Smart Transportation Alliance

Smart infrastructure investments: Changing from arch to node

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1. Introduction

Economic development is inextricably linked to the development of transportation infrastructures that foster mobility of both passengers and goods. Higher mobility increases competitiveness across the industrial and service sectors.

As developed nations continue to strengthen their economic competitiveness they have expanded investments. The focus has been mainly on road and railway infrastructure networks, but ports and airports have also been included to grow transportation infrastructures and, in turn, to promote trade.

The unlimited expansion of transportation infrastructures has been unable to solve all mobility problems and has even increased public debt or financial stresses. Additionally, environmental and land use issues associated with the linear growth model are a growing concern to society.

Continuing along with this legacy growth model does not seem to be an optimal solution. Therefore, it is essential to adopt a new expansion model based on network functionality where 'smart' infrastructures are able to improve node connections and to eliminate congestion points.

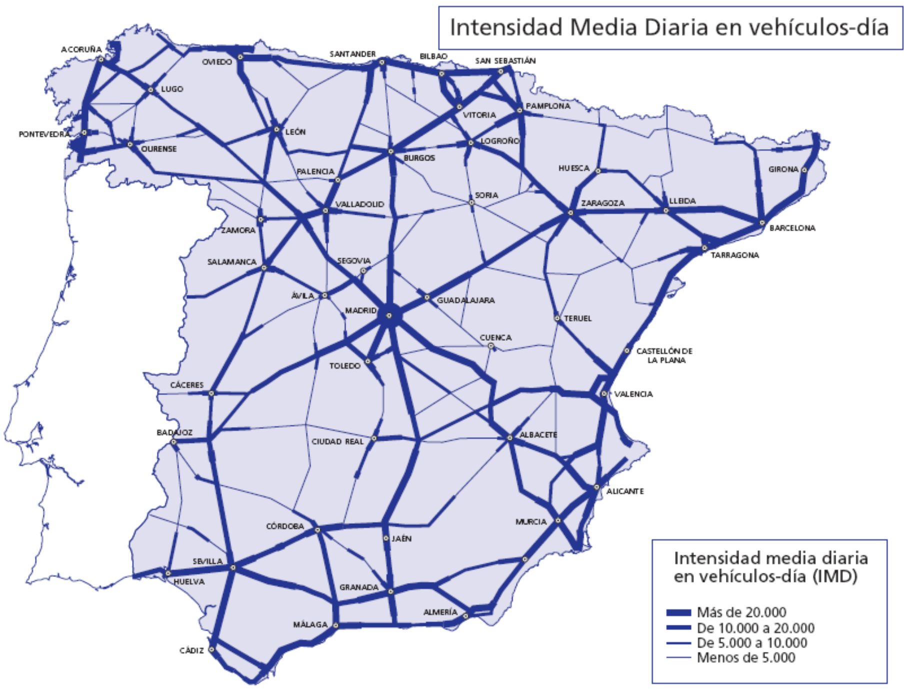

Figure 1: Congestion points in the Spanish road network. High Average Daily Traffic (ADT) intensity at specific points (Source: Spanish Ministry of Public Works)

2. 'Traditional' growth of infrastructures

There are several explanations for countries' development of linear transport networks to increase capacity and land use, including governments convinced that expanding transportation infrastructures improves mobility or political agendas based on striking a regional balance.

In the linear model, although initial investments are homogeneous across a country, economic concentrations caused by negligible modifications from external factors are unavoidable; for example, a new factory opening. Economic activity tends to concentrate in the areas where accessibility is high and transport costs are low.

While increased accessibility has a positive effect on economic growth, increased concentrations of economic activity cause heightened traffic intensity and a push for expansion of local infrastructure to maintain transportation efficiency. As a consequence, the inability for unlimited growth devolves into greater congestion and into diseconomies of scale that negatively affect industrial profits.

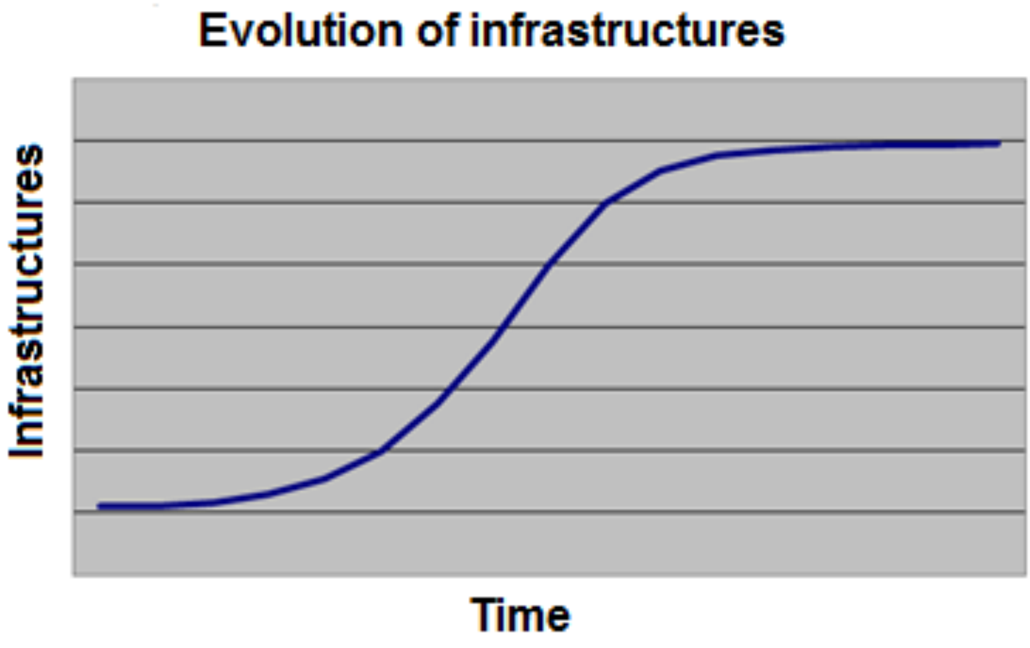

Figure 2: Asymptotic expansion of infrastructures

Higher concentration of economic activity at specific points in the transportation network implies vast potential areas of underuse in the system. Moreover, congestion causes negative social and environmental externalities such as noise, emissions or delays (mainly in public transport) that are unacceptable in a developed society.

As a result, it is the author's opinion that the traditional linear expansion infrastructure model does not offer a solution to the demand of a modern and evolving transport system.

3. Increasing underuse and congestion

As noted above, the main effect of adopting a linear expansion model is that, since infrastructures grow faster than traffic demands, the result is a low utility ratio and reduced profitability. Moreover, the concentration/congestion effect implies the existence of some unsolvable bottlenecks within this model.

Figure 3 illustrates a linear transportation infrastructure used to connect points A and B. The infrastructure is designed based on estimated traffic demand; that is to say, infrastructure capacity is calculated to absorb demand.

Over time, concentrations of economic activity will develop at key points producing excess demand (SD1), while potential supply for the rest of the network increases (SO1). Traditional models based on linear expansion respond by increasing the capacity of the infrastructure at these key points of excess demand (growth from t0 to t1). However, this response only worsens the problem (comparing SD2 to SD1) while under-usage continues to grow (the increases from SO1 to SO2).

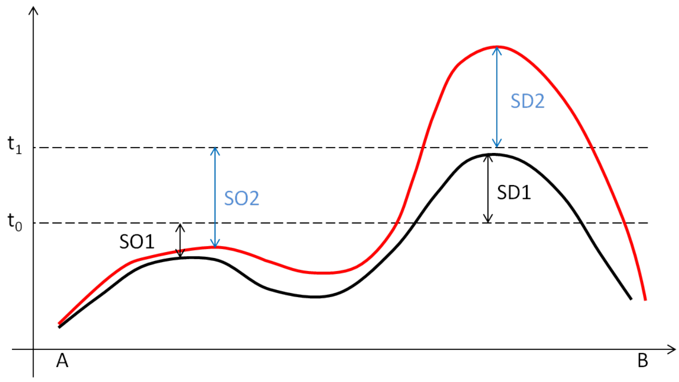

Figure 3: Consequences of linear infrastructure capacity increase

Inefficient use of infrastructure and congestion problems are not the only negative outcomes of such linear expansion. Continuous growth also means:

- Increased land use, leading to higher territorial fragmentation as well as serious social and environmental effects.
- Larger investment demands, both during construction and operation, leading to financial pressures and a permanent deterioration of existing infrastructure due to the lack of funding.

Although the solution to this problem is not easy, a focus on changing the model into a 'smart' one based on the overlap of independent networks at key pressure nodes would boost the co-modality of transport and network connection. In this way, node pressure can signal the need for transport network growth and will trigger innovative construction projects.

4. New expansion model

The linear expansion model was useful in the past because it was able to handle the demand for more and better infrastructures to improve mobility. However, demands have changed and expansion models must now not only solve mobility problems (underuse and congestion), but also adapt to new and diversified societal demands. As a result, infrastructure plans must address a greater set of questions:

- Greater societal purchasing power than in the second half of 20th century, with a focus on quality of life rather than on economic growth.
- A not in my backyard (NIMBY) society that will pushback against lifestyle changes it views as invasive.
- Vertiginous technological change led by information and communication technology (ICT).
- Growing environmental awareness that can take precedence over economic growth, development or employment.

Any new model of infrastructure expansion must solve mobility problems while also satisfying the demands of modern society; this can be achieved by focusing on the unique interconnection of overlapped networks by means of intermodal nodes.

These nodes occur most often in urban areas where land use is a key factor. Consequently, it will be necessary to build underground and over-road (bridges) connections that consider users as key variables in the planning and design stages, prioritising sustainability and quality of life over massive infrastructure growth.

Figure 4: A new expansion model. Transport interchange in Moncloa (Madrid)

5. Sustainability of smart investments

Environmental, economic and social sustainability are all relevant factors that must be considered within any model of infrastructure growth. These innovative construction projects have traditionally been considered as overambitious actions, where the cost versus benefit was questioned.

It is true that some past construction projects have generated controversy for their lack of consideration for environmental impact and misuse of funds. However, past planning and execution mistakes do not make the project unsustainable in the long term.

Congestion problems at specific pressure points are extreme. Traffic jams in rush hour in big cities remain unresolved. Increasing the capacity of the existing infrastructure or building duplications are clearly inefficient solutions. Moreover, linear expansion projects within transport infrastructures imply excessive expense in maintenance that can pose risks for the economic sustainability of countries.

The alternative, as discussed above, is a neuronal-growth model where nodal points become a key element to identify where growth in the network would be most effective.

Therefore, it is necessary to address the pressure nodes and their viability as a solution. These large ‘smart’ investments could solve or, at the very least, mitigate congestion problems, while allowing urban areas to provide a better quality of life to their citizens. This work must be carefully planned to diminish additional costs over and above the unavoidable inherent costs associated with construction.

These ‘smart’ infrastructures must be durable as the size of the work implies irreversible change but further, higher durability ensures initial investment and societal impact amortization over the long-term. Based on the results, sustainability of ‘smart’ investments appears as the unequivocal solution and should lead future transportation infrastructure expansion models.

6. Conclusions

To sum up, any construction work on transportation infrastructures must be analysed holistically, considering the three pillars of sustainability. The nodal approach, that defines key pressure points and targeted public works, is definitely a smarter solution than the legacy linear expansion approach to infrastructure development. As shown in this paper, these legacy systems are incapable of solving congestion problems over the long term and only partially address issues of general underuse of the network with its associated economic, social and environmental costs.

A development of infrastructures based on linear expansion and low complexity will not be able to tackle mobility problems in the future, stressing congestion at specific points without optimal use for most of the network.

This challenge requires a model based on higher concentration, higher complexity and higher ’smartness’ in the system.

In this context, politicians, designers and builders from materials to construction companies, must adopt solutions based on nanotechnology, ICTs and ad hoc services that satisfy the requirements of an evolving ‘smart’ society.