Leo Wagner

Simon

Urban Studies

Transit mode, passenger experience, and carbon emissions in the Maghreb

Introduction

The world's population is rapidly urbanizing, with cities of the Global South the most dramatic examples of this phenomenon. From Mexico City to Manila, urban growth is occurring at breakneck speeds, and cities are faced with numerous challenges that come with this growth, often with limited resources for implementing solutions. One such domain is transportation. As these cities grow in population, they also grow outwards, which along with industrialization and changing urban economies means that their inhabitants' commuting distances grow as well. Though a significant proportion of inhabitants continue to walk as their primary mode of transportation, in many places public transport becomes a significant component of a city's transportation mode share (Guerra 2017).

Cities of the Global South, despite the many challenges and limited resources they may face, are also fortunate to have avoided many of the mistakes made by North American cities leading to high per-capita carbon emissions. Their high population densities, reduced percentage of urban space occupied by roadways, and low rates of car ownership provide an environment conducive to frequent, fast, well-patronized public transport that can mitigate urban carbon emissions and promote social and environmental wellbeing. As such, proper transport planning in the region will have a disproportionate impact on carbon emissions and quality of life for urban areas worldwide.

Cities of the Maghreb (a region of north-western Africa consisting of Morocco, Algeria, Tunisia, Libya, Western Sahara, and Mauritania) are no exception to these conditions. The largest

metropolitan areas of the region, Casablanca and Algiers, have close to 5 million inhabitants each, with several others breaching the 1 million mark. Transport in these cities has long been a challenge, with proposals for centralized higher-order transportation systems such as a metro dating back to the colonial era. In recent decades, car ownership and per-capita carbon emissions have skyrocketed, negatively affecting quality of life in these cities and exacerbating the problem at hand (Allaire and Chèvre 2016). As such, beginning in 1985 in Tunis, several of the region's cities have implemented some form of higher-order transit mode located primarily in an exclusive right of way, providing faster service than mixed-traffic buses or trams. Today, ten cities in the region have a higher-level urban transit system in operation: Casablanca, Marrakesh, Rabat (in Morocco), Oran, Sidi Bel Abbes, Algiers, Setif, Constantine, Ouargla (in Algeria), and Tunis (in Tunisia). An additional three systems are under construction in the Algerian cities of Annaba, Batna, and Mostaganem.

In the majority of these cities, a light rail or modern tramway system was chosen as the transportation mode of choice, with at least a partially-dedicated right-of-way, often through dedicated road space and/or with substantial at-grade crossings. In Marrakesh, a bus rapid transit line with similar right-of-way characteristics was built. In Algiers however, a full-scale metro system was constructed. The tradeoffs between these two approaches are clear. While the former results in more miles of high-quality transit mileage being constructed, light rail and BRT do not offer the speed or capacity that a fully grade-separated metro does. On the other hand, the punitive costs involved with the latter mean construction is slow and may only cover a small portion of a sprawling Maghrebi metropolis for the same cost as a substantial light rail or BRT system. In other words, Maghrebi cities that in higher-income countries would often construct a metro, or a transit line with a more segregated right-of-way, for their primary transportation axes (e.g., Casablanca, Tunis) rely instead on more economical solutions.

So, based on the results of existing transit systems in the Maghreb, which approach is better for mitigating per-capita carbon emissions, and how do riders' experiences, choices, and changes to urban quality of life differ based on the type of system built?

Literature Review

Transportation in the Maghreb has been the subject of research by a diverse group of academics, ranging from development and international economists to urban and transportation planners to civil engineers. This literature review will therefore sample a diverse, multidisciplinary range of works, representative of the body of research generally devoted to the topic, to understand existing avenues of research on the politics, performance, history, and operations and rider experience of public transport in the Maghreb. Even with such a broad range in the literature's focus, a few major trends are apparent, which will be elaborated here.

The body of research devoted to transportation in the Maghreb has grown rapidly in the latter half of the twentieth century, accompanying a rapid growth in the region's cities. Transportation-related research, in the Western tradition, has surrounded the region's metropolitan areas since the early-20th century with the formalization of French control in the region, in the form of early feasibility studies and proposals for metro systems in Casablanca, Algiers, and Oran. Because, however, the first urban public transport system *operating within its own right of way* opened in 1985 and urban development in the region has rendered the region's contemporary cities unrecognizable to their colonial counterparts, this review looks only at studies produced in the 21st century.

The ten reviewed papers, the oldest of which dates from 2007, can be broadly divided into several different types. Allaire and Chevre (2016) and Chadali (2009) are holistic overviews of the existing situation from a government-adjacent (or what can be described as

"pro-establishment") and policy focused perspective. Both focusing on Morocco, they look at the history of transport policies in the region and, with an emphasis on bureaucratic achievements, the positive outcomes of recent policy changes. Said and Abderrahmane (2017), Godard (2007), and Bouder et al. (2017) are all city-specific overviews of higher-order transit development, including some quantitative evaluation of network performance or its expected performance, in Setif, Tunis, and Algiers, respectively. These studies use a multidisciplinary overview of things like ridership and an analysis of existing urban mobility habits compared to areas the lines serve to make general conclusions and evaluations of the systems at hand. Kerrouche and Madani (2015) and Beier and Nolte (2019) look critically at the implications of tram construction in both Casablanca and Oran as examples of larger-scale political agendas, and what these projects indicate about general political visions and what, and who, is left behind by them. Finally, Ait Boubkr (2018), Jawab and Zehmed (2021), and Khelf et al. (2019) are the only studies to use qualitative data in their analysis of systems in Casablanca, Rabat, and Constantine to look at their performance from a passenger-centric perspective. Whereas Ait Boubkr focuses on questions of equity specifically, both Jawab and Zehmed and Khelf et al. are focused on passenger experiences and preferences with respect to the cities' tramway systems.

One of the major trends found in this review is that existing literature is largely focused on a particular transit system or city. Even when studies or analyses are larger-scale in nature, such as Allaire and Chevre (2016), they are not comparative in nature. When references *are* made to a peer city or country, it is typically to one in the Global North or to a particularly successful implementation of a particular technology or financing scheme, and not necessarily to peer cities within the Maghreb. A notable exception, however, is Jawab and Zehmed (2021)'s comparative analysis of the performance of the Rabat and Casablanca tramways as far as passenger satisfaction is concerned, using the same metrics in both cities. While these two cities are both in Morocco, comparison at this level allows for an understanding of how cities in the

region, which face many similar challenges and mobility and demographic characteristics, are doing with respect to one another. This sort of analysis then allows researchers and policymakers to determine what cities that are performing particularly well are doing differently for local application, making additional research with an explicit comparative component at the regional level so important.

Outside of comparison to peer cities in the Maghreb, several studies do include some element of comparative evaluation, in particular with respect to the former metropole, France. This is of heightened importance given France's continued role in the region's transportation policy, including the planning, construction, and operation of its higher-order transit systems. This is often done by Veolia Transdev or RATP Dev, the internationally-focused arms of two French transport operators, while rolling stock for every system but the Algiers Metro and Tunis Light Rail is supplied by Alstom, a French company. As such, Allaire and Chevre (2016) include direct references to Moroccan policy counterparts in France, and the performance of the former with respect to the latter. Another interesting example is that of Beier and Nolte (2019), whose study of the politics and motivations behind Casablanca's tramway compared these aspects to a similar tramway built in Jerusalem, also outside the region but in a similarly middle-income country with a nationwide political agenda of presenting a westernized, globalized face to the world.

Second, the existing literature is relatively polarized in two opposing directions, with little necessarily quantitative-qualitative mixed-methods overlap. On one hand, several studies take a much more critical, social science-based approach, and in doing so eschew the use of more quantitative hard data to indicate larger-scale trends. Whether through qualitative surveys or in-depth policy analysis, Ait Boubkr (2018), Jawab and Zehmed (2021), Khelf et al. (2019), Kerrouche and Madani (2015) and Beier and Nolte (2019) all fall into this category. These sorts

of studies take into account important nuances between the experiences of different places and their citizens of various identities, but are not as ideal for identifying definitive evidence of larger-scale trends in the same way that quantitative evidence provides. On the other hand, the remaining five studies and analyses are frequently written with an engineering focus when quantitative in nature, looking at information about a city's general mobility behaviors. Where these studies fall short, however, are in the conclusions drawn from this research. These studies remain fairly objective, stating the results of a calculation or ridership count without drawing a direct connection between this and policy implications. If not with an engineering focus, they are still at a large-scale view, and even if pertaining more to policy continue to be very objective in nature. In other words, these studies give official figures that *propose* what transit should look like or will do (i.e. improving quality of life and reducing carbon emissions), but fail to include a critical evaluation of whether the infrastructure projects built as a result have done that. For studies which "go the extra mile" and do the latter, such as Bouder et al. (2017), questions which qualitative analysis would help answer, such as *why* the Algiers tramway is underperforming its ridership expectations, are not posed.

Finally, two smaller, less significant, trends can be noted in the literature. The first pertains to the abovementioned studies' relationships with sustainability. The existing body of literature includes frequent mention of sustainability and its importance in urban life as a rationale for improving urban public transport, or as a stated goal of a project being evaluated. However, critical analyses of these transit systems do not attempt to quantify or study the direct impact of these transit systems on urban sustainability, at either the citywide (quantitative) or per-capita (qualitative) level. For example, vehicle miles traveled, qualitative studies of how individual citizens' travel behaviors have changed following the introduction of the higher-quality transit system, or carbon emissions/capita are all potential metrics that would exhibit this trend well, but that are not utilized within existing literature. Second, spatial mapping techniques such as

GIS are rarely used by existing studies. Existing visualizations tend to consist of static official diagrams showing where in a city a proposed higher-order transit line will run, but this is not mapped along with important information about the built and social environments, ranging from population/employment density to median income to car ownership to carbon emissions to median temperature. By doing so, studies would visualize many of the determinants of a project's success in improving urban quality of life and/or sustainability.

The state of existing literature in the field thus highlights the need for a study of the sort I propose. The four major gaps, as outlined above, are either ignored or underrepresented in today's literature when considering their importance to the field. These gap areas are also important for ensuring that the region's higher-order transit systems accomplish the goals so often set out for them of improving urban quality of life and creating more sustainable, equitable cities. As such, I aim to conduct a mixed-methods, comparative research study focused entirely on public transport with a dedicated right of way within the region to understand how well different approaches ameliorate urban quality of life, with a particular focus on passenger experience and carbon emissions.

Research Design

As established in the literature review, existing scholarship in the field does not tend to compare peers within the Maghreb to one another, does not use the sort of quantitative-qualitative mixed-methods approach applied here, does not incorporate GIS-enabled spatial visualizations, and lacks specific metrics for measuring sustainability. To respond to this, I aim to conduct a mixed-methods, comparative analysis of higher-order transit systems in the Maghreb to understand their impact on citizens' mobility patterns, urban quality of life, and carbon emissions. To do this, I will incorporate two principal elements: the first, passenger mobility surveys (qualitative) consisting of the same questions asked in multiple cities, would gauge how

these transit systems changed urban mobility through passenger testimonials and demographic information. The second, spatial visualizations of cities' higher-order transit networks, will compare the networks with quantifiable indicators of the built and social environment that play a significant role in carbon emissions and transit use, such as population and job density, the frequency of marginalized social identities, or the presence of major educational institutions.

Additional components will also, under ideal circumstances and pending their availability, be included to reinforce conclusions made from the two core survey metrics described above. For example, information about ridership/mile, average stop distance, and other specifications as to operations and line characteristics will accompany the passenger mobility survey data, while carbon emissions information will accompany the spatial visualizations. This will help point to potential conclusions about *why* a particular trend or outcome has been observed. A key component of the study will be comparing the *type* of transit service offered with how it is *used* to determine its ability to deliver on its oft-stated promise of improved sustainability and urban quality of life. In other words, how does a system like Algiers's fully grade-separated metro compare with an at-grade tram system (albeit almost entirely in independent right-of-way) in a peer city of similar metropolitan area population, like Casablanca? To this end, a table comparing network attributes, such as average line length, stop spacing, ridership, vehicle capacity, line capacity, frequency and service span, annual trips per inhabitant, and right-of-way type, may be useful.

Mobility Behavior Survey

This component of the study will focus on qualitative analysis of passengers' mobility behavior, gleaned from survey results. In essence, this component will attempt to understand how bigger-picture trends outlined by mapping out the network, and how differences between various cities' transit systems, play out in passengers' use of the system. For example, a system

with shorter average stop spacing should see many passengers taking shorter trips. The purpose of passengers' trips should vary as well based on the destinations served by a system, as should the manner by which passengers access a stop. Passenger trip duration should also vary depending on the system type and trip length.

Network Mapping

Network mapping, done using ArcGIS, should indicate how well cities' higher-order transit systems are improving urban sustainability and quality of life. Maps comparing the transit networks' extent to urban population density, job density, and markers of propensity to transit use broken down by commune or other local-level jurisdiction will be produced. Additionally, maps will compare the transit networks' extent with important locations in the city such as new development, educational and healthcare facilities, and employment hubs. This may require the use of geocoding, if existing shapefiles and data sets are not available, to determine site locations, as well as the application of buffers to determine their accessibility to transit stations. Shapefiles for the location of stops and lines of the transit system may also need to be created.

Challenges and Changes

The largest challenge I envision arising in this study will be data collection and availability. For the mapping component, as discussed above much of the information may be difficult to acquire, for example lying behind paywalls (which is also the case for many pertinent existing research papers) or not existing if local Censuses do not ask about and gather the information. Because the study is comparative, another issue may arise given the cities' locations in different countries, so treatment, collection, and display of data (for example, at a commune, neighborhood, or postal code/census tract level) may vary, limiting the ability to draw direct comparisons and make inferences.

With regards to the passenger mobility behavior survey, data collection will likely be an issue. Ensuring that enough responses are recorded and that data is representative of the larger population at hand is also a concern. Given that surveying will be done online, the ways in which this survey is diffused may skew respondent demographics, especially if distributed through a university. Respondents, owing to the prerequisites of internet access and literacy, will likely skew wealthier and younger than the cities' averages. Moreover, survey translation will be necessary to acquire a wider range of results, and while I am capable of French translation additional translations for Modern Standard Arabic, Moroccan/Tunisian/Algerian Arabic, and potentially various Berber languages may be necessary.

For both of these questions, I aim to reach out to involved Penn faculty, continue to do my own research, and reach out to local experts at universities engaged in this sort of work. Faculty at local universities, for example, may be able to provide important datasets, as could professors here at Penn who may also help establish contact with partners in the Maghreb. Lastly, some calculations may be necessary which may require some research into best practices for determining estimates, such as resident vehicle miles traveled or carbon emissions per capita.

The scope of the study, namely of all cities in the Maghreb with higher-order transit systems in place, is a large one. This requires the collection of lots of data, including from many cities which are less well-studied by international academia and, owing to more limited resources, may have less information about population distribution available. Additionally, the wide range of cities also increases the presence of confounding factors, such as varying incomes and population. As such, a potential future direction for the study will be to reduce its scope, for example to a comparative study between Casablanca and Algiers owing to the different transit modes employed in each city and their similar population size and characteristics, as well as in the interest of data availability.

Proposed Draft Timeline

Note that the proposed timeline below is a *rough* estimate of task duration. Many of the tasks, given the research's mixed-methods approach, can be done simultaneously.

Task	**Duration**
Dataset Collection (incl. permissions)	2-3 weeks
Calculation (for missing data values, such as employment density if given area and population)	1 week
Contact establishment (with local universities, advocacy groups, professors)	2-4 weeks
Survey formation, translation (French, MSA, Darija, Berber languages)	1 week
Survey distribution	1 week
Collection of results (for online, near-simultaneous with above)	4 weeks
Potential Geocoding (part of mapping, for example if new datasets must be manually created for schools, transit lines, etc.)	1 week
Mapping	2 weeks
Survey interpretation	1 week
Report formation	4 weeks

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9.4.2022: Refined Components

Statement of purpose: I added an additional component to the "introduction" section to account for how transit construction in the Maghreb is different from in wealthier countries, despite large populations in urban areas, owing to different financial conditions.

In terms of further narrowing the topic, I need to better determine what I should be evaluating these systems for, which will depend largely on what data I have available. Some major contenders include how the systems perform for mitigating per-capita carbon emissions, number of transit trips per capita, increase in transit use, percentage of trips on transit, changes to development patterns, etc.

Body of literature: My existing bibliography is extensive. My literature review and introduction frame both the existing literature's evolution and the broader thematic arguments that public transport in the Global South and specifically the Maghreb present. However, to expand the existing body, I am going to cite and learn from several pieces included in the themed journal « Le tramway à l'épreuve des mobilités dans les villes algériennes et du bassin algérien » which includes several pertinent research papers and articles on the place of the tramway in Algerian urban planning. The journal, the result of a research lab headquartered at the Université d'Oran II, includes input from faculty at a variety of French institutions, as well as from the Université de Tunis in Tunisia.

Primary data: In terms of the primary data, I have sought to include a wide variety of data in my analysis, but continue to struggle with how I want to quantify the difference between "higher" and "lower" order transit as I describe it in my introduction. Average speed, right-of-way type (shared, separate lane, separate transitway–elevated/underground), capacity (pphpd), and stop spacing are all elements to consider. I am not sure if I should use specific thresholds for each of these (e.g., if more than 60% of the line is underground it is "higher order") or create a comprehensive table comparing each system based on these attributes, and then seeing if I can determine a general pattern from there as far as discerning high and low order systems.

To answer both the above question and that listed under "statement of purpose," I have reached out to Dr. Eric Guerra of the Weitzman School of Design here at Penn, who specializes in transportation planning in the Global South, to solicit his input.

Timeline: I updated certain components based on personal and student experiences shared by both Benjamin Moss-Horowitz and David Garnick. I extended the timeframes I allocated to tasks/phases of my thesis that rely on correspondence with other people, and getting information from groups outside of Penn.