It can provide users with real-time transit schedules, travel updates and other immersive experiences. Real-time updates on flight/train/bus schedules, maintenance alerts, and safety information can help improve operational efficiency by reducing delays and enhancing safety. This technology has only been introduced in the aviation industry and is at a very nascent stage of development.

Drivers

- Customer expectations: Customers today expect a more personalized and engaging experience in all aspects of their lives, including their transportation. Multiview display technology can help transportation companies achieve that.

- Technological advancements: With the world moving toward advanced technologies, the need for innovation has enabled transportation companies to invest in futuristic technologies.
- Focus on digital transformation: The transportation industry is focusing more on digital transformation with a focus on implementing technologies that improve efficiency, safety and customer experience.
- Internet of Things (IoT): IoT is playing an increasingly important role in the transportation industry. Multiview display technology can leverage the data generated by IoT devices to deliver personalized information
- Competition: Transportation companies are facing increasing competition from each other, especially after the pandemic. Multiview display technology can help provide companies with a competitive edge by offering a unique and innovative solution.

Obstacles

- Costs: Implementing multiview technology is expensive particularly when it comes to the hardware required, such as displays, sensors, and computing equipment. Rail companies may be hesitant to invest in this technology if the costs outweigh the potential benefits.
- Integration with legacy systems: Many transportation agencies have legacy systems that may not be compatible to work with parallel technology.
- Privacy and security concerns: Like many other technologies, multiview display technology can also raise some privacy concerns as it relies on collecting and analyzing data about individual users.
- Adoption by customers: Since this is a new and unfamiliar concept, customers might be hesitant to adopt it.

User Recommendations

- Identify use cases: Multiview display technology is still a new concept and so transportation agencies must identify use cases where it can provide the most value.
- Pilot and test: Before implementing at a large scale, test the technology to identify any issues and gather feedback from users.

- Implement at high-footfall areas: Multiview display technology should ideally be implemented at high-footfall areas (busy airports like Heathrow Airport) where it can provide the most benefits.
- Ensure privacy and security: Since this technology collects a large amount of personal data, it is important to ensure privacy is protected.
- Ensure accessibility: It is important to ensure that this technology is accessible and designed to meet the needs of all travelers.
- Focus on user experience: The success of this technology depends on providing a seamless and intuitive user experience with a focus on an easy-to-use interface and clear direction for its use.

Sample Vendors

MisappliedSciences

Gartner Recommended Reading

Technology Assessment of Transforming Trends in the Rail Industry for 2030

Heavy-Duty EV Charging

Analysis By: Pedro Pacheco

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Heavy-duty electric vehicle (EV) charging technology is used to efficiently charge heavy-duty electric vehicles, including buses, trucks and electric ships at a 2 megawatt (MW) power or higher. Solutions are designed to enable high levels of operational efficiency by limiting vehicle charging time and maximizing operation time.

Why This Is Important

Regulations across markets such as Europe, China and some U.S. states such as California will boost adoption of electric buses and trucks. For instance, California has mandated the end of internal-combustion truck sales by 2035. Charging equipment designed to deliver the very high voltage necessary to recharge large batteries will be necessary in order to make battery-powered large vehicles practical for long-distance travel.

Business Impact

Heavy-duty vehicle OEMs will struggle to sell electric trucks, buses and ships without a dense network of purpose-made heavy-duty EV chargers, because the passenger car charging network doesn't deliver enough charging speed. The European Automobile Manufacturers' Association (ACEA) has asked the EU to impose specific regulations prompting member states to install at least 11,000 chargers for heavy-duty vehicles until 2025. This clearly defines an urgent necessity for heavy-duty chargers.

Drivers

- Regulation is and will be the major driver for heavy-duty vehicle electrification in land, sea or air. Truck and bus regulation is currently the most advanced from all heavy-duty vehicles. Chinese government incentives resulted in 49% of the buses sold in the world last year being electric. California and some other U.S. states have been approved by federal regulators to enforce a 2035 ban on internal combustion truck sales. In addition, the EU has mandated new heavy-duty road vehicles to, by 2035, reduce its CO2 emissions by 65% in comparison with 2020 values. Electric ships and other heavy-duty vehicles will indirectly benefit from this regulation by having cost-competitive EV charging solutions they can source from heavy-duty road vehicles.

- Given that buses and trucks require a much larger battery than a passenger car, they need higher-power chargers, reaching 2 MW and beyond. These vehicles have a much higher utilization rate, being driven much more than a passenger car, and profitable operations depend on the ability to deliver a short recharge time for these vehicles' batteries.

- Besides the need for a dedicated charging infrastructure, a high number of chargers is also essential. For instance, in Europe, truck stops across main road corridors are frequently packed during nights and weekends. If parking is already an issue, then imagine what this says in terms of the needed number of chargers.

- The shipping sector is also driving heavy-duty EV charging, but to a lesser degree. Even though shipping produces 2.5% of global greenhouse gas emissions, regulation lags well behind road vehicles in supporting zero-emission ships. For instance, the EU has pledged to reduce ship emissions by 80% but only by 2050.

- As road-going EV technology evolves fast, this will make it more economically feasible to adopt it in shipping — especially since electric powertrains have considerably lower operating costs. Currently, this enables a steady pace of adoption in recreational boats and ferries for short sea connections.

Obstacles

- **Slow rollout of specific chargers:** The Megawatt Charging System is still at an early phase of deployment and there aren't yet trucks on the market designed to handle these chargers. Tesla's Semi truck uses their own megacharger design, but so far has only seen a slow roll-out.
- **Regulation:** Only some regions have already developed stringent legislation prompting the progressive phase-out of internal combustion engines in heavy-duty vehicles. This heavily conditions the need for a heavy-duty EV charging network in other parts of the world.
- **Risk aversion:** Even in regions where incentives for EV charger installation are in place, such as the EU, charge point operators fear a long investment payback period. The higher power of these chargers also requires upgrades to the public electricity grid, such as installing substations, which adds to the size of investment. Hence, companies fear investing too early, before there are enough vehicles to justify it.

User Recommendations

Any type of incumbents must:

- Invest in a dedicated heavy-duty charger network only in regions adopting a strong regulatory framework that supports the electrification of this type of vehicle. Without regulation, vehicle adoption will grow slowly, which is a threat to infrastructure profitability.

Vehicle OEMs must:

- Take a chance to invest and build partnerships for developing a heavy-duty charging network. Infrastructure may not grow fast enough to respond to vehicle user needs. Start by investing in roads where infrastructure is needed to unlock major deals with large customers.

Charge point operators must:

- Overcome risk aversion.
- Partner with OEMs, utilities and investors to set up infrastructure.

- Keep track of vehicle sales penetration to judge the right time to deploy infrastructure.
- Implement loyalty models where charging will be an enabler to profit from selling other services and products.

Gartner Recommended Reading

Guide to New Business Models in the Electric Vehicle Ecosystem

Market Guide for Turnkey Electric Vehicle Charging Solutions

Quick Answer: IIJA Presents EV Charging Opportunities and Challenges

Industry Insights: Top 10 Trends Driving the Utility Industry in 2021

Forecast: Electric Vehicle Shipments, Worldwide, 2020-2030

Hypersonic Aircraft

Analysis By: Mike Ramsey

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Hypersonic aircraft are capable of flying at speeds exceeding Mach 5 or five times the speed of sound. Current commercial jet aircraft fly slower than Mach 1. Flight speeds between Mach 1 and Mach 5 are called supersonic. At Mach 6, one would be flying at around 2 km per second, which is 7,200 kph, allowing an aircraft to fly, fuel permitting, around the world in less than six hours.

Why This Is Important

Hypersonic aircraft could enable same-day intercontinental return travel and parcel delivery. With speeds exceeding 7,200 kph, almost any destination could be reached within a few hours. Most jet airliners operate today in the Mach 0.71 (approximately 540 mph or 870 kph) to 0.85 (approximately 647 mph or 1,041 kph) speed range.

Business Impact

There are many potential advantages of hypersonic flight, including extremely reduced travel times and improved space access for people and goods. It allows the transport of VIPs, executives and troops or critical supplies around the world within just a few hours. Such efficient usage of time is something that no type of transport is able to provide today.

Drivers

- **Need for speed:** There's an inherent value to speed. VIPs, critical components and even body organs can't be airlifted today with the required urgency, even when the cost isn't an issue.
- **Prestige:** Being able to produce and sell these aircraft is a way for a country, for example, China, to not only catch up but even leapfrog its aerospace competitors.
- **Work here, live there:** As hypersonic aircraft reduce the duration of transoceanic or transcontinental flights, they would also allow for longer commutes. At hypersonic speeds — above Mach 5 in aviation parlance — it would be possible to travel from New York City to London in less than two hours, instead of the seven hours the trip takes on a conventional airliner.
- **Same-day transcontinental delivery:** At hypersonic speeds of Mach 5 and above, aircraft could perform several same-day package deliveries worldwide.
- **Large investments in the technologies required for propulsion have been made over the years:** A number of companies are building supersonic jets for delivery by the end of the decade. One Atlanta-based company, Hermeus, plans to test a Mach 4+ speed aircraft called the Quarterhorse in 2023.
- **Noise is being harnessed:** The most famous commercial supersonic aircraft, the Concorde, reached Mach 2.04 and was retired in 2003. Besides high fuel consumption, it was prohibited from flying supersonic over land due to the noise pollution from its sonic boom. To circumvent this limitation, NASA is working on a quiet supersonic technology. It experiments with an aircraft shape that would turn the sonic boom from an aircraft flying at Mach 1.4 at 55,000 feet into just a perceived "heartbeat" to individuals on the ground.

Obstacles

- **Demand uncertainty:** Building civilian airplanes capable of flying faster than the speed of sound has proven to be an elusive economic goal. The demand for superfast transcontinental flight in a future where remote collaboration will be greatly intensified by technology is questionable.
- **Business case uncertainty:** At the hypersonic speed of Mach 5, fuselage friction can create temperatures of 1,000 degrees Celsius. The use of materials like titanium or even ceramics will be needed to avoid melting metal in the engine, requiring extensive research. Also, while hypersonic flights are more fuel efficient, ramjets perform better with hydrogen, whose cost is majorly dependent on the technology used to obtain it.
- **Timeline:** New technologies promise to make passengers and cargo travel at hypersonic speeds a reality in five-to-10 years, but given how long it has taken to develop a commercially viable supersonic, not even the hypersonic, it might take longer than desired (see United Airlines Orders 15 Supersonic Jets to Cut Travel Time in Half — Some Day, NBC News Digital).

User Recommendations

For airlines and transportation providers:

- Include this technology for your long-term planning, as it is approaching peak. Start developing use cases with a high ROI that will allow you to play a role in bringing the technology to market — for the transport of VIP travelers as well as for shipping goods where time is a critical requirement.

For governments:

- Ensure this strategic technology is on your innovation radar because it will require many other technologies to be developed. Consider it for both civil as well as military applications given its potential to quickly connect far-away locations with main economic hubs.

Sample Vendors

Boeing; Boom Supersonic; Exosonic; Hermeus; IO Aircraft; Lockheed Martin

Carbon Measurement in Transportation

Analysis By: Pedro Pacheco

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Carbon measurement is a digital solution that is used to accurately measure the carbon footprint generated in the transport of people or goods. This can encompass the measurement of direct transport emissions (Scope 1), the measurement of emissions generated by the energy used by transportation companies (Scope 2) or all other indirect emissions in the company's supply chain (Scope 3).

Why This Is Important

Determining the carbon footprint of each journey will be important for mobility providers and governments to determine reductions of greenhouse gas (GHG) emissions required by the Paris Agreement. Travelers and transportation providers are becoming increasingly conscious of their carbon footprint. A digital carbon footprint measurement platform provides the visibility that allows these stakeholders to make informed decisions.

Business Impact

The ability to measure the carbon footprint per journey will be of great value in countries prioritizing GHG reduction. More accurate and granular direct carbon measurement allows transportation companies to more effectively determine where and how to reduce carbon footprint. These measurements may become a business requirement, set by management boards. Travelers may be able to choose their door-to-door itinerary according to its carbon footprint, which allows users to make more informed decisions.

Drivers

- The existence of particular regulations in terms of CO2 emissions taxation or reduction of tailpipe emissions puts pressure on transportation companies to reduce their CO2 emissions. Moreover, global CO2 emissions from transportation have grown 8% since the pandemic, which puts even greater pressure on carbon footprint reduction.
- There is a growing wave of activist investors for whom carbon footprint is a key factor, to the point that even BlackRock has named sustainability a cornerstone of its investment strategy. This puts pressure on companies to reduce their carbon footprint as much as possible.
- The CEO Alliance — an association of CEOs from major European companies focused on supporting the EU's Green Deal plan — has defined digital carbon footprint measurement as one of the eight strategic initiatives it will be developing. As such, this will raise the importance of this topic across the European corporate world.
- The drive by transportation companies to reduce vehicle energy costs indirectly supports digital carbon measurement. Such tools allow these companies to not only understand their main sources of carbon footprint, but also to develop insights on how to reduce those by looking at how vehicles are operated. For instance, a bus company can train drivers to reduce fuel consumption when that is deemed an area for improvement.
- A growing new generation of consumers and travelers focused on sustainability want more information on the carbon footprint in relation to the products and services they consume. Although this type of visibility is still not generalized, it opens opportunities for the growth of digital carbon footprint measurement.

Obstacles

- The business need for digital carbon footprint measurement will vary across regions, depending on the regulatory pressure on its reduction and reporting.
- Data availability is often a limitation, especially when it refers to Scope 3 emissions — those not produced by the company nor its assets (such as when transportation is outsourced to a third party). The lack of a highly connected transportation ecosystem means that carbon footprint measurement will have to be done indirectly by comparing similar use cases that have been previously measured. For instance, this is like calculating the CO2 emissions of a bus by the distance traveled, not by its actual emissions. The use of estimates may lead to lower precision, something that counters the purpose of the solution.
- There is a lack of uniform regulation or standards applicable to such solutions. Consequently, the acceptance of the carbon footprint measurement produced by each solution may not be consensual across all governments and organizations, and it will be challenging to audit results.

User Recommendations

- Build governance that leads to a connected open data ecosystem for transportation. This will, ultimately, lead to an easier implementation of carbon footprint measurement solutions. For instance, Germany's Mobility Data Space initiative intends to create a platform for data-driven business models across the transportation ecosystem.
- Lead the effort to define standardization of digital carbon footprint measurement solutions to allow a sound "apples to apples" comparison.
- Invest in solutions that increase the level of vehicle connectivity and data collection. These will drive operational efficiency improvements, as it will allow the implementation of direct digital carbon footprint measurement.
- Share carbon footprint information with travelers as a way to motivate them to choose the best means of transportation in terms of carbon footprint.

Sample Vendors

Arviem; carbmee; Emitwise; Normative; Plan A; SAP; Sphera

Gartner Recommended Reading

Maverick* Research: Climate Change Needs a Digital Drug Against Delusion

Apply Digital Business to Sustainability

Emerging Technologies and Trends Impact Radar: Environmental Sustainability

Market Guide for Gas Emissions Management Solutions

On-Demand Aviation

Analysis By: Ivar Berntz, Vivid Gong

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

On-demand aviation is a ride-hailing experience, similar to an Uber. It can be used when booking an airplane or helicopter today or an electric vertical takeoff and landing aircraft in the future. It is a more affordable version of the fractional ownership or charter flight business models that already exist at the higher end of the market.

Why This Is Important

The sharing economy has expanded itself to become one of the most recession-proof business models with successful companies such as Airbnb and Uber. On-demand aviation (ODA) entrants want to create a new market for aviation-sharing services for urban air mobility. To scale, it will require the development of extensive new infrastructure, aircraft and regulations, among others.

Business Impact

- **On-demand aviation meets clients closer to where they are:** It allows boarding an on-demand or ride-sharing flight quickly — in some cases even from downtown locations by using a helicopter or other means of urban air mobility.
- **It saves time:** There is no need to get through airport security, wait for boarding, and depending on the location, spend time in traffic.
- **It demands a premium:** It creates an elevated experience that customers may afford and thus elect to pay a premium price for.

Drivers

- Prestige and competitiveness: Given its potential to solve or preempt problems, governmental agencies prioritize innovations that show leadership and develop new, exportable solutions.
- **Increased asset utilization:** Private airplanes, like cars, are an underutilized asset that sits idle for considerable periods of time and are expensive to own and operate. ODA competition increases the odds of on-time departures and arrivals, as commercial aviation timeliness tends to suffer as asset utilization needs to be kept high due to low profit margins.
- Time savings: ODA saves time as current airport infrastructure is located outside of urban centers, requiring passengers to spend plenty of time on transportation as well as security procedures.
- **Less bottlenecks:** Flight sharing makes economic sense as it bypasses current road and flight traffic bottlenecks for existing routes and allows for new ad hoc destinations.
- Cost: Autonomous aerial taxis using electric vertical takeoff and landing (eVTOL) aircraft could eventually be cheaper than cars on some routes. Spreading the cost of urban mobility across a large number of users will enable eVTOL operations to scale, reducing the price to something comparable to ground transportation.
- **Minimum flight hour certification upkeep:** Pilots have an incentive to work for ODA as they need to fly a certain number of hours to keep their licenses and can do so more easily.
- **Promising pilot initiatives:** Some early pilots by Uber and others of on-demand helicopter flights demonstrate that some existing technology platforms can be adapted to aviation.
- **New services creating new markets:** Other ecosystem participants, such as catering, hospitality and ground transportation, can offer new services and locations to discerning clients, leveraging flexible schedules and group sizes.

Obstacles

- **Infrastructure:** Current airport and heliport infrastructure can't accommodate urban air mobility at scale. Helipads might add charging capabilities, but eVTOLs will need new custom-built, large facilities requiring prime real estate in densely populated urban environments.
- **Cost:** Current interest rates are high. So, infrastructure investment money is projected to remain tight, keeping prices high and demand accordingly low.
- **Public acceptance:** Several attempts to "Uberize" helicopter flights have failed. Early adopters may be willing to try pilotless eVTOL aircraft, but most flights will remain piloted. To scale ODA, early adopters will need a fully autonomous solution, requiring them to work to drive customer acceptance.
- **Tools, regulations and air traffic control:** Tools and processes for monitoring air traffic and flight data at the required scale do not exist yet and will require new digital systems. Legislation must also allow for pilot and aircraft remuneration.

User Recommendations

- Monitor and evaluate how several new on-demand aviation experiments evolve worldwide.
- Act preemptively and strike tentative partnerships early so that you can educate yourself and your organization about the hurdles and benefits encountered by others.
- Prepare your infrastructure and systems to connect to these new players by moving to a composable digital architecture.
- Evaluate alternatives or complement partners, as some of the development will be done by ecosystem partners.
- Co-develop the requirements and get the benefit of early lessons and a jump-start into the market by strategically choosing the experiments in which to participate.

Sample Vendors

Airbus; EHang; Jaunt Air Mobility; Joby Aviation; Lilium; SkyGrid; teTra aviation; Urban Aeronautics; Volocopter

Gartner Recommended Reading

Emerging Tech Impact Radar: Autonomous Vehicles, 2022

Predicts 2023: Automotive and Smart Mobility

Case Study: An Intelligent Urban Ecosystem Approach to a Sustainable Smart City

Hyperloop

Analysis By: Pedro Pacheco

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

Hyperloop is a mode of transport that uses low-pressure vacuum tubes to propel transport pods at beyond 1,000 km/hour or 621 mph in a virtually friction-free environment from one point to another. Hyperloop technology can be used to transport people or goods.

Why This Is Important

If Hyperloop's future claims materialize, it would be able to transport a large number of passengers on land at speeds even faster than a commercial airliner. After a period of apathy, the world's first full-size hyperloop test took place last year, thanks to the North University of China. This provides more hope for the future success of this technology, even being still in an inceptional phase.

Business Impact

Hyperloop could play an important role in achieving Paris Agreement objectives for low-carbon but fast mass transit. The high speeds that hyperloop offers could make it more environmentally friendly and an alternative to air travel. Some studies suggest hyperloop could be one-half to two-thirds the cost of a high-speed train and more than double or triple the speed of the fastest train. Hyperloop requires less energy consumption than a conventional train, and it is positioned as safer and quieter.

Drivers

- There has been a lot of hype around this technology, starting with Elon Musk. He has driven the concept forward from the original Hyperloop Alpha paper published in 2013 to the annual SpaceX-sponsored competitions, which has resulted in prototypes and signed development agreements with nations around the world, including the United Arab Emirates, France, India and Indonesia.
- China has finally joined the hyperloop race. Despite arriving late, its immense capabilities are already making a difference, as the North University of China has run the world's first full-size hyperloop test in 2022.
- The Paris Agreement and a major effort to reduce transportation's carbon footprint has triggered the interest of many investors, companies and governments.
- Currently, there aren't any alternatives to an airplane when it comes to transporting a large number of people at the highest possible speed across hundreds of miles. However, the aerospace industry struggles to develop a propulsion system that is carbon-neutral, fast and cost-effective. This gap is opening the door to alternatives.
- High-speed trains are already a main form of transportation in countries like China, Japan, France and Germany. However, they cannot compete with the plane in speed across distances beyond 200 to 300 miles. Countries like China and Japan are investing large sums to expand their coverage of magnetic levitation (maglev) trains. These use magnetic levitation to reduce the friction with the tracks, which allows them to ride at speeds around 700 km/hour (435 mph). However, the level of energy required to operate a maglev is still substantial.
- Hyperloop — because it runs on near vacuum — could still present an advantage over maglev trains. In addition, in July 2020, HyperloopTT and TÜV SÜD announced the first completed certification guidelines for hyperloop systems, which is a reassuring step forward in terms of safety.

Obstacles

- On paper, hyperloop presents better performance than maglev trains, however it also faces significantly larger technical hurdles to overcome. If organizations developing hyperloop technology are not able to produce breakthroughs in the next few years, there is a chance the focus may change toward maglev. Even if a maglev train is slower than a hyperloop, this technology is already in commercial use today and, hence, only needs to be expanded in terms of coverage. Besides, maglev trains' speed already makes them a strong point-to-point alternative to commercial flights.
- Concerns have been raised about pod development, oxygen requirements, and the necessary safety equipment and emergency exit considerations.
- Claims related to hyperloop's greater energy efficiency and reduced cost against maglev are not totally accepted. The doubts come from the fact hyperloop needs a full-length tunnel and near-vacuum to operate, and both of these add significantly to the level of investment and operational costs.

User Recommendations

The transport authorities and their CIOs must:

- Keep monitoring the developments toward a commercial hyperloop system and the existing roadblocks before deciding to invest.
- Focus on the work being done in China and South Korea to understand the progress to market for this solution.

The governments must:

- Examine other alternatives in their mass transport strategy, like maglev technology or high-speed rail, as a low-carbon alternative to aviation.
- Don't totally discard aviation as a high-speed, zero-carbon mass transport solution. Even though many challenges lie ahead for aviation, synthetic fuels could also become viable more toward the end of this decade.

Sample Vendors

Delft Hyperloop; Hyperloop One; Hyperloop Transportation Technologies; The Boring Company; TransPod

Gartner Recommended Reading

2023 CIO and Technology Executive Agenda: A Transportation Perspective

Technology Assessment: Urban Mobility, 2030

Technology Assessment of Transforming Trends in the Rail Industry for 2030

Digitopia 2035: All Stories Collected

Digital Twins in Transport

Analysis By: Shivani Palepu

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Emerging

Definition:

A digital twin is a virtual representation of an entity such as an asset, person or process, and is developed to support business objectives. It uses real-time data and advanced analytics to simulate the performance and behavior of the physical assets. The application of digital twins in transportation is used for planning, simulation, station information modeling and other use cases by providing real-time analytics of any faults and defects.

Why This Is Important

Digital twins can be used to assess a situation, map the environment and predict outcome-based scenarios for planning and strategy purposes. Simulations improve operational performance in a virtual environment as compared to physical runtime of assets that take time and resources. Using digital twins can improve performance in terms of better customer service, reduced operating costs, optimized routes and sustainability. Digital twins can also enable intelligent connected infrastructure.

Business Impact

Digital twins improve asset management practices by optimizing performance, predictive maintenance and reducing downtime. Simulations, such as the impact of sand to an aircraft jet engine, have proven the need for increased maintenance, thereby improving safety and optimizing costs. The modeling of a new airport terminal can determine passenger flow impact. Digital twins of rail can help rail operators increase the frequency of trains, while digital twins of a port can identify bottlenecks in operations.

Drivers

- Digital twins can be used to reduce maintenance costs, help transportation organizations in optimizing their efficiency and reduce dependency on manual inspection.
- Digital twins can assist in the planning and forecasting of infrastructure demands, and expose any weaknesses in the processes, assets, governance and IT competencies. Funding for new infrastructure is always limited and there always will be a need for more accurate forecasting and better construction design.
- Digital twins can be used for building information management of new airport builds, as well as simulations of aircraft parts to determine maintenance schedules.
- A broad range of airports and rail organizations have been exploring the use of digital twins and releasing RFPs to acquire digital twins.
- Equipment, operations services and IT vendors are increasingly highlighting the business benefits of digital twins in transportation. Benefits include cost optimization, asset lifetime improvement and passenger health monitoring.
- Digital twins can be used to simulate sustainability goals via monitoring of carbon footprint and energy consumption, and modeling of supply chain and transport movement.

Obstacles

- The adoption of digital twins is rather nascent in this industry because there are challenges with understanding the use-case potential, and the applicability for how digital twins can really enhance overall business operations' efficiency and improve the bottom line.
- A digital twin requires highly accurate data from a variety of sources and must be updated with real-time information to ensure the model remains accurate.
- Initial implementation of a digital twin requires clear business metrics, joint operations and IT teams to drive training and the business culture change effort needed to ensure adoption.
- Standards lag market needs for not just integration across technologies and subdigital twins (digital twins that represent a specific component of the system), but also to address metadata management and a broad security threat surface.

User Recommendations

- Quantify the possible financial benefit brought by digital twins as a way to generate a strong business case for investment.
- Strengthen the data collection capabilities of your critical processes as a way to set the foundations for digital twin models.
- Engage with peers to ensure the business case has clear metrics that the IT organization can support and the business unit pays for the upkeep of the digital twin.
- Ensure there is a culture change process in place to drive adoption of the digital twin by frontline workers. The key factors could include accurate cultural assessment and facilitate employee engagement.
- Assign an IT team to prioritize the range of relevant technologies (Internet of Things [IoT], GIS, 3D, analytics) to build useful digital twins for transportation.
- Refer to Gartner use cases of utilization of digital twins in several other sectors and even in transportation. This will provide the necessary insight to find a broad number of use cases within your own organization.

Sample Vendors

ABB; Cosmo Tech; General Electric; SAP; Siemens Digital Industries

Gartner Recommended Reading

Toolkit: 5 Digital Twin/IoT Project Success Drivers

What Data and Analytics Leaders Need to Know and Do About Digital Twins

Autonomous Urban Air Mobility

Analysis By: Mike Ramsey

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Definition:

Flying autonomous vehicles or unmanned aerial vehicles (UAVs) are used for carrying passengers, primarily over short distances in urban areas. These encompass self-operating aircrafts that are sometimes referred to as “flying cars” or passenger drones, and are designed to operate without a human pilot, neither in the vehicle nor remotely operating. These vehicles include air taxis, but do not include commercial delivery drones.

Why This Is Important

A significant number of companies are working on new aircrafts that are piloted by artificial intelligence and designed to create a more agile, less expensive, and quicker way to execute air travel, primarily in congested areas. The goals of the projects include faster travel in densely populated areas, economical air travel over short distances, safer operations and lower carbon emissions.

Business Impact

The impact of UAVs is likely to be moderate for most enterprises, though it could be quite high in a limited set of mobility service businesses. For most people, these vehicles will provide extra convenience, but not primary travel. They may be the equivalent of robot-piloted electric helicopters, lowering the cost of operations and perhaps increasing the availability of a preexisting service. Special use cases in remote areas or difficult topography will lead to much faster adoption on a limited basis.

Drivers

- The development of clear safety standards, air navigation regulations and operating guidelines by countries, states, and provinces will help to speed the implementation of autonomous urban air mobility when the technology is ready to be deployed. In 2022, the U.S. Federal Aviation Administration published airworthiness criteria for vertical lift and landing electric aircraft, which was a significant advance toward providing a means of certification.
- A new network of information collection and sharing between different parts of the ecosystem that would provide the location of vehicles, determine clear flight paths, and track passengers would aid with the deployment of the vehicles.
- Advances in high-performance computing and sensors, and high-energy-density batteries in the automotive industry, should help accelerate deployment.
- The continued flow of capital and investment over a long period of time, based on the prospect of fast, economical and safe flight in urban areas, will help to advance the technology.

Obstacles

- The autonomous technology and air traffic control is not currently validated by federal authorities, and ensuring safety of such a system could take several years.
- Regulations are such that distances of a mile or more may be required between the vehicles over urban areas, limiting their usefulness.
- Infrastructure in cities is not currently available for landing areas to accommodate large numbers of vehicles. Moreover, the vehicles produce significant noise.
- Many versions of the vehicles are battery-powered, limiting their range significantly when compared with liquid-fueled helicopters or planes.
- Cost is a significant obstacle to the widespread use of the technology. For instance, in comparison to a helicopter, even after eliminating the cost of the pilot, the total operation cost will still make autonomous urban air mobility prohibitive to the vast majority of the population in the foreseeable future.

User Recommendations

- Add these vehicles to the long-term technologies that may need to be obtained or used in your processes. This is the recommendation for CIOs in organizations dependent on transportation and logistics. While it may be decades before these vehicles proliferate, they are nearly certain to be put into service at some point.
- Assess what problems in transportation, both for moving people and cargo, might be solved by using these vehicles. Consider how systems might need to be altered internally to allow for use of these vehicles.
- Start investing in autonomous delivery drones as a stepping stone to urban passenger UAVs. These are less challenging to implement as they are not meant to transport people. Furthermore, many of their supporting technologies, such as traffic control solutions, should be common to UAVs for transport of people.

Sample Vendors

Airbus; Archer Aviation; Bell Textron; Hyundai Motor; Joby Aviation; Lilium; Reliable Robotics; Skyryse; Volocopter; Wisk Aero

Gartner Recommended Reading

Emerging Tech Impact Radar: Autonomous Vehicles, 2022

Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide

Sliding into the Trough

5G

Analysis By: Sylvain Fabre

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

5G is the fifth generation cellular technology standard by the 3rd Generation Partnership Project (3GPP). The standard targets maximum downlink and uplink throughputs of 20 Gbps and 10 Gbps, respectively. Latency is as low as 4 milliseconds in a mobile scenario and can be as low as 1 millisecond in ultra reliable low-latency communication scenarios, down to centimeter-level location accuracy indoors, and massive IoT scalability. New system architecture includes core slicing and wireless edge.

Why This Is Important

5G supports the 4th industrial revolution and IoT. Its fast and reliable real-time data transfer will benefit many industries. 5G supports eMBB, URLLC and MIoT — vital for enterprise transformation. 3GPP 5G standards releases deliver incremental functionality in: R15, extreme mobile broadband; R16, industrial IoT (massive IoT, slicing and security) — latest commercially available release; R17, MIMO enhancements, sidelink, DSS, IIoT/URLLC, bands up to 71GHz, nonterrestrial networks; and RedCap R18 is under definition with a planned freeze date in 1Q24.

Business Impact

- 5G enables three main technology deployments; each supports distinct new services for multiple industries and use cases of digital transformation, and possibly new business models (such as latency as a service). These are enhanced mobile broadband (eMBB) for HD video, mMTC for large IoT deployments, and URLLC for high-availability and very low-latency use cases, such as remote vehicle operations.
- Promising applications for 5G use include fixed wireless access, IoT support and private mobile networks.

Drivers

- Over 249 operators have rolled out 5G (see GSA), 30% of public mobile networks, and some form of 5G capability is penetrating lower cost smartphones in vendors' portfolios (with over nine versions of the technology depending on the band and the 3GPP release).
- Gartner estimates that 5G-capable handset penetration in 2025 will reach 54% worldwide, and 78% in Western Europe, with 5G-capable handset share of sales reaching 80% in 2023 in Western Europe from 51% in 2021. North America share will rise to close to 87%.
- 5G capability is starting to deliver value in emerging always-on wearables use cases.
- Increased data usage per user and device requires a more efficient infrastructure.
- Requirements from industrial users value 5G lower latency from ultra reliable and low-latency communications (URLLC) and expect 5G to outperform rivals in this area.
- Demand continues for massive machine-type communications (mMTC) to support scenarios of very dense deployments up to the 5G target of one million connected sensors per square kilometer. While diverse networks can offer adequate and cost-effective alternatives to 5G for many use cases (e.g., LPWA, NB-IoT, LoRa, Wi-SUN), overall total cost of ownership (TCO) and future proofness may not be as good.
- Availability has increased for industry-specific spectrum options (e.g., CBRS).
- Competitive pressures continue, for example, if one CSP launches 5G in the market others usually have to follow or risk losing market share — this includes both public as well as private 5G offerings.

Obstacles

- Issues with availability and cost of spectrum, in particular for industrial private networks, occur in some countries.
- Security concerns arise when using 5G in critical industrial scenarios.
- Availability and pricing of networks and modules for R16 and beyond solutions.
- Upgrade to 5G SA (stand-alone) core is needed for more advanced R16 releases (such as slicing), and commit to the continuous evolution of 5G releases over R17, R18 and beyond.

- Cost of radio network upgrades for 5G coverage and availability may require additional sites.
- Use of higher frequencies and massive capacity requires denser deployments with higher frequency reuse, which could raise network costs.
- Uncertainty exists about use cases and business models that may drive 5G for many CSPs, enterprises, and technology and service providers (TSPs).
- Feedback from some industrial clients mentioned that the majority of their use cases could be serviced by a 4G private network, Wi-Fi and/or NB-IoT, and other LPWA such as LoRa.

User Recommendations

- Enable R16 and above 5G for enterprise connectivity for mobile, nomadic and FWA secondary/tertiary use cases for branch location redundancy, as long as 5G is not the primary link for high-volume or mission-critical sites and unless there are no other options.
- Provide clear SLAs for network performance by testing installation quality for sufficient and consistent signal strength, signal-to-noise ratio, video experience, throughput and coverage for branch locations.
- Ensure backward compatibility to 4G devices and networks, so 5G devices can fall back to 4G infrastructure.
- Focus on architecture readiness — such as SDN, NFV, CSP edge computing and distributed cloud architectures, and end-to-end security — in preparation for 5G.
- Build an ecosystem of partners to target industry verticals more effectively with 5G before your competition.

Sample Vendors

Ericsson; Huawei; Mavenir; Nokia; Qualcomm; Rakuten Symphony; Samsung Electronics; ZTE

Gartner Recommended Reading

Emerging Tech: 5G mmWave at a Crossroads

Infographic: 5 Steps for Vendors to Scope and Run Successful POCs for Enterprise 5G PMNs

Invest Implications: Magic Quadrant for 5G Network Infrastructure for Communications Service Providers

Market Guide for 4G and 5G Private Mobile Networks

Quick Answer: What Vendor Product Leaders Need to Know About MWC Barcelona 2023

Public Transit Blockchain

Analysis By: Ivar Berntz, Vivid Gong

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Definition:

Public transit blockchain is an expanding list of cryptographically signed, irrevocable blocks of records shared by all participants in a peer-to-peer (P2P) network. Public transit blockchain use-case ideas often involve multipart transactions, such as mobility as a service, intermodal commute tracking and payments, toll collection or spare parts origination and usage tracking.

Why This Is Important

Public transport use cases leveraging blockchain (Union Internationale des Transports Publics) can reduce risk and waste for:

- Event tracking and information storage (e.g., for sustainability)
- Asset management
- Capacity optimization and matching
- Authentication of ticketing, source-to-usage goods or payments

While blockchain is leaving the trough, public transit blockchain is still heading toward it due to bad technology implementation choices and difficulty in achieving business and technical design convergence.

Business Impact

Blockchain allows nontrusting members of a public transit transaction to interact in a verified way, without the need for a trusted intermediary (U.S. Department of Transportation). It provides traceable data exchanges with secure confirmation of private operations. For instance, a payment done via a mobility-as-a-service (MaaS) app, like ICBC's Icago (Forbes), to the transportation provider(s) is faster and saves commissions while rewarding users for making use of energy-efficient choices.

Drivers

Blockchain's architecture has inherent benefits that attract governmental support for public transit organizations (System for Award Management [SAM.gov]), including:

- Immutability
- Disintermediation
- Automation
- Decentralization
- Speed
- Cost-effectiveness
- Data security and privacy

Additionally, public transit organizations are looking into blockchain due to:

- **Growing need for privacy:** Blockchain enables a holistic, open-data ecosystem in transportation as all parties can easily exchange information with trust and traceability, while protecting data deemed private or confidential, like bank information.
- **Need to orchestrate large ecosystems:** There is a demand for more collaborative and orchestrated delivery of products, assets and services. For example, integrated ticketing for trip chains composed of various service providers — one per leg, using automatic, tamper-proof and transparent accounting procedures — are able to realize significant business improvements (XINHUANET).

- **Simpler, unified access:** Large cities, with taxis, buses, rental cars and light rail, among others, require travelers to be individually registered with each service. A blockchain platform unites all transport stakeholders under one trusted application (see Can Blockchain Tokens Drive Smarter Commuting Choices?, GCN). This means that the onboarding and validation process of user information can be the same for all the mobility services offered. Also, users can use biometrics for the validation process, to pay securely or touchless and receive a consolidated invoice.
- **First mover advantage:** Early collaborators and adopters can obtain competitive advantages by being the de facto standard (see Flybondi Becomes First Airline to Issue NFT Tickets, Globetrender).
- **Other uses:** Early hype has been focused on financial transactions, but given competition, it is likely that contract management will see increasingly higher volumes of adoption, albeit at slower rates.

Obstacles

- **Support:** Blockchain tools and platforms are still evolving, as is the expertise to develop, maintain and govern its solutions. It requires all the main constituents to participate or it has limited value.
- **Carbon footprint:** Blockchain's energy consumption calculation is controversial (CoinDesk).
- **Alternatives:** Use cases for blockchain across public transit are yet to be proven and have simpler solutions. For example, London's Oyster Card is used by multiple entities and does not use blockchain.
- **Governance and culture:** Public transit organizations are often risk averse. Blockchain requires cultural shifts focused on shared value creation, trust and consensus across all levels of the business to establish protocols for secure transactions and governance mechanisms for the entire ecosystem.
- **Regulations:** Solution adoption could be affected by regulators' demand of interdependent process steps and verifications across digital and physical transactions for high-risk or critical stages of transportation, insurance or maintenance.

User Recommendations

- Evaluate with your peers whether the advantages brought about by blockchain are appealing to your organization's reality and whether there's a vendor that can provide and support a suitable solution.
- Establish or join a dedicated working group or consortium to accelerate the deployment of blockchain in your operations.
- Educate your peers and co-workers, recognizing that the terminology surrounding blockchain across transportation is in flux and in need of a more granular and broader interpretation, especially between public and commercial transportation use cases.
- Identify specific high-risk transportation routes or markets that exhibit transactional complexity or have exhibited variable or low levels of service. These are prime candidates for blockchain.
- Assess blockchain's ability to map and execute across specific transportation use-case criteria and risks — such as location, status and ownership — and its planned timing and positioning across your strategy technology roadmaps.

Sample Vendors

DOVU; Fleetio; HCLTech, MaaS Global; Tencent; Vottun

Gartner Recommended Reading

Guidance for Blockchain Solution Adoption

Guidance for Blockchain Assessments

Supply Chain Executive Report: Realizing the True Potential of Ecosystem Partnerships

Quick Answer: What Are the Attributes of an Emerging Metaverse in Transportation?

Hydrogen Transportation

Analysis By: Pedro Pacheco

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Hydrogen transportation includes vehicles for land, sea and air, incorporating a propulsion system that uses hydrogen as a fuel. They may rely on a fuel cell that converts hydrogen and air into electricity and vapor. Some other vehicles rely on an internal combustion engine that burns hydrogen. Some aircraft may also use jet propulsion that replaces jet fuel with hydrogen.

Why This Is Important

Hydrogen propulsion represents a possible alternative for long-distance, zero-emission travel, including buses, trucks, ships and aircraft propulsion. The Paris Agreement will have a gradual but dramatic impact on the decarbonization of transportation, making future zero-emission mobility a must. Despite heavy investments in battery electric vehicles (BEVs), propulsion is not expected to cover all transportation

needs, at least in this decade, due to limitations in energy density, time to recharge and weight.

Business Impact

Hydrogen technology is not yet fully viable, so for land and sea transportation, the business impact of hydrogen hinges heavily on public incentives and the pace of BEV technology. Hydrogen still has a chance to develop quickly if incentives can enable a price-competitive green hydrogen distribution network before BEV technology can fulfill use cases for long-distance travel on land and sea. Batteries' very low energy-to-weight ratio means hydrogen still stands some chance of becoming the main green solution for aviation within 15 years.

Drivers

- Both the EU and China have put together regulations and incentives promoting hydrogen vehicles, even though they are similar for BEVs.
- Hydrogen has a strong role to play in energy storage and heating. For instance, the EU predicts hydrogen's part of the energy mix will grow from 2% in 2018 to 13% to 14% by 2050. For that matter, the European Green Deal is subsidizing several projects of green hydrogen production and distribution. Governments and companies investing in hydrogen production for several purposes will lower production costs and, hence, will benefit the transportation sector. In addition, Europe's rush to reduce dependence on Russian natural gas represents another opportunity for hydrogen.
- Refueling a hydrogen vehicle is considerably faster than a BEV, especially for large vehicles. This factor drives some companies to see hydrogen as a serious alternative to BEV technology.
- Both Airbus and Boeing plan to put hydrogen-powered planes on the market by the middle of the next decade, even if the latter still prioritizes synthetic fuels. This means hydrogen is, at the moment, a strong, viable carbon-neutral alternative for aviation.
- In 2018, the International Maritime Organization defined that global shipping emissions must fall by at least 50% by 2050 compared with 2008 levels. The European Commission has also recently mandated a reduction of 80% by 2050 in the carbon intensity of the fuel used for ships. Even if less stringent than road vehicle legislation, it creates an opportunity for hydrogen applications.
- Some major automakers still focus on developing and commercializing fuel cell technology for a broad range of transportation solutions. For instance, Toyota Motor is now providing its fuel cell stack to two bus makers in Europe (Daimler Truck and CaetanoBus) and is also providing the technology to a European consortium supporting the adoption of hydrogen for rail, FCH2RAIL.

Obstacles

- Cost-competitive production and distribution of hydrogen are not yet possible, especially for green hydrogen, which is a low-efficiency, energy-intensive process. Infrastructure is not abundant enough to allow broad coverage for hydrogen vehicles, with no significant growth in 2022, compared to the growth in EV chargers count.
- Jump-starting the use of hydrogen in transportation and its supply chain is only possible through major incentives and regulation. Even so, there is the risk of a market collapse after ending those incentives.
- BEV adoption for buses/trucks grows a lot faster than hydrogen, for vehicles and infrastructure. For instance, Volvo Group (Volvo Trucks), Daimler Truck and TRATON GROUP (Scania) have created their own charger network, but the same type of commitment is not visible for hydrogen (see Daimler, Traton & Volvo Invest €500 Million in Charging Infrastructure for Trucks, electrive.com).
- Fuel cells so far require rare metals like platinum and palladium. Scarcity will raise fuel cell prices, possibly causing future supply constraints if mass adoption is reached.

User Recommendations

For transport operators and vehicle manufacturers:

- Prioritize hydrogen transportation investments for regions with incentives favoring not only hydrogen-powered vehicles but also the production of green hydrogen. Hydrogen supply infrastructure is a key bottleneck to the adoption of hydrogen-powered vehicles, and the reason why it needs governmental support.
- Focus on the entire business model to address all the obstacles to the successful adoption of hydrogen in transportation. This may include looking at infrastructure and hydrogen production, and even driving the adoption of hydrogen in other areas, such as energy storage and heating for cost reasons.
- Prioritize aviation applications for long-term investments in hydrogen transportation. While BEV technology remains a threatening competitor for hydrogen in road transportation and shipping, it is not yet in a position to become an alternative in commercial aviation.

Sample Vendors

Airbus; Ballard Power Systems; Bloom Energy; Doosan; General Motors; Honda Motor; Hyundai Motor Group; Robert Bosch; Toshiba; Toyota Motor

Gartner Recommended Reading

Emerging Technologies and Trends Impact Radar: Enabling Power and Energy Technologies

Maverick* Predicts 2022: The Future According to Gartner's Unconventional Thinking

Maglev

Analysis By: Pedro Pacheco

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Adolescent

Definition:

Maglev is a train system that operates through magnetic levitation, where electric coils generate a strong magnetic field that effectively enables the train to move without touching the ground. This reduces friction, effectively allowing this train type to reach cruise speeds above 500 kph.

Why This Is Important

The Paris Agreement puts pressure on countries to decarbonize transportation. However, aviation lacks technologies to do so in a cost-effective manner. This is leading to a growing focus on rail, as renewable energy can be easily used to power trains. Conventional high-speed trains are not fast enough to beat the convenience of commercial flights in routes over 300 km (186 miles), but Maglev trains can handle these speeds.

Business Impact

A maglev train can get to top speeds above 700 kph (435 mph). This is practically the speed of a commercial airliner. This could result in loss of business for airlines in short- and mid-haul journeys. It will also spur major investment in dedicated tracks, with all subsequent implications. It will also allow faster travel between urban centers, and benefit business efficiency.

Drivers

- The need to decarbonize transportation due to Paris Agreement targets is a major factor pushing nations to review their transportation technology roadmap toward more carbon-neutral alternatives. This puts pressure on governments to adopt low-carbon transportation.
- Commercial aircraft manufacturers are unable to offer cost-competitive carbon-neutral propulsion technologies, at least within this decade. Synthetic aviation fuel (SAF) is widely spoken about but its price would be exorbitant even when produced at scale. Electric planes would be slower than maglevs because they must rely on propellers. Plane manufacturers are also working on hydrogen propulsion systems, but these won't be available before 2035. This leaves a 12-year gap where aviation will struggle to provide compelling solutions toward decarbonization.
- Most current maglev development is related to cost reduction. China is set to expand its maglev track extension and Japan will start a maglev commercial service by 2027; this will generate economies of scale that make maglev technology more economically accessible.
- Conventional high-speed train technology is approaching its limit. It's hard to extract more power from the current electric motors, and the stability of catenaries and pantographs at higher speeds is also a concern. Moreover, friction forces — like at the rolling stock and pantographs — increase exponentially with speed. This means it becomes problematic to further increase the speed of conventional high-speed trains because above a certain speed, there will be a cost tipping point that favors maglev trains.

Obstacles

- Maglev suffers from a “chicken and egg” problem: Many governments reject it so far because it’s too expensive and this, consequently, denies it the chance to reach economies of scale.
- This technology makes sense only for covering distances above 300 km. However, this raises problems for small countries in terms of transnational cooperation; such is the case in Europe.
- Maglev will remain an expensive transportation technology at least until the end of the next decade. Therefore, its adoption should be limited to countries that traditionally prioritize rail within their transportation policy and simultaneously have the public budget to commit to such a substantial investment.
- This type of train probably won’t make sense for countries that lack a strong urgency to decarbonize transportation.

User Recommendations

For transportation government organizations:

- Maglev must be a part of your transportation strategy for connections above 300 km. You must aim for deployment within this decade if you have aggressive targets for transportation carbon reduction.

For aviation companies:

- The success of maglev will be a serious competitor to commercial aviation. As such, you must also invest in maglev technology. Take, as an example, Japan Airlines, which set up its own maglev research center.

For rail operators and train manufacturers:

- Invest in the transition from conventional high-speed trains to maglev as conventional high-speed trains approach technology limits.

Sample Vendors

Central Japan Railway Company; CRRC Zhuzhou Locomotive.

Gartner Recommended Reading

Technology Assessment of Transforming Trends in the Rail Industry for 2030

Technology Assessment: Urban Mobility, 2030

Intelligent Traffic Management Systems

Analysis By: Jonathan Davenport

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Definition:

Intelligent traffic management systems (ITMS) utilize IoT data to improve traffic flow. Decisions about traffic signal timings, variable road speed limits and vehicle routing are made based on data from roadside infrastructure, computer vision (camera, lidar or 4D imaging radar) and vehicle telematics. ITMS can be used to prioritize certain vehicles (emergency services or VIPs), enable free-flowing road tolling, while also delivering safety, efficiency, air quality and congestion benefits.

Why This Is Important

ITMS can improve the traffic congestion of a city center by optimizing traffic flow with the use of intelligent traffic systems. Likewise free-flowing tolling eliminates the need to stop and pay at a booth. Both use cases reduce commute time, subtly enhancing drivers' emotional well-being and perceived quality of life. Governments can improve their duty of care to their emergency service employees and other road users by enabling a "green wave" of traffic lights for first responders, safely improving incident response times.

Business Impact

While improving traffic flow is the primary benefit, some consider ITMS as a potential secondary source of new revenue, such as dynamic pricing and tolling. Using intelligence from intersection cameras enables law enforcement to use this data for driving violations, such as not wearing a seatbelt or talking on mobile devices while driving. Accidents caused when first responders go through a road junction on a red light can be eliminated, reducing associated insurance and lost time injuries costs of insurance.

Drivers

- ITMS improves traffic flow to provide a better experience for road users.
- Intelligent traffic management could provide additional revenue sources for motor agencies considering it for dynamic pricing to enable single drivers in high-occupancy vehicles (HOVs), or by adjusting pricing based on time of day or during peak holiday traffic.
- Public safety can be enhanced with intelligent traffic management via tracking illegal driver behavior with those using video images.
- Variable speed limits can be enforced using computer vision enabled average speed checks. These systems utilize license plate recognition to track the time it takes vehicles to cover a set distance and calculate an average speed. This also prevents drivers from learning where traffic enforcement systems are located and adjusting speed (sometimes dangerously) when they see a camera.
- Some advanced ITMS use technologies to eliminate the electronic toll infrastructure and gantry with infrastructure at the side of the road to further reduce setup costs.
- Traffic management with edge computing done at the traffic light intersections can analyze patterns of driving violations and send the relevant information to central operations. Faster processing and lower cost have enabled smaller boxes to do powerful calculations to enable traffic management systems to become more advanced and sophisticated.
- Traffic light synchronization has been implemented for many years, but ITMS avail multiple sources of data to analyze and automatically take action in real time.
- Improvements in the systems should reduce the physical infrastructure road requirements.

Obstacles

- Many cities have implemented a traffic management system so the additional cost to migrate to an intelligent system could be cost prohibitive.
- Privacy concerns with using AI-based cameras in some jurisdictions will also pose challenges.
- The ideal state of adjusting traffic lights to enable emergency vehicles to quickly maneuver the city streets will only be possible if different municipal government agencies work together to enable data to be pulled together into the traffic management systems. This would require coordination of and participation across multiple agencies and other entities in the wider ecosystem, such as transport agencies working with public safety, health and human services, and hospitals/emergency vehicles.

User Recommendations

- Collate benchmark data on before-and-after implementation to use as a business case justification for investment in ITMS.
- Utilize a cyclical hypothesis, implement, test cycle to continually expand the scope of ITMS investments by utilizing traffic flow and safety data to identify areas where the biggest potential benefits can be derived.
- Establish a broader view of how traffic data can be monetized by providing additional insights to other government agencies and divisions, as well as third parties.
- Examine additional revenue potential of intelligent traffic management system use cases and potential business models that can be explored with dynamic pricing of road tolls and parking.

Sample Vendors

Advantech; Econolite; Efftronics; INRIX; Iteris; Kapsch TrafficCom; Panasonic; SCATS; Siemens; TRL Software

Gartner Recommended Reading

Hype Cycle for Connected, Electric and Autonomous Vehicles, 2022

Technology Assessment: Urban Mobility, 2030

Technology Opportunity Prism: IoT in Smart Cities

Autonomous Things: Technology Use Cases for R&D

AI in Transportation

Analysis By: Pedro Pacheco

Benefit Rating: Transformational

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

AI is a discipline that applies advanced analysis and logic-based techniques, including machine learning, to interpret events, support and automate decisions and take actions. AI in transportation provides benefits such as improving safety, customer satisfaction, and saving time, effort and cost.

Why This Is Important

AI presents major opportunities of optimization at several levels of transportation like safety, maintenance, route and scheduling optimization, and greater customer satisfaction, among others. The fast pace of AI development means transportation companies investing in this technology can unlock strong potential for growth.

Business Impact

The application of AI in transportation creates the following factors of business impact:

- It improves transportation planning, design and forecasting, passenger engagement, operations and maintenance, surveillance systems, passenger identification, and automation of driving, flying or steering.
- Autonomous vehicles, drones and robots can provide efficient and reliable operations to optimize transit. This means safer transportation with greater punctuality and greater energy efficiency.

Drivers

- There is growing market traction for AI solutions that track movements in population agglomerates and determine their behavior patterns. These are being adopted by organizations like transit agencies, transportation operators and chargepoint operators to better understand traveler needs and, with that, achieve a more customer-centric service.
- There are several major challenges affecting transportation that require enhanced predictive and prescriptive capabilities, like need for better service, cost reduction, carbon footprint reduction and efficient maintenance. All these provide opportunities for further adoption of AI in transportation.
- The speed of development of AI is enabling a broad diversity of tools that deliver multiple business and operational improvements. Generative AI is a good example of that, considering its number of applications keeps growing fast. As such, this is generating a substantial interest from organizations at large, including transportation companies.

Obstacles

- There is a lot of hype around AI, which is causing confusion. Several vendors use AI as a marketing ploy, making it difficult for transportation CIOs to identify truly valuable AI-based offerings.
- Companies sometimes struggle to see a tangible benefit from the technology due to technical limitations and an inability to define tangible targets for success. In addition, in some cases, the integration of AI solutions with existing infrastructure proves challenging.
- There isn't an alignment across the industry in terms of data standards, something that represents an obstacle to the success of analytics and AI.
- Privacy regulations may become an obstacle for organizations who want to use AI to improve customer-related performance but don't know how to do it in a compliant fashion.
- Some companies invest in AI without determining suitable business cases in advance. Therefore, obtaining executive leadership sponsorship to start or proceed with AI investment becomes a challenge.

User Recommendations

- Ensure AI use cases are linked to business performance metrics to further justify and contribute to future investments. For instance, link AI to the amount of cost savings or the percentage of customer satisfaction improvement.
- Build an AI strategy for the whole organization to ascertain economies of scale. Employing multiple vendor solutions for different use cases will later lead to vendor management challenges and siloed systems.
- Retrain internal IT skill sets to build up AI capabilities, such as machine learning, generative AI, computer vision programming and operational research, depending on your AI application.
- Learn about the ethical and legal implications for AI in applications such as facial recognition for passengers as well as the use of autonomous technologies internally and externally, and jurisdictional regulations.
- Start exploring the adoption of generative AI to improve the efficiency of both internal and customer-facing processes.

Sample Vendors

Google; Hexagon; NTT Group (NTT Data); Optibus

Gartner Recommended Reading

Technology Assessment: Urban Mobility, 2030

5 Building Blocks to Achieve Autonomous Transportation

Why Autonomous Flying Drones Must Be on the Radar of Mobility Sector CIOs

Use-Case Prism: Artificial Intelligence for Transportation

Cool Vendors in AI in Automotive and Smart Mobility

Micromobility

Analysis By: Shivani Palepu

Benefit Rating: Moderate

Market Penetration: 20% to 50% of target audience

Maturity: Emerging

Definition:

Micromobility refers to the use of small, lightweight, one-person vehicles for short trips, typically within urban areas. The vehicles could include bicycles, e-scooters, e-bikes and one-person vehicles. Micromobility solutions aim to provide convenient, low-cost and environment-friendly alternatives to traditional transportation modes. They are particularly suited for commuting short-distance trips that are too long to walk or too short to make use of a car.

Why This Is Important

Micromoiblity addresses the challenge of first- and last-mile transport which helps provide door-to-door mobility to transit hubs and other destinations (home, workplace, etc.). The seamless integration of micromobility with public transportation can encourage more riders to use mass transit systems. It helps decongest roads by reducing dependency on private cars, leading to a more sustainable transportation ecosystem. It also helps in reducing emissions, congestion and the demand for parking.

Business Impact

Micromobility services can help transit organizations attract new ridership segments to the traditional mass transit systems like buses, trams or trains. They can provide easy access to mass transit systems and can also lead to a reduction in operational costs by utilizing cost-effective mobility options for short-distance commutes. Micromobility can also drive technology innovations in urban transportation that can foster the growth of a vibrant transportation ecosystem.

Drivers

- Consumer preferences are shifting toward more sustainable, convenient, cost-effective and flexible transportation options. Micromobility, with its focus on active transportation and flexibility, aligns perfectly with these changing preferences.
- Advancements in technology, particularly in batteries and electric motors, have made electric micromobility vehicles more efficient, affordable and accessible.
- Concerns related to climate change and air pollution have led to a growing demand for more sustainable transportation alternatives. Micromobility with its low- or zero-carbon emissions is seen as a perfect alternative to traditional fuel-powered vehicles.
- Micromobility is more often enabled and fueled by digital technologies such as mobile apps, MaaS platforms and the Internet of Things (IoT). Leveraging these technologies for micromobility initiatives can align with the transit organization's overall goal of digital transformation.
- User and asset data captured through micromobility systems can be leveraged to gain insights into transportation patterns, optimize operations and make data-driven decisions.
- Many governments and local authorities are actively promoting micromobility as a solution to urban transportation challenges. This includes supporting the growth of micromobility infrastructure, promoting shared mobility programs and offering various incentives.

Obstacles

- Safety is a critical factor for micromobility adoption. Accidents, injuries and vandalism involving e-scooters and e-bikes have raised serious concerns among government authorities. This has also led to regulatory ambiguity and public penetration challenges.
- Micromobility is subject to local regulations and laws that may vary across regions and countries. This can pose a challenge for micromobility operators to navigate and comply with a complex landscape of regulations, permits and licensing requirements in various regions.
- The economic viability and sustainability of micromobility business models can be a challenge.
- In a few scenarios, micromobility has the ability to replace public transport and other transportation modes for shorter commutes. Hence, many transit agencies and transportation service providers might feel threatened and oppose the adoption of micromobility in the market.

User Recommendations

- Set up a data ecosystem and data governance to ensure interoperability and make sure there aren't any barriers to data sharing with all stakeholders involved in the ecosystem, either public or private.
- Provide ticketing and payment integration for end users by creating a MaaS platform.
- Ensure data security measures are in place to protect the privacy and security of the organization.
- Formulate standards and regulations that support the growth of the micromobility market.
- Focus on user experience by providing a seamless and enjoyable journey. This includes the user interface of the apps/platforms, payment integration, various options for mobility and more.
- Implement safety measures such as safety guidelines, speed limits, geofencing and more.

- Use fleet management software to track the vehicle in real time, monitor battery life, and plan optimal routes.
- Collaborate with local governments to ensure integration with public transportation networks.

Sample Vendors

Bird Rides; Bolt Technology; Dott; Grow Mobility; Lime; Mobike; TIER; Voi

Gartner Recommended Reading

Quick Answer: How Can Transit CIOs Leverage Micromobility to Strengthen Public Transportation?

Mobility-as-a-Service Platform

Analysis By: Shivani Palepu, Pedro Pacheco

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Definition:

A mobility-as-a-service (MaaS) platform provides users with access to multiple modes of transportation, allowing them to plan, book and pay for their entire journey through a single interface. Its aim is to provide users with a convenient, door-to-door, cost-effective, and sustainable alternative to private vehicles, and to promote the use of shared mobility. Supporting systems enable providers to efficiently serve travelers by providing intelligent, real-time, context-aware information.

Why This Is Important

A MaaS platform could reduce congestion and provide door-to-door solutions that integrate all forms of mobility including public transport. It especially promotes the use of shared mobility, which reduces the dependence on private vehicles. MaaS allows public transport organizations to offer better services by improving accessibility to their services, reducing costs and, in some cases, emissions. It also offers an opportunity to collect more data that can be used to better respond to travelers' needs.

Business Impact

A MaaS platform, when properly developed and managed, can contribute to reducing congestion, emissions and public costs. As such, it represents a major tool that local, regional and even national governments can leverage to achieve emissions targets, optimize service offerings with data-driven decision making and improve customer satisfaction. It can also create new revenue streams, enabling innovative business models for transportation operators and mobility service providers.

Drivers

- The pandemic fueled the importance of diversifying transportation options and gaining better visibility into the availability and capacity of transport services.
- An integrated system that combines mass transit and shared mobility modes has the potential to address gaps that currently require people to own and use a personal automobile. By meeting diverse transportation needs and providing door-to-door connectivity, a MaaS platform can easily cater to user requirements and create a more sustainable and convenient transportation platform.
- Transportation providers are trying to build greater visibility for travelers as their travel patterns have, in many cases, been permanently affected by the pandemic due to remote working. MaaS platforms can aid in that visibility.
- The MaaS app is also a direct line of communication between travelers and transit authorities, which the latter can use to improve customer service and to better understand the needs of these travelers. This can be done by leveraging anonymized and contextual information about travelers, businesses and mobility needs, mapped against real-time data. Moreover, the MaaS app provides the opportunity to measure environmental impact factors more accurately, such as carbon footprint per traveler and noise.
- The MaaS platform is also a springboard that allows transit agencies and mobility providers to more easily launch services that use the same digital architecture, like on-demand transit or special MaaS packages for tourists.

Obstacles

- MaaS providers face challenges in integrating various transportation modes into a seamless and interoperable platform, as they have different data formats, APIs and business models.
- Transit authorities have been sluggish in defining rules and governance for MaaS. In some other cases, there is a lack of standards alignment between transit authorities of different cities, which only creates more obstacles to MaaS deployment.
- Some mass transit players have an old integration infrastructure, which makes it hard for MaaS to operate due to limitations in data collection and exchange.
- Some shared mobility providers are not embracing a spirit of cooperation, trying to protect their “territory” and not sharing any data with other transportation players in the ecosystem.
- MaaS can also trigger a move of users from mass transit to personal shared mobility, such as car sharing or ride-hailing. If the move reaches a certain proportion, this could generate higher emissions and more congestion.

User Recommendations

For transit agencies:

- Set up a data ecosystem to ensure interoperability and data exchange among all stakeholders.
- Ensure digital integration by upgrading systems that integrate easily with modernized transportation systems and their digital architecture.
- Adopt a strategy that uses MaaS as a springboard to deploy other models like on-demand transit.
- Ensure a single payment system is used across all platforms to reduce friction.

For regional/national governments:

- Build policy and a digital data ecosystem for a regional MaaS ecosystem.
- Advocate for pilot programs and regulatory sandboxes that allow testing and experimentation of MaaS systems in a controlled environment.

For MaaS operators:

Use MaaS as a way to provide transportation in a more flexible, on-demand way.

- Use MaaS to integrate with complimenting transport options like micromobility to provide door-to-door connectivity.
- Use MaaS to improve user experience by providing real-time information and details on carbon savings for each mode.

Sample Vendors

Axon Vibe; MaaS Global; Moovit; SkedGo; Trafi; Via Transportation

Gartner Recommended Reading

Quick Answer: How Can CIOs Establish a Successful MaaS Platform?

2023 CIO and Technology Executive Agenda: A Transportation Perspective

Autonomous Vehicles

Analysis By: Jonathan Davenport

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Definition:

Autonomous vehicles use various onboard sensing and localization technologies, such as lidar, radar, cameras, global navigation satellite system (GNSS) and map data, in combination with AI-based decision making, to drive without human supervision or intervention. Autonomous vehicle technology is being applied to passenger vehicles, buses and trucks, as well as for specific use cases such as mining and agricultural tractors.

Why This Is Important

Autonomous vehicles have the potential to change transportation economics, cutting operational costs and increasing vehicle utilization. In urban areas, inexpensive fares and high-quality service may reduce the need for private car ownership. Road safety will also increase, as AI systems will never be distracted, drive drunk or speed. Autonomous features on privately owned vehicles will enable productivity and recreational activities to be undertaken, while the vehicle handles the driving operations.

Business Impact

Autonomous vehicles have the potential to disrupt established automotive business models. Self-driving systems will stimulate demand for onboard computation, radically increasing the semiconductor content of vehicles. After the office and home, vehicles will become a living space (like airplanes) where digital content is both created and consumed. Over time, it is likely that fleet operators will retrain and redeploy commercial drivers to other, higher-value-adding roles within the company.

Drivers

- The formalization of regulations and standards for autonomous vehicles will aid implementation. Automated lane-keeping system (ALKS) technology has been approved by the United Nations Economic Commission for Europe (UNECE). This is the first binding international regulation for SAE Level 3 vehicle automation, with a maximum operational speed of 37 mph. To take advantage of the new regulatory landscape, automakers are beginning to announce Level 3 solutions. Honda is the first company to announce a commercially available ALKS equipped vehicle, though only 100 will be produced.
- Other companies are quickly following, with Mercedes-Benz being the first automotive manufacturer worldwide to secure internationally valid system approval and has launched in Germany. Its Level 3 solution has secured approval from the state of Nevada and an application to enable cars to drive autonomously in California has also been made.
- In China Changan, Great Wall Motor and Xpeng have announced Level 3 systems. Other global automakers are following suit. Hyundai's new Genesis G90 and the Kia EV9 vehicles will come equipped with a Level 3 Highway Driving Pilot (HDP) function.
- This signals that the autonomous vehicle market is most likely to evolve gradually from ADAS systems to higher levels of autonomy on passenger vehicles, rather than seeing a robotaxi-based revolution. This will require flexible vehicle operational design domains (ODDs). Progress is being made by companies like Mobileye who's perception system was developed on the roads of Israel, but required minimal retraining to perform well in diverse cities like Munich and Detroit.
- The most compelling business case for autonomous vehicles relates to self-driving trucks. Driver pay is one of the largest operating costs for fleets associated with a commercial truck, plus goods can be transported much faster to their destination because breaks are no longer necessary. The Aurora Driver product is now at a "feature complete" stage, with a plan to launch a "middle-mile" driverless truck service at the end of 2024.

Obstacles

- Designing an AI system that is capable of driving a vehicle is hugely complex. As a result, the cost of bringing a commercial autonomous vehicle to market has been greater than companies could have previously envisioned, requiring significant investments to be made.
- When autonomous vehicles are commercially deployed, autonomous vehicle developers, not the human occupants, will be liable for the autonomous operations of the vehicle. This raises important issues, should a vehicle be involved in an accident, and the need for associated insurance.
- Challenges increasingly include regulatory, legal and societal considerations, such as permits for operation and the effects of human interactions.

Analyst Notes:

- Volvo's EX90 vehicles are being deployed with hardware-ready for unsupervised autonomous driving (including a lidar from Luminar), despite the self-driving software not being ready for deployment. Volvo plans to deploy an over-the-air software to move capability from Level 2 ADAS system to Level 3 in the future.
- Despite continued improvements in Level 4 autonomous vehicle perception algorithms and broader self-driving systems used for mobility use cases (such as robotaxis), driverless operations have not scaled to different cities quickly. Waymo — one of the early leaders of operations without a safety driver — has struggled to expand outside of Arizona.
- Slow progress saw Ford and VW pull their investments in Argo AI at the end of 2022, causing the joint venture's operation to close. VW had invested approximately 2 billion Euros in the company.
- Likewise Pony.ai's permit to test driverless vehicles in California was suspended after an accident and in San Francisco, Cruise's autonomous operations led to traffic disruptions — local transit officials cited 92 unique incidents between 29th May and 31st December 2022.

User Recommendations

Governments must:

- Craft national legislation to ensure that autonomous vehicles can safely coexist with a traditional vehicle fleet as well as a framework for their approval and registration.
- Work closely with autonomous vehicle developers to ensure that first responders can safely respond to road traffic and other emergencies and self-driving vehicles don't obstruct or hinder activities.

Autonomous mobility operators should:

- Support consumer confidence in autonomous vehicle technology by remaining focused on safety and an accident-free road environment.

Traditional fleet operators looking to adopt autonomous technology into their fleets should:

- Minimize the disruptive impact on driving jobs (bus, taxi and truck drivers) by developing policies and programs to train and migrate these employees to other roles.

Automotive manufacturers should:

- Instigate a plan for how higher levels of autonomy can be deployed to vehicles being designed and manufactured to future-proof vehicle purchases and enable future functions-as-a-service revenue streams.

Sample Vendors

Aurora; AutoX; Baidu; Cruise; Mobileye; NVIDIA; Oxbotica; Pony.ai; Waymo; Zoox

Gartner Recommended Reading

Emerging Tech Impact Radar: Autonomous Vehicles, 2022

Lessons From Mining: 4 Autonomous Thing Benefit Zones for Manufacturers

Forecast Analysis: Autonomous Vehicle Net Additions, Internet of Things, Worldwide

Tech Providers 2025: Product Leaders Must Strategize to Win in the Evolving Robotaxi Ecosystem

Climbing the Slope

Shared Mobility

Analysis By: Shivani Palepu, Mike Ramsey

Benefit Rating: Moderate

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Definition:

Shared mobility refers to transportation services or on-demand transit that are shared among users, either simultaneously, as a group or over time as personal rental. It encompasses the use of car sharing, ride-hailing, bike sharing or others that manage the pickup and drop-off, primarily through a mobile application. Shared mobility reduces the dependency on private vehicles and aims to optimize the use of shared resources, reduce congestion, and promote sustainability.

Why This Is Important

Shared mobility has fundamentally transformed the way people travel and transportation assets are utilized, creating a new channel and methodology for mobility. It allows for a more sustainable and accessible way to move around. It can also enhance the reach of public transportation, particularly in regions with limited transportation options. Shared mobility also addresses the challenge of first-and last-mile mobility which is a major bottleneck for transportation agencies.

Business Impact

Shared mobility, primarily through ride-hailing services, has had a huge impact on transportation by reducing private vehicles dependency. As shared mobility continues to grow, there may be an increased demand for technologies that enable efficient booking, payment processing and more. Shared mobility has also fueled the adoption of MaaS, which offers a common platform for booking, routing and payment for low-cost alternatives.

Drivers

- The return of workers to offices and urban areas, postpandemic rise in business and increased social travel had a positive impact on the use of shared mobility.

- Advancements in technology such as mobile apps, GPS trackers, real-time information, payment processing and more, have made it easier to access shared mobility services.
- The adoption of shared mobility would increase given the rise in electric vehicles adoption. In addition, the cost of operating ride-hailing vehicles should fall as more vehicles use electricity rather than fuel. This could also reduce pollution concerns in urban centers where the increase in traffic from ride-hailing initially raised concerns.
- The increase in usage of shared mobility modes to access mass transit systems as they integrate well with long-distance transportation modes.
- The proliferation of mobility-as-a-service platforms that connect different forms of transportation could increase demand for shared mobility services by making them easier to access.
- The rise of autonomous vehicles (AVs) could also increase adoption of shared mobility by making the system more swift and futuristic.

Obstacles

- The economics of shared mobility have always been a problem. Many shared mobility platforms have been unprofitable, although they are inching toward better results.
- User behavior and safety can be a major challenge in the adoption of shared mobility. Addressing issues like wearing helmets, thefts, vandalism or misuse of vehicles can pose a major challenge to operators.
- Changes in culture around working from an office versus at home and the corresponding vitality of urban centers could impede shared mobility. It may also shift the focus to active transportation like walking and bicycling.
- Laws in certain regions that require ride-hailing providers to be considered employees or limit them against taxi operators may change the structure of the primary companies offering services and make expansion difficult.
- Rapidly evolving market dynamics with changes in customer preferences, competitive pressure, regulations and technological advancements can pose a challenge for the operators.

User Recommendations

Transit agencies or service providers should:

- Form partnerships and integrate shared mobility services with public transport to provide effective door-to-door connectivity.
- Invest in data and technology to better understand the demand for shared mobility.
- Use shared mobility to provide transportation options for people who feel uncomfortable in public transportation or who aren't always able to use public transport, like the elderly.
- Enable payment or scheduling options that complement other public and private transportation options.
- Develop a MaaS platform to further support the integration of shared mobility with transportation systems. This will improve traffic congestion, to address pollution concerns and to even provide lower-cost transit.
- Prioritize sustainability by investing in electric vehicles and promoting bike-sharing.
- Be wary of investing in, or connecting with, services that skirt city regulations, because the services could quickly be frozen out for an individual town.

Gartner Recommended Reading

Quick Answer: How Can Transit CIOs Leverage Micromobility to Strengthen Public Transportation?

Quick Answer: How Can CIOs Establish a Successful MaaS Platform?

Biometrics in Aviation

Analysis By: Vivid Gong, Venecia Liu

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Adolescent

Definition:

Biometrics in aviation use unique biological or behavioral traits to corroborate a person's claim to an identity previously established to obtain access to an electronic or digital asset or admittance into a secure or privileged area.

Why This Is Important

Biometrics techniques have the ability to efficiently and quickly verify a person's identity and speed up the process by eliminating the need to show documentation at each stage of the passenger airport process. The automated process can help reduce costs and reduce lengthy queues. Several airports have already implemented the International Air Transport Association (IATA) One ID standard as a step toward a seamless passenger experience.

Business Impact

Biometric identification facilitates a more secure verification process with less friction and fewer resources in aviation. Biometric methods have expanded across the airport passenger journey in an efficient manner applied from curbside to boarding gate.

Drivers

- Identity verification that is efficient and less prone to falsification/human error.
- The need to eliminate documentation handling through contactless technologies across multiple parties.
- The need to reduce lengthy queues and improve process time.
- The pressure to reduce operating costs in airports.
- The potential to improve passenger experience by providing automatic access through secure areas or to purchase goods or services using only biometrics.

Obstacles

- Data integration challenges across different airport stakeholders such as airlines, airport and immigration and border control.
- Concerns on passenger privacy and data usage.
- Collecting passenger information requires regulatory compliance on data ownership, data storage, data retention, data security and data vulnerability.
- The cost of implementing this technology including hardware technology.

User Recommendations

- Examine the end-to-end passenger journey and how biometrics can be applied by collaborating with stakeholders such as immigration and border control to assess technological challenges.
- Follow the IATA One ID developments and conduct a peer exchange with airports that have implemented to uncover their technical challenges.
- Explore ecosystem links of applying biometrics to other modes of transport connected at the airport such as bus or subway.

Sample Vendors

Cognitec Systems; Materna IPS; NEC; Safran; SenseTime; SITA; Thales (Gemalto); Vision-Box

Gartner Recommended Reading

Innovation Insight for Biometric Authentication

Biometric Verification: An Opportunity and a Regulatory Risk

Emerging Technologies: Emergence Cycle for Biometric Sensing

Invest in Hands-Free Technology to Encourage Customer Visits Postpandemic

Market Guide for User Authentication

Appendixes

See the previous Hype Cycle: Hype Cycle for Transportation and Smart Mobility, 2022

Hype Cycle Phases, Benefit Ratings and Maturity Levels

Table 2: Hype Cycle Phases

(Enlarged table in Appendix)

Phase	Definition
Innovation Trigger	A breakthrough, public demonstration, product launch or other event generates significant media and industry interest.
Peak of Inflated Expectations	During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the innovation is pushed to its limits. The only enterprises making money are conference organizers and content publishers.
Trough of Disillusionment	Because the innovation does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales.
Slope of Enlightenment	Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the innovation's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process.
Plateau of Productivity	The real-world benefits of the innovation are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase.
Years to Mainstream Adoption	The time required for the innovation to reach the Plateau of Productivity.

Source: Gartner (July 2023)

Table 3: Benefit Ratings

Benefit Rating ↓	*Definition* ↓
Transformational	Enables new ways of doing business across industries that will result in major shifts in industry dynamics
High	Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise
Moderate	Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise
Low	Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings

Source: Gartner (July 2023)

Table 4: Maturity Levels

(Enlarged table in Appendix)

Maturity Levels	Status	Products/Vendors
Embryonic	In labs	None
Emerging	Commercialization by vendors Pilots and deployments by industry leaders	First generation High price Much customization
Adolescent	Maturing technology capabilities and process understanding Uptake beyond early adopters	Second generation Less customization
Early mainstream	Proven technology Vendors, technology and adoption rapidly evolving	Third generation More out-of-box methodologies
Mature mainstream	Robust technology Not much evolution in vendors or technology	Several dominant vendors
Legacy	Not appropriate for new developments Cost of migration constrains replacement	Maintenance revenue focus
Obsolete	Rarely used	Used/resale market only

Source: Gartner (July 2023)

Document Revision History

Hype Cycle for Transportation and Smart Mobility, 2022 - 25 July 2022

Hype Cycle for Transportation and Smart Mobility, 2021 - 12 July 2021

Hype Cycle for Transportation Industry, 2020 - 13 August 2020

Hype Cycle for Transportation Industry, 2019 - 29 July 2019

Recommended by the Authors

Some documents may not be available as part of your current Gartner subscription.

Understanding Gartner's Hype Cycles

Tool: Create Your Own Hype Cycle With Gartner's Hype Cycle Builder

Total Experience in Automotive Manufacturing and Transportation

IT Key Metrics Data 2023: Industry Measures — Transportation Analysis

Technology Assessment of Transforming Trends in the Rail Industry for 2030

How to Integrate Micromobility With Public Transport

Quick Answer: How Can CIOs Establish a Successful MaaS Platform?

Table 1: Priority Matrix for Transportation and Smart Mobility, 2023

Benefit ↓	*Years to Mainstream Adoption*			
	Less Than 2 Years ↓	***2 - 5 Years*** ↓	***5 - 10 Years*** ↓	***More Than 10 Years*** ↓
Transformational			AI in Transportation Autonomous Vehicles	Autonomous Ships Commercial Space Travel Hyperloop Hypersonic Aircraft
High		5G Biometrics in Aviation Mobility-as-a-Service Platform	Battery Electric Trains Carbon Measurement in Transportation Connected Ships Heavy-Duty EV Charging Intelligent Connected Infrastructure	6G Electric Aircraft Electric Ships Mobility Quantum Optimization
Moderate	Shared Mobility	Intelligent Traffic Management Systems Micromobility	Digital Twins in Transport Hands-Free Ticketing Multiview Information Display Technology On-Demand Aviation Public Transit Blockchain Trackless Tram	Autonomous Urban Air Mobility Hydrogen Transportation Intuitive Mobility Ion-Propelled UAVs Maglev
Low				

Benefit	*Years to Mainstream Adoption*			
↓	***Less Than 2 Years*** ↓	***2 - 5 Years*** ↓	***5 - 10 Years*** ↓	***More Than 10 Years*** ↓

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