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Preparing a Historical GIS for the Mass Transit Systems of Metro Manila from the Nineteenth Century to the Present

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ABSTRACT. Historical documents in the forms of maps, books, plans, and blueprints reveal functional mass transport systems in Manila long before the present-day rail-transit lines of the city's metropolitan area. Text bundles from the National Archives of the Philippines provide accounts of Manila's tramways in the late 1800s to the early 1900s, while transport documents from the 1970s to 1980s contain information on meticulously studied yet discontinued plans regarding Metro Manila's mass transit system. This research note deals with the processes and challenges of accommodating and piecing together information from these sources together in a geographic information system (GIS). GIS, in turn, is used to create maps to visualize the spatiality, chronology, and evolution of these lines, plans, and their environments. The study focuses primarily on the application of GIS methods to historical transport studies as it seeks to visualize the transport history of Manila, as well as to contribute to the growing literature and set of techniques employed in historical GIS.

KEYWORDS. Historical GIS · urban transport · transport planning · railways

Introduction

The predicament of heavy traffic in Metro Manila has resulted in the notion that the region's mass transit system is poorly planned. However, transport documents from the nineteenth century to recent history reveal that this is not entirely true. Historical documents, photographs, oral history, and physical remnants of the old lines of the *tranvia* (trams) or horse-drawn carriages are proof that a functional mass transport network in Manila and surrounding localities had existed before it was destroyed in the Second World War. Since the 1960s, several plans for a railway system—a number of which are notably different from the railways that we have today—were drafted in anticipation of Manila's ballooning population, traffic demand, and eventual metropolitanization but many of these were not implemented.

A geographic information system (GIS) is used to consolidate historical data and create a geodatabase of Metro Manila's mass transit systems from the nineteenth century to the present. This research note is primarily focused on methodologies and strategies in putting together a historical geographic information system (HGIS) of Metro Manila's mass transit system, as well as the challenges encountered in preparing data from disparate sources before accommodating them in the geodatabase. The digital geodatabase is created by compiling and processing information from print and digital maps, nineteenth and twentieth century documents from the National Archive of the Philippines, blueprints, satellite imagery, and transport plans such as those created by the former Department of Public Works, Transportation, and Communications, the former Overseas Technical Cooperation Agency of Japan, and from planners from different local and international institutions. The types of data obtained include historical maps, shapefiles, and images of the road and rail network, and local administrative and topographic boundaries.

Central themes in the discussion include the characteristics of data sources and the techniques required to make them compatible with HGIS. The computer software used in processing spatial data and producing the maps for this paper are a) ArcMap 10, one of the programs in the ArcGIS 10 Suite by the Environmental Systems Research Institute, b) Quantum GIS, an open-source GIS application, and c) Google Earth, a desktop viewer of global satellite imagery. The geodatabase produced by gathering historical data can be used to create thematic and time-series maps of the railways. Hence, the prewar transport system, the discontinued plans, and the current road and railway system can be analyzed side-by-side, and overlaid with the environment and demography of the study area through the years. These in turn can aid in policymaking and planning the transport systems of Metro Manila.

GIS AND ITS APPLICATION TO HISTORICAL STUDIES

A GIS is a computer-aided system of hardware, software, methods, and users that allow the visualization, analysis, and interpretation of data to understand relationships, patterns, and trends in space (ESRI 2016; Felias 1997). It has a wide array of applications such as mapping, prediction, and modeling. It can also be seen as an interdisciplinary approach to understanding the world through the application of computer science, mathematics, and statistics, to surveying, architecture, forestry, and geosciences, among other fields (Kainz 2004). Fan et al. (2013) noted that GIS has developed rapidly as a tool in various fields and as a discipline on its own in the past two decades.

HGIS, which generally refers to all applications of mapping to historical studies, has been an emerging field since the 1980s. It was not easily integrated into the practice of historians since it poses the challenge of a "steep learning curve and proficiencies in geography, cartography, and computer science" (Bol 2012, 1). However, there has been a significant increase in the number of HGIS-related studies in the previous decade. Hiroshi Kawaguchi (2013) attributed the newfound popularity of the practice with the ability to combine the three geographic axes of latitude, longitude, and altitude with the fourth axis of time, which is more familiar to historians. The modern information system and geodatabase also allow the users to a) reduce time and effort for data processing, b) ensure the reliability of data processing, c) convert and preserve historical materials in digital form, and d) share data analysis methods with other researchers (Knowles 2014; Rumsey and Williams 2002). Finally, the attribution of the time axis to phenomena that occur in space allows researchers and cartographers to create time-series maps for multiple comparisons (Kawaguchi 2013). GIS operations also involve the attribution of data that can be imported from a table to a digital map. Morillas-Torné (2012), for example, used this capability to create maps and build a comprehensive database of the railways, population, and housing in Europe from 1830 to 2010.

One of the key features of GIS is that it allows a database to be organized with respect to the actual locations of objects and variables of interest in space (Lloyd et al. 2012). Hence, the GIS user can sort, extract, combine, and process data based on their locational attribute. An essential dataset in studying the history of mass transit in Metro Manila is the road network. This importance is recognized in several studies about urban transportation in Metro Manila, where it was noted that the road network and the rail transit system are always closely related to each other (Pinnock 1976; Jucaban 1976; MOTC 1985; Reyes 1990). The 2011 road data is obtained from OpenStreetMap, a mapping platform with data sourced from volunteers around the world (Perkins 2014). In figure 1, the road network contained in the administrative boundary of Manila was isolated from the entire Philippine road network data using the Clip Tool in ArcMap. Land use, population, physical structures, and other place-specific information can also be clipped and presented in the same

Figure 1. *Left,* The Philippine road network. *Source:* OpenStreetMaps (2011). *Right,* Road network in the City of Manila. *Source:* Isolated using the clipping function in ArcMap.

fashion. Performing clipping, as the isolation of geographic features per area of analysis, opens opportunities for further transport network analysis.

RECONSTRUCTING SPATIAL INFORMATION FROM HISTORICAL MAPS AND OTHER DOCUMENTS

A recurring challenge in this HGIS project is addressing the differences of scale and representation between historical maps and the modern GIS environment. Case in point, GIS allows both the map-maker and the end-user to manipulate the scale of the digital workspace and hence, vary the scale of the output maps and the resolution of visible data. This feature is evident in Google Earth's interface, where barangay-level and local information is shown only after the user zooms in on the map. Cartographers using the Google Maps Application Programming Interface as basemap are able to incorporate the same functionality in their Internet-based maps (Dalton 2015). Such flexibility of scale does not apply to historical maps, since their digital formats are often not readily available, if they exist at all.

For example, Arturo G. Corpuz used several maps of the Luzon lines of the Manila Railway Company in his book, *The Colonial Iron Horse: Railroads and Regional Development in the Philippines* (1999). The maps indicate the locations of the stations across Luzon, but not the precise locations at the barangay scale (for example, see figure 2). Zooming into such a map will only enlarge the image but it will not reveal additional information to accompany the zoom level. The map shown in figure 3 consists of the digitized Manila-Dagupan Line, which is uploaded to the Google Earth Environment afterwards. Additional research was needed to pinpoint the actual locations of the Manila Railway Company stations on the geodatabase, given that not all its stations were explicitly listed in Corpuz (1999). Such cases require cross-referencing with various sources and oftentimes, the use of the cartographer's imagination (Rumsey and Williams 2002).

The use of cartographic imagination is also required for maps that were originally drawn without a scientific scale or projection system. The land use plans in *Transportation Systems: Metropolitan Manila Assignment Report* by Sigurd Grava (1972) serve as good example. Grava reviewed the transportation programs by the Philippine Government in the Manila Bay metropolitan region, and part of his recommendations was to develop the land mass transit of the area with respect to marine

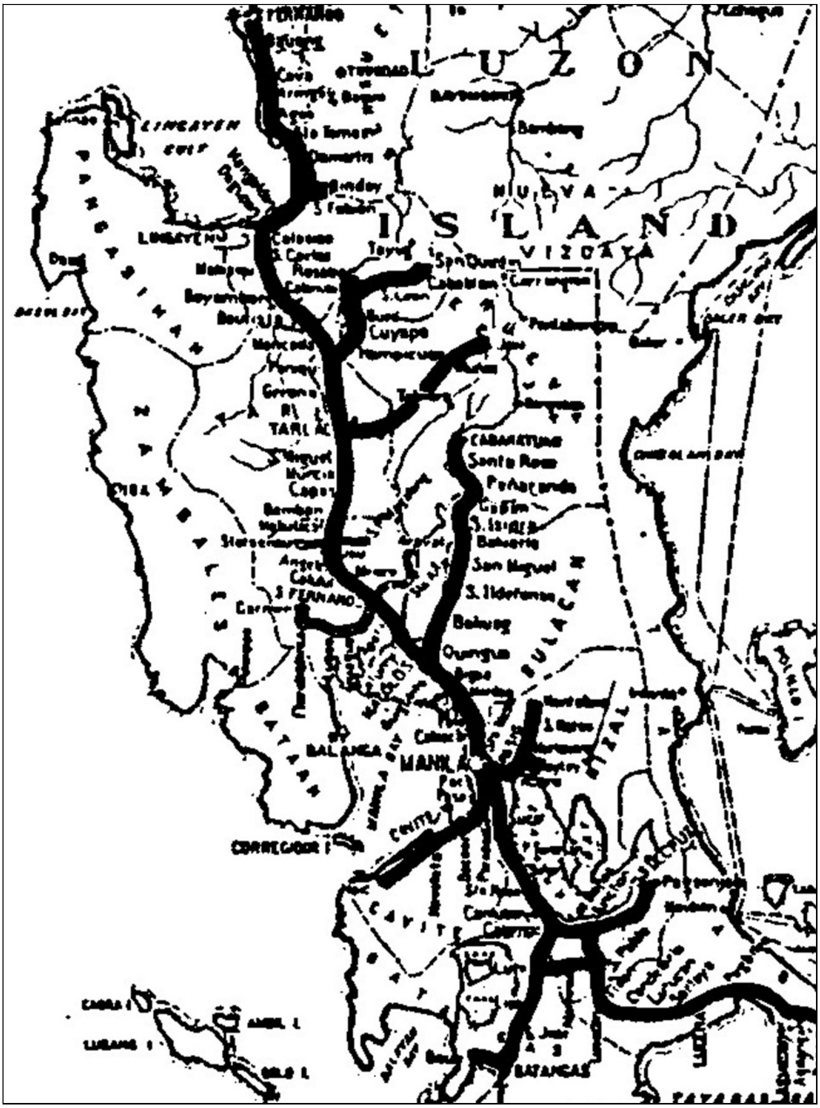

Figure 2. Print and static map of the Manila Railway Company lines by 1992, including the Manila-Dagupan Line. *Source:* Corpuz (1999, 52).

ports. The maps of the transport plans, which are centered on the Manila Bay area, overlaid with the existing and planned land-use of the region, were hand-drawn on a blank polygon of Luzon. The same issues can be observed on maps included in the documents *Metropolitan Manila: Towards the City of Man; Total Human Resource Development* (Metropolitan Manila Commission 1985), and the *Metro Manila Ring*

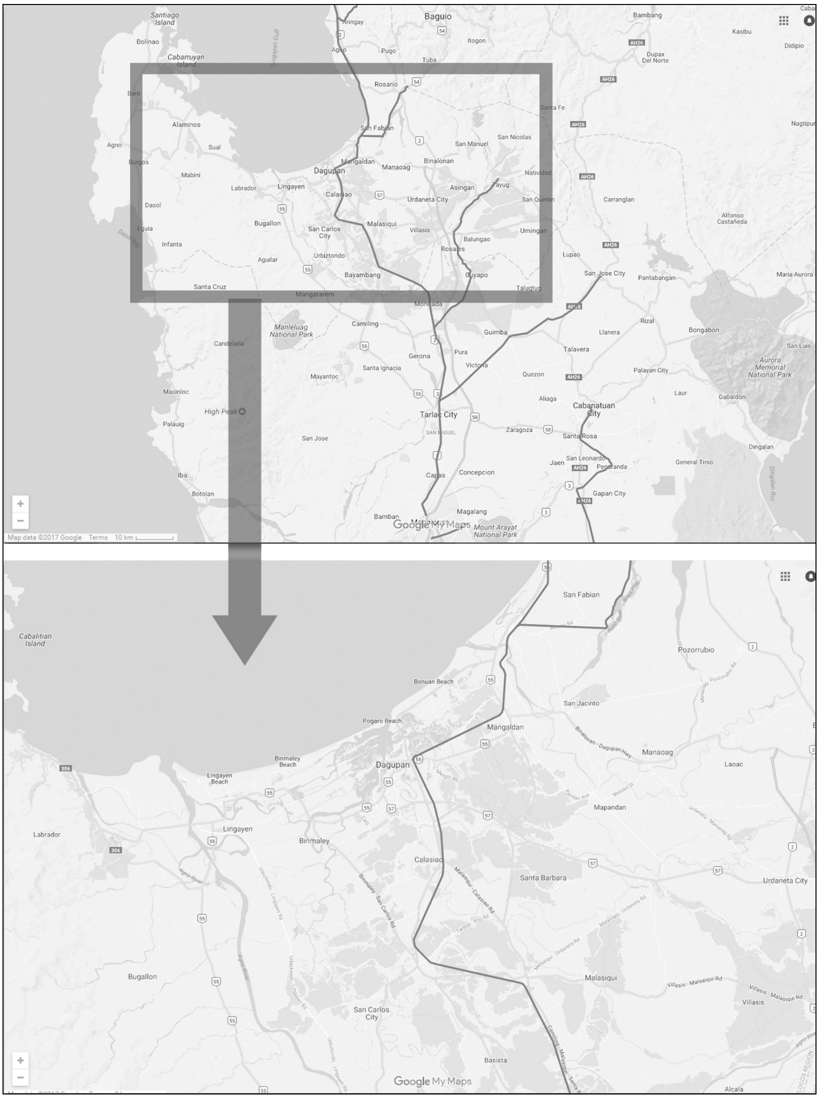

Figure 3. The digitized Manila-Dagupan Line, accurate up to the municipal scale. Magnifying the scale in the Google Earth API reveals additional locational information. *Source:* Google Maps (2016).

Development Projects: Office Situation Report (PPDO, DPWTC, and MBMRPT 1972). Maps of these kinds were possibly drawn with the intention of serving an audience that is not particular with scale and accuracy, resulting in problems in discerning which localities precisely contain geographic features such as railways and stations. This gap must be addressed before creating digital versions of these maps.

One way of aiding the cartographer's imagination is the use of satellite imagery. The interpretation of satellite images belongs to the umbrella discipline of remote sensing, which involves the science of obtaining and interpreting satellite imagery and aerial photos (Aggarwal 2004). Wakako Kumakura (2014) partially reconstructed in maps the irrigation system of the fourteenth to sixteenth century Egypt through the combined use of GIS, historical maps and documents, and interpreting remotely sensed data (see figure 4).

An approach similar to Kumakura's was employed by Hiroshi Kato et al. (2014). They used satellite imagery to identify trends in land cover and land use change. Rajnish Kumar and Milap Punia (2014) used remotely sensed data to gather information on the urban development of Bihar, an urbanized state in India. Satellite imagery together with data from the Census of India were used to identify the clustering of settlements in the area, which they hypothesized as an effect of rapid migration from nearby rural areas. These recent works highlight the importance of remotely sensed data in augmenting the information that can be found in historical maps and documents.

Mapping the Evolving Composition of Metropolitan Manila

The extent of the study area is another central concern in mapping the changes with the mass transit system, especially with Metro Manila being an evolving geographic entity. Mapping the railways against the corresponding composition of Metro Manila at each time period will provide a more nuanced understanding of how the mass transit system progressed. However, the cities and municipalities that had been considered parts of the region were not always explicitly mentioned in historical documents except for a few official definitions by the government.

In the 1960s, Metro Manila's composition was defined by the Bureau of Census and Statistics as comprising of four cities (Manila, Quezon City, Pasay, and Caloocan) and three municipalities (Makati, Mandaluyong, and San Juan), which all share a border with the city of Manila. This definition was primarily used by the Bureau of Census and Statistics as classification system for collecting and reporting demographic statistics (Encarnacion 1969). However, urban and transport plans took into account the rapid urbanization of towns in contingent provinces such as Bulacan, Batangas, Cavite, Laguna, Rizal,

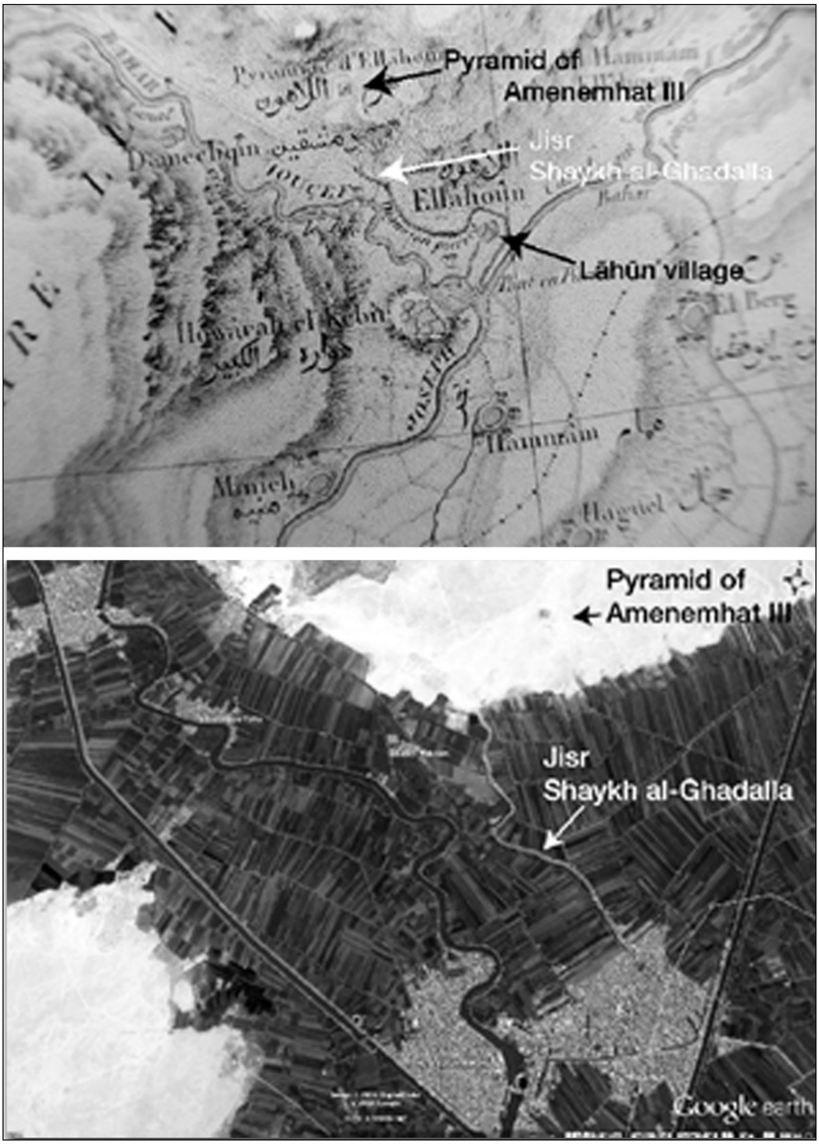

Figure 4. Through the cross-examination of historical maps and satellite imagery of the Nile area, Kumakura (2014) was able to approximate the location of ancient irrigation infrastructure such as the Jisr Shakyh al-Ghadalla.

and Quezon. Rosauro Paderon (1970) presented a history of Metro Manila's geographic composition. Paderon cited a set of criteria used by planners to identify five cities and twenty-five municipalities, including localities from central and southern Luzon, based on contiguity, population, and interdependence with the city of Manila. However, the names of these localities were not enumerated. Only the outermost limits of the area were defined, namely the Antipolo foothills in the east, Manila Bay in the west, Rosario, Cavite in the southwest, and Bocaue, Bulacan in the north.

Mapping the 1970s Metro Manila would then require the application of Paderon's criteria for inclusion. For instance, contiguous areas can be easily identified and cropped using GIS based on the stated outermost limits (see figure 5). The criterion of interdependence with Manila, on the other hand, was defined as referring to municipalities that can be reached within an hour by commuting from Manila on land (Encarnacion 1969). Network analysis tools in GIS can identify these locations when fed with the road network map specific to the period (ESRI 2010).

It was only in 1975 that Metro Manila was formally established under then president Ferdinand Marcos through Presidential Decree 824. This formal definition of Metro Manila, otherwise known as the National Capital Region, include the present-day cities of Caloocan, Las Piñas, Makati, Malabon, Mandaluyong, Manila, Marikina, Muntinlupa, Navotas, Parañaque, Pasay, Pasig, Quezon, San Juan, Taguig, Valenzuela, and the municipality of Pateros.

Another strategy that can be used in mapping the study's geographic extent is the consideration of topography and physical-geographic boundaries. For example, the University of the Philippines Institute of Planning (1968) included fourteen additional municipalities, including Malolos, Angat, and Binan, to the 1960 definition of Metro Manila. The bases of the new definition are geographic limits such as the Laguna de Bay at the southeast and the Sierra Madre mountain range at the eastern boundary. Black and Veatch (1970), in their study on waterworks and sewerage, used topography, watershed, and land use in denoting the limits of the metropolitan area which is practical for the field of planning waterways.

The topographic map in figure 6 is created by combining figure 5 and the land elevation data obtained from the Philippine GIS Clearing House (PhilGIS 2012). This new map, in turn, may be overlaid with the road network and railway lines that are yet to be converted to digital format. Other shapefiles, such as those of present-day Metro Manila, railways, and roads both implemented and not, can be overlaid with the topography and other physiogeographic features of an area.

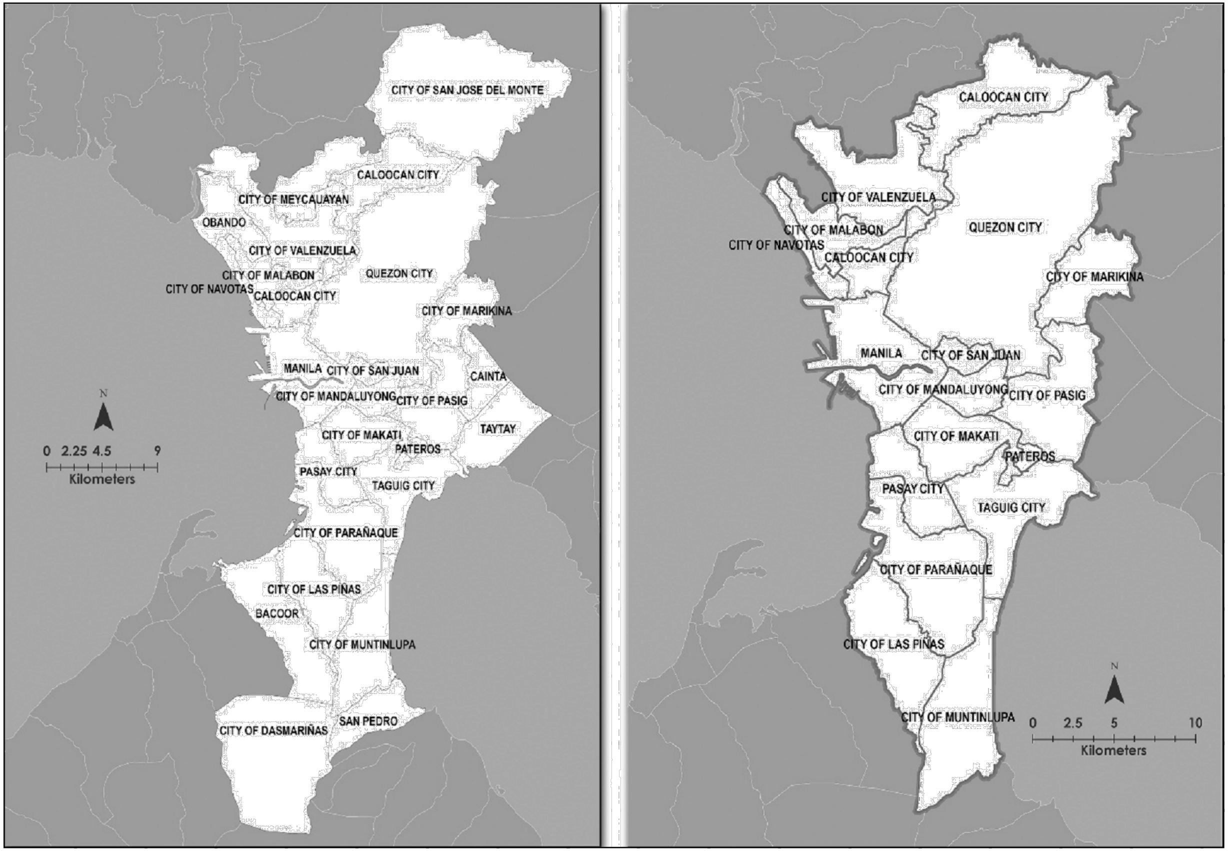

Figure 5. *Left,* Metro Manila as envisioned by planners in the 1970s. *Right,* Present-day Metro Manila as established through Presidential Decree 824. The clip tool in ArcGIS easily allows the isolation and extraction of selected areas based on Paderon's (1970) criterion for inclusion to "metropolitan" Manila.

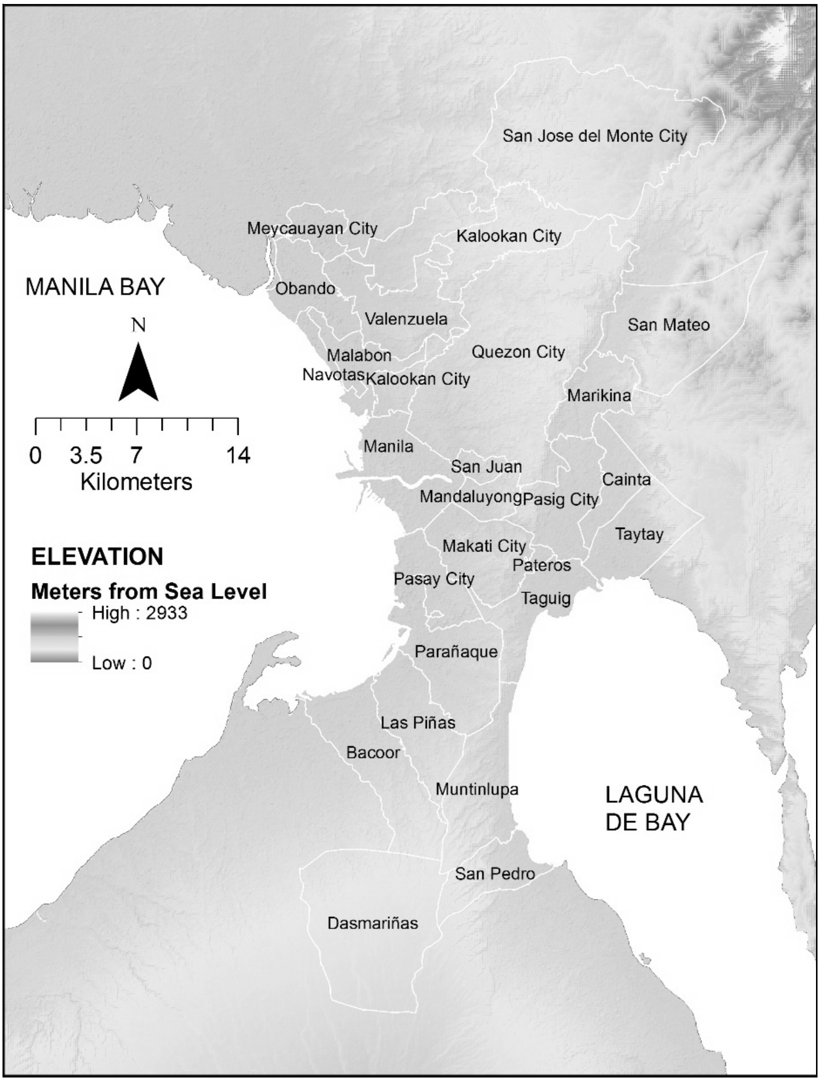

Figure 6. Topographic map of the Metro Manila area and the composition of the region as proposed by Paderon (1970). *Source:* PhilGIS (2011).

GIS Techniques for Digitizing Historical Maps

Besides reconciling scales and interpolating for lost historical information, specific GIS techniques are required to transform historical maps into usable formats. The first step is to create digital copies of the old maps and store them in an image format such as joint photographic experts group, bitmap, portable document format, and portable network graphics. However, they cannot be directly accommodated in a geodatabase because of two reasons. First, these images by themselves have no spatial referencing, i.e. latitudinal and longitudinal values. Secondly, the images are likely to contain distortions due to their inherent projections, artist's or cartographer's interpretation, angle of capture for aerial photos, and user errors in scanning the old maps (Felis-Rota, Henneberg, and Mojica 2012).

Historical maps that denote the study area or a portion of the study area are given spatial referencing through the process of rubbersheeting. Also known as georeferencing, rubbersheeting involves the selection of control points on the historical map that correspond to known coordinates in the GIS. Transformation algorithms built within GIS software systematically stretches the image file to match the old maps with the digital map's coordinate system (Rumsey and Williams 2002; Hackeloeer et al. 2013). For example, Alastair Pearson (2006) primarily employed rubbersheeting in reconciling the scale and representations in maps across the nineteenth century.

After rubbersheeting, the features on the georeferenced map can then be digitized and used in the geodatabase. Mirko Husak (2009) argues, however, that "georeferencing does not necessarily improve a historical map or make it more accurate. In the course of changing the original map to make it amenable to digital integration, georeferencing transforms lines and shapes, the distance between objects, the map's design, and its value as a cultural artifact" (839). To inform the maps' audience about these changes, an image of the original map must be included by the cartographer in publication (Husak 2009).

In an attempt to digitize the lines of the horse-drawn tranvia in the early twentieth century, rubbersheeting was applied to a 1918 map of Manila published by the Bureau of Commerce and Industry. The digital image was scanned from the original paper map and saved in the bitmap format (see figure 7). Using Google Earth's interface, the image was systematically warped by selecting prominent locational features such as Calle Azcarraga (now Recto Avenue) and the Pasig River as control points. The transformation made the roads and tranvia lines suitable for digitization and storing in the geodatabase (see figures 8 and 9). Consequently, the roads and boundaries in the historical map was also used to cartographically reconstruct the boundaries of historical Manila, which consisted of Intramuros and its surrounding districts (figure 10).

Distortions with geometry may be caused by changing the format and warping the plane of the original historical map (Monmonier

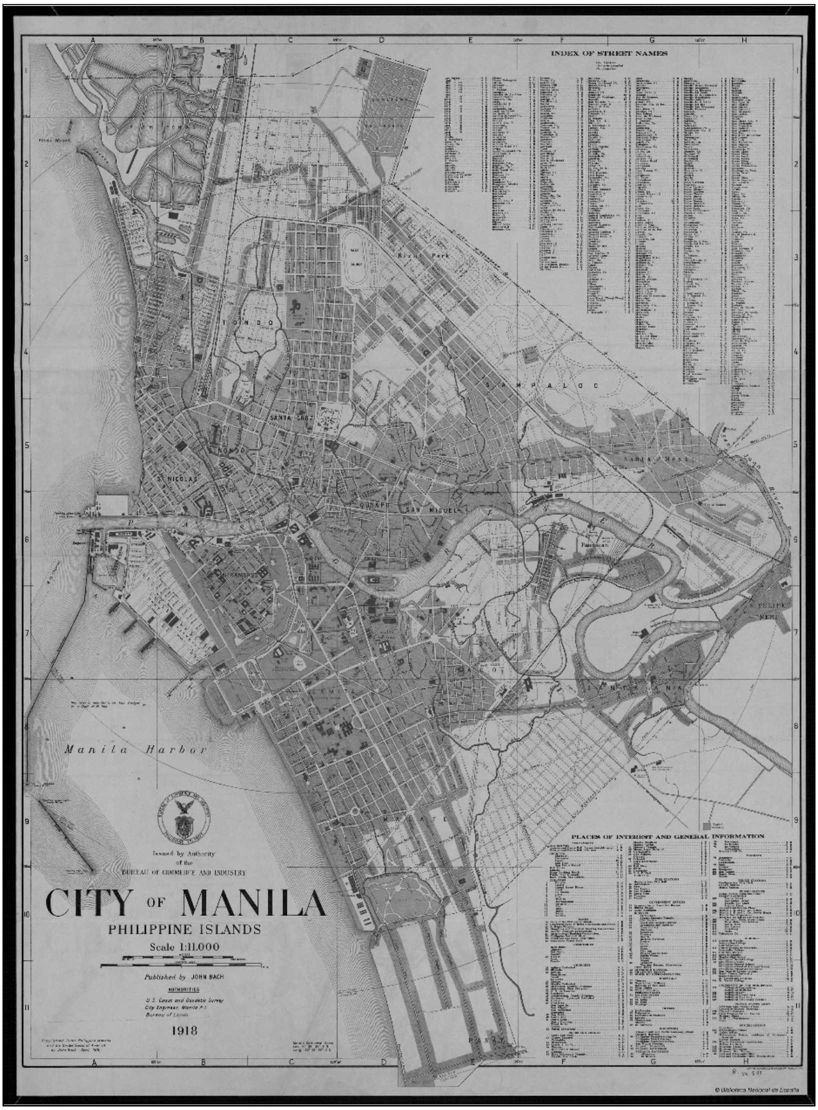

Figure 7. Land use map of the city of Manila, 1918. *Source:* Map by John Bach (1918), printed by the Bureau of Commerce and Industry.

1996). Moreover, the correctness of the 1918 map and the exact locations of the tranvia stations must be verified. Unfortunately, site inspection of the study area reveals that most of the traces of the transport infrastructure have already been replaced by markets, houses, newer roads, and other structures, or obscured from view by current land use. A way to address this challenge is to consult documents from

Figure 8. A portion of the 1918 Manila map rubbersheeted across the Google satellite image of the area. Pasig River was selected as visual guide in matching the map image with the satellite image.

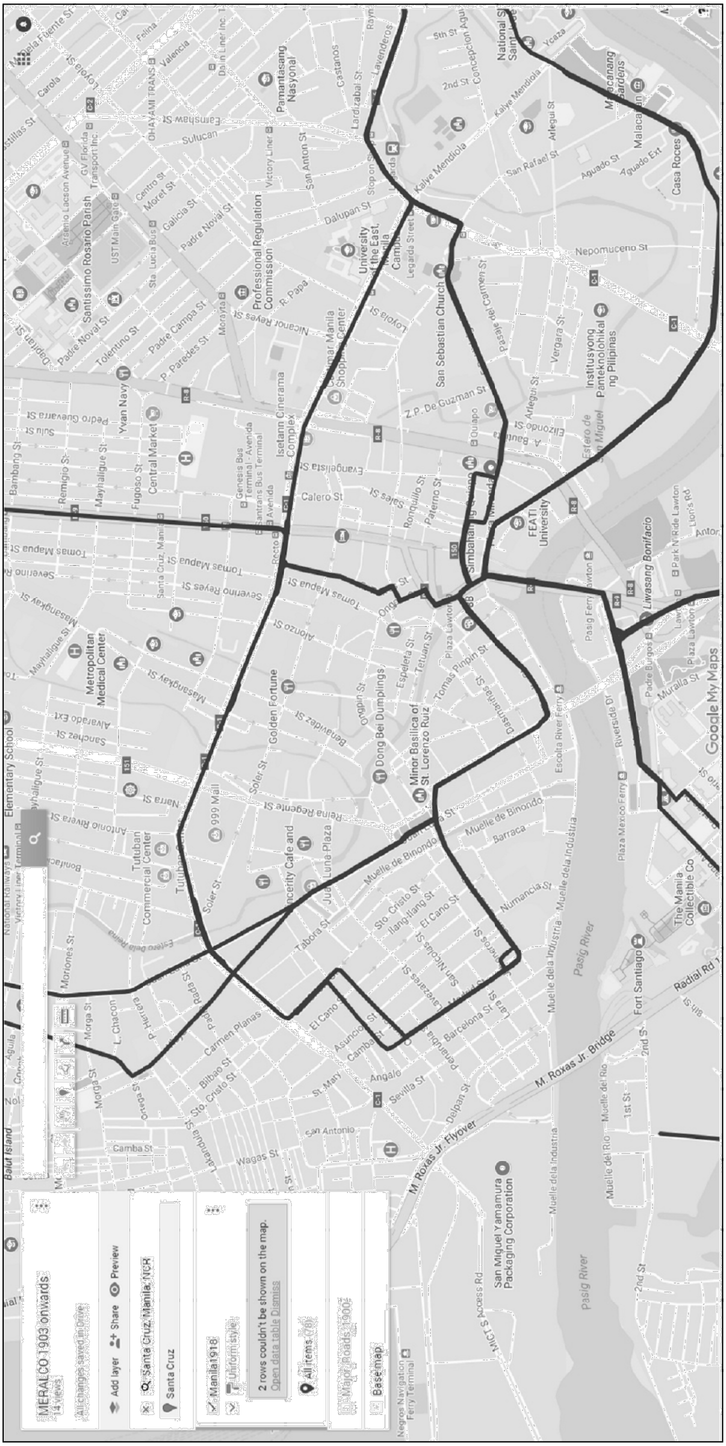

Figure 9. A section of the tranvia lines in the Santa Cruz area in Manila, digitized from figure 8. *Source:* Background map imagery from Google Maps (2016).

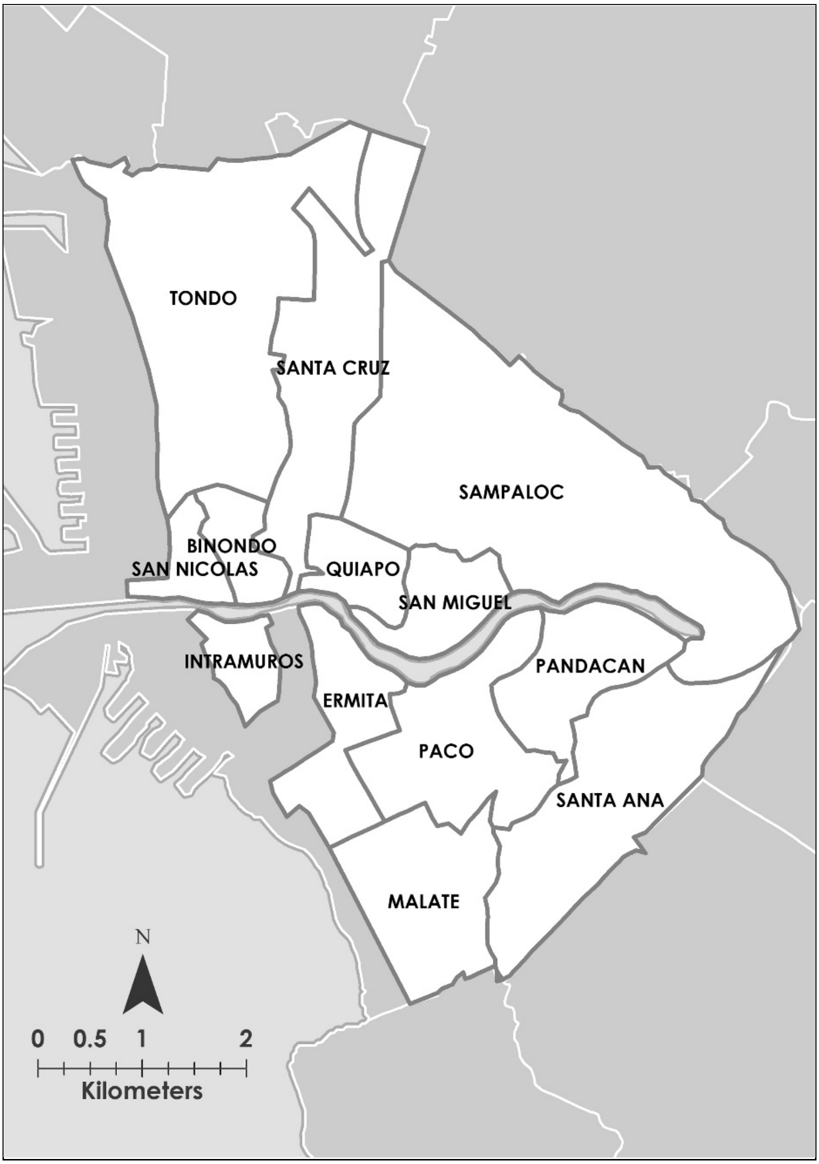

Figure 10. Boundaries of historical Manila reconstructed cartographically in ArcGIS and overlaid with the current boundaries of the area.

the National Archives of the Philippines. Tranvias 1882–1892 SDS No. 5287 and Tranvias SDS No. 5291 are two of the twelve document bundles in the National Archives of the Philippines about the Compania de Tranvias de Filipinas. These bundles were selected for the preliminary browsing and scanning of archival documents for this study. Tranvias

SDS No. 5291, in particular, contained *ytinerarios* or the schematic illustrations of the tranvia lines in 1898 Manila alongside inspection reports and ledgers of the tranvia company.

The ytinerarios are fold-out documents that can span more than 5 meters when completely spread out. These documents are topological straight-line illustrations of the tranvia stations and the lengths of each segment (see figure 11). Drawn at a scale of 1 meter to 2000 meters, these straight-line depictions of the tranvia railways were used to verify the order of stations and the length of the lines in the geodatabase. Besides locational information, the ytinerarios and the aforementioned archival bundles are also rich sources of engineering and technical information about historical railways in Manila.

After verifying its correctness with the ytinerarios and other archival documents, the entire 1918 Manila map was digitized in a GIS environment. The tranvia lines, now in digital format, can be accommodated and interoperated among applications such as Quantum GIS, ArcMap, and Google Earth. In figure 12, the tranvia lines from the 1918 map are superimposed with the present road network to demonstrate compatibility among initially incompatible sources of data. This capability to merge geographic and historical data from different sources and time periods open new possibilities in the field of research, particularly in mass transit studies. Modern methods in transport modeling may be applied to the tranvia system or to other transportation plans given today's traffic demand. In addition to visualization of the past through digitized historical maps, the knowledge HGIS can yield may be used in making more informed planning decisions in the future.

Conclusion and Directions for GIS Data Generation

This research note has been a survey of data sources for Metro Manila's historical transport networks and GIS methods, which allow them to be rendered in digital and mappable formats. The enumeration of challenges and techniques can be likened to looking at the tip of an iceberg, given that the compendium of raw data is still growing.

The types of processed data that can be generated from GIS include, but are not limited to, high-resolution printed maps and digital maps. Both formats can be used to visualize both the chronology of changes with Metro Manila's transport system, and overlays of spatial data such as topography, geologic features, land use, and

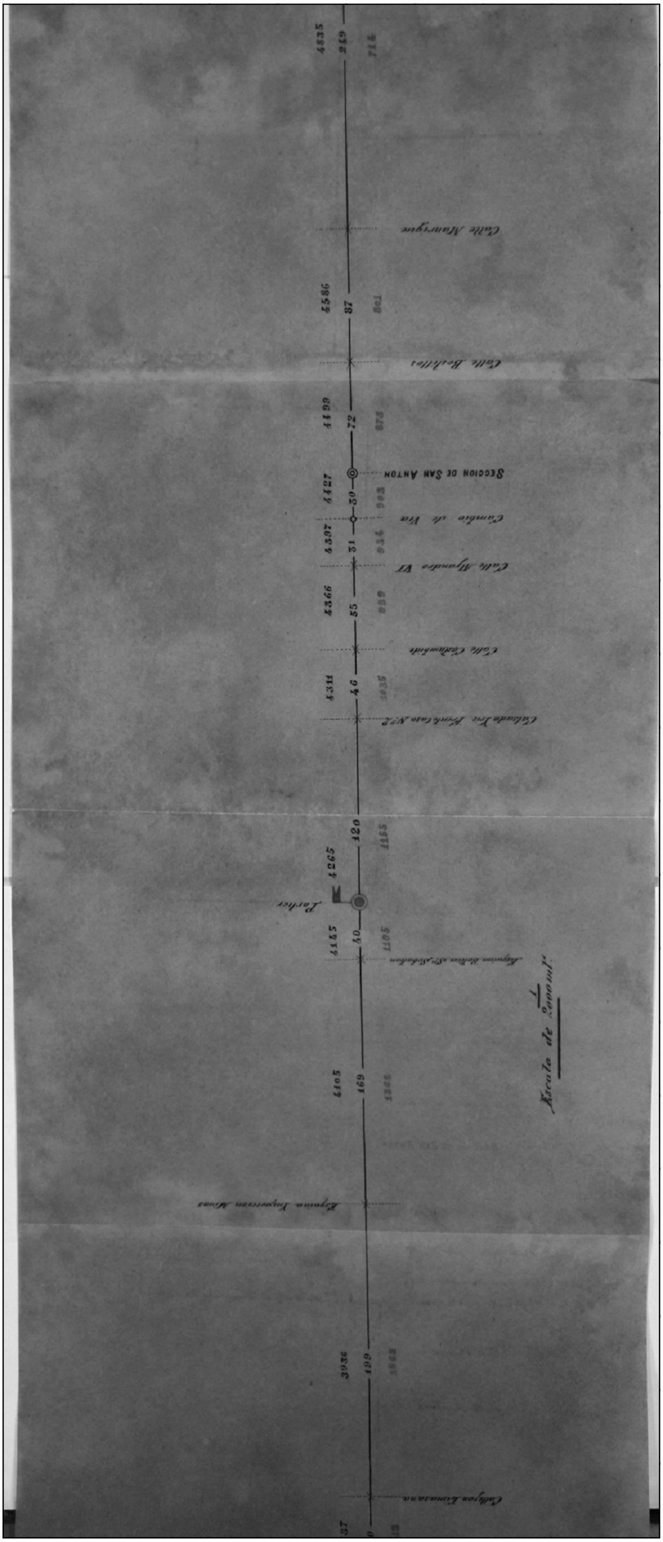

Figure 11. A portion of the ytinerario of the tranvia lines in Manila. *Source:* Tranvias SDS No. 5291 Page 645E.

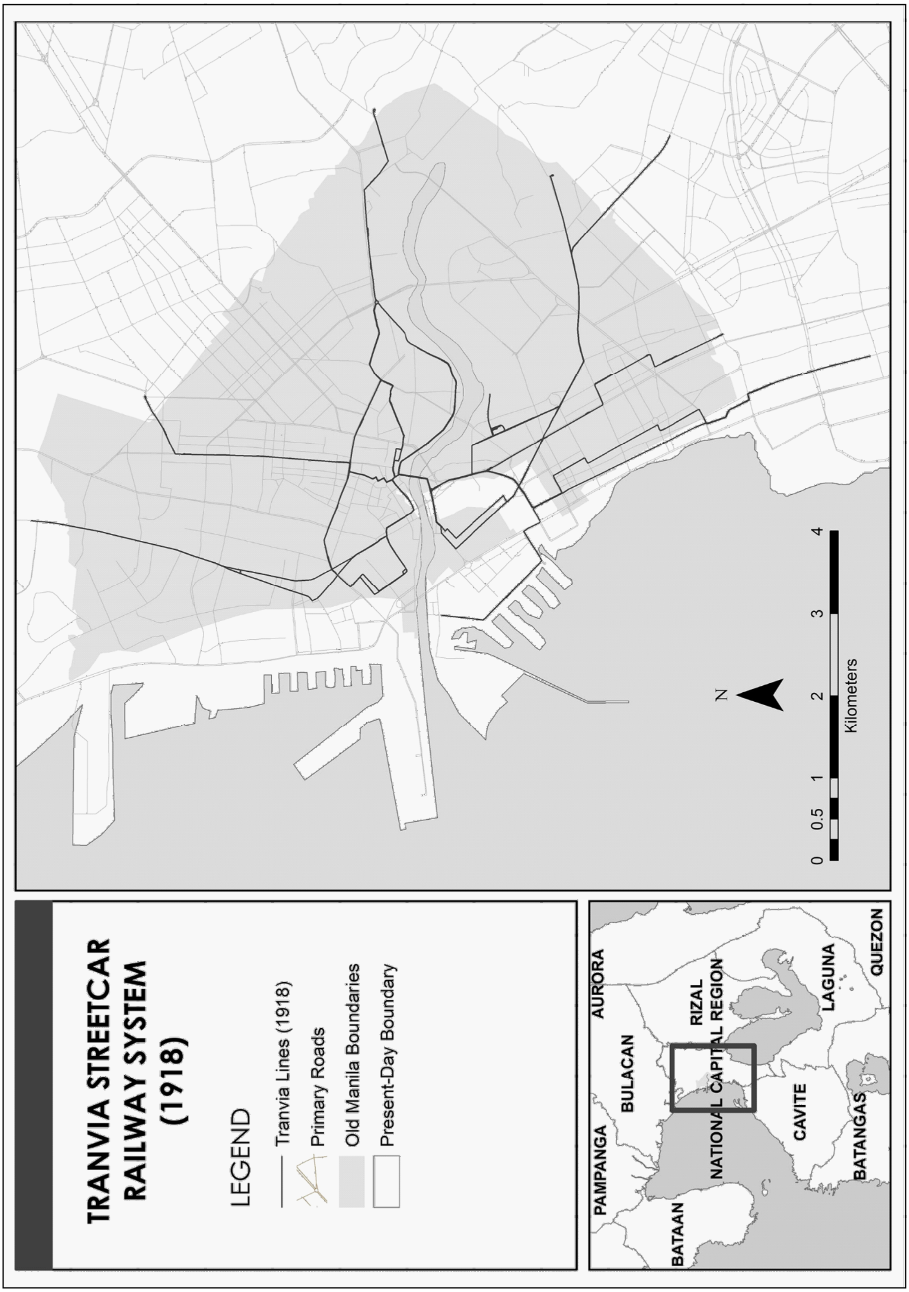

Figure 12. 1918 Manila tranvia lines overlaid with the present-day road network and old Manila boundaries in a GIS environment.

settlements. The superimposition of these layers allows for better appreciation of the environment in which the rail systems developed.

More flexibility and greater resolution is expected with the digital map format. As shown in the example of the digitized line of the Manila Railway Company (figure 3), changing the view scale or zooming in on the digital map in a computer reveals more information about the dataset. Digital maps allow paperless animation and web-based presentations. These can also be seamlessly uploaded to websites where users can interact with the data through Google's interface.

In addition to maps, GIS can also be used to create digital shapefiles of historical geographic features such as railways, roads, and waterways as digitized and georeferenced. The shapefiles can then be shared among cartographers and transport planners, and they can be used for analytical purposes such as transport modeling.❁

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