Leapfrog Technology and How It Applies to Trackless Tram

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Abstract

Rapid innovation and development of modern technology has brought about the opportunity for developing economies to technological leapfrog. In particular, rather than going through all the learning curve and costly process experienced by developed countries, emerging economies instead can take advantage of the opportunities presented by technological shifts. However, inadequate infrastructure is the cause of most challenges that these developing economies presently face. Energy, road, transport and telecommunication networks are the most critical infrastructure needed to drive a sustainable development and economic growth. As seen in many emerging economies, small private cars are still dominating the public transport sector, even though it is evident that they are congesting the poorly managed and crumbling road infrastructure. Most emerging economies’ cities are currently experiencing rapid urbanisation that is leading to massive population explosion. These rapidly growing cities should adopt latest technologies, such as Trackless Trams Systems (TTS). There is no doubt that TTS can probably help in dealing with most of the transport problems experienced in rapidly growing urban areas within emerging economies. This paper seeks to explore the opportunities presented by TTS to bring about the needed technological leapfrogging for the developing countries that are resource constrained to build modern and expensive mass public transport infrastructure. An ideal example of a recent successful technological leapfrog in emerging economies is the low-cost mobile phones and increasingly expanding wireless access in urban areas. As such, countries have been able to eliminate the challenge of building fixed-line telecommunications infrastructure, which is capital-intensive. In this study we are undertaking a literature appraisal on technological leapfrogging, and demonstrate how TTS measure up as a potential technology to aid the leapfrogging for the urban transport systems more so in developing countries. The study discusses the features, quality, and proficiencies of the new tech-
nology. To consider technology for leapfrogging, it ought to be economical enough, less technical, lends itself to partnership, lends itself to community engagement, allows co-development, and fulfils sustainable development goals (SDGs). The paper is organized into four sections, the introduction, literature appraisal, experiential evidence and debate on Trackless Trams, and conclusion.

Keywords
Technological Leapfrogging, Trackless Trams, Socio-Technological Regime

1. Introduction
The surging urban explosion in emerging economies, an aspect attributed to rapid urbanization, has overwhelmed their public infrastructure, which is already lagging in many aspects [1]. Addressing the problem would require concerted efforts from both the government and the private sector [2]. However, to skip the learning curve of the developed countries, there is a suggestion that emerging economies should explore the concept of technological leapfrogging by adopting modern technologies [3]. As previously mentioned, this idea appears to be validated by the accomplishments that have been made in the telecommunication sector [4]. The telecommunication infrastructure is one of the other critical networks necessary for promoting economic growth in developing nations. A cost-efficient and effective transport network is equally vital and necessary when it comes to promoting the desired economic development of these countries [5].

This study will explore the use of Trackless Trams technology as a way through which emerging economies can combat the problems associated with inadequate transport infrastructure in their increasingly growing cities. More importantly, the paper will also examine the ability of TTS to promote the restoration of the towns’ passageways through the transition-oriented development (TOD). Currently, the concept of leapfrogging is being considered by various jurisdictions, policymakers, scholars, and other experts. Given that most emerging economies are still in the process of exploring their options when it comes to building their various network infrastructure, they are likely to benefit from this idea [6]. The study will attempt to address the questions below:
• How can leapfrog technology be defined?
• What are the key requirements for enabling leapfrog technology?
• What is TT?
• How does TT apply to leapfrog technology requirements?

Additionally, the study will explore the technological leapfrogging literature, which will include an examination of various experimental evidence, as well as instances where the idea has been effectively implemented. The discussion will also cover various stages or types of leapfrogging, as outlined by different authors. Literature appraisal will then be followed by a detailed exploration of the
Trackless Tram technology. The paper will present a comparative study of the technology against what has been discussed in numerous works of literature. Emphasis is placed on the essential criteria that might determine whether a given technology has the potential to be used for leapfrogging. For a technology to be able to enhance leapfrogging it is expected to at least have most of the traits below:
- Economical enough;
- Less technical;
- Lends itself to partnership;
- Lends itself to Community Engagement;
- Allows co-development;
- Fulfils Sustainable Development Goals.

2. How Can Leapfrog Technology Be Defined?

Despite the numerous benefits of technology leapfrogging, there is currently little research on this area of study [7]. As such, the literature on technological leapfrogging is still not fully developed to support this inquiry. The paper will explore the different notions and concepts about the various forms and phases that technical leapfrogging can take.

According to Steinmueller [8], technological leapfrogging can be described as “bypassing stages in capability building or investment through which countries were previously required to pass during the process of economic development” [8]. The description implies that for leapfrogging to be accomplished, the technology must possess the following capabilities:
- **Develop an absorptive capacity to create or utilize the expertise:** concerning this requirement, Steinmueller [8] deliberates on the importance of the necessity to be capable of building the ability to come up with the same know-how in the local market and adopt the technology economically. Doing so will ensure that the technology can be easily domesticated to suit the needs of the locals. The argument will be addressed further in the subsequent sections of the paper.

- **Ease of access and ability to make productive use of the technology:** according to experts, such a prerequisite emphasizes the ability to obtain the technology as well as use it effectively to facilitate development [8]. As will be illustrated further on the details of the trackless trams in the next section, the paper will demonstrate how it is easy to operate the trackless trams. The discussion will also include the productive use and advantages of the technology as a promoter for the desired economic growth and the restoration of the cities’ corridors.

- **The technology should have corresponding technical abilities:** this requisite examines the complementary strength of the technology to enable it to work with matching but not necessarily the same know-hows [5]. Trackless trams can lead other sectors to raise their standard. Introducing the trackless trams
would mean that the roads must also be kept in high standard. At the same
time, the ticketing systems and stations used by the trackless trams can also
be utilized by buses. More so, the technology has the ability to stimulate
cooplemental projects such as battery recharging stations.

- **Realizing downstream incorporation capabilities**; this precondition highlights
a vital need to create some degree of assimilation with other sectors down-
stream or upstream [8]. The technology being used in Trackless Trams have
a higher likelihood of downstream connectivity. The technology can exchange
and use data cohesively, an aspect that can enable it to be utilized as the pri-
mary and the last mile service.

The leapfrogging concept can take different forms, phases or stages [3]. Kim-
ble and Wang for instance, identified several leapfrogging phases that can con-
tribute to industrial growth. These phases include the standard path, catch-
ing-up, and technological leapfrogging [9]. The standard path is the usual path-
ways of technological development that was taken by the original inventors. It is
not considered as an “actual” leapfrogging path but the typical path of growth
[10]. While the catching-up form is a fast-tracked leap that leads to economic
and technical development through technological transfer [9]. In such a case, an
“actual” leapfrogging does not occur. Instead, there is a technology transfer that
necessitates the need to follow all stages of development but at an accelerated
pace [11]. However, the actual technological leapfrogging assumes that bypass-
ing certain stages of development is necessary if its benefits are to be felt [10].

Kimble and Wang [9] further identify three forms of technology leapfrog. They
include stage skipping leapfrog, path creating leapfrog, and paradigm-changing
leapfrog. With the stage skipping leapfrog, one or more stages in the growth of
the technology are omitted, as demonstrated in Figure 1 below which illustrates
stages A, B and D with a skip of stage C.

Path creating leapfrog, on the contrary, involves creating an alternate route
for one or more stages instead of skipping a phase in the adopting of the tech-
nology [9] [12]. Such a scenario is commonly seen in sectors where technologi-
cal progress or improvements are continuously shifting, for instance, in the ICT
software industry [9]. In contrast, paradigm-changing leapfrog occurs when the
skipping lands in new advanced expertise than the present socio-technological
regime [9].

Based on the needs of the emerging economies, the paradigm-changing leap-
frog stage appears to be the best form of leapfrogging developing countries can
attain. However, the accomplishment of this phase does not necessarily imply
the redevelopment of the know-how itself. Instead, it could involve the implement-
ation and use of expertise in a way to combine other matching technological capa-
bilities. At the same time, it could suggest that the utilization of the technology can
be associated with gains resulting from the ability to have smooth downstream integration capacities, which could not be feasible with the older infrastructure commonly found in advanced countries [13] [14]. For instance, TT stations could be made with amenities that can permit public battery charging stations. In his address, James [4] deliberated the leap from fixed-line to mobile phones. He came up with a ratio focused model to evaluate the idea and the effect of leapfrogging to mobile phones in developing countries [4].

Africa is recognized as the most prominent case of how the adoption of mobile phones eliminated the need to create resource-intensive fixed-line phone substructures [15]. However, a thorough assessment of the infiltration of the mobile phone in Africa showed that the region still lags [3]. Nonetheless, a comparative study of the proportion of measure between the numbers of mobile phones to fixed-line set-up demonstrated that Africa was able to leapfrog by adopting mobile phones as their means of communication [15]. Another notable example of technological leapfrogging is when Papua New Guinea transitioned from telecommunications systems to satellite-based communications in one leap [16].

Azerbaijan, a developing country in Asia, is also known to have reached a higher level of ICT connectivity in a short space of time [17]. In a bid to explain the transition taken by Azerbaijan to leapfrog technological, Tan, Ng [7] came up with the “Four Ps Framework Model” while tracing the Asian’s nation path of the ICT growth. The model helps to understand the phases executed by the Azerbaijan government to pass its industrial leapfrogging within its ICT sector fruitfully. Unlike the model created by Lee and Lim [12], which is inadequate when it comes to general applicability due to its originality sensitivity effects, the “Four Ps Framework Model” is practical and scientifically appropriate for different jurisdictions. In other words, it can be applied universally. Different governments and policymakers in various jurisdictions can utilize the framework to create and adopt their prospective technical leapfrogging schemes. Below is the “Four Ps Framework Model” of technological leapfrogging developed by Tan, Ng [7]:

- Stage 1: Psyching;
- Stage 2: Planting;
- Stage 3: Propelling;
- Stage 4: Perpetuating.

Stage 1, according to Tan, Ng [7], mostly involved building publicity around the project and designing the plan. In Stage 2, the project stakeholders established the resources that need to be used to make the project a success [17]. This stage entailed understanding the existing capabilities. During the process, decisions on whether to procure new resources or adopt the “bricolage” strategy were made [17]. Bricolage can be less expensive and usually the only alternative for countries that have few resources. According to Tan, Ng [7], the real ICT Development was implemented during stage 3. In other words, stage 3 mainly
entailed launching the project through the development of the ICT infrastructure [17]. Finally, as previously discussed, leapfrogging is not merely a single incident but a continuous process. Therefore, during the perpetuating stage, there was an emphasis on maintaining the path of ICT development [17]. For Azerbaijan’s ICT development project, the buy-in attitude and commitment to supporting the plan were influenced by the sharing of the quick wins and benefits among the stakeholders [7]. Also, it is essential to understand that technological leapfrogging in Azerbaijan, mainly the ICT Development project was directed by sound and policy-driven tactics, which were endorsed by the ruling government [17]. As such, it was handled as a national scheme and supported by several governmental organizations. Besides, the vision and the project’s outcomes were well articulated and made public for all stakeholders to understand [17].

Lee and Lim [12], on the contrary, studied Korean industries to document how they have managed to leapfrog using modern tools by developing a framework of technological and market catching-up. However, as mentioned above, Lee and Lim’s model is inadequate when it comes to its universal applicability due to its originality effects of sensitivity. As such, it cannot be applied outside the Korean context with ease. Nevertheless, their findings about the Korean industries, reveal that “path following” was mostly seen in private initiatives within the various sectors [12]. On the other hand “path-creating” was mainly witnessed when a public-private partnership in the adoption of technology was involved, and when it was resource-intensive and riskier initiative [12]. These findings are thought-provoking when it comes to the deliberation of the adoption of Trackless Trams, as they will probably be realized through a public-private partnership and require some significant capital investment.

3. What Are the Key Requirements for Enabling Leapfrog Technology?

3.1. Capability and Capacity

No doubt, leapfrogging is an appealing concept for developing countries. However, studies reveal that one of the main hindrances to implementing the concept is the lack of capability to produce such technologies in these emerging economies [18]. The developed countries contribute to the development of most of these technologies [3]. The challenge is that developing countries have to procure these technologies from advanced nations through arrangements that prohibit them from developing the ability to produce the technology [19]. The leaping concept can only be sustained if a country possesses the expertise to create and manage the related technology [18]. Gallagher [20] alludes that “there is a danger that selecting technology on or very near the frontier” can be damaging if a country fails to continue with the expansion of knowledge base. Besides, some scholars emphasize the necessity of balancing the two, so goes the saying “In order to leapfrog, you have to be a frog, not a tadpole” [21]. The general implication here is that to get the technology right, there is a need to have people with
the essential set of skills and abilities to run and manage the technology, an argument that highlights the importance of training.

3.2. Government Policy

The other impediment to leapfrogging technology, according to some scholars, is the reluctance of governments to come up with policies that endorse better techniques [14]. The unwillingness is usually driven by the perception that superior technologies could harm local businesses. Government policy is essential for enhancing the ability to facilitate and support technological leapfrogging [18]. The case of Azerbaijan reinforces the necessity of government policy. A supportive environment that is buoyed by the regulatory setting is essential for such initiatives to be successful. Malaysian “Multimedia Super Corrido” project that is aimed at catapulting the country into the group of advanced economies is also an ideal case of the importance of government influence [8]. In other words, leapfrogging technology is not just a motivating conceptual occurrence, as it only works if it is executed as part of a more critical strategy, which is designed and reinforced by various policymakers [14]. The Chinese automobile industry is another example that highlights the need of creating policies that can overcome the barriers to progress.

3.3. Cargo Cult

Cargo cult mindset is another leapfrogging challenge that needs to be addressed. Cargo cult mentality is the belief that the gains observed from the utilization of a know-how or technology by developed countries will be realized by simply adopting the same know-how or technology in a given different context or domain. It is vital to look at the real facts because the context might not be the same with where the technology was used successfully. In some cases, the social context of technology has been underemphasized, despite being crucial in making the adoption successful. In most cases, it is the social settings that determines the recognition and successful implementation of the technology. As such, it highlights the importance of planning and policies in increasing the likelihood of success. Azerbaijan and its ICT Development project stand out as an ideal example in this case. Planning and conducting an assessment of a fitting technology by taking into account the cultural and socio-economic settings and universal standard for interoperability is critical in avoiding costly errors and failure [16].

3.4. Stakeholder Engagement

Lack of stakeholder engagement is also considered a challenge to leapfrogging technology. In most cases, the success of specific leapfrogging projects has been attributed to the ability to have all stakeholders on board [3]. For instance, the importance of including the stakeholders at the start of the initiative is also evidently demonstrated in the Azerbaijan ICT Development technological leapfrog
project. The initiative had a vibrant vision and implementation plan. According to Tan, Ng [7], it was a continuous event that needed resources, including numerous stakeholders’ input, to sustain its momentum.

3.5. Funding

There is no doubt that to get leapfrogging projects off the ground, capital investment is required. However, it is evident that inadequate financial resources, more so in developing countries, is a problem that could hinder any plan, despite how ambitious it is [22]. Furthermore, even though aid could help in eliminating the challenge, there is a consensus that relying on aid agencies too much could be risky. According to the secretary of the International Telecommunication Union (ITU), aid agencies can only be helpful if they act as intermediaries that bring together private sector players, network operators, and governments (ITU). The private sector can provide the needed capital for such projects [23].

4. What Is a Trackless Trams System (TTS)?

According to Newman, Hargroves [24] TTS can be categorized as light rail. The main difference is that TTS run on rubber tyres. TTS can offer a rapid transit transfer service that is provided by the light rail systems [25].

Physical Attributes of Trackless Trams. Trackless trams use an electric drive system that is power-driven by battery technology [24]. Such an attribute eliminates the need to use overhead electrical cables or using non-renewable fuel [26]. Using rubber tyres instead of steel rails is also another feature of trackless trams technology that makes it have an advantage over the light rail [24]. For instance, the rubber tyres eliminate the massive cost and the disruption associated with building steel rails. Furthermore, trackless trams possess the same ability obtainable by light rail, which offers stabilization technologies through train-type bogeys with low set axles and hydraulic systems intended to avoid sways and bounce [24]. Lastly, trackless trams utilize up-to-date self-directed driverless technology using the ultra-modern optical guidance system that enables the tram to offer smoother trips and accurate docking at various locations [24].

The trackless tram use dedicated passages, an aspect that enables it to offer rapid transit and supports self-directed driverless technology [27]. Having this capability gives TT an advantage when it comes to future city planning because it means they have the potential to be used for city modeling and redevelopment purposes. Fixed stations and control centers will be constructed within the dedicated corridors to monitor and direct the movement of the trams. The control centers that will be used to monitor the trams are similar to the ones used to run the light rail systems. Additionally, the autonomous system can be overridden to enable one to operate the trams manually. This ability means that they could be driven around obstructions or obstacles in a scenario where it needs to pass through construction and accident sites. Table 1 summarises the main physical design of a three-carriage trackless tram.
Table 1. Vehicle Specifications for a 3-Module Trackless Tram.

| Specification                  | Value                        |
|-------------------------------|------------------------------|
| Length                        | 31.6 m                       |
| Weight                        | 2.65 m                       |
| Weight (loaded)               | 51 tonnes (average 9 tonnes per axle) |
| Capacity                      | 250 - 300 people             |
| Max speed                     | 70 km/hr                     |
| Gradient                      | 13%                          |
| Turning Radius                | 15 m                         |
| Design Life                   | Over 30 years                |
| Power supply                  | Rechargeable electric batteries |
| Operation                     | Automatic/manual             |
| Car body construction         | Space frame with bolted-on panels |
| Wheels driven                 | Rubber wheel                 |
| Bogies                        | Multi-axle steering system   |

Source: [24].

4.1. Rubber Tyres

The most significant task associated with adopting a light rail system is the need to construct steel rail [24]. This requirement is primarily considered a challenge because it is costly and disruptive to the environment and local community. On the contrary, a trackless tram runs on rubber wheels on the road, a feature that offers an opportunity to circumvent disruptive and capital-intensive construction works associated with building steel rail substructure required by the light rail trains [24].

4.2. Self-Guiding

The latest guided routing technology utilized by trackless trams is also a feature that makes the technology unique. In particular, the technology enables TT to pass along “virtual rails”, an ability that is also aided by up-to-date satellite navigation technology and the differential global positioning system (DGPS) [24]. At the same time, there is also a detection system that boosts the vehicle capability to distinguish road signs, and any intrusion that may be encountered. Finally, to aid the self-guidance ability, lines are marked on the road to offer optical control needed for virtual rails and enhance other road users’ visibility [24].

4.3. Electrification and Energy Storage

The vehicles utilize electric energy that is powered by lithium-ion phosphate batteries. The batteries used to power the TT can be recharged at a 10 kV platform-style overhead charging stations during regular operation [24]. The 600 kW-Hr onboard batteries recharge faster compared to most cells [24]. However, recharging can be done at the depot overnight. CRRC Corporation, manu-
facturer of the TT systems, projects that their next third-generation trams will be able to provide enough energy to cover a distance of approximately 15 to 25 km using a 10-minute charge [24]. Interestingly, it is estimated that with a 10-minute charge, the fourth generation trackless trams can offer a prolonged 50 to 60 km of travel [24]. The highly projected move away from the consumption of fossil fuels makes the incorporation of Trackless Trams a suitable choice since it utilizes renewable energy. The exploitation of sustainable energy sources, as well as the electrical drive system, offers a smooth trip, which surpasses the ride-experience attained from fuel-based combustion engine automobile.

4.4. Cost Efficiency

The budget associated with building a light rail system is relatively higher in comparison to the investment in a Trackless tram system [25]. Specifically, a survey conducted by Bodhi Alliance and EDAB in 2017 reveals that constructing a Trackless Tram will be threefold cheaper as opposed to adopting a light rail system [25]. The significant differences in capital costs are associated with the fact that light rails are usually erected in high-density areas that have buried pipes and wires, which complicate the entire construction process [24]. As such, the cables and pipes have to be dug up and relocated, increasing the associated costs. Such complications and high costs were witnessed in the building of The Sydney Light rail. It is estimated that the system costed approximately 130 million US dollars per km, a figure that is tenfold more than the expenditure on a trackless tram [24].

4.5. Interoperability

Trackless trams can be interconnected with heavy point mass rapid transportation stations considering their capacity to be utilized for the “first and last-mile service” [25]. For instance, the trackless trams can be linked to the central bus depots or massive rail stations [24]. In essence, it would mean that the trackless trams could transport passengers from the fringe of the central business district (CBD) to the inner parts of the city, thereby decreasing the number of small vehicles or buses flooding the CBD areas [25]. Similarly, the trackless trams can ferry passengers from the CBD to the major rail stations or bus stops.

Considering all the factors discussed above, it is seemingly apparent that this advanced technology has the ability and potential to offer the highest quality ride that one can experience from the light rail and bus rapid transit systems. The trackless trams can provide smooth rides and versatility, which is similar to what is experienced in light rail vehicles and buses, respectively. Furthermore, the cost associated with adopting the trackless trams is considerably lower, making it an attractive option. Using the trackless trams as the first and last-mile service could decrease the number of buses and small cars entering highly populated areas such as the CBDs.
5. How Does TT Apply to Leapfrog Technology Requirements?

5.1. The Socio-Economic Impact of the Trackless Trams—Do They Measure up as a Leapfrog Technology?

If strategically adopted, trackless trams have the potential to restructure the city and boost the revival of urban areas along identified passages. The following benefits could be realized if trackless trams are implemented.

5.1.1. Sprawl Relief
High urban density levels are associated with many benefits, such as economic growth [28]. Strategic and practical adoption of trackless trams along transit corridors will increase urban density on those passages, consequently minimizing the impending urban sprawling. For example, Perth, a city with more than 2 million people that have sprawled along its coastal beaches, could benefit from transit trams [24] [29].

5.1.2. Congestion Relief
Traffic congestion is one of the leading transport problems experienced both in the developing and developed countries [30]. Traffic congestion is a matter that is perceived as a challenge by transport and city planners [30]. It is projected that developed countries lose billions of dollars as a result of road traffic congestion, as valuable time is lost in a traffic jam. For instance, it was estimated that the cost of congestion in the US was roughly $121 billion in 2012 [24]. The figure is equivalent to $818 per commuter every year [24]. Moreover, according to [24], an additional 25 million tonnes of greenhouse gases are emitted annually due to traffic congestion. Furthermore, inhalation of vehicle fumes for long periods is associated with adverse health outcomes. For instance, according to Newman, Hargroves [24], health problems, such as brain cell damage, is linked to inhalation of car fumes for extended periods. Strategic and practical adoption of trackless trams can considerably minimize the number of vehicles in the road, thereby reducing the emission of harmful gases.

5.1.3. Reclaim Car Parking
Most cities, more so those that are highly dependent on the automobile, have allocated vast portions of land to car parks. According to Newman, Hargroves [24], urban areas that are dependent on vehicles around the globe usually allocate between 5 and 8 parking spaces for every single vehicle in the city. These pieces of land can be redeveloped for productive and profitable use. There is no doubt that trackless trams can be a valuable addition to the reclaimed sites. Trackless trams can be integrated into the redevelopment programs to create value through Transit-Oriented Development Scheme [24].

5.1.4. Job Creation
Studies reveal that a high level of urban density is positively associated with an improved level of the knowledge-base [24]. Companies, conversely, tend to follow the human resource factor of production. Therefore, there is no doubt that a
high urban density index level would lead to additional opportunities for work creation and increase employment levels. As stated by Newman, Hargroves [24], the proximity of companies and commercial centers within compact urban areas increases the possibility of direct interaction of knowledge-based economy workers. As a result, it facilitates the flow of information and expertise in any modern city, an aspect supported by numerous business literature. For instance, studies have revealed that an increase in a country’s level of density index was associated with the improvement of state-level productivity [24] [31].

5.2. Impact of Trackless Trams on the Environment—Do They Measure up as a Technology that Promotes SDGs?

As mentioned above, the technology associated with trackless trams will considerably reduce the emission of harmful gases [27]. Therefore, trackless trams should bring some social and environmental benefits. Adoption of trackless trams would lead to a decrease in cars on roads, thus minimizing the amount of CO₂ emissions [24]. Furthermore, as the urban density surges, the proportion of energy use per person lessens, resulting in a smaller amount of CO₂ emissions. Moreover, the adoption of trackless trams could potentially restore the down-trodden corridors, consequently discouraging urban sprawling and saving agricultural land on the borders of the city [24].

Based on the above discussion, there is no doubt that trackless trams have the potential to aid emerging cities to technological leapfrog while also contributing to the realization of SDGs. The low capital cost associated with trackless trams means that developing countries also have a chance to provide a modern infrastructure network that will increase their cities’ ability to grow sustainably. As outlined by Newman, Hargroves [24], the technology is viable enough to encourage partnerships and attract private investors who seek a stable return on their investment. Table 2 below summaries all the qualities and traits that make the TTS an ideal leapfrog technology.

**Table 2. Summary of the TTS’ leapfrog capabilities.**

| Leapfrog Technology Requirements | Application to Trackless Tram Systems | Comments |
|----------------------------------|--------------------------------------|----------|
| 1) Economical enough             | ✔️ ✔️                                 | Very cheap mass transit, not as cheap as separate buses or jitneys. See also 3. |
| 2) Less Technical                | ✔️                                   | Requires some smart systems but only enough for mobile phone telephony. |
| 3) Lends itself to Partnership    | ✔️ ✔️ ✔️                              | Ideal for working with developers who can help finance it through urban centres at stations. |
| 4) Lends itself to Community Engagement | ✔️ ✔️ ✔️                         | Communities are very keen for better transit. |
| 5) Allows Co-development         | ✔️ ✔️ ✔️                              | Many overlaps with economic development as it creates agglomeration economies. |
| 6) Fulfils Sustainable Development Goals | ✔️ ✔️ ✔️                       | Very strong on all SDG’s due to equity, health and environmental improvements. |
6. Conclusions

There is an expectation that a successful technological leapfrog will facilitate the adoption of a progressive socio-technical regime that will lead to socio-economic development. The discussion included the techno-physical and socio-economic attributes of the trackless trams technology. Based on the analysis of physical features that make a technology to be considered to have the abilities to enable leapfrogging, the paper concludes that the trackless tram system certainly meets those requirements. One of the main looked-for attributes of a technology needed to augment leapfrogging discussed in the article is the ease of implementation and deployment. TTS can be easily deployed and integrated into other systems within society. Acquiring and utilizing TTS for commercial purposes is less challenging. As mentioned above, a three carriage trackless tram system can considerably minimize the current problem of having numerous cars on the road. At the same time, a TTS has the interoperability and matching technological proficiencies and utilization. They can be adopted as the first and last mile service technology to move passengers back and forth between the massive transport stations and the CBD.

The paper has also examined the social and economic benefits associated with trackless trams. Developing countries are struggling to build the infrastructure needed for driving economic growth and development. From the discussion above, TTS can improve and create social and economic benefits. For instance, the technology can help minimize urban sprawl and increase urban density levels. Studies have revealed that there is a correlation between population density index levels and the knowledge-based economy. For example, higher density index levels encourage the flow of knowledge and expertise. At the same time, traffic congestion can significantly be reduced if TTS is effectively and strategically adopted. The paper has also deliberated on the possibility of financial gain should the vast parking land be reclaimed and be put into commercial use.

Finally, leapfrogging technology has its challenges. Certain factors might make its implementation difficult. The paper has outlined some of the expected barriers to this idea. The impediments identified include lack of capability and capacity, government policy, cargo cult, and lack of stakeholder engagement and funding. The paper has deliberated on the need for developing strategies and plans that support technological leapfrog initiatives. As previously discussed, Azerbaijan is an ideal case of how government involvement is key to the success of such projects. There should be a need to promote a favorable environment that facilitates the adoption of such inventions to encourage investment from the private sector. The adoption of trackless trams technology is mostly feasible if delivered using an entrepreneurial approach and includes the private sector and essential all stakeholders from onset. In brief, the paper has also identified some benefits that can be realized if the trackless tram system is adopted, and demonstrated that the technology has most of the needed attributes to augment technological leapfrogging in transport.
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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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