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Reevaluating the 'China Model': The Carbon Emission Burden of China's Infrastructure Overinvestment

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KEY TAKEAWAYS

- In the last decades, China has heavily invested in road, rail, subway, and airport infrastructure and stimulated its economy through infrastructure investment. However, this has increasingly been overshadowed by concerns about the deepening debt spiral and numerous negative economic, socio-economic, and ecological impacts.

- Ecological aspects have received little attention and primarily involve large emissions during the procurement of materials, construction, operation, and demolition of infrastructure. Recent studies show that certain types of infrastructure in China have a larger ecological footprint compared to similar projects in other countries. What is more, infrastructure expansion without sufficient demand leads to underutilization, resulting in wasted resources and unnecessary destruction of the natural environment.

- Especially in the context of the EU's Global Gateway initiative, China's infrastructure overcapacity serves as a cautionary example for EU policy, illustrating the risks of extensive infrastructure spending. It also highlights significant environmental impacts, particularly the massive generation of CO2 emissions, which should be a key point of emphasis in discussions with countries in the Global South, ultimately calling into question China's credibility as a leader in climate and environmental issues.

Keywords

China's debt-economy model

Local debt

Chinese infrastructure investment

Carbon Emissions

Global Gateway

Introduction

In recent years, China has heavily invested in various types of infrastructure, including roads, railways, subways, and airports. While infrastructure development is initially *necessary for development* and crucial for a country's economic growth, in China, misaligned incentives have driven local governments to overinvest in infrastructure, leading to significant overcapacity and substantial socio-ecological consequences. Despite infrastructure construction being inherently linked to large-scale emissions, and overcapacity resulting in a waste of resources and unnecessary environmental degradation, China's model of excessive infrastructure investment has often been *praised globally* as *fast, flexible and effective*. However, *concerns in terms of size and impact* have been raised, too.

One trigger for the excessive investment in domestic infrastructure was the *1994 tax reform*, which aimed to centralize tax collection and allocation to address central government deficits. This *created pressure* on municipal administrations, which retained responsibility for public goods and raised funds through land leasing or sales of land use rights to offset the tax revenue shortfall. [1] Hence, municipal administrations were incentivized to increase land value through infrastructure and real estate development, with *Local Government Financing Vehicles (LGFV)* [2] proving to be a pragmatic solution for financing these projects. Thus, the practice of debt-driven infrastructure investment emerged: Beginning with the response to the 2008 global financial crisis, *three rounds of monetary expansion* in 2008, 2015, and 2020 fueled extensive infrastructure investments. These investments eventually led to soaring LGFV debts, overcapacity in real estate, and rising social tensions. Efforts to reduce local debt have failed, leaving China heavily indebted and economically vulnerable. By the end of 2022, outstanding interest-bearing LGFV debts *totaled 54 trillion yuan* (approximately 7 trillion euros), accounting for about 44.6% of the national GDP. Moreover, overcapacity in the construction sector, particularly in *steel and cement*, has been *transferred abroad* in recent years through the *Belt and Road Initiative (BRI)*, as reducing it domestically too quickly would risk causing significant disruptions to China's economy.

So far, China's extensive infrastructure investments through LGFVs have primarily been studied from an economic perspective, while environmental consequences of excessive and unnecessary infrastructure expansion have not received enough attention. Given that Chinese infrastructure projects are often more emissions-intensive than their counterparts abroad and that construction without demand has led to underutilized infrastructure, the environmental implications including wasted resources and unnecessary environmental destruction must be taken into account when evaluating China's debt-economy model and infrastructure investment.

In fact, China's infrastructure overcapacity serves as a cautionary lesson for EU policy, highlighting the risks of large-scale infrastructure spending without thorough economic planning and long-term demand. The EU should highlight the significant negative environmental impacts in international climate discussions and the exchange with the Global South, which *has praised* China's *infrastructure investments*; furthermore these lessons should be incorporated into the planning of the *Global Gateway initiative.* [3] Ultimately, the case also reinforces the view that China's role as a *climate and environmental leader* is rather questionable.

Emissions, ecosystem destruction and contamination related to infrastructure construction

Research thus far indicates that infrastructure projects exhibit diverse environmental impacts across their *life cycle phases*, including construction, utilization, maintenance and refurbishment, and demolition. While the emission burden arising from resource extraction, energy provision, component manufacturing, transportation services, as well as product use and disposal, can be *effectively quantified*, numerous other environmental impacts may be less obvious at first glance or more challenging to measure or quantify. These include the destruction of ecosystems and land, both where the infrastructure is built and where resources are extracted for construction (such as sand and gravel from riverbeds, steel, coal from mountains where they are mined, etc., as well as metals, etc., from natural areas). Contamination of the environment (air, water, soil, light, noise) during construction and operation of the infrastructure also represents a significant *environmental impact* of infrastructure projects. Additionally, heavy infrastructure construction, such as airports and groundwater extraction, has caused *gradual soil sinking*, harming ecosystems and increasing flood risks, especially in coastal and river regions already threatened by rising sea levels.

Yet, aside from infrastructure expansion itself being an environmentally harmful way to stimulate the economy, there are two additional factors that are crucial to the environmental impact of China's debt-driven infrastructure investments: Firstly, depending on the material choice, project management and energy consumption, infrastructure construction in China is often *more emissions-intensive* than in other countries; and secondly, inefficient or inadequate project management led to construction without demand and standstills due to excessive debt. Underutilized or stalled infrastructure projects, as well as those that do not function optimally, can have negative ecological impacts. Each infrastructure project has a *finite lifespan*, and for public transport systems like railways and metro, the goal is to offset construction emissions to achieve a net reduction in *per capita emissions* for passenger transport. Poor project management or financial oversight can delay projects, reducing their effective lifespan and thus diminishing the emissions advantage. For example, China's local debt and liquidity crisis has resulted in some completed infrastructure projects *being halted*.

Why Chinese infrastructure construction is often more emissions-intensive than in other countries

A study comparing the lifecycle emissions of two road projects– the Chinese Qinling Road project and the American Route 35 in New Jersey – found that the Chinese road project emitted 41.5 kg/m² more CO2, primarily due to the use of lime-fly ash in its subbase, a material far more emissions-intensive than the hot-mix asphalt (HMA) used in Route 35. Lime-fly ash accounted for 26.86% of Qinling's total emissions, whereas Route 35's material choice resulted in lower CO2 output. Additionally, machinery used in Qinling had significantly longer work times, particularly for earthwork and transportation, further increasing emissions—earthwork alone took 11.48 times longer than in Route 35. Reducing emissions in such projects could involve improved lime and cement production technologies, alternative materials like cement-stabilized gravel, and cleaner energy sources for machinery. Although Qinling's on-site material transportation was more efficient, its overall emissions from materials and construction were still much higher than those of Route 35. Despite experts suggesting the use of more eco-friendly materials in construction, a shift remains unlikely. China is the world's largest cement producer, and the cement industry is deeply integrated into both *the domestic economy* and international projects like the *Belt and Road Initiative (BRI)*. As a result, China's cement expansion through the BRI reinforces the industry's central role, making significant change difficult.

In terms of urban railway, *a comparative study* analyzed the Shanghai metro system alongside other global metro systems. While traction emissions per person in China were relatively low, emissions per vehicle were relatively high when compared to systems in Delhi, San Diego, Los Angeles, San Francisco, Sacramento, and Rome. Additionally, the study highlighted that Shanghai's metro stations exhibit high emissions during operation, compared to the Seoul metro system, suggesting significant energy-saving opportunities. Despite Shanghai's newly constructed urban and high-speed rail transit stations featuring energy-intensive facilities and ornate designs, the city's emissions per passenger remained lower than those in Seoul, possibly attributed to higher travel demand in Shanghai.

An additional study proposed that optimized spatial planning for the distribution of subway lines and stations, as evidenced by the spatial analysis of Chinese subway networks, can effectively minimize material and energy consumption across all lifecycle stages, including construction, operation, and waste management.

In the category of High-Speed Railway Infrastructure, a study from 2019 analyzed the carbon footprint of the Beijing-Shanghai Fast Track Transportation Project compared to other High-Speed-Rail Projects in Asia and Europe.

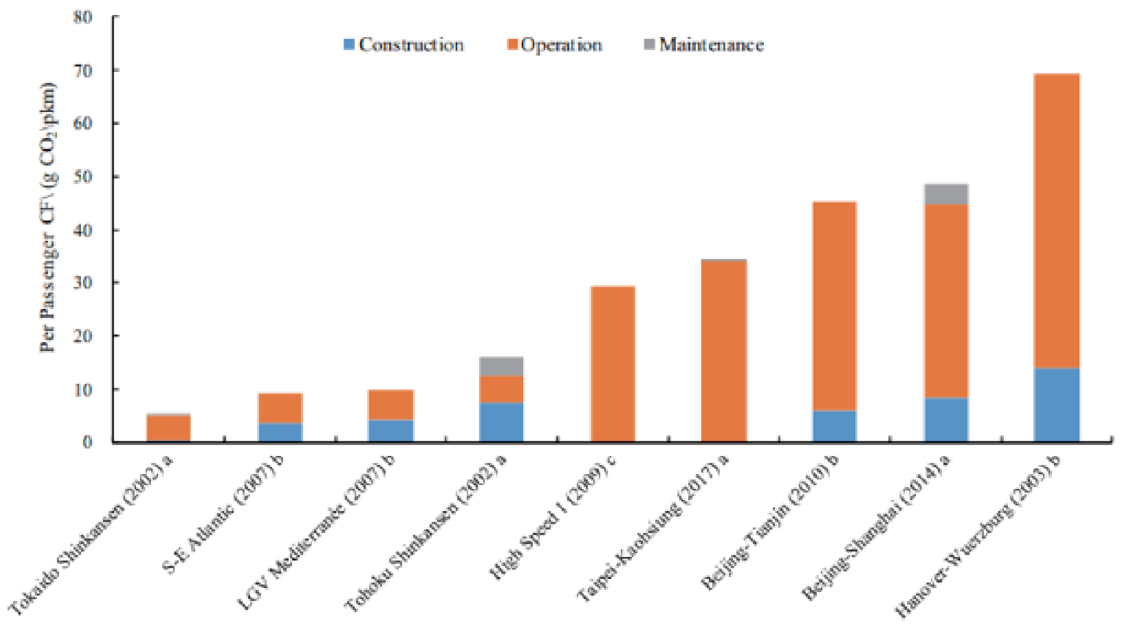


Figure 8 Comparison of the per-passenger carbon footprints of the different HSRs. *Note: (a) which carbon footprint included Construction, Operation and Maintenance; (b) which carbon footprint included Construction and Operation; (c) which carbon footprint included Operation.*

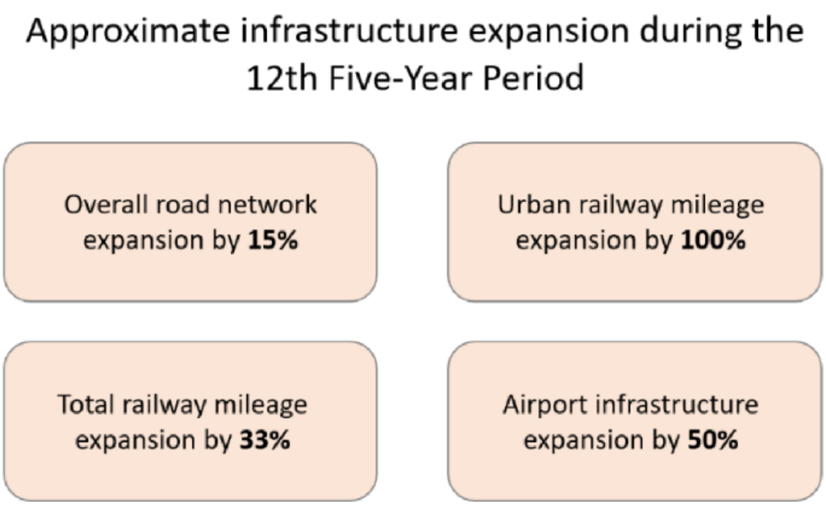
Source: Lin, Jianyi, Huimei Li, Wei Huang, Wangtu Xu, and Shihui Cheng. 2019. "A Carbon Footprint of High Speed Railways in China: A Case Study of the Beijing Shanghai Line." J of Industrial Ecology 23 (4): 869–78. https://doi.org/10.1111/jiec.12824.

The results indicated that the Chinese high-speed rail (HSR) infrastructure was relatively emissions-intensive, second only to Germany's Hanover-Wuerzburg HSR line, which had higher per capita carbon emissions during both construction and operation due to lower passenger turnover and more spacious seating. [4] In contrast, the high emissions of China's HSR lines were not linked to seating or passenger turnover but were driven by the country's reliance on a coal-based, carbon-intensive energy mix, as well as a higher proportion of bridges, faster operating speeds, and heavier train bodies. In order to reduce carbon emissions in construction and operation the study suggested to work on cleaner electricity supply options, more efficient raw material production, and enhancements to train technology are crucial for reducing the carbon footprint of Chinese high-speed railways.

For airports, the lack of scientific studies on total carbon emissions throughout an airport's life cycle, especially for Chinese airports, makes it impossible to draw conclusions about the emission intensity of Chinese versus other airport projects. However, it is important to note that aviation, including the construction of airports is more emission-intensive than any other infrastructure transport mode: *A study from 2021* calculated the carbon emissions of the landing and take-off from China's airports with the highest annual passenger throughputs. Results indicated that China's then busiest airport (in terms of annual passenger throughput), Beijing Capital International Airport, emitted approximately *828,048.88 tons of CO2* annually solely from landing and take-off activities. When accounting for emissions from power station operations and various support vehicles owned by the airport, the total CO2 emissions reached *2,897,484.52 tons*. This is nearly three times the annual operational emissions of the *Shanghai metro system* and roughly equivalent to the annual operational emissions of the *Beijing-Shanghai High Speed Railway line*. However, the emissions for the above-mentioned airport do not include the total emissions during the flight but only those emitted during start and landing. Therefore, airports remain the most environmentally harmful infrastructure type, making it essential to carefully consider whether their construction is truly necessary. Against this backdrop, it is particularly problematic that China constructed a large number of *new airports* in the last decade, many of which *remained underutilized*.

The dimensions of Chinese infrastructure overcapacity

During the 12th Five-Year Plan Period from 2011 to 2015, large quantities of infrastructure were developed, leading to substantial infrastructure overcapacity.



Source: Own calculations based on literature analyses.

China's overall road network was set to expand from around *4 million km in 2010* by about 15%, reaching approximately *4.5 million km in 2015*. Expressways were set to grow by over 60% from *74,000 km in 2010* to *108,000 km in 2015*, which is almost *twice the length* of the U.S. Interstate Highway System. *Urban railway mileage doubled*, rising from around 1,500 km in 2010 to around 3600 km in 2015. *Total railway mileage* expanded by about one third, increasing from 90,000 km in 2010 to 120,000 km in 2015, of which 45,000 kilometers were *fast railroads*. Finally, airport infrastructure was set to expand by almost 50% by building *82 new airports by 2015*. However, overcapacity and underutilization remain significant issues in China's infrastructure. By 2011, 70% of airports were *operating at a loss*, and between 2010 and 2015, the average occupancy rate of China's high-speed rail was only *around 60%*.

Although urban railways experienced the highest percentage of expansion, it was the investment plans for airport infrastructure that sparked the most debate in China. *Experts throughout China* were already *cautioning against the need* for such expansion. They argued that '*China does not need any new airports*' citing environmental and economic concerns. Instead, they advocated for directing resources towards integrating existing transportation networks. Furthermore, they pointed out that many Chinese airports *were underutilized*, and constructing new ones was unsustainable. The majority of these new airports would primarily serve passengers from remote Chinese cities, shuttling them to hubs connecting to major destinations. However, with Chinese airlines compelled to lower prices to compete with the rapidly expanding high-speed railway network, the solution lies not in more airports, but in better-developed transportation networks, so argued experts. Existing airports would already be *struggling to compete*, with some coastal cities even *encouraging government officials* to fly rather than travel by train for business trips in a bid to boost local airport usage.

The push for extensive new airport construction investment was driven mainly by *two factors*. Firstly, the Civil Aviation Administration of China (CAAC), tasked with expanding China's airport network, felt mounting pressure to catch up with the aviation infrastructure of larger Western nations like the US or Brazil. However, this pressure was based on an overestimation of the size of the US aviation network when comparing the number of commercial airports in China to flight facilities in other countries. In reality, by 2011, China *had almost caught up* with the US in terms of large airports. Moreover, comparing China and the US directly was inaccurate, given the less developed passenger railway network in the US. With the rapid expansion of railways in the 2000s and 2010s, Chinese airports were already experiencing overcapacity. Furthermore, US airports were also *facing financial challenges* and running deficits.

Secondly, aside from the miscalculations by the CAAC, there was another reason for the promotion of extensive airport infrastructure expansion despite lacking demand: the responsibility of local governments to initiate airport projects. Unlike railway projects initiated by the central Ministry of Railways, airport projects were driven by local governments incentivized under the debt-driven economic model to increase land value through infrastructure and real estate development. Thus, local governments were incentivized to introduce and build new airport projects, even when there was not sufficient demand for the airport. Additionally, China's system of cadre rotation and bureaucratic promotion plays a significant role, as the officials who initiate airport construction are typically not the ones for *repaying the debts* or overseeing the airport's long-term development. Instead, these officials are usually incentivized during their 3 to 5-year tenure to promote policies that bring them *short-term economic and political success*. And not only did individual officials face performance pressure, but entire local governments were also competing with one another for the highest economic growth. This competition often led to *local protectionism*, as governments prioritized maximizing economic benefits within their own regions.

This large-scale creation of overcapacity aimed at stimulating the local economy, however, came with significant ecological consequences, including wasted resources and unnecessary environmental destruction during resource extraction and construction, as well as from the overcapacity and debt-related challenges. In some cases, infrastructure faced further setbacks due to local debt or liquidity crises, causing standstills. Since 2022, more than 20 cities have *experienced disruptions* in public transportation due to inadequate financial support.

In January 2024, the State Council *issued a directive* to manage China's $13 trillion municipal debt, instructing state-owned banks and 12 local governments to postpone or suspend projects with less than half of the planned investment utilized. This includes infrastructure projects like expressways and *urban rail* in high-risk regions. Among the *rejected subway projects* due to high local debt were those proposed for Harbin (Heilongjiang), Kunming (Yunnan), and Baotou (Inner Mongolia).

Lessons for the EU

China's debt-driven economic model has led to a significant increase in infrastructure investment and construction. However, infrastructure construction is associated with numerous ecological impacts, which necessitate a reevaluation of the infrastructure investment related parts of the "China model" from an environmental perspective. Recent comparative studies of global infrastructure projects reveal that material choices and inefficiencies, as well as the reliance on a coal-based energy mix during management and construction phases in China have led to increased CO2 emissions. Moreover, China's debt-driven economic model created incentives to launch projects without proper consideration of demand or essential economic factors such as profitability or the ability to repay debts. In some cases, this has led to the construction of unnecessary infrastructure, resulting in waste of natural resources and significant destruction of the environment. The increasing indebtedness of local governments has exacerbated the situation, as stalled or incomplete infrastructure projects contribute to further resource waste.

Therefore, the substantial environmental costs associated with China's infrastructure expansion under a debt-economy model, as well as the additional negative implications stemming from overcapacity and indebtedness, must be recognized as a serious issue.

Recommendations

When developing the Global Gateway Initiative, the EU should avoid copying China's infrastructure model, which often overlooks ecological impacts and supported construction without demand. Instead, it should focus on thorough planning and the use of eco-friendly materials and processes.

The EU should highlight the ecological impacts of extensive infrastructure development, particularly in discussions with the Global South, where China's initiatives are increasingly admired. Emphasizing the link between infrastructure expansion, CO2 emissions, and local social and environmental costs is essential in climate negotiations.

As China is increasingly positioned as a *leader in climate issues*, the EU should highlight the ecological impacts of China's infrastructure expansion model (domestically and abroad in the BRI context) in international climate negotiations to provide a more realistic understanding of China's environmental status.

[1] In China, there is no private ownership of land. Urban land belongs to the state, while rural areas are owned by collectives, subject to state expropriation.

[2] An LGFV describes a *financing mechanism* of local governments, typically appearing in the form of companies or investment firms, aimed at generating revenue for local governments through targeted investments in infrastructure projects. Unlike local governments, LGFVs can borrow directly from banks. Much of the LGFV bonds are not traded on the public market, making them implicit and opaque debts. As LGFVs act on behalf and in the interest of local governments, their debts can fundamentally be seen as implicit indebtedness of local municipalities.

[3] In response to China's Belt and Road Initiative, the EU launched the Global Gateway initiative in 2021, aiming to support developing countries and emerging economies by mobilizing investments in infrastructure.

[4] The number of seats on a train has a minor impact on total carbon emissions but plays a *significant role* in the per-passenger carbon footprint of high-speed rail. This factor is a key reason why the Hanover-Würzburg HSR line in Germany has the highest per-passenger CF. The German line had the fewest seats per train, roughly 30% of those on the Beijing-Tianjin line and 50% of the S-E Atlantic line. This highlights a trade-off between providing more comfort space and reducing carbon emissions.

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