Cartographic Reconstruction and Spatial Analysis of Manila's Historical Railway System and Land Use (1895-1925) using a Geographic Information System

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Abstract: Archival documents, maps, and plans were digitized and adopted in a Geographic Information System (GIS) to cartographically reconstruct the urban railway system of Manila (1895-1925). Commonly known as the *tranvias*, the lines traversed by these rail-based streetcars were mapped against indicators of land use such as the population of Manila's historical districts, concentration of built-up areas, and dominant construction materials used per district. Railway statistics such as rail lengths and densities were also computed whenever applicable to provide better insight to the cityscape's history.

The study focuses primarily on the application of GIS methods to historical transport studies as it seeks to visualize the transport and land usage history of Manila and uncover trends in historical urban transport planning and land use development in the Philippines as well as contribute to the growing literature and set of techniques employed in Historical GIS.

Keywords: GIS, Railways, Manila, Transport, Mapping, Historical GIS

1. INTRODUCTION

1.1 The *Tranvia* and GIS

Historico-geographical research on mass transit systems and the localities they serviced can be likened to fitting the pieces of a jigsaw puzzle. The fragments of information can be found in various and often separate, incompatible sources such as transport plans, physical and electronic archives, and historical maps. These apply to the early rail-based transport system in Manila. Commonly known back then as the *tranvia* (plural "*tranvias"*), these electric-powered streetcars roamed the city on their tracks, alongside cars, autobuses, and other modes of transportation in the early 1900s. An image of the *tranvia*, taken from the collection of Philippine-History.org (2017), is displayed in Figure 1.

This research focuses on integrating information from these archival sources and applying modern techniques in Geographic Information Systems (GIS) to visualize how the railway lines changed from 1885 to 1925. GIS is also used in overlaying the rail system with indicators of the configuration and intensity of land use in Manila over time. This was done to illustrate the coincidental development of Manila's cityscape and transport network. Quantitative spatial analysis such as the determination of rail lengths and rail densities per district was also applied.

Map overlays in GIS reveal that areas with high railway density had relatively more concentrated land use based on indicators such as population, concentration of built-up areas, and the most dominantly used construction material for structures. This research also highlights the methods employed and the challenges encountered in implementing GIS to the dataset, as well as the methods employed to address these challenges.

Figure 1. The Manila electric *tranvia* circa 1900s

1.2 The Study Area

Manila, formally the City of Manila, is the capital of the Philippines. It is located in the island of Luzon, at the northern portion of the Philippines, and it is bounded by the Manila Bay in the west. Its centroid is located at 14.5995 degrees north and 120.9842 degrees south and it has a present-day land area of around 43 square kilometers (PHIVOLCS, 2013) after subsequent reclamations toward Manila Bay. Manila became the seat of the Spanish colonial government in the mid-1500s. Old Manila, currently referred to as *Intramuros* or "inner city", was fortified with walls for protection from invaders and native uprisings (The Philippines Company, 1899). This study deals with this Manila of the past, specifically Intramuros and the eleven (11) districts identified as its suburbs (see Figure 2). Most of the land area of these districts are comprised by the present-day city. However, the total land area of Intramuros and its districts in the early 1900s are estimated at 26.3 square kilometers using GIS.

1.3 Scope and Limitations of the Study

The time coverage of 1885 to 1925 was selected based on the current availability of data and historical documents from the National Archives of the Philippines (NAP), online libraries, and the collection of the Manila Electric Company (MERALCO) Museum. It is important to note that most of the *tranvia* before 1905 were horse-drawn rail cars, except for the steam-powered cars that run from Manila to Malabon in the north. *Tranvias*, since 1905, were exclusively operated by MERALCO and were all electric-powered. However, this distinction among the power sources used by the streetcars and the car types were no longer represented in this paper's maps.

There was a significant decrease of available maps and documents on the *tranvia* after 1920s due to what would be the eventual shift of the rail-oriented transport to autobuses in Manila (MERALCO Rail System Report, 1941). The maps generated in this study, as shown in the chapter dedicated to cartographic findings, do not represent a strict time-series of the birth, augmentation, and decommissioning of *tranvia* lines using equal intervals of years or decades. Instead, it should be noted that the rendered maps are snapshots of transport, land use, and demographic data of Manila across irregular intervals due to data availability. The development of transport networks is, after all, sporadic and spasmodic in nature with respect to time and location (Lowe and Moryadas, 1975). Nonetheless, it can be said with confidence that these snapshots can provide substantial insight on Manila's transport more than a hundred years ago.

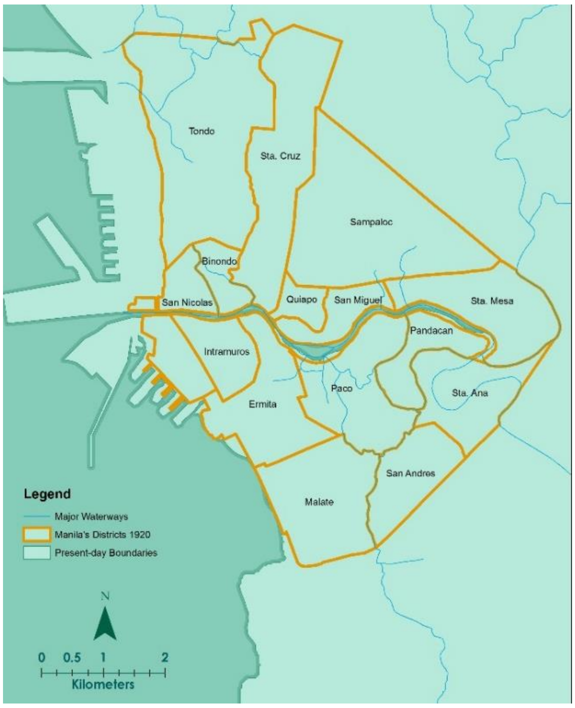

Figure 2. A map of Old Manila – Intramuros and its suburbs

2. LITERATURE REVIEW

2.1 Spatial Variables to be Mapped: A Conceptual Framework

Land use can be defined as how humans transform land by building structures and designating areas for particular purposes (Serote, 2004). It may refer to how people modify or manage the natural environment to accommodate settlements and establishments. Land use may also refer to a land cover classification system according to how people use, change, or maintain land, and such may be characterized according to its intensity (FAO, n.d.). In the context of urban planning in Metro Manila, land use intensity generally pertains to the degree of the utilization of space and the construction of physical structures with respect to the locality's total land area and these variables are highly related to an area's population (Magno-Ballesteros, 2000). This preliminary study postulates that the patterns of *tranvia* lines are interconnected with the intensity of land use. The latter can be indicated by the patterns of population density and settlements and number and agglomeration of establishments, as well as the dominant building material used for each district. Additionally, overlaying old maps and information from the reports of the Municipal Board of Manila (1905) reveal that there was less concentration of *tranvia* lines in Manila districts where *nipa* was used as the primary construction material of housing and establishments.

The methodology in this paper was inspired by several historical transport studies and cartographic strategies. Felis-Rota (2012) correlated the growth of urban settlements in England from 1851 to 2000 with the expansion of the railway system while the work of Wang (2006) mapped China's railway in the 1900s against the location of the then-emerging residential areas. In both studies, there are noticeable agglomerations of settlements, and hence built-up areas, along the rail systems. Felis-Rota and Wang, although they did not conclude a causal relationship between rail and land use, have established co-development between the two variables across history and space. It should be emphasized that these works dealt with large study areas and the stance of this research is that the same relationship between rail and land use can be observed at the city level.

For instance, Levinson (2007) used data on population and railway densities in London from 1871 to 2001 in an attempt to disentangle the chicken-and-egg question of which came first in the city – the rail network or land use development. Rail density was generally defined as the total length of rail tracks in a borough divided by the land area. Levinson found out that the current configuration of land use and population distribution in London greatly co-developed with the high rail density at the city's center. The transport system facilitated the transition of London's center from a place with "high-residential and commercial densities to one with low residential and very high commercial densities" (p.19). The rail network followed a radial form to connect commuters from more exterior locations to the city center, while a dense network could be found near and at the center itself. While the rail network of London was much thicker and more intricate across its 33 boroughs, the concentration of lines at a central area and the radial pattern of the rails to the suburbs is very similar to the *tranvia* lines of 19th century Manila. As for this study, information on Manila at this point is sufficient only to map and describe the changes of rail and land use, but not enough to establish a cause-and-effect relationship between them. After all, it is an established paradigm in the field of transportation studies that there is a positive feedback relationship between land use and transport systems (Hoel, 1992). That is, land use intensifies transport systems and transport enhances land use growth simultaneously.

This study also follows the framework employed by the Metro Manila Commission (MMC, 1985) in assessing the impacts of LRT-1 stations to their nearby areas. The MMC selected variables which serve as proxy indicators of land use and it was determined that variables such as lot size and ownership, foot traffic, and agglomerations of commercial establishments positively correlated with the locations of LRT-1 stations. In particular, some stations were surrounded by sizeable commercial plots such as the Galleria Baclaran and the Gotesco Shopping Complex. Hence, the LRT-1 stations served as transport nodes – nuclei which attracted a larger number of people and activities within the area. These transport nodes have high potential for trip generation which, in the context of transport studies, refers to locations that serve as source of commuters. The aggregated number of travels within an area is referred to as total trip demand (Lowe and Moryadas, 1975). Ultimately, mapping trip demand is required in transportation planning and in determining the location of transport stations with respect to where trips are generated (Ortuzar and Willumsen, 2001).

It can be argued, however, that these more recent studies on transport and land use such as by the MMC used approaches and measures which may not apply to 19th and 20th century Manila. It is mandatory to perform some adjustments in applying present-day methods to assessing the impacts of a historical transport system. In particular, statistics is scarce for foot traffic and land valuation in Old Manila. The lack of trip generation and trip demand data also limits the amount of quantitative analysis that can be performed. As such, indicators of land use become the most viable gauge of the locational effects of the *tranvia* lines and stations since they are usually documented or mapped by the city's planning and engineering sectors. Three general land use characteristics are chosen for mapping and analysis in this study, namely 1) population, (2) land use intensity as indicated by the location of built-up areas, and (3) the dominant type of construction materials used for the buildings in each district of Manila. These variables are then mapped against the locations of *tranvia* lines. The overlaid information can be visually scrutinized in a GIS-environment, as discussed in the following section. Illustrated in Figure 3 is the conceptual framework employed in this study's cartography:

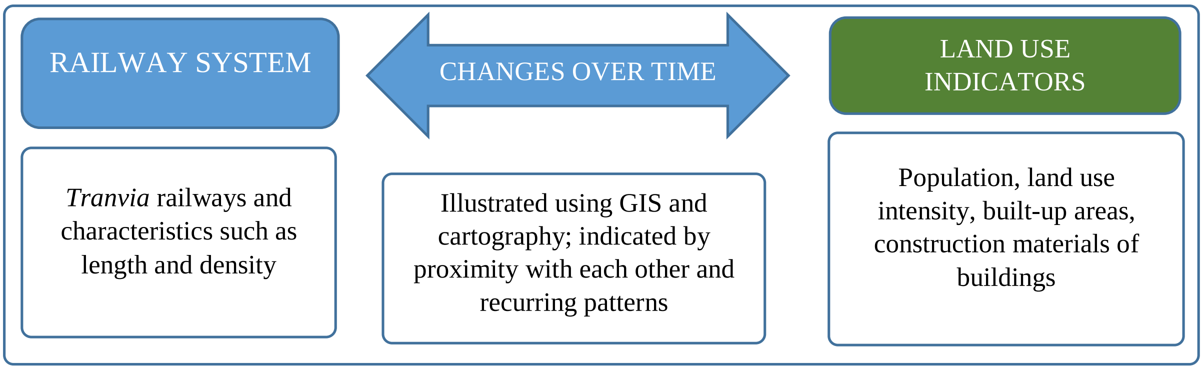

Figure 3. Conceptual framework of the mapping of historical railways and surrounding land use

3. METHODOLOGY

3.1 GIS and Supporting Applications

A Geographic Information System (GIS) is a system of hardware, software applications, methods, and operators which uses digital spatial information to create a database to produce maps. It is a tool for cartography and analysis of spatial data. Besides visualization by mapping, GIS allows the user to answer queries of location, pattern, proximity or distance across various scales of analysis (Bolstad, 2005). A GIS database is commonly referred to as a "geodatabase" since all entries in it are attributed with locational characteristics, which may be in the form of latitudinal and longitudinal coordinates. Given sufficient information, GIS can be used to perform sophisticated analysis such as transport modeling and pattern analysis.

Google Earth and ArcGIS 10, a dedicated Windows GIS application, are used in processing historical transport maps in this paper. Google Earth is a global map and satellite imagery viewer with basic tools for navigation, cartography, and geo-tagging. The collection of satellite images in Google Earth was used to verify the correctness of features in the historical maps through comparison of the geometries of land and water features as illustrated in the old maps versus those captured in satellite photos. Google Earth was also used to search and compare place and street names over time. This was done in order to correctly tabulate street information in the geodatabase, since most present-day street names in Manila are different from their historical names.

Shown in Figure 4 is the process of manually overlaying a photo of an old map over Manila in Google Earth. Note that this process is completed by manually stretching the edges of the overlaid map to be visually congruent to the features of the current cityscape. It was observed that present-day primary roads in Manila are mostly identical with major roads back in the early 1900s. Overlaying simplifies the task of matching historical road names with present-day names, as well as tracing how the place names have been changed through the decades. It is also notable that the profile of the Pasig River remains barely unchanged over the past century. This greatly aided the georeferencing process, which is further discussed in the succeeding sections. The rather slow geomorphology of the river, however, is not part of the scope of this study.

ArcGIS 10, on the other hand, is a program developed by the Environmental Science Research Institute (ESRI). ArcGIS was used in georeferencing the historical maps and creating a comprehensive geodatabase of railways, streets, population, and land use. It is also used as the primary software for drawing map features as well as map symbolization. The overlay analysis of these aforementioned variables and the final layout of the maps were also completed in ArcGIS 10.

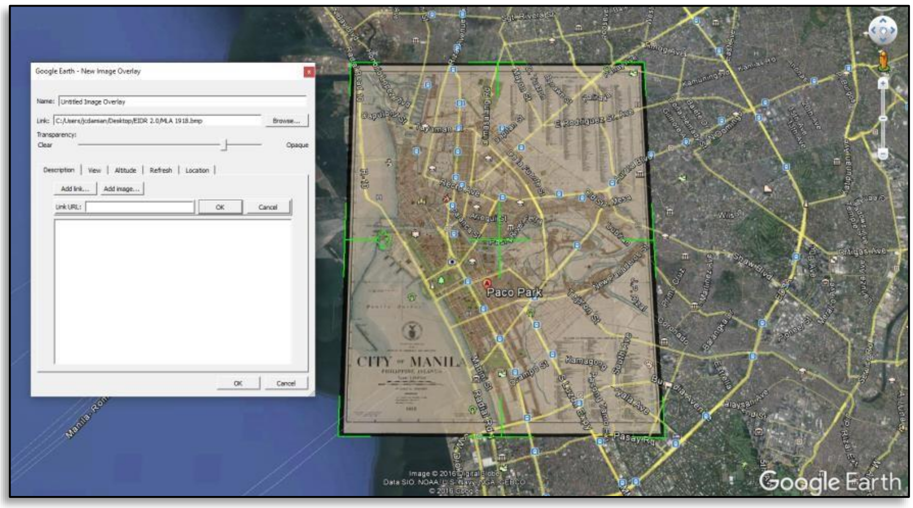

Figure 4. Overlaying historical maps by manual stretching in Google Earth

3.2 Georeferencing

Digitized historical maps are not automatically recognized by GIS as attributed with spatial information. Such digital images are initially accepted as plain pictures or rasters unless they become georeferenced. Geographic referencing or georeferencing is the process where points on a scanned map are matched with a projected coordinate system by assigning them actual latitude and longitude values. Apart from attributing scanned images with locational characteristics, georeferencing also allows the measurement of lengths and areas of geographic features (ESRI, 2009). This process is commonly known among GIS practitioners as "rubbersheeting" since it involves stretching and warping historical maps to match the geographic projection and geometry set in a GIS environment (Rumsey, 2002).

Georeferencing entails the selection of control points or easily identifiable locations on both the historical map and the locationally-accurate GIS environment (ESRI, 2009). In effect, the control points anchor parts of a scanned map onto their identified locations in a GIS environment. The other parts of the map are stretched or "rubbersheeted" according to the locations of the control points. For this study, cross-referencing the names of places and streets and the top-view profiles of areas across ArcGIS, Google Earth, and the historical maps were done to verify the correctness of georeferencing. `

Figures 5 below is a screenshot of the georeferencing process in ArcGIS 10 for one of the maps used in this study. The GIS screen is zoomed out to show John Bach's map (1920) and the shapefile to where it was matched. There is no strict rule stating the number and how to select control points across a map. At least two should be selected to initiate the process and increasing their number tends to improve the locational match between GIS and the scanned map (ESRI, 2017).

Alternatively, georeferencing can be performed by looking for tick marks or geographic grid intersections on the old map, which carry degrees latitude and degrees longitude values given that they are included or still readable from the old documents. These intersections can be selected as control points and their coordinates can be directly entered to ArcGIS for rubbersheeting.

Maps from the Meralco Museum and the NAP include some notable control points which were easily identified since they remain unchanged over the period of study even up to the present-day. Some of them are the southern end of Jones Bridge which crosses the Pasig River, the northeast corner of the Manila Northern Cemetery, and the rotunda in Paco Park. It is also noteworthy that the profile of the Pasig River across Manila stayed the same across the decades, so sections of it were also used as control points.

Finally, the correctness of rubbersheeting can be measured through visual inspection and by looking at the individual residual values of each control point. Residual values, or simply residuals, are numerical measures of how each control point caused stretching across the digitized map (ESRI, 2009). If the majority of residual values tend to be low or close to zero, it means that the georeferencing process resulted in a generally good fit. It should be emphasized that a perfect match in rubbersheeting i.e. zero residuals for all control points may be difficult to achieve especially when georeferencing old maps (Felis-Rota, 2012). Distortions are inevitable due to differences with scale or even perhaps due to damages to the original documents (Rumsey, 2002).

It was fortunate that most historical maps used in this research were marked with coordinate systems and respective grid and tick marks, hence rubbersheeting yielded generally good results. Case in point, the residual in Figure 5 is equal to zero. In contrast, the resulting rubbersheeted map of Manila (1885) in Figure 6 looks slightly warped when adopted by the digital map in GIS, an indication that there were distortions possibly caused by physical damage to the original map. From this point, any feature such as road, railway, or land use to be digitized from the georeferenced map were accurately attributed with locational information.

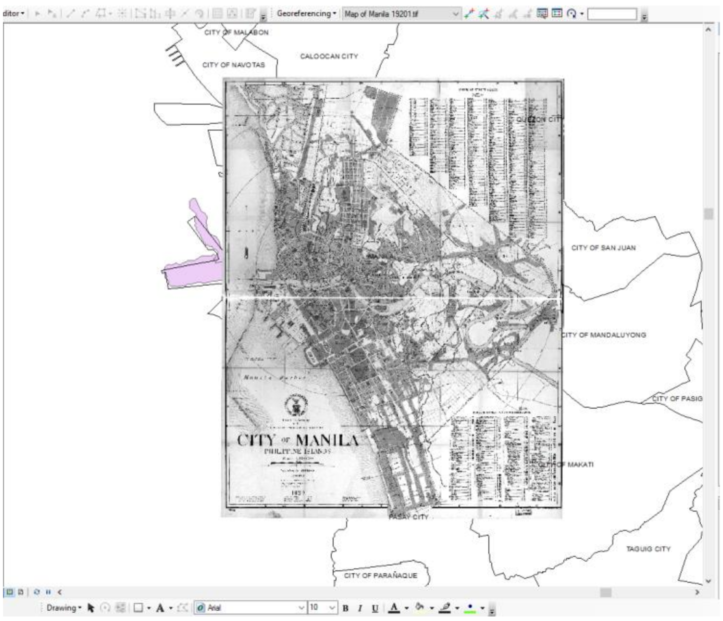

Figure 5. A historical map of Manila (1920), georeferenced in GIS

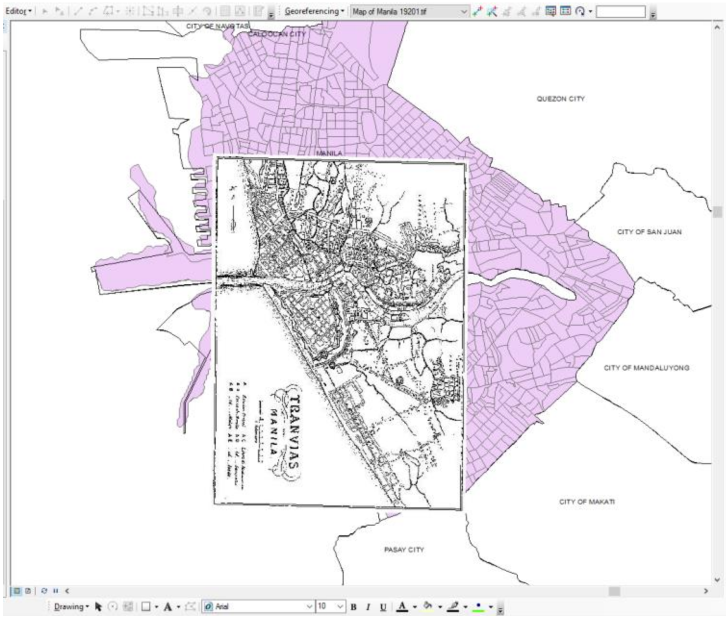

Figure 6. Systematic warping is inevitable for some historical maps to be georeferenced

All other scanned and digital maps were georeferenced according to the methods stated above. Using tick marks is often the better alternative because they often yield zero residuals and their coordinates are explicitly given instead of manually selecting control points, which is often a trial-and-error process. However, not all historical maps contained these grid markings and therefore required the latter treatment.

3.3 Digitization: Drawing Old Manila's Boundaries and Transport-related Features

Digitization in GIS refers to the process of creating new map elements by outlining a geographic feature on a map (ESRI, 2009). This effectively creates a new file for features such as *tranvia* stations, railways and roads, and district boundaries. Such objects, when traced and rendered as new GIS files, are represented by points, lines, and polygons, respectively. As long as they are drawn on a georeferenced map, the features are attributed with correct latitude and longitude coordinates automatically. Figure 7 shows a portion of the georeferenced map of 1918 Manila, with solid dark red lines representing the *tranvia* railway system. These lines are only recognized by the GIS as a spatial feature after digitizing, shown by the thick yellow line in the same figure.

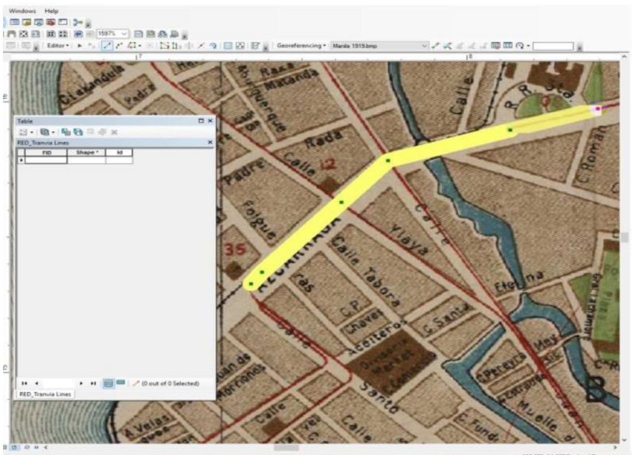

Figure 7. Digitizing in GIS and the resulting attribute table

An important consequence of digitizing in ArcGIS 10 is the creation of a tabular database known as the attribute table. The attribute table can carry locational, temporal, qualitative, and even quantitative information about all the objects mapped in a geodatabase (ESRI, 2009). Every feature digitized in the system has a corresponding entry and the table fields and entries can be edited and shared among GIS users. Furthermore, geometric characteristics such as lengths in kilometers of linear features or land area in square kilometers of shape features can also be computed in the attribute table. As such, it was necessary to reconstruct historical Manila and its districts with defined shape boundaries in GIS to serve as basis for areal computations and to provide clear illustrations. Unfortunately, early maps of the area do not contain clear-cut boundaries of Intramuros and its suburbs. Instead, they contain floating place names as labels to show the rough location of districts. The task required compositing several maps from 1900 to even beyond 1925 to approximate the appearance and locations of these district boundaries. Case in point, maps on the medical-geographic history of Manila from 1903 to1939 (Pante, 2011) were used in the cartographic reconstruction of Old Manila (see Figures 8 and 9, respectively).

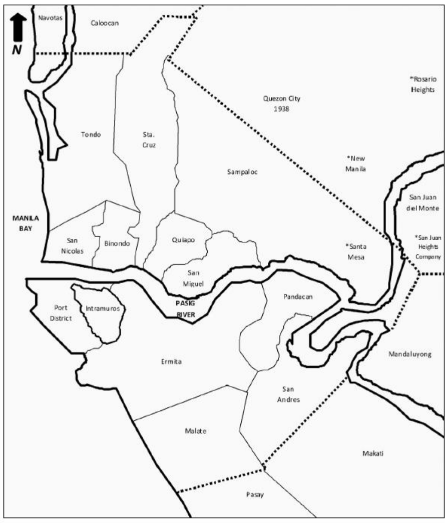

Figure 8. Map of Manila and adjacent towns, circa 1939, based on a map from the Philippine Commission of the Census, 1940 Manila subsection (Pante 2011, p.189)

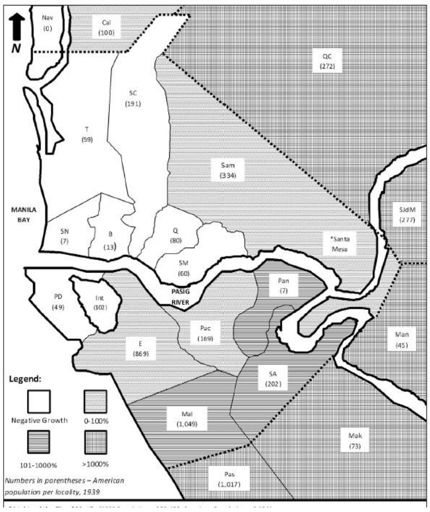

Figure 9. Map of the distribution of resident Americans in Manila and its environs from 1903 to1939 (Pante 2011, p.196)

The coastal profile of the city and the boundaries of the old districts are drawn by compositing maps of Manila from 1903 to 1925. Shown earlier in Figure 2 are the overlaid present-day and historical coastal boundaries of Manila while Table 1 contains the resulting estimates of land areas for each of the districts. These would then be used in computing for the population densities and railway densities in the succeeding sections.

Table 1. Historical districts of Manila and respective land areas as estimated in GIS

District	Area (sq.km)
Binondo	0.6
Ermita	1.31
Intramuros	**0.55**
Malate	2.03
Paco	2.35
Pandacan	1.52
Quiapo	0.74
Sampaloc	7.28
San Miguel	0.79
San Nicolas	0.51
Santa Ana	3.25
Tondo	5.39
MANILA (TOTAL)	**26.32**

3.4 Notes on the Projection System

Since distortions and errors are inevitable when representing real world measurements in maps (Monmonier, 1991), it is important to mention that a Projected Coordinate System (PCS) is used for the geodatabase and all the maps in this study. Specifically, the projection applied to all shapefiles in the geodatabase is the PCS Universal Transverse Mercator (UTM) for Zone 51N, World Geodetic Survey (1984). Unlike Geographic Coordinate Systems (GCS) which are based on spheres or spheroids, PCS is projected onto a flat surface with constant angles and areas (ESRI, 2017). Such system is required in order to compute land areas, rail lengths, and densities with minimal errors due to projection.

UTM Zone 51N is suitable for places located between 120 and 126 degrees east and from the equator up to 84 degrees north. Countries that belong in this projection zone include the Philippines, China, Indonesia, Japan, North Korea, and South Korea (GeoRepository, 2017).

3.5 Mapping Historical Locational Information in Text Format: The Case of Philippine Commission Act No. 484

GIS can also be used in digitizing objects that were not mapped in historical documents in the first place. A rail segment, for example, can be digitized when its terminal stations or its stops are mentioned explicitly and the cartographer is able to reconcile historical place names with present-day names. This functionality can be used to map transport plans or ideas which were drafted in text form but never implemented or were never mapped at all. Case in point, several *tranvia* rail plans were mentioned in The Acts of the Philippine Commission (Act Numbers 425-949) Volume VIII compiled by the War Department of the Bureau of Insular Affairs and printed in 1904. Note that the entirety of these plans did not materialize as illustrated in the following series of maps. Nevertheless, mapping these hypothetical lines provide additional insights.

Meanwhile, Act No. 484 was ratified in 1900 and provided the granting of a franchise to Meralco to construct an electric street railway on the streets of Manila and its suburbs. Paragraph 2 of the Act indicated segments of roads and streets which were intended for excavation, construction, and the eventual operations of the electric *tranvia*. The supposed trajectory of the lines are summarized below:

A. From the south end of the Bridge of Spain, along Calzada de Magallanes, across Plaza de Martires, Calle de Santo Tomas, Calle Cabildo, Calle Fundicion, Calle Palacio, through the wall and across the moat to Paseo de Vidal, then along Paseo de Bagumbayan, Calle San Luis, Calle Real, Calle Cabanas, then over the Bridge of San Antonio, then finally to the race track in Pasay
B. From the eastern end of Calle Aduanas to Calle Palacio, then to Calle Fundicion
C. From the southern end of the Bridge of Spain to Paseo de Vidal, Calzada de Nozaleda up to its junction with Calzada de San Marcelino
D. From the junction of Calzada de Vidal and Calle Concepcion, Calzada de San Marcelino, Calle de Nozaleda, Calle Real in Paco up to its end in Santa Ana
E. From the southern end of the Bridge of Spain to the Bridge of Santa Cruz, across the Bridge of Santa Cruz through Plaza Goiti, Calle Echague, Calle San Miguel, Calle General Solano, Calzada de Aviles, and along Calzada Santa Mesa to Santa Mesa
F. From Plaza Goiti to Plaza Santa Cruz, Calle Enrile, Calle Lacoste, Calle Carballo, Calle Nueva, and finally to and across the Bridge of Spain
G. From the intersection of Calle San Jacinto and Escolta, along Calle San Jacito to Calle Sacristia, then across the Bridge of Binondo to Calle San Fernando, Calle Madrid, Calle Aceyteros, Calle Sagunto, Paseo de Azcarraga, Calle General Izquierdo, Calle San Bernaldo, Calle Paz, Calle Bilibid, Calzada de Iris to Plaza Santa Ana, then along Calle Alix to Rotunda de Sampaloc
H. From the intersection of Pase de Azcarraga and Calle Ylaya, along Calle Ylaya around Plaza Leon XIII, to and along Calle de Sande to the Reina Bridge
I. From the intersection of Paseo de Azcarraga, along Calle de Reina Regente, across the Bridge of Maura, then to the intersection of the line on Calle Sacristia
J. From the intersection of Calle San Bernaldo (Calle Paz) and Calle Arranque to the intersection of Calle Arranque and Calle Lacoste
K. From the intersection of Calle de Bilibid and Calle Cervantes, along Calle Cervantes to the race track in San Lazaro
L. From the northern end of the Bridge of Spain along Escolta, across the bridge over the Sibacon Estero to Plaza Santa Cruz

Using various historical street maps and Google satellite imagery of present-day streets with labels, the aforementioned lines were digitized and overlaid with the boundaries of Intramuros and its surrounding districts (See Figure 10). Note, however, that the locations of some of the planned lines have not yet been identified at this stage of the research.

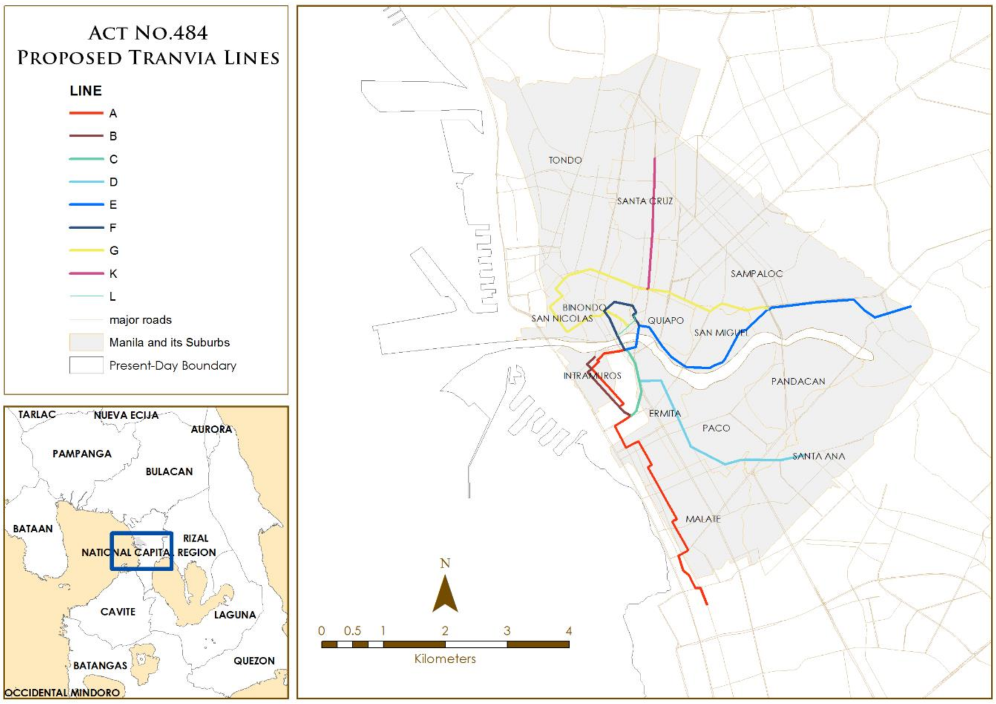

Figure 10. Planned street car lines as stated in the franchise granted by Act No. 484 of the Philippine Commission. The line labels A through L correspond to the list in Section 3.5

4. CARTOGRAPHIC FINDINGS

4.1 The Railway System Over Time

The maps in this section are products of rubbersheeting and digitization of several maps and historical text from 1895 to 1925. The *tranvia* system of 1895 (Figure 11) shows a pattern clustered around the districts of San Nicolas, Binondo, Quiapo, and Intramuros. Two of the lines reach out eastward to the districts of Sampaloc and San Miguel, while a line from Intramuros reaches southward to Malate. It is evident that Act No. 484 of the Philippine Commission (Figure 10) was intended to use the 1895 configuration as nucleus in expanding to the suburbs – expanding yet still maintaining high concentration of rail in the core areas north of Intramuros.

Year 1905 (also in Figure 11) on the other hand illustrates the first year of Meralco in operating the streetcars. It can be seen that the lines reached as far as Malabon to the north and Pasay to the south. Changes from 1905 to 1925 are easy to miss upon visual inspection except for the augmentation of the east-southeast line toward Santa Ana. Also, there have been some changes with the configuration of the lines within Intramuros as seen upon comparing Maps B and C, which can be seen as the removal of some tracks within the area. Generally, the configuration of the rail lines remained stable over the course of 20 years since 1905.

Besides visualizing the rail system, numerical figures that serve as indicators of land use have been placed in their respective attribute tables. This was done so that they could be symbolized using graduated colors and used to generate statistics for the time period. For example, computation in ArcGIS reveals that a total of 68.37 kilometers of *tranvia* lines were operational in 1918 in the study area. Meanwhile, the district boundaries would be used to compute the percentage of rail that were enclosed in each district's area. The bar graph in Figure 12 shows thetotal length of operational rail across the years. There were noticeable augmentations with the system between 1895 and 1905, while the total length of the rail was maintained at around 70 kilometers from 1905 to 1925. Thus, it can be inferred that changes with the rail over the last 20 years of the study period involve the disassembling and transferring of certain rail segments from one place to another and that little to no new rail lines were constructed at the time.

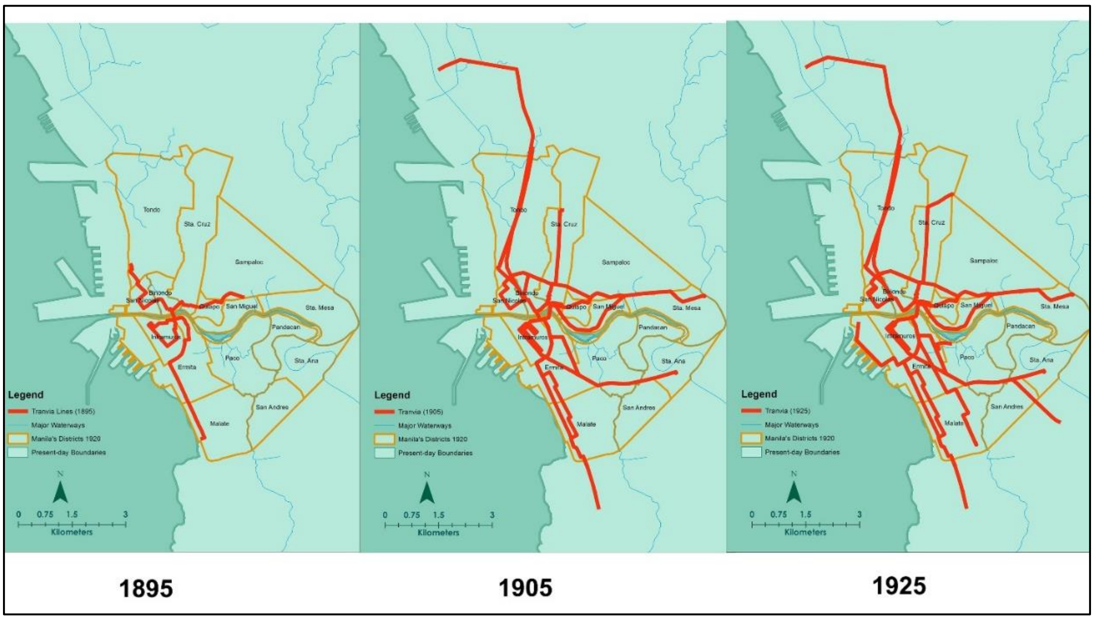

Figure 11. GIS-rendered *tranvia* railways (1895, 1905, and 1925)

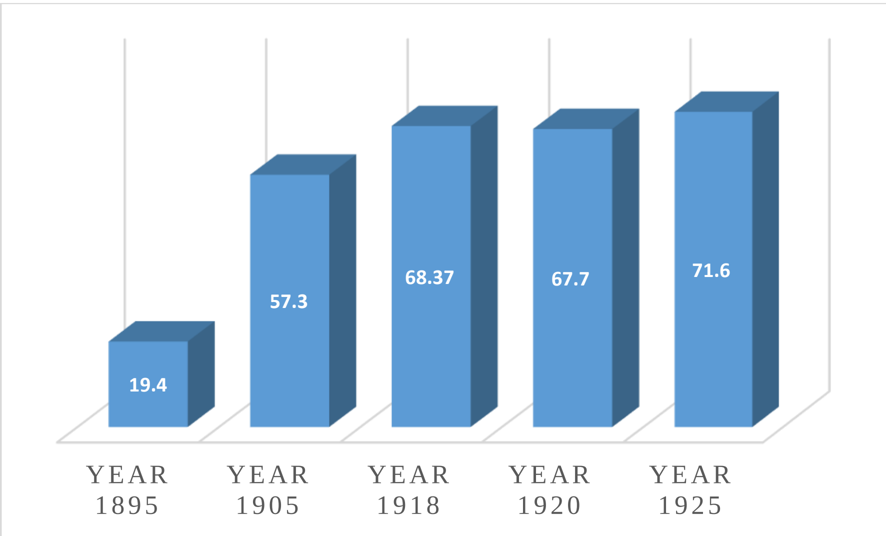

Figure 12. Length in kilometers of operational *tranvia* railways in the study area

4.2 Land Use and Rail-related Statistics

As mentioned earlier, population and the nature of construction materials in the area were used as indicators of land use. It was hypothesized that patterns between rail distribution and land use characteristics can be identified. As such, further computations in ArcGIS are summarized in the attribute table in Figure 13. District population data is obtained from the 1903 to 1925 statistics, as printed by the Department of Commerce and Labor, Bureau of Census. The previously determined land areas of the districts were used to find the respective population densities (“DENSITYYEAR” i.e. the ratio of the population and the variable “LANDAREA” in square kilometers). The table also includes the “RAILDENSITY” variable, wherein the total length of *tranvia* lines enclosed by a district is divided by the respective usable land area of the district. This is done to determine whether certain areas were prioritized in constructing the early railway system, since these areas are not easily discernible with visual inspection. Finally, a value called “POPRATIO” is generated as descriptive statistic pertaining the length of *tranvia* railway in meters per person. Note that a variable “OBJID”, short for “object ID”, is created just for the ease of matching the attribute table with other map databases used in this study. The values in the OBJID column are purely arbitrary.

DISTRICT	LANDAREA	POP1903	POP1918	DENSITY1903	DENSITY1918	LENGTH1903	LENGTH1918	RAILDENSITY1918
Binondo	0.56	16657	15696	29744.64286	28028.57143		3609	6.444642857
Ermita	1.31	12246	14371	9348.091603	10970.22901		7971	6.084732824
Intramuros	0.55	11460	13027	20836.36364	23685.45455		2186	3.974545455
Malate	2.03	8855	14663	4362.068966	7223.152709		4244	2.090640394
Paco	2.36	6691	14277	2835.169492	6049.576271		6491	2.750423729
Pandacan	1.52	2990	5215	1967.105263	3430.921053		0	0
Quiapo	0.74	11139	14128	15052.7027	19091.89189		4593	6.206756757
Sampaloc	7.28	18772	35346	2578.571429	4855.21978		5848	0.803296703
San Miguel	0.79	8834	3949	11182.27848	4998.734177		3311	4.191139241
San Nicolas	0.51	29056	25972	56972.54902	50925.4902		2575	5.049019608
Santa Ana	3.25	3255	5950	1001.538462	1830.769231		3226	0.992615385
Santa Cruz	2.94	35030	46518	11914.96599	15822.44898		4742	1.61292517
Tondo	5.39	39048	71905	7244.526902	13340.44527		5309	0.984972171

Figure 13. Screenshot of the attribute table for rail, area, and population-related statistics as displayed in ArcGIS 10

Averaging rail lengths over the districts reveal that the same districts have been prioritized from 1905 to 1925. Shown in Figure 14 are the respective percentages of each district when it comes to the percentage of rail length enclosed within each boundary.

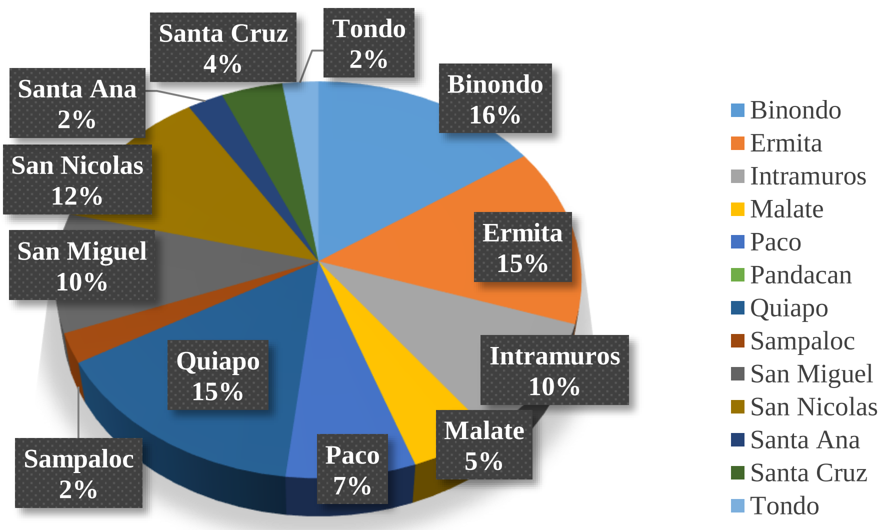

Figure 14. Percentage of rail lengths across the study area (1905-1925)

Mapped in Figure 15 are the populations per district in 1903 and 1918 respectively. They were overlaid with the railway configurations of 1905 and 1925. In Figure 16 and 17, maps of years 1903 and 1918, respectively, shows that the distribution of population densities changed little over the course of 15 years. The color gradients show that there had been an increase in population but it can be inferred that districts such as Binondo and Quiapo remained to be activity and settlement centers over the time-period of the study. It is notable that these areas are clustered around Intramuros and most of them lie at the northern bank of the Pasig River.

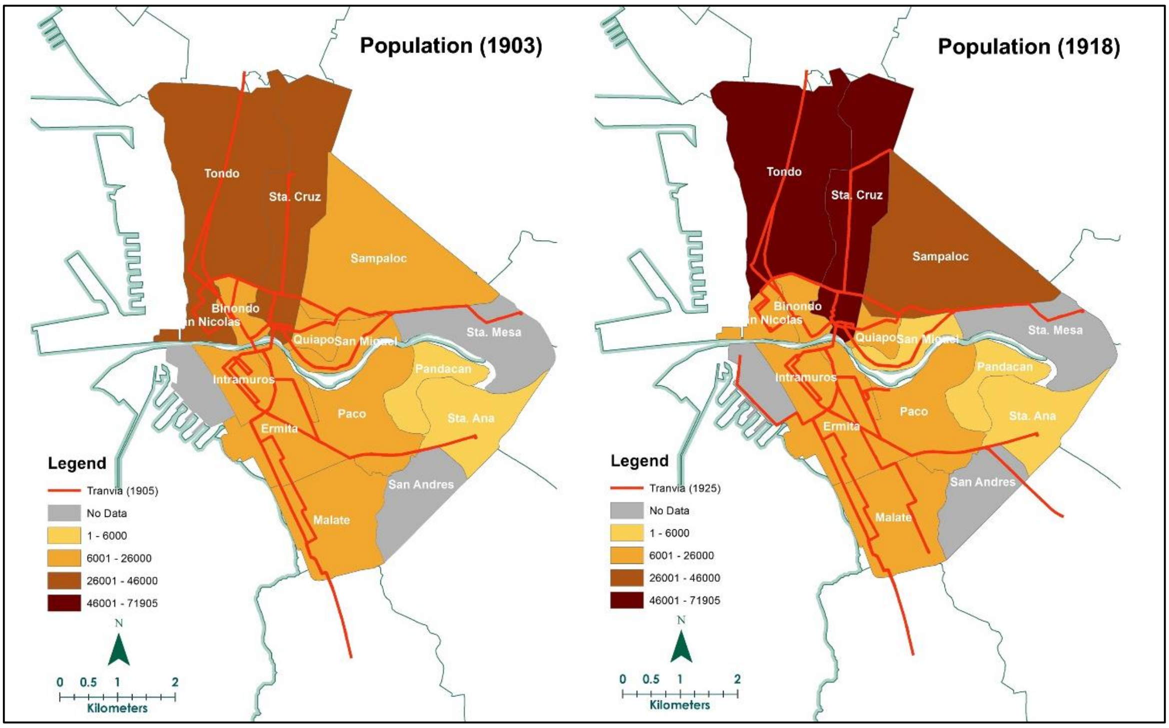

Figure 15. Railways and district populations of 1903 and 1918

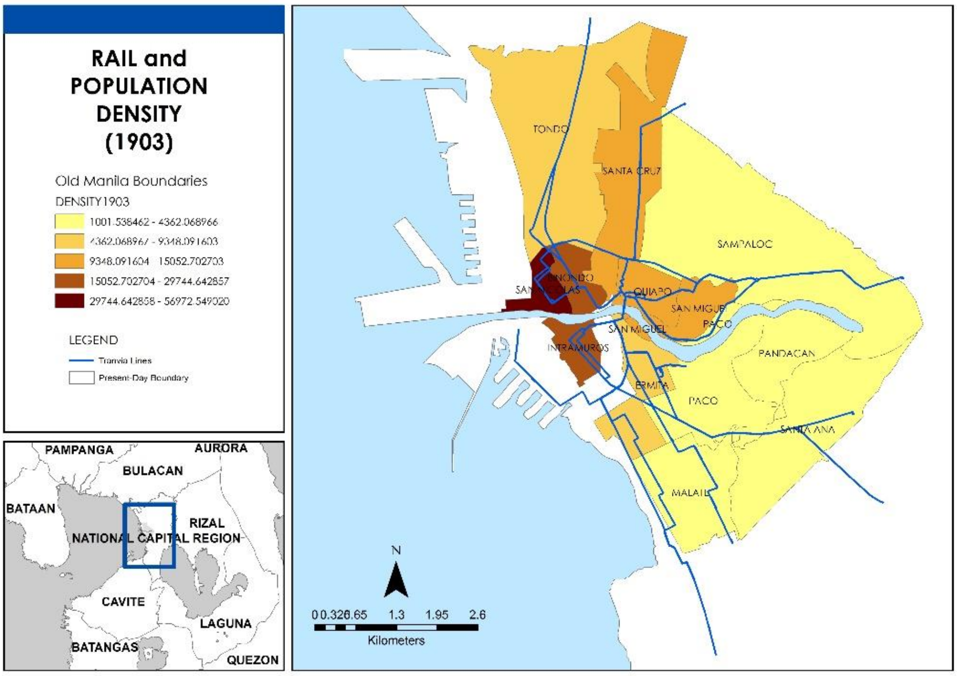

Figure 16. Population density (1903) mapped against tranvia lines

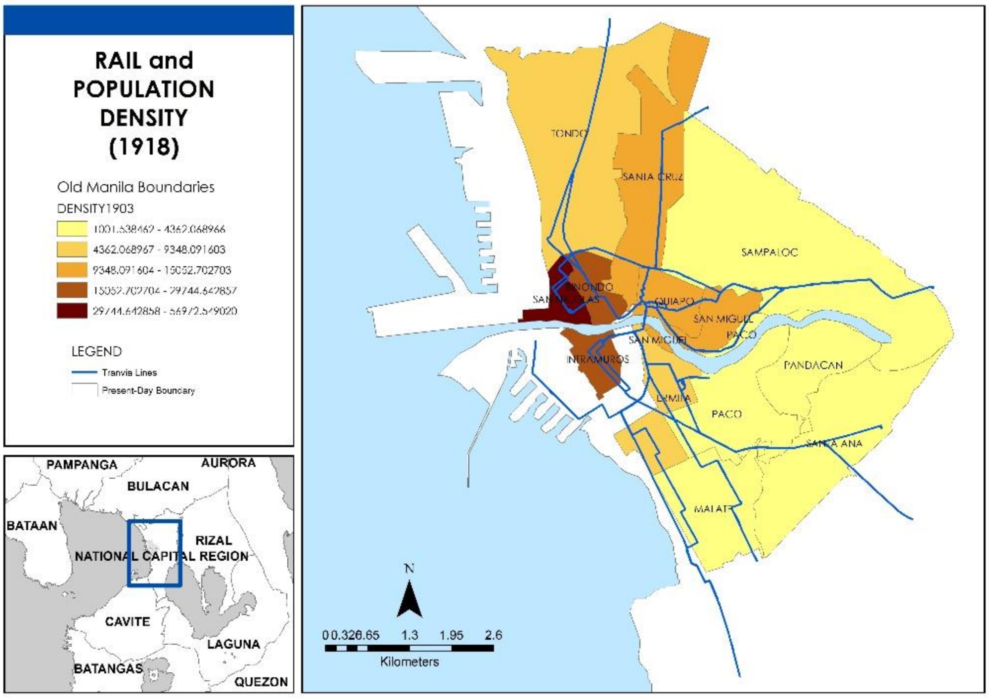

Figure 17. Population density (1918) mapped against *tranvia* lines

The highlighted districts in Figure 18, namely Tondo, Santa Cruz, Sampaloc, and Malate, were explicitly called “*Nipa* Districts” in the Municipal Board Report of 1905. In the same document, *nipa* districts were described as areas with lower incomes and higher susceptibility to fire due to the major construction material used for their buildings and *bodegas*. In contrast, the other districts, particularly Intramuros, Binondo, and Quiapo, were described as densely populated, highly commercial, and with more concrete structures. It is notable that the *nipa* districts tended to have fewer *tranvia* lines within their boundaries and they were located at the northern and southern outskirts of the city. However, it is also evident that the radial pattern of the *tranvia* lines throughout the study period can be attributed to the location of these *nipa* settlement areas. These places, while lacking in commercial establishments, played the role of supplying labor to the busier districts of Binondo and Quiapo. At the end of each day, these radial lines were then used by the workers to go back to their homes in the *nipa* districts. Such configuration can be likened to the historical rail system of London as mapped by Levinson (2007).

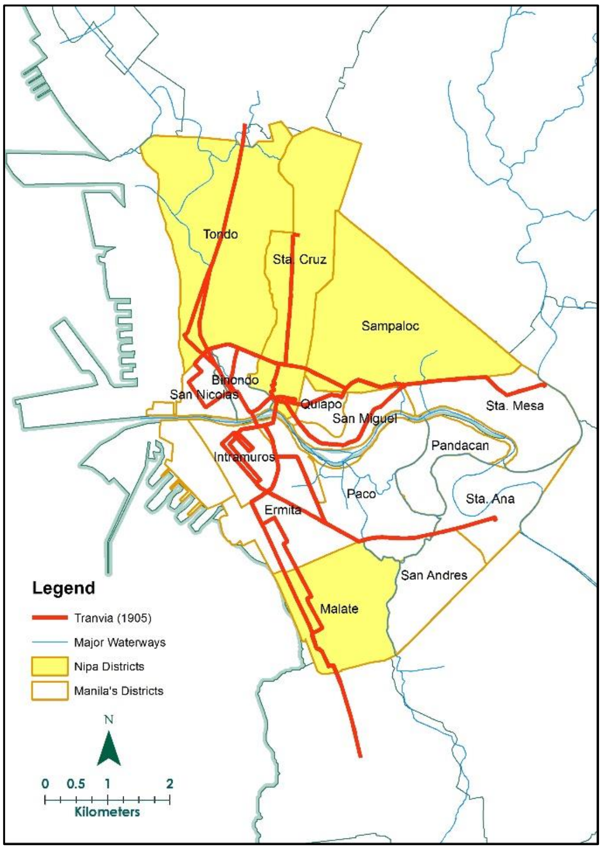

Figure 18. The *tranvia* lines overlaid with the *nipa* districts, Manila (1905)

5. SUMMARY OF FINDINGS AND CONCLUSION

Through digitizing and georeferencing archival data and historical maps, a geodatabase of the railway system's lines and stations was created using GIS. The recurring challenges encountered in the process are the initial incompatibility of the sources with GIS and incomplete information on scale and absolute location of features such as stations and the railways themselves. There are also numerous stations with precise locations not formally recorded in historical documents. These issues were addressed by using a variety of static maps, print sources, and historical train itineraries and cross-referencing them with visual traces observable in Google satellite imagery.

There was drastic change with the total length and density of lines since Meralco took over the tramways in 1905. It was observed that the radial pattern of the railways in Manila was meant to bridge the city center to residential "nipa" districts. Over the study period, there were notably higher concentrations of population at settlements north of Intramuros. Nevertheless, it appears that Meralco prioritized areas directly contiguous with Intramuros and the north of the Pasig River since 1905. Evidence of this is the high density and circuitous characteristic of the railways in the area, in contrast with the less dense connections with the settlements at the peripheries.

At this point in the research, the GIS database allows the visualization of the chronology and evolution of the early train system in terms of length and number of stations. The preliminary maps generated from it can serve as baseline information for subsequent historical studies on Philippine railways.

6. DIRECTIONS FOR FUTURE RESEARCH

Visualizing the temporal change of the *tranvia* and Manila's land use configuration requires the digitization and overlay of additional historical maps, preferably capturing finer increments over the years. This may augment the findings of the study in terms of additional snapshots of population, land use, and the rail system. Network analysis using GIS is not possible at this point because of insufficient data on transport stations and their locations. Once these nodes are mapped and properly drawn on a network graph, new levels of examination such as connectivity and accessibility analyses can be applied.

Narratives from the Annual Report of the Municipal Board of Manila from 1905 through 1919 will serve as a goldmine of information on the specifications of the *tranvia* system, as well as leads on which locations in Manila experienced consequent land use growth. It would also be more interesting if the establishments listed in the Rosenstock Directory (1900-1925) can be cataloged and classified according to establishment types. Such database will be used in comparing the intensities of commercial establishments in each of the districts and their respective rail densities. It is hypothesized that high rail densities can be found in areas with high concentration of commercial establishments.

It would also help to map the population of the old districts from annual censuses against the development of *tranvia* lines, since the number of residents in an area is a more direct measure of trip demand (Lowe and Moryadas, 1975). Interestingly, preliminary rail-versus-population maps reveal that high population districts were usually situated at the north of the Pasig River, particularly in Tondo, Santa Cruz, and Sampaloc. These were served with a few radial branches of the *tranvia* system, unlike the denser network which can be found in Quiapo, Binondo, and Intramuros. Through visual inspection, it can be inferred that these districts, while highly populated, had low population densities because of their large land areas. Further investigation dedicated to this angle is recommended.

Finally, it would be interesting to consider Pante's (2014) hypothesis that the motorization of the *tranvia* is closely related to the urbanization and modernization of areas in Manila. Was there a noticeable spurt of urbanization or population growth in areas of horse-drawn *tranvias*? As such, the time period of the study can be extended to explore and map the changes from animal-drawn *tranvias* and the beginnings of Manila's mass transit system.

REFERENCES

______________. (n.d.). Bundle 5291, Tranvia Manila. National Archives of the Philippines.

______________. (1904). Population of the Philippines by Islands, Provinces, Municipalities and Barrios Taken in the Year 1903. Bureau of the Census, Department of Commerce and Labor 1904 - New York Public Library

______________. (1919) Census of the Philippine Islands Volume II: Population and Mortality for the Year 1919. Census Office of the Philippine Islands 1919

Bach, J. (1918) City of Manila Map. Manila City: Bureau of Commerce and Industry.

Bolstad, P. (2005) *GIS Fundamentals: A first text on Geographic Information Systems* . White Bear Lake, MN: Eider Press.

ESRI. (2009, November 12) *ArcGIS Desktop 9.3 Help*. Retrieved September 1, 2016, from http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Georeferencing_a_raster_dataset

ESRI. (2017, February 12) *Coordinate Systems, Map Projections, and Geographic (Datum) Transformations*. Retrieved from ESRI Resources:

http://resources.esri.com/help/9.3/arcgisengine/dotnet/89b720a5-7339-44b0-8b58-0f5bf2843393.htm
Felis-Rota, M. (2012) *A GIS analysis of the evolution of the railway network and population densities in England and Wales 1851-2000*. Universidad Autónoma de Madrid (2012)
Food and Agriculture Organization (FAO) of the United Nations. (n.d.). *Land Resources*. Retrieved July 27, 2016, from http://www.fao.org/nr/land/use/en/
GeoRepository. (2017, February 10) *WGS 84 / UTM Zone 51N*. Retrieved from GeoRepository: http://georepository.com/crs_32651/WGS-84-UTM-zone-51N.html
Hoel, G. G. (1992) *Public Transportation 2nd Edition.* New Jersey: Prentice-Hall.
Levinson, D. (2007) *Density and Dispersion: The Co-development of Land Use and Rail in London.* Journal of Economic Geography Vol. 8 2008
Lowe, J and Moryadas, S. (1975) *The Geography of Movement.* . Boston: Houghton Mifflin Company.
Ortuzar, J. and Willumsen, L. (2001) *Modellling Transport 3rd Edition.* England: John Wiley & Sons, Ltd.
Magno-Ballesteros, M. (2000, June) Land Use Planning in Metro Manila and the Urban Fringe: Implications on Land and Real Estate Market. Makati City: Philippine Institute for Development Studies.
MERALCO (1941) *MERALCO Rail System Report.* Manila: Meralco.
Metro Manila Commission (MMC). (1985) Urban Land Management Study: Urban Redevelopment in Connection with Metrorail. *Philippine Planning Journal*, 46-56.
Monmonier, M. (1991) *How to Lie with Maps.* City of Chicago Press.
Municipal Board of Manila. (1905) *The United States and its Territories 1870- 1925*. Retrieved July 22, 2016, from http://quod.lib.umich.edu/p/philamer/AAF8875.1905.002?rgn=main;view=fulltext
Pante, M. (2014) Mobility and Modernity in the Urban Transport Systems of Colonial Manila and Singapore. *Journal of Social History vol. 47 no. 4,* pp. 855–877.
Pante, M. (2011) Peripheral Pockets of Paradise: Perceptions of Health and Geography in Early Twentieth-Century Manila and its Environs. *Philippine Studies vol. 59 no. 2*, 187-212.
PHIVOLCS. (2013) *An Update on the Earthquake Hazards and Risk Assessment of Greater Metropolitan Manila Area.* Manila: Philippine Institute of Volcanology and Seismology.
Rosenstock's Directory of China and Manila (1924) The Bulletin Publishing 1924, accessed on November 4, 2016 University of Michigan Online Archives http://quod.lib.umich.edu/p/philamer/ACS9103.0001.001?rgn=main;view=fulltext;q1=Manila
Rumsey, D., Williams, M. (2002). *Historical Maps in GIS Chapter 1 Past Time, Past Place*: GIS for History. ESRI Press (2002)
Schneider, W. (2016) *BBBike.org*. Retrieved July 21, 2016, from http://extract.bbbike.org
Serote, E. (2004) *Property, Patrimony and Territory: Foundations of Land Use in the Philippines*. School of Urban and Regional Planning (SURP) University of the Philippines Diliman, Quezon City
The Acts of the Philippine Commission (425-949). (1904) War Department of the Bureau of Insular Afairs.
The Philippines Company. (1899) *Manila and the Philippine Islands: an Up-to-Date Handbook of Facts.* New York: The Philippines Company.

Wang, J. (2009). *Spatiotemporal evolution of China's railway network in the 20th century:An accessibility approach*. Transportation Research Part A Vol. 43 2009