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Lunar Mobility: Solar-Powered Elevated Guideways

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Abstract

The proposed system is a unique, modular, solar-powered transit network designed to revolutionize lunar mobility and freight movement, as well as logistical operations on the Moon. It introduces elevated guideways that carry autonomous passenger pods and freight cars, specifically engineered for the harsh lunar environment and powered entirely by solar energy. This system, which can be developed after a significant settlement has been established, represents a significant leap in lunar transportation technology. Proposing the use of elevated guideways for a lunar PRT system is not just a fascinating concept, but a truly innovative and forward-thinking one. These elevated guideways, explicitly designed for lunar PRT systems, offer a futuristic yet entirely workable solution to the challenges of lunar transportation. With lunar-specific engineering and the use of lunar materials, they could form the backbone of human mobility and freight mobility to support lunar settlements, ushering in a new era of lunar exploration and development. When discussing automated guideway transit systems, there is no reason a guideway cannot also be used for freight transportation from the resource extraction areas to the lunar settlement. This research aims to support future lunar exploration, base development, and resource extraction by enabling safe and autonomous transport across the lunar surface. The paper discusses the design, energy systems, structural components, implementation roadmap, and challenges associated with deploying such a system on the Moon. A solar-powered PRT system using elevated guideways offers a transformative solution to lunar mobility challenges. Its modularity, autonomy, and sustainability are in perfect harmony with the goals of upcoming lunar missions and the vision of establishing a long-term human settlement on the Moon.

Keywords: Lunar Transportation, Elevated Guideways, Solar Powered Systems, Personal Transit, Freight Transport

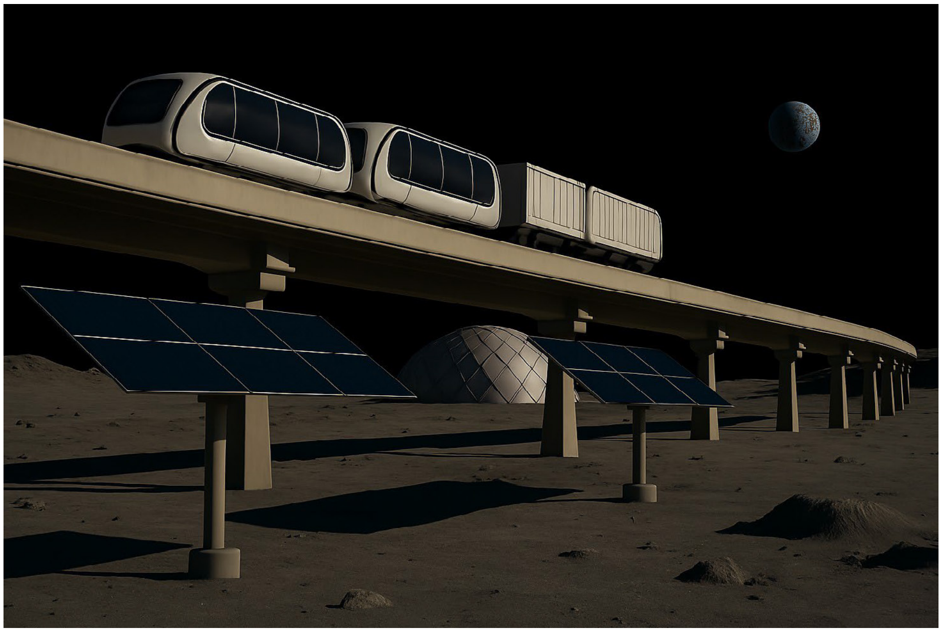


Figure 1: Lunar Mobility: Solar-Powered Elevated Guideways

1. Introduction

The proposed system is a unique, modular, solar-powered transit network designed to revolutionize lunar mobility and freight movement, as well as logistical operations on the Moon. It introduces elevated guideways that carry autonomous passenger pods and freight cars, specifically engineered for the harsh lunar environment and powered entirely by solar energy. This system, which can be developed after a significant settlement has been established, represents a significant leap in lunar transportation technology.

Proposing the use of elevated guideways for a lunar PRT system is not just a fascinating concept, but a truly innovative and forward-thinking one. These elevated guideways, explicitly designed for lunar PRT systems, offer a futuristic yet entirely workable solution to the challenges of lunar transportation. With lunar-specific engineering and the use of lunar materials, they could form the backbone of human mobility and freight mobility to support lunar settlements, ushering in a new era of lunar exploration and development. When discussing automated guideway transit systems, there is no reason a guideway cannot also be used for freight transportation from the resource extraction areas to the lunar settlement.

This research proposes a sustainable and efficient lunar transportation system using solarpowered PRT vehicles that operate on elevated guideways. The system aims to support future lunar exploration, base development, and resource extraction by enabling safe and autonomous transport across the lunar surface. The paper discusses the design, energy systems, structural components, implementation roadmap, and challenges associated with deploying such a system on the Moon. A solar-powered PRT system using elevated guideways offers a transformative solution to lunar mobility challenges. Its modularity, autonomy, and sustainability are in perfect harmony with the goals of upcoming lunar missions and the vision of establishing a long-term human settlement on the Moon.

The resurgence of interest in lunar exploration has led to the planning of permanent lunar habitats and facilities for resource use. One critical part of such infrastructure is a reliable and scalable transportation system. Traditional wheeled rovers face challenges, including lunar dust contamination, rugged terrain, limited passenger capacity, and energy constraints. This research explores an alternative: a solar-powered PRT system using elevated guideways to provide autonomous, efficient, and dust-resistant lunar transportation.

The objectives of this transport system are to design a lunar PRT system powered by solar energy; to minimize contact with the lunar surface using elevated guideways, thereby reducing the risk of dust contamination and enhancing safety; to ensure sustainability, autonomy, and scalability; and to support mobility for freight, astronauts, equipment, and potentially lunar tourists. These goals guide the design and functionality of the system, ensuring it meets the unique challenges and requirements of lunar transportation.

However, the proposed system will meet some challenges. Due to the prolonged lunar night, the proposed system will need reliable energy storage or hybrid systems. The extreme temperature variations will require engineering materials to be constructed that can withstand temperature spikes ranging from -173°C to +127°C. Shielding and self-cleaning materials for tracks and pods will be necessary to overcome challenges posed by lunar dust (regolith). It will be a challenge to construct elevated structures in one-sixth of the normal gravity. None of these challenges will be insurmountable.

2. Passenger Pods

Personal Rapid Transit (PRT) is a transportation system that uses small, automated vehicles operating on a network of specially designed guideways. On the Moon, this would involve small pods transporting individuals and small cargo, as well as freight cars carrying larger cargo. Irving et al. define the term "Personal Rapid Transit" (PRT) as a system which might be regarded as an automated taxicab system of small three- to six-passenger computerized vehicles for the private use of the traveler and traveling companions; the traveler is carried nonstop and without transfers from his origin station to his destination station (p. 4) [1].

The pods would be autonomous and powered by battery/solar energy. They might include low-friction magnetic levitation (maglev) or wheeled systems with pressurized cabins for human transport with life support. Since GPS is not available on the Moon, location tags along the guideway would be sufficient.

Each of the passenger pods could have a pressurized cabin with panoramic shielding windows. Otherwise, having pressured EVA suits and hookups to support suits in the pods would suffice. There will be on-demand routing through centralized AI control. For safety, the system will include an emergency override and manual piloting options. Each day, inspection pods will traverse the system and monitor it for operational, safety, and maintenance issues.

The system's traffic coordination is a key aspect of its operation, and AI/ML powers it. This advanced system, driven by artificial intelligence and machine learning, can predict and prevent potential collisions, optimize the path for each pod to minimize travel time, and ensure smooth traffic flow. It continuously learns from the data it collects, improving its predictions and optimizations over time. This innovative technology is essential for the safe and efficient operation of the PRT system.

Each pod would house up to five astronauts and workers in a pressurized cabin, equipped with a life-support system and autonomous navigation capabilities. Zadshir describes PRT as lightweight, weighing a few hundred pounds compared to an automobile, which weighs more than a ton [2].

The propulsion systems, whether solar-powered for maglev or electric wheel motors, are designed with safety as a top priority. The personal pods are equipped with robust radiation shielding and emergency override systems, ensuring the safety and security of the passengers. Battery packs and electric motors are strategically placed underneath the chassis, with the front and sides housing sensors and navigation units that further enhance the safety features of the PRT system.

Figure 2: Source: Lowson (n.d.- a)

The vehicles would be similar to the ULtra (see figure above), which features four wheels with rubber pneumatic tires, front-wheel steering, and conventional damped-spring suspension. They include an aluminum ladder frame chassis on which most of the vehicle's propulsion and guidance equipment is mounted. “Sitting on top of the chassis is an aluminum honeycomb floor. Above this honeycomb floor, the vehicle is constructed of a steel frame and ABS-panel body that can be fitted with single- or double-sided electric doors” [3].

If vehicles/trains were dynamically coupled and decoupled as they progressed through a transitway system, and, if offline, stations were created to facilitate demand-responsive service, operational costs could be reduced, travel time decreased, and the level of service improved significantly. Liu’s research states that this high level of efficiency ensures the reliable and consistent performance of the PRT system, meeting the needs of all passengers (p. 186) [4].

Unique features of PRT include its ability to provide a direct origin-to-destination service without the need for transfers or stops at intermediate stations. The small vehicle size allows it to cater exclusively to an individual or a small group, enhancing privacy and comfort. It runs on a demand-driven service functionality, adapting its schedule and routes based on passenger needs rather than fixed service schedules. The system is fully automated, from vehicle operation to station management, and is part of a fully connected network of vehicles, guideways, and stations. These unique features make the system a cutting-edge and user-friendly transportation solution for the Moon, ensuring a comfortable and private journey for all passengers.

3. Freight Cars

A freight route from a mining crater to a polar settlement on the Moon presents a fascinating logistical challenge, and an excellent opportunity to integrate multiple propulsion and infrastructure systems.

When freight cars return to a lunar settlement after a delivery or resource collection run, several operational and environmental challenges can arise. These issues stem from the Moon's harsh conditions, the nature of the cargo, and the settlement's infrastructure. Regolith kicked up during loading/unloading or transit can cling to freight cars. This can contaminate airlocks and docking bays, damaging seals and sensitive equipment. To mitigate these concerns, the system can use electrostatic dust removal systems before entering the settlement zones. The freight cars should be designed with smooth, dust-repelling surfaces and sealed compartments.

Cars returning from sunlit areas may be extremely hot, while those in shaded areas can be frigid. This would create thermal stress on docking mechanisms and cargo containers.

Additionally, these thermal issues could compromise temperature-sensitive payloads.

Freight cars will be exposed to radiation during transit, which may cause degradation of electronics or sensitive materials. Solutions can include shielded containers, radiation sensors, and quarantine protocols for high-risk cargo. Cargo may shift or degrade during transit due to low gravity or vibration, causing a risk of spills or damage to fragile items. Robotic arms equipped with adaptive grips and vision systems will be used for unloading cargo from freight cars.

4. Guideway and Support Beams

The vehicles travel along a network of guideways, which are rail beams supported by concrete columns; the deflection of these beams affects comfort, raises safety concerns, and affects the visual aesthetic. The guideway structure consists of lightweight trusses made from insitu resources, such as sintered regolith or locally produced aluminum girders. Using elevated guideways minimizes lunar dust interference, avoids terrain changes such as craters, and reduces thermal conduction from the surface. The anchored pylons must dampen vibration from moonquakes. The support beams would be constructed from in-situ resources (e.g., sintered regolith, lunar concrete, or regolith-bound polymers). They will be anchored in the regolith using drilling and fusion techniques. The performance of the supported beam is based on the thickness of the rolled hollow section, which forms the side beam. Kerr and Oates caution that the "choice of wall thickness is a consequence of considering factors such as load, design life, fatigue, and welding" (p. 455) [5].

The PRT guideway is typically located at a height of around 6m above the adjacent ground level. Kerr and Oates indicate that this height provides clearance to lunar rover vehicles travelling beneath. In the event of an incident, a rescue machine —a specially designed vehicle equipped with advanced safety features —would drive back up the guideway and hook up to the stranded pod, towing it and its passengers to the nearest emergency disembarkation point (p. 459). For inspection of all system components, inspection pods will travel the system daily.

It is best to use a modular design for an elevated guideway. The goal of modular design is to "maximize the repetition of design solutions, to perfect the application of routine factory fabrication, and to simplify the construction effort," highlighting the innovative design of the PRT system [5]. Because the weight and the costs of the guideway are proportional to the weight of the vehicles, special attention must be given to minimizing vehicle weight [6]. Anderson recommends that "the guideway weight be designed at 140 lb/ft" [6].

Considering the weight of the guideway itself, moving vehicles do not significantly alter the point of zero bending moment. This means that the weight of the vehicles does not significantly affect the structural integrity of the guideway, allowing for consistent and reliable operation of the PRT system. The concept of zero bending moment is a critical design and operational consideration that ensures the structural stability and safety of the system. PRT guideways will have curves. They may be routed over small craters and on small lunar hills. Anderson mentions that "[t]he horizontal and vertical curves must be calculated to support passenger ride comfort within accepted standards for lateral and normal acceleration and jerk" (p. 24) [6].

Lowson recommends adding a guardrail to protect construction and maintenance workers, as well as to safeguard passengers who evacuate from a vehicle that has malfunctioned. Kerr and Oates (2009) stress that side beams should provide the supported spanning elements, as well as an upstand to protect against errant vehicles and provide navigational direction (p. 452) [5,7].

For pods traveling on a wheeled system, the running surface would be a "pair of 450 mm wide pre-cast concrete planks" [5].

Structural analysis confirmed that the critical location in the model was at the welded junction of the cross member with the side beam. "The thickness of the main girders was dictated over their entire length to accommodate welding on the cross-girders at 2m intervals" [5]. Hollow elements are the most efficient structural form; however, each form is sealed with a cathodically protected welded zinc closing plate [5].

5. Concrete Structures for Lunar Prt

The gravitational loads on the Moon are less than the corresponding ones on the Earth, due to one-sixth gravity. Structural systems that use local (indigenous) materials will be favored, reducing the number of components brought from the Earth and resulting in significant savings on the mission budget [8].

Akhnoukh et al.showed that both lunar and Martian regolith can be used in producing flowable concrete with high strength. NASA is testing materials to support infrastructure construction on the lunar surface [9]. It evaluated the suitability of different cementitious materials for implementation through additive manufacturing (3D printing) techniques on the Moon, including "lunar regolith simulant mixed with magnesium oxysulfate cement or calcium sulfoaluminate cements, geopolymers, and a sulfur- and nickel-based concrete" [10].

Temporary mitigation of surface pressure and temperature extremes is necessary for any hydraulic cement or other materials with aqueous components to prevent the vaporization or freezing of the solution. Finally, the gravitational acceleration is 1.62 m/s2 (0.17 g) on the Moon.

Collins et al. add that "[t]he influences of reduced gravitational accelerations on the formation and structure of cementitious materials is a topic that requires significant exploration" (p. 2) [10].

The particle size distribution of the lunar regolith simulant has previously been compared to the limits set forth for fine aggregate, and it is much finer than the specified range. Another consideration to keep in mind is the particle shape of the lunar regolith. The particle shape of the lunar regolith itself is highly angular, while the shape of simulants has been noted. If not processed, Collins et al. warn that "the fineness of the lunar regolith simulant combined with the angularity of the particles would lower the workability of the concrete mixtures and increase the water demand" (p. 8) [10].

The in-situ micromechanical properties of Portland cement and lunar regolith composites are unaffected by gravity. However, changes in air void structure and consolidation observed at reduced gravity could negatively influence the mechanical properties [10].

Design challenges are the uncertainty in "lunar soil modulus of elasticity for compacted regolith; the potential for deflections >5 cm even with well-distributed loads, high energy consumption for sintering regolith or extracting and processing metals, and the reduced gravity vector reduces traction force and either increases required cannot angle in turns or limits speeds in turns [11].

The lunar regolith has abundant supplies of iron, titanium, and magnesium that can also be used for the transportation system [12]. According to the analysis of lunar soil samples, the Moon holds abundant resources. The total ilmenite ($FeTiO_3$) resource is estimated to be 130–190 trillion tons. "The total resource of 3He can reach 1 to 5 million tons; meanwhile, the lunar soil is rich in thorium, uranium, and rare earth elements" [13].

Because the lunar surface is close to a vacuum environment, there are almost no obstacles when meteorites and micrometeorites with a mass of less than 10^{-2} g hit the lunar surface at a speed of 20–70 km/s, which produce dense craters on the Moon. The lunar surface thermal environment includes direct solar irradiation, lunar reflections of sunlight, and infrared radiation on the lunar surface.

During the lunar day, the solar irradiance on the moon reaches as high as 1358 W/m², and the limit temperature of the lunar surface exposed to direct sunlight can exceed 150°C. At midnight on the moon, solar irradiation drops to zero, and the night-time temperature can be as low as 180°C [13].

Lunar remote sensing infrared spectroscopy and Apollo sample analysis results confirmed that OH– and even H_2O could be generated on the lunar surface [13]. There is some evidence for hydrated minerals (and/or adsorbed water or hydroxyl molecules) covering high latitude, but non-permanently shadowed, areas of the lunar surface. The "OH/H_2O, which cannot exist as ice in sunlit regions, is produced by the reduction of iron oxides in the regolith by solar wind-implanted hydrogen" [14]. An indigenous source of lunar water, either in the form of polar ice or in hydrated regoliths and/or pyroclastic deposits, would be the preferred choice as a source of oxygen on the Moon [14].

The Moon is believed to be a treasure trove of raw materials, including SiO_2, Al_2O_3, CaO, and Fe_2O_3, which are crucial components of ordinary concrete [13].

"These materials can be used to create a diverse range of concretes, including calcium aluminate concrete, sulfur concrete, magnesia-silica concrete, polymer concrete, and geopolymer concrete" [13]. Despite the challenges posed by the presence of water on the Moon for specific types of concrete, the preparation of sulfur concrete and polymer concrete, which do not require water, offers a promising advantage [13].

The compressive strength of calcium aluminate concrete, magnesia-silica concrete, and polymer concrete, which exceeds 70 MPa, make them excellent choices for lunar construction.

However, the compressive strength of sulfur concrete and geopolymer concrete, which is below 55 MPa, may limit their use in specific structural applications. Hu et al. indicate that the durability of lunar concrete, a crucial factor in the longevity of lunar structures, is an area that requires further study (p. 13). Understanding the implications of these compressive strengths on the design and construction of lunar structures is crucial for the success of lunar missions [13].

A maximum height must be established to prevent failure. “A minimum thickness of 20 cm is used to include extensive safety factors, as it is a building guideline intended for loadbearing exterior walls” [15]. The ideal tower should be both tall and require as little concrete as possible for construction. To minimize the mass of building material, a tower’s walls should be as thin as possible, particularly for a tower made of lunar concrete, which requires that “the compressive stress must not exceed 30 MPa anywhere” [15].

Rupert et al. have proven the robustness of kilometer-scale concrete towers on the Moon. These structures are “robust against both compressive failure and buckling up to multiple kilometer heights” (p. 10). The negligible mass contribution of solar panels further bolsters the stability of these structures, with their maximum contribution being 0.6% of the tower mass per meter height (at the tower's narrowest section) [15]. “Future studies should consider metal truss frame towers as they are likely to require much less mass” [15].

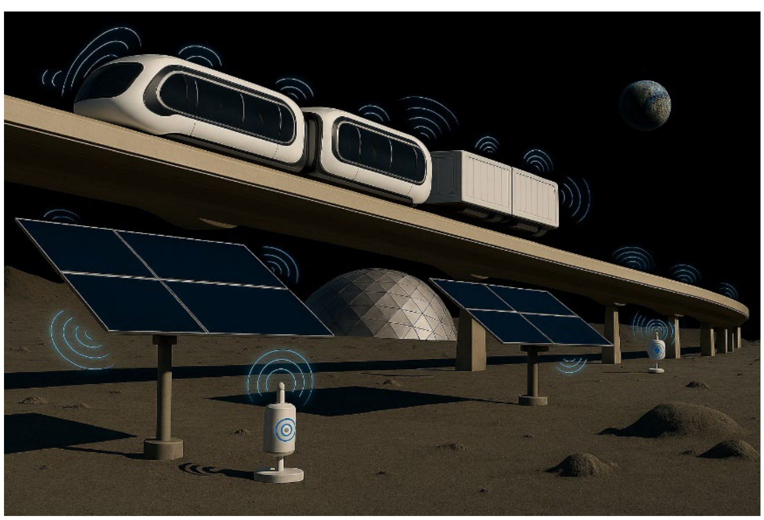
Lunar regolith is rich in functional elements, including oxygen, aluminum, iron, and titanium, and these elements are readily available. It can be reacted with hydrogen to produce water and oxygen for life support and fuel. Additionally, when sintered (heated to just below its melting temperature), it can be formed into a material analogous to concrete. Cox emphasizes that the increased density of fine regolith particles results in improved strength of sintered material (p. 17) [16]. However, he states that the “lunar regolith varies from region to region and between samples from the same area,” meaning the sintering or refining methods will need to be location-specific [16]. Numerous studies have been conducted investigating the various applications of Lunar regolith and its constituent elements.

The lunar highlands are rich in Ca, Al, Si, and O, but poor in Mg and Fe. The mare basalts are richer in Mg, Fe, and Ti, and more deficient in Ca and Al [14]. Extracting iron from ilmenite will be energy-intensive, although it would be a natural by-product of producing oxygen through ilmenite reduction [14]. Silicon can be found in Moon rocks, and “it is critical for making solar cell arrays to convert sunlight into electricity” [14].

6. Propulsion Systems

Magnetic levitation, which uses a linear motor, is the most efficient and scalable option for both pods and freight, particularly when limited maintenance and high speed are desired. Maglev propulsion systems are ideal for long-distance and high-throughput routes. Their benefit is that they can be dust-resistant.

Magnetic levitation for a lunar personal rapid transit (PRT) system (see Figure below) could be designed using NASA’s FLOAT concept (Flexible Levitation on a Track), which is designed specifically for the Moon’s unique environment. This system has two components: diamagnetic levitation and electromagnetic propulsion [17]. The FLOAT system uses a graphite layer that enables robots to passively levitate using diamagnetic levitation, eliminating the need for power to maintain lift. This is ideal for the Moon’s low gravity, which drastically reduces the energy needed to achieve and maintain levitation. Beneath the graphite is a flex-circuit layer that generates electromagnetic thrust. This layer propels the pods and freight cars along the guideway on the elevated track in a controlled manner, allowing for smooth, autonomous movement. Smart sensors are used to monitor the system integrity. These sensors check pod alignment, track integrity, and environmental conditions, such as lunar dust and radiation. They would be mounted near the solar panels and along the guideway for optimal coverage.



Alternatives to the FLOAT system, mechanical guideways with embedded guide fins or wheels could slot into recessed tracks, similar to roller coaster undercarriage designs. These would offer physical constraint without relying on gravity for traction. Further, it is useful for freight pods with variable mass or autonomous routing. It is possible to design the pods with a low center of gravity and active suspension systems helps maintain stability. Even in low gravity, mass distribution and damping can reduce wobble or lift during motion.

Rail-based systems are easier to build but require frequent upkeep due to dust and mechanical wear. Although rail-based systems provide a simpler technology, they are vulnerable to regolith abrasion and wheel wear.

Cable systems excel in niche applications, such as steep inclines or heavy mining transport. They offer a centralized propulsion system, but they are best for fixed routes and steep terrain.

7. Stations

When a passenger vehicle enters a station, it leaves at “line speed” and decelerates on the siding. When it leaves the station, it accelerates on the “siding” before re-entering the “throughline." The higher the line speed, the longer the siding must be [1].

A mating tunnel must be located between the settlement stations, the destination stations, and the pod. After the passengers have boarded the vehicle and the door has closed, the vehicle is under automatic control until it reaches the platform of the destination station. In summary, upon entering the departure station, the passengers travel nonstop to their destination station [1]. The riders will wear their EVA suit upon leaving the station or vehicle. These passengers can board the automated vehicle upon arrival at a station and, with a sufficiently extensive network of tracks, take direct routes to their destination without making any stops [18]. Lateral bays or “slots’ extend from the bypass guideway. Vehicles enter these slots to drop off or pick up passengers. While in the slots, the pods do not obstruct other traffic passing along the bypass guideway.

A vehicle entering the station [can] turn off the transit path through a slight angle and then continue along a straight path to park remarkably close to the parking section, [thereby] eliminating any significant gap between the vehicle and the platform [19].

The spacing and sizing of PRT stations differ vastly from those of conventional rail, in which all stations must accommodate the entire train length along the corridor [20]. PRT stations are located away from the main line and are designed based on passenger and vehicle loads. Initially, there will be no stops from the lunar settlement to the destination.

The features of the stations would have autonomous navigation and docking. Camera data, LiDAR, and inertial sensors will guide pods and freight cars precisely into the stations. To manage the low gravity on the Moon, at stations or intersections, electromagnetic clamps can secure pods precisely. Braking systems may use eddy current dampers or electromagnetic drag, avoiding reliance on friction.

During low-light conditions, the stations can be fitted with infrared or laser guidance. To repel regolith at the stations, the system can be designed with charged plates or fields. To enhance passenger safety, all incoming vehicles will need to be scanned for damage, radiation exposure, and system faults.

8. Solar Power Generation

Only two power generation methods are possible on the Moon in the short term: solar and nuclear fission. Solar power is the preferred choice because it poses no safety or security concerns and has been successfully used on both the Moon and Mars.

Solar power can be integrated with tilt-adjusted solar arrays mounted above the guideway or on adjacent pylons. Solid-state batteries are housed in guideway nodes with redundancy provided by power banks in passenger pods and freight cars. For nighttime operations, the system could use stored energy as a backup for critical routes.

The lunar South Pole offers unique advantages for solar energy, with some ridges receiving near-continuous sunlight. The orientation and tilt of the solar arrays would be true south-facing (in the Northern Hemisphere) to capture maximum sunlight, but they will rotate along their vertical axis to follow the sun. The solar array tilt must be adjusted for lunar seasons, although the Moon’s axial tilt is only ~1.5°. The solar arrays need to be constructed on tall towers.

The advantages of solar power include its abundance, as the Moon receives constant sunlight for ~14 Earth days in its lunar day cycle. Solar panels power the transit pods and recharge during daylight. Batteries or fuel cells store power for operations during the 14-day lunar night (or nuclear backup if needed). Solar panels are mounted on tall towers along the guideways, with power storage of electrical energy provided by lithium-ion batteries or advanced solid-state storage. Solar photovoltaic energy can not only convert energy into electricity but also divide water into hydrogen and oxygen [2].

Although the PRT system consumes less energy compared to moon trains and rovers, the pods are light enough to be solar-powered, which is a significant advantage in utilizing alternative renewable energy sources. “Solar panels will add 0.6% to the load of the towers. The weight of the photovoltaic panels is negligible for towers” [15]. The site of the first permanent lunar base will be at a high latitude near the lunar South Pole. There are highly illuminated regions (HIRs) near the south pole of the Moon that are continuously in sunlight [21]. A promising solution to the challenge of energy supply on the Moon is the continuous energy available in high-illumination areas, sometimes referred to as the “Peaks of Eternal Light.” These “Peaks” are exposed to sunlight for over 90% of the lunar cycle, making them ideal locations for future lunar missions.

As PRT is lightweight, the solar energy collected can be sufficient to meet the required energy needs. In cases where additional energy is available, it can be fed into the grid. The solar system could also serve as a grid. When a circumferential solar-powered electric grid is in place, a Lunar Power System (LPS) concept will provide "continuous electric power at megawatt to gigawatt levels, thereby satisfying the energy needs of global lunar exploration and development projects" [12].

Once installed and properly maintained, it can provide energy for years, alleviating concerns about energy shortages. Energy is a significant operating cost, but since it is powered by solar power, there is one less item to worry about, which could reduce transportation costs (Zadshir, 2021, p. 436). Research by Rupert et al. (2022) has proved that kilometer-scale concrete towers on the Moon are robust against both compressive failure and buckling up to multiple kilometer heights. The negligible mass contribution of solar panels further bolsters the stability of these structures, with their maximum contribution being 0.6% of the tower mass per meter height (at the tower's narrowest section). Future studies should consider metal truss frame towers as they are likely to require much less mass [15].

"There is an incentive to build solar power towers to heights of 100 m, and preferably higher" (Ross et al., 2023, p. 618). In the worst case, it may be that only those towers closest to the horizon, where the Sun is located at any given time, will receive solar illumination, and towers built behind them will be overshadowed [21]. Not all the highly illuminated areas will necessarily be helpful for power generation. As the Sun is always near the horizon, "overshadowing may occur when an illuminated region on a rotated map lies within the shadow of another tower built in a sunward illuminated region" [21]. "At 100 m, it is only possible to create multiple towers per column at illumination thresholds of 70% and 80%" (p. 622).

9. Conclusion

The implementation of passenger pods and freight cars on an elevated guideway represents a transformative leap in lunar infrastructure—merging sustainability, modularity, and resilience into a cohesive transit solution. The deployment of passenger pods and freight cars on elevated guideways presents a practical and strategically advantageous solution for lunar surface mobility. Elevated systems offer critical benefits over surface-level transit, including reduced exposure to regolith-induced abrasion, improved thermal isolation, and enhanced reliability across uneven terrain [22,23]. By minimizing direct contact with the lunar surface, elevated guideways also mitigate dust accumulation—a persistent challenge for long-duration operations [24].

Passenger pods designed for pressurized, shielded transport can ensure crew safety while maintaining operational efficiency. Incorporating autonomous navigation, thermal control, and radiation shielding aligns with current standards for extraterrestrial human-rated vehicles [25]. Freight cars, customized for modular cargo handling and remote operation, support scalable logistics for construction, resource extraction, and scientific exploration [22].

Passenger pods offer safe, pressurized transportation for crew members, equipped with radiation shielding, thermal regulation, and autonomous navigation, which enhance both comfort and reliability. Freight cars, designed for modular cargo handling, facilitate the movement of essential supplies, construction materials, and scientific payloads with minimal human intervention.

This dual-system approach, integrating human transport and automated freight, forms the backbone of a sustainable lunar infrastructure. It enables inter-settlement connectivity, supports ISRU (in-situ resource use), and lays the foundation for future expansion toward permanent habitation and industrial activity. As lunar development progresses, elevated guideway systems will be essential for setting up resilient, high-throughput mobility networks on the Moon [26].

Together, these systems form the backbone of a scalable lunar logistics network. Their integration supports long-term habitation, resource extraction, and settlement, as well as resource extraction connectivity, laying the groundwork for a thriving lunar economy. As we push the boundaries of extraterrestrial engineering, elevated guideways with specialized pods and freight units will be central to unlocking the Moon's potential as a permanent frontier [27-38].

References

1. Irving, J. H., Bernstein, H., Olson, C. L., & Buyan, J. (1978). Fundamentals of personal rapid transit.
2. Yin, H., Zadshir, M., & Pao, F. (2021). *Building Integrated Photovoltaic Thermal Systems: Fundamentals, Designs and Applications*. Academic Press.
3. Lowson, M. (n.d.- a). Ultra-Global PRT: Low-cost transport for a sustainable future [Brochure]. Ultra-Global PRT.
4. Liu, R. (2016). *Automated transit: Planning, operation, and applications*. John Wiley & Sons.
5. Kerr, A. D., & Oates, R. J. (2009). Heathrow PRT Guideway, Lessons Learned. In *Automated People Movers 2009: Connecting People, Connecting Places, Connecting Modes* (pp. 450-470).
6. Anderson, J. E. (2000). A review of the state of the art of personal rapid transit. *Journal of advanced transportation, 34*(1), 3-29.
7. Lowson, M. (2002). *The ULTra personal rapid transit system* (No. 2002-01-0174). SAE Technical Paper.
8. Boni, C., & Royer-Carfagni, G. (2024). Flextegrity arched structures for Lunar bases built from indigenous materials. *Acta Astronautica, 215*, 107-116.
9. Akhnoukh, A., Al-Khateib, H., Edmunson, J., Fiske, M., & Fikes, J. (2021, April). Developing concrete mixes using micro sized Lunar and Martian regolith for space applications. In *57th Annual Associated Schools of Construction International Conference*, Virtual.
10. Collins, P. J., Thomas, R. J., & Radlińska, A. (2023). Influence of gravity on the micromechanical properties of portland cement and lunar regolith simulant composites. *Cement and Concrete Research, 172*, 107232.
11. Floyd, S., & Levin, S. (2024, April). DARPA 10-year lunar architecture (LunA-10) capability study: Lunar rail network infrastructure study (pp. 1-13). Northrop-Grumman.
12. Schrunk, D., Thangavelu, M., Cooper, B., & Sharpe, B. (1998). Physical transportation on the Moon: The lunar railroad. In *Space 98* (pp. 347-353).

13. Hu, Z., Shi, T., Cen, M., Wang, J., Zhao, X., Zeng, C., ... & Zhao, Z. (2022). Research progress on lunar and Martian concrete. Construction and Building Materials, 343, 128117.
14. Crawford, I. A. (2015). Lunar resources: A review. *Progress in Physical Geography, 39*(2), 137-167.
15. Ruppert, S., Ross, A., Vlassak, J., & Elvis, M. (2021). Tall towers on the moon. *arXiv preprint arXiv:2103.00612*.
16. Cox, T. A. (2023). *Investigation into Sintered Lunar Regolith Construction Methods and Novel Usability Evaluation*. The University of Maine.
17. Schaler, Ethan, & Hall, Loura (2021, February). FLOAT: Flexible levitation on a track. NASA Jet Propulsion Laboratory.
18. Teka, L., Li, L., & Yin, H. (2023). Deflection reduction of the guideway of aerial PRT systems by horizontal supports. *Engineering Structures, 291*, 116371.
19. Lowson, M., Cook, C., & Hughes, D. (2007, June). Patent application publication. U.S. Patent and Trademarks Office.
20. Furman, B., Fabian, L., Ellis, S., Muller, P., & Swenson, R. (2014). Automated transit networks (ATN): A review of the state of the industry and prospects for the future.
21. Ross, A. K., Ruppert, S., Gläser, P., & Elvis, M. (2023). Preliminary quantification of the available solar power near the lunar South Pole. *Acta Astronautica, 211*, 616-630.
22. Kim, S., Goodliff, K., & Ennico-Smith, K. (2024). Modular cargo handling for lunar surface logistics. NASA Moon to Mars Architecture White Papers. 24.
23. Zhao, L., & Lin, J. (2022). Elevated guideway design principles for extraterrestrial transit systems. City of Toronto Transit Design Guide.
24. Jones, P. B., & Patel, M. D. (2021). Lunar dust mitigation: A guide and reference (1st ed.). (NASA/TP-20220018746). NASA Technical Reports Server.
25. NASA. (2022). Extravehicular activity and human surface mobility: Program overview.
26. Garcia, M., & Thompson, R. (2023). NASA's lunar communications and navigation architecture. NASA Technical Reports Server.
27. Abel, P. B., Anderson, M. D., Blom, E. T., Calle, C., Dunlap, P. H., Greenberg, P. S., ... & Wohl, C. J. (2023). *Lunar Dust Mitigation: A Guide and Reference:* (2021) (No. E-20102).
28. Boyd, R. K., & Lukas, M. P. (2007). How to run an automated transportation system. *IEEE Transactions on Systems, Man, and Cybernetics*, (3), 331-341.
29. Ceder, A. (2021). Urban mobility and public transport: future perspectives and review. *International Journal of Urban Sciences, 25*(4), 455-479.
30. Csank, J. (2023, April). Nasa lunar surface operations & power grid. In 1*1th Annual Center for Ultra-Wide-Area Resilient Electric Energy Transmission Networks* (CURENT) Industry Conference.
31. Edwards, B., Wagner, R., Zemba, M., Millard, W., Braham, S., Gifford, K., & Somerlock, O. (2023, March). 3GPP mobile telecommunications technology on the Moon. In *2023 IEEE Aerospace Conference* (pp. 1-12). IEEE.
32. Goodliff, K. (2025). Lunar logistics and mobility architecture [White Paper]. NASA Strategy and Architecture Office.
33. Mueller, R. P. (2022). Lunar base construction planning. In *Earth and Space 2022* (pp. 858-870).
34. Plescia, J. B., Cahill, J., Greenhagen, B., Hayne, P., Mahanti, P., Robinson, M. S., ... & Zellner, N. (2023). Lunar surface processes. *Reviews in Mineralogy and Geochemistry, 89*(1), 651-690.
35. Reches, Y. (2019). Concrete on Mars: Options, challenges, and solutions for binder-based construction on the Red Planet. *Cement and Concrete Composites, 104*, 103349.
36. Rezich, E., Bickel, V. T., Francis, P. L., Rogg, A., Tardy, A., Creager, C., ... & Hirabayashi, M. (2025). Investigating the geotechnical properties of the Lunar South Pole with NASA VIPER's mobility system. *The Planetary Science Journal, 6*(7), 169.
37. Schrunk, David G., Sharpe, Burton L., Cooper, Bonnie L., & Thangavelu, Madhu (Eds.). (2009). Governance of the Moon. In the Moon: Resources, future development, and settlement (2nd ed., pp. 157-168). Springer-Praxis Publishing.
38. Swenson, R., & Fund, G. T. PERSONAL TRANSPORTATION, ONE HUNDRED PERCENT SOLAR POWERED.