Tracing the History of the Philippine National Railways: Historical Geographic Visualization of the *Ferro-Carriles en Isla de Luzon* (1891-1945) 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 visualize the historical geography of the *Ferro-carriles* railway system in the Philippines (1891-1945). These rail lines, which would soon be the property of the Manila Railroad Company (MRC) and eventually the present-day Philippine National Railways (PNR), were mapped using ArcGIS 10.

The study focuses primarily on the application of GIS methods to historical transport studies as it seeks to visualize the history of a railroad system which is now just a shadow of its former self in the early 1900s. Using GIS, factors which possibly impacted the development of the railways such as historical plans and population were mapped and investigated. Moreover, this research aims to uncover trends in transport planning and development in the Philippines, as well as contribute to the growing literature and set of techniques employed in GIS for historical transport studies.

Keywords: GIS, Railways, Urban Transportation, Transport History, Mapping, Historical Geography

1. INTRODUCTION

1.1 The *Ferro-carril* and GIS

Historico-geographical research on urban transport systems and land use can be likened to fitting the pieces of a jigsaw puzzle. Through the implementation of a Geographic Information System (GIS), this research focuses on mapping and visualizing the Philippines' historical *ferro-carril* system by piecing together data from multiple and initially incompatible sources. This railroad system is known today as the Philippine National Railways (PNR). Data was obtained and digitized from historical maps, archival documents, plans, blueprints, and itineraries obtained from both physical and digital libraries. The software suite ArcGIS 10 is then used to overlay information from 1895 to 1945 to create time-series maps of the apparently simultaneous development of the city's land use and urban transit network.

This research focuses on integrating information from the aforementioned archival sources and applying GIS techniques to see how the railway lines changed from the 1891 to 1945. Brief historical accounts are discussed in this paper for a more nuanced understanding of key events that propelled the development transport system. Factors that possibly influenced the railway's development such as transport planning and population across settlements are also visualized and discussed in the section on cartographic findings. Moreover, the study is intended to create baseline information in the form of maps and GIS shapefiles which can be used to analyze how transport developed in across Luzon in the 1900s. While outside the scope of the study, the findings may prove to be correlated with the present-day configuration of settlements and land use in Luzon.

1.2 Scope and Delimitation of the Study

The time coverage of 1891 to 1945 was selected based on currently available data but primarily because the period effectively encompasses the construction and peak of the system before World War II. The first line of the rail system was the result of the promulgation of a royal decree by King Alfonso XII of Spain in 1875. However, it was intended only to connect Manila and Dagupan in the north by a line traversing Central Luzon. During the American period and the Commonwealth Government, the system would eventually unify Luzon in terms of land transport by connecting La Union in the north and Bicol Region in the south to the capital city of Manila (Corpuz, 1999).

The study area, on the other hand, spans northern Philippines, specifically the provinces in the island of Luzon. The extent of the area is based on the initial plans for the railway of the Spanish Engineer Eduardo Lopez Navarro in 1876 (McIntyre, 1907). By the end of the 19th century, there were only three clearly defined land routes across Luzon: northwest (Manila-Central Luzon-Ilocos), northeast (Manila – Central Luzon – Cagayan Valley), and south (Manila-Laguna-Batangas-Tayabas-Bicol) (Corpuz, 1999).

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 the rail lines using equal intervals of years or decades. Instead, it should be noted that the rendered maps are snapshots of transport and demographic data in Luzon’s localities across irregular intervals due to data availability. The development of transport networks is, after all, can be seen as sequential stages with respect to time and location just like the birth, growth, maturation, and eventual death of a human being (Lowe & Moryadas, 1975). Nonetheless, it can be said with confidence that these snapshots can provide substantial insight on PNR’s roughly first five decades of history.

It is also important to note that provincial and municipal boundaries, and place names as of 2017, are used for the maps in this paper. Further research and digitization of several historical maps are needed to accurately represent the administrative boundaries of Philippine settlements in from the late 1800s to the early 1900s. Nevertheless, most towns and capitals with relatively high historical populations have retained their names and relative locations up to the present.

2. BRIEF HISTORY OF THE FERRO-CARRIL

2.1 Between World Wars: Key Historical Events in the Rail System’s Lifetime

Discussed briefly in this section are important events that led to the development of the rail system. The corresponding lengths of the rail and its extensions per time period according to archival documents and secondary sources as well as lengths computed using GIS are also noted here.

A royal decree by King Alfonso XII of Spain in 1875 directed the Office of the Inspector of Public Works of the Philippines to create a railroad plan for Luzon. The resulting study, called the *Memoria Sobre el Plano General de Ferro-Carriles en Isla de Luzon* by Engineer Eduardo Lopez Navarro, is the first and most comprehensive study of railroad utilization for economic growth in the country (PNR, 2016).

The study of the first railroad project was approved in 1883. The said line would traverse provinces in Central Luz on, particularly from Manila to Dagupan, and was intended to connect key trade points to steer development in provinces where stations would be built. As evidence of the concessions and plans following the approval of the project, a total of 570 copies of documents, maps, plans, and feasibility studies related to the railroad in Luzon were found among the records of the *Consejo Superior de Investigaciones Cientificas* (CSIC, 2017). Among these bundles, 501 documents correspond to the construction of the Manila-Dagupan Line from 1875 to the early 1900s while 51 papers relate to the line that would be constructed to connect Manila southward to Batangas.

Come January 1887, the construction of the rail was granted to the concessionaire Don Edmundo Sykes who represented *Ferrocaril de Manila-Dagupan*. For reasons still unknown, the concession was transferred to Don Carlos E. Bertodano, a representative of the Manila Railroad Company (MRC), on July 1887. Filipino workers then started the construction of the line at the end of the same month, beginning at the Tutuban Station in Manila (PNR, 2016).

The very first section of the rail was completed in March 24, 1891. The 45-kilometer line connected Manila to Bagbag (present-day town of Calumpit in Bulacan) and was opened to commercial operations. The first and central station was located in Tutuban. This station’s office was opened to the public for the transaction of all business connected with the company (Manila Directory, 1901). The whole Manila-Dagupan Line, with a total length of about 195 kilometers, was completed and opened to passengers in November 24 of the following year. According to the *memorias* in Bundle 5291 from the National Archives of the Philippines (NAP), the railway system operated simultaneously with the horse-drawn streetcars called *tranvias*. The latter started operations in 1895, with the highest density of lines in the central business district of Manila. The map published by the US Government in 1918 (Figure 1) shows the city of Manila and its two railway systems. To avoid duplication of services, the train operated mainly in outer Manila and was intended to bridge the capital to the towns in the north, while the *tranvias* connect districts within Manila.

Figure 1. 1918 Manila, Cartography by John Bach

It should be noted that train operations began while the Filipino Revolution was brewing. The Revolution broke out in August 1896 in the province of Cavite. This resulted in the interruption of railroad traffic in certain locations due to crossfires, barricades, and civilian evacuation. The railway operations resumed in 1898 after a successful revolution against the Spanish. It was again interrupted one year later, after the spark of the Filipino-American War. In 1900, the American military returned the rail to the owner, Don Carlos E. Bertodano. The US Congress then granted the Philippines to authorize concession for the construction of public infrastructure and services in 1902. After some time, the railway system acquired an English name and was called the Manila Railroad Company (MRC). The Philippine government was able to expand the services of the railroad up to about 1,140 kilometers when it effected the nationalization of the MRC in January 1917. World War I broke out during this period in Europe but it had no direct impact to the Philippines as an American colony.

During the time of peace in the early 1900s, the Commonwealth Government owned and maintained the train system. The first line from Manila to Bicol was then opened in September 1931. Finally, within the decade, a unified system was formally inaugurated in May 8, 1938. The new system links Legazpi in the south to San Fernando, La Union in the north.

Eventually, the United States got involved in World War II when the Japanese bombed Pearl Harbor in 1941. Japan occupied the Philippines in 1942 and took control of the railway. At the end of the war in 1945, the Americans returned ownership of the rail to the Commonwealth Government.

2. LITERATURE REVIEW

The methods used in this research were drawn from several works on historical transport, GIS, and cartographic strategies. Examples are the studies of Marta Felis-Rota (2012) who correlated the growth of urban settlements and the expansion of the railway system in England from 1851 to 2000; and Jiaoe Wang (2009) who mapped China's railway in the 1900s against the locations of then emerging residential areas. In both studies, there are noticeable agglomerations of settlements and population growth along the rail systems. However, both studies did not include a statistically causal relationship between railways and urban population but established a co-development between the two variables across time and space instead.

Additionally, David Levinson (2007) also conducted a similar historical research at a city level. He used data on population and railway densities in London from 1871 to 2001 in positively correlating and proving the intertwined growth of the rail and land use. Levinson found out that the transport system facilitated the transition of London's city center from a place with high residential and commercial densities to one with low residential and very high commercial densities. The rail network followed a radial form to connect commuters from more exterior locations to the city center and the densest parts of the network could be found near and at the center itself. While the rail network of London was significantly denser and more intricate across its 33 districts, the concentration of lines at a central area and the radial pattern of the rails to the suburbs is very similar to the streetcar lines of 19th century Manila.

The map series in Figure 2 illustrate this configuration. It is important to note early in this section that the railways coexisted with the intra-urban streetcar system of Manila. It is also shown that while the lines in the city had diminished in intensity, the built-up areas continued along the locations of the streetcar and rail networks. It can be gleaned from this that there is a positive spatial relationship between the location of the rail and the location of settlements and establishments.

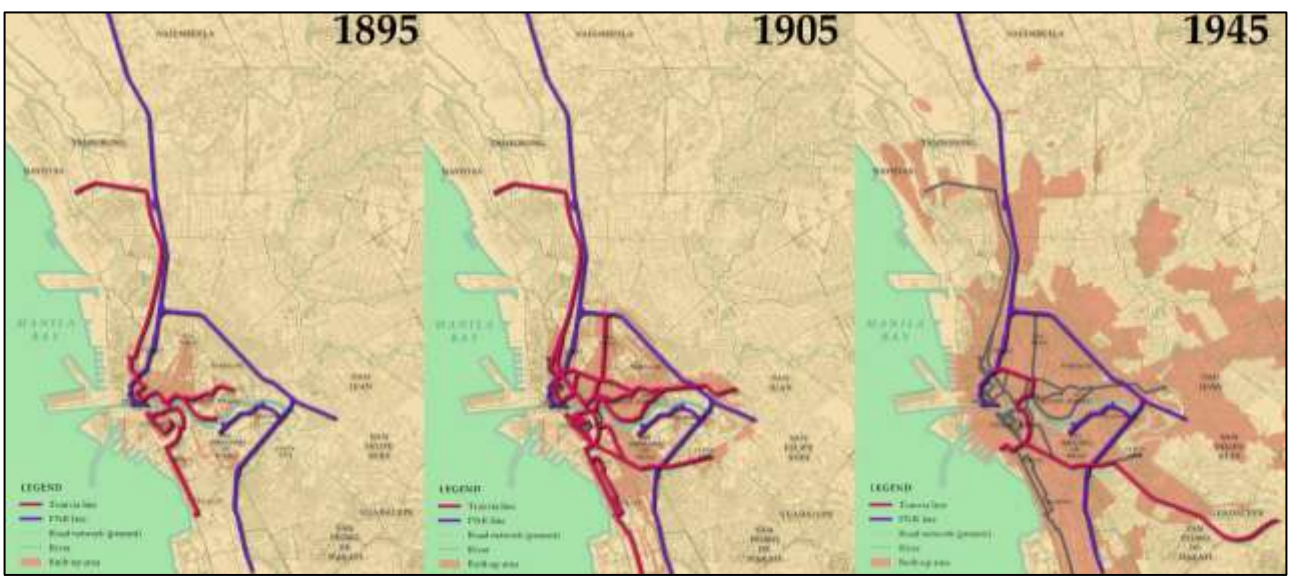

Figure 2. Time snapshots of the railway systems mapped against the expanse of built-up areas. The dark heavy lines represent a section of the trains which operated within and near Manila.

While the study provides emphasis to the application of GIS to historical transport studies, it also seeks to uncover trends in transport planning in the past. Digitizing and mapping documents from the NAP, besides saving centuries worth of data, were done to provide new insights to the discourse on transport development and even traffic congestion in the Philippines, as well as contribute to the growing literature of GIS applications to transport studies.

This study also follows the framework employed by Droes and Rietveld (2014) in statistically proving that the existence of railways does not necessarily end urban traffic congestion. After comparing capital cities and their hinterlands around the world, they concluded that the population in localities with the presence of rail stations are higher by six to ten percent than locations without one. As Droes and Rietveld have noted, “Since travel time by train is relatively low, workers have an incentive to reside in a location that is distant from the place of work and in close proximity to a train station. Population clusters because access to the rail network is clustered” (p.2). To wit, populations in Luzon in the early 1900s had the tendency to cluster around the locations of railway stations in lieu of actually residing within Manila. In line with this, identified towns with train stations outside Manila can be argued as the first major urban settlements across Luzon.

These towns served as transport nodes. In the context of transport studies, these are locations which attracted a large number of people and activities within the area and serve as sources of commuters. These transport nodes have high potential for trip generation. The aggregated number of travels within an area is referred to as total trip demand (Lowe & Moryadas, 1975). Ultimately, mapping trip demand is required in various transportation planning methods and in determining potential locations of transport stations with respect to where trips are generated (Ortuzar & Willumsen, 2001).

It can be argued, however, that more recent studies on transport and development used approaches and measures which may not apply to early 20th century Luzon. It is therefore mandatory to perform some adjustments in applying present-day methods to assess the impacts of a historical transport system. In particular, statistics for daily PNR commutership around Luzon is scarce. This lack of trip generation and trip demand data also limits the amount of quantitative analysis that can be performed at this point.

3. METHODOLOGY

3.1 ArcGIS and Supporting Computer Applications

This paper heavily focuses on the methodology and documentation of how historical transport data were mapped and accommodated into a modern processing platform. 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 suite, are used in processing historical geographic data. 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 names and street names over time. This was done in order to correctly tabulate provincial and town information in the geodatabase, since some present-day place names in Luzon are different from their historical names.

On the other hand, ArcGIS 10 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, provincial and municipal boundaries, and population. It was 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.

In addition to Google Earth and ArcGIS, open-source data from Open Street Maps (OSM) also played an integral role in the completion of the geodatabase. Through the extraction module of Schneider (2016), present-day railway data on Luzon was downloaded in the form of shapefiles. Commonly known for its filename extension ".shp", this is a file format that can readily be uploaded to ArcGIS and most GIS programs. Among the shapefiles downloaded are the present-day light rail systems and train lines of the PNR. While these files are not necessarily needed for mapping archival data, they can be used in verifying the correctness of geometries and positions of the digitized files. Moreover, these shapefiles carry within themselves databases called "attribute tables" which are further discussed in succeeding sections.

3.2 Georeferencing Manila's Historical Railways

Digitization in GIS refers to the process of creating new map elements by outlining a geographic feature on a map or other image sources (ESRI, 2009). This effectively creates a new file for features such as train stations, railways and roads, and administrative boundaries. When traced and rendered as new GIS files, such features are represented by points, lines, and polygons respectively. As long as they are drawn on a properly georeferenced map in GIS, the features are automatically attributed with correct latitude and longitude coordinates based on the used projection system.

An important consequence of digitizing in ArcGIS is the creation of a tabular database called an 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. Available population data at the municipal levels from the US Bureau of Census for the time period was inputted to the attribute table of settlements and municipalities.

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. Besides attributing scanned images with locational characteristics, georeferencing them also allows the measurement of lengths and areas of geographic features (ESRI 2009). This process is 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. Figure 3 is a screen capture 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 (1918) and the shapefile to where it was matched.

There is no strict rule stating how to select the number and locations of control points across a map. However, 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 latitude and longitude values in degrees given that they are included or still readable from the old documents. These intersections can be selected as control points and their latitude and longitude coordinates can be directly entered into ArcGIS for rubbersheeting.

There are some notable control points among the maps from the NAP and online archives such as the *Biblioteca Digital Hispanica* which were easily identified since they remained unchanged. Some of these control points are 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 centuries and so sections of it were also used as control points. Note that the control points most frequently chosen in this research were the train lines on the maps themselves and they were made to overlay directly with the present-day PNR lines previously extracted from OSM (See Figure 3). It is evident with the maps that most locations of the railway lines in Manila have not been moved since the early 1900s.

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 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 also be emphasized that a perfect match in rubbersheeting, i.e. zero residuals for all control points, may be difficult to achieve especially when georeferencing scans of 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). Fortunately, most historical maps used in this research were marked with coordinate systems and respective grid tick marks, hence rubbersheeting yielded generally good results. Case in point, the residual in Figure 3 is equal to zero.

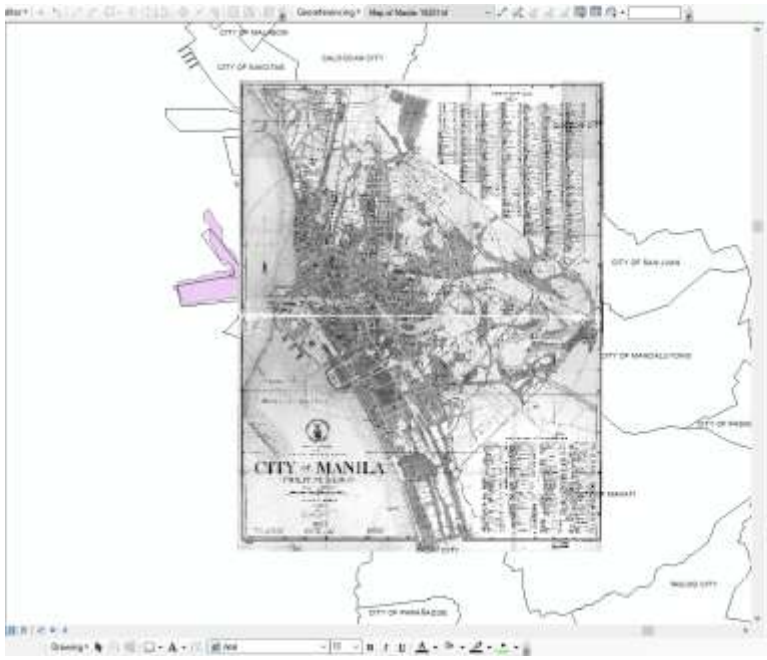

Figure 3. A historical map of Manila (1918) which contains a section of the rail system, accommodated and georeferenced in ArcGIS

Most of the scanned and digital maps were georeferenced according to the two aforementioned techniques. Using tick marks is often the better alternative. 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 contain these grid markings and therefore require the latter treatment.

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 therefore 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 at those scales. Cartographers who use the Google Maps Application Programming Interface (API) as base map are able to incorporate the same functionality in their internet-based maps (Dalton, 2015). Such flexibility of scale no longer applies to historical maps since their digital formats are no longer available, if they existed at all. For example, the Luzon railway maps of Corpuz (1999) indicate the locations of the stations across Luzon but not the precise locations at the barangay scale (see Figure 4). 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 5 consists of the digitized Manila-Dagupan Line. Additional research was needed to pinpoint the actual locations of the MRC stations on the geodatabase given that not all its stations were explicitly listed in Corpuz (1999) or in other archival sources. Such cases require cross-referencing with various sources and oftentimes, the use of the cartographer's imagination (Rumsey, 2002).

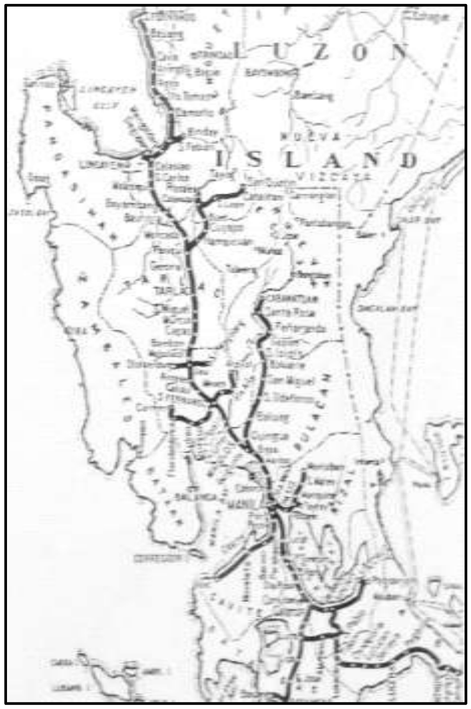

Figure 2. Print and static map of the Manila Railway Company lines in the 1930s including the Manila-Dagupan Line from Corpuz (1999, p.52)

Figure 5. The digitized Manila-Dagupan Line, accurate up to the municipal scale. Magnifying the scale in the Google Earth API reveals additional locational information. (Image copyright: Google Maps, 2016)

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 is the science of obtaining and interpreting satellite imagery and aerial photos (Aggarwal, 2003). The researchers used Google Earth in closely approximating the locations of the stations by looking into traces and markings found in historical maps. Google Earth's tools such as the ruler function was used to verify present place names and their respective locations based on their distances from Manila as mentioned in archival documents.

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 produced 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 rail lengths with minimal errors due to projection.

UTM Zone 51N is suitable for places located between 120 degrees 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 Tabular or Text Format

As for the current stations of the PNR, they can easily be identified with maximum accuracy through the use of Google satellite images and matching them with the maps readily downloadable from their official website (see Figure 6). However, information gathered to date is insufficient to pinpoint the exact location of the stations of the railway system in the early 20th century.

Figure 6. Map of present-day PNR Lines

Locational data on these stations are gleaned from travel itineraries which are found in directories and guidebooks for the time period. For example, the train schedule found in Figure 7 was used in filling the GIS database with station data, stops, and particular times of arrival and departure per station (Kemlein & Johnson, 1908).

Manila Railroad Co.

Time Table No. 24

Manila and Dagupan Line and Branches.

North Bound Trains No. 1	No. 3	No. 5	No. 7	No. 9	No. 11	STATIONS	South Bound Trains No. 2	No. 4	No. 6	No. 8	No. 10	No. 12
A. M.	A. M.	A. M.	Noon	P. M.	P. M.		A. M.	A. M.	P. M.	P. M.	P. M.	P. M.
6.00	6.25	9.34	12.00	3.00	5.35	Dep. Manila Arr.	8.09	9.39	12.25	1.31	5.28	7.01
7.03	7.15	10.40	1.04	4.11	5.18	Arr. Bigaa Dep.	7.26	8.18	11.00	12.26	4.13	6.02
		No. 13	No. 15		No. 17	(Junction)		No. 14		No. 16		No. 18
7.12		10.57	1.00	4.16	6.43	Dep. Bigaa Arr.	7.12	8.4	10.55	11.22		5.50
7.47		11.35	1.48	5.00	7.18	Arr. Baliuag Dep.	6.35	7.59	10.13	11.47		5.04
8.41			2.43	6.14		Arr. S. M. Mayumo Arr.	A. M.	6.24	8.50			3.44
9.36			3.38	7.06		Arr. S. Isidro Arr.		5.34	7.56			2.50
9.54			4.04	7.33		Arr. Peñaranda Dep.		5.09	7.34			2.27
10.38			4.59			Arr. Cabanatuan Dep.			6.57			1.31
	7.17	11.05	1.05		6.42	Dep. Bigaa Arr.		8.54		12.22	4.07	5.34
	9.18		3.21		8.48	Arr. Angeles Dep.		6.55		10.26		4.08
	No. 19		No. 21		No. 23	(Junction)		No. 20	No. 22		No. 24	
	9.30		4.08		8.50	Dep. Angeles Arr.		6.40	3.18	in con-	6.45	
	10.02		4.40		9.20	Arr. Stotsenberg Dep.		6.15	2.53	nection	6.20	
	9.30		3.74		No. 105	Dep. Angeles Arr.		A. M.		10.24		4.04
	10.42		4.53		A. M.	Arr. Tarlac Dep.				8.56	No. 106	2.36
	10.52		5.03		5.00	Dep. Tarlac Arr.				8.48	7.14	2.26
	12.11		6.25		7.03	Arr. Bautista Arr.				7.22	4.30	1.03
	1.18		7.30		9.09	Arr. Dagupan Dep.				6.13	3.00	10.00
										A. M.	P. M.	Noon

NOTE.—Passengers for Stotsenberg change coaches at Angeles, Passengers for Stations on Cabanatuan Line by Trains Nos. 1, 7, 11, 4, 8, and 12 must change coaches at Bigaa. Train No. 3 will not stop at stations between Manila and Bigaa unless flagged to pick up passengers for Guiguinto or a station further north.

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Cavite Line

Time table No. 56.

Down or South Bound Trains. Up or North bound trains.

STATIONS.	501	503	505	507	509	511	STATIONS.	502	504	506	508	510	512
	A. M.	A. M.	P. M.	P. M.	P. M.	P. M.		A. M	A. M.	A. M.	P. M.	P. M.	P. M.
Manila Dep.		8.28	12.08	1.58	5.39	7.28	Cavite Dep.		7.43	11.24	3.03	5.15	8.00
San Lazaro		8.35	12.15	2.05	5.46	7.35	San Roque.		7.46	11.27	3.06	5.18	8.03
Santa Mesa		8.48	12.26	2.16	5.57	7.46	Caridad.		7.51	11.32	3.11	5.23	8.08
Pandacan		8.53	12.31	2.21	6.02	7.51	Noveleta.		8.02	11.43	3.22	5.34	8.19
Paco	5.48	9.01	12.36	2.27	6.07	7.56	San Juan.		8.05	11.46	3.25	5.37	8.22
Singalong	5.53	9.07	12.40	2.32	6.12	8.01	Cavite Viejo.		8.10	11.51	3.31	5.42	8.30
Pasay	5.58	9.12	12.45	2.37	6.20	8.07	Binacayan.	4.22	8.16	11.57	3.37	5.48	8.36
Maricaban	6.04	9.18	12.51	2.43	6.27	8.13	Bacoor.	4.28	8.22	12.03	3.43	5.54	8.43
Pildera	6.10	9.24	12.57	2.49	6.33	8.19	Zapote.	4.35	8.29	12.10	3.50	6.01	8.50
Paranaque	6.16	9.30	1.03	2.55	6.35	8.25	Las Piñas.	4.42	8.36	12.17	3.57	6.08	8.57
Las Piñas	6.21	9.35	1.08	3.00	6.44	8.30	Parañaque.	4.47	8.41	12.22	4.02	6.13	9.01
Zapote	6.28	9.42	1.15	3.07	6.51	8.37	Pildera.	4.53	8.47	12.28	4.08	6.19	9.07
Bacoor	6.35	9.49	1.22	3.14	6.58	8.45	Maricaban.	4.59	8.53	12.34	4.14	6.26	9.13
Binacayan	6.41	9.55	1.28	3.20	7.04	a.8.50	Pasay.	5.09	9.02	12.44	4.23	6.35	9.19
Cavite Viejo	6.50	10.04	1.37	3.30	7.10		Singalong.	5.14	9.08	12.49	4.29	6.40	9.24
San Juan	6.55	10.09	1.42	3.35	7.15		Paco.	5.19	9.14	12.54	4.34	6.45	a.9.28
Noveleta	6.58	10.12	1.45	3.38	7.18		Pandacan.	5.24	9.18	12.59	4.39	6.50	
Caridad	7.09	10.23	1.86	3.49	7.29		Santa Mesa.	5.29	9.26	1.07	4.47	6.55	
San Roque	7.14	10.28	2.01	3.54	7.34		San Lazaro.	5.38	9.35	1.16	4.56	7.04	
Cavite Arr.	7.16	10.30	2.03	3.55	7.36		Manila Arr.	5.44	9.41	1.22	5.02	7.10	

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Figure 7. Samples of train trip itinerary from Kemlein & Johnson (1908)

Using maps shown in Corpuz (1999) and the preceding list of stations from the trip schedule, the locations of each station were identified and marked in GIS. For stations with locations which cannot be directly identified visually from historical maps or traces of it in Google Earth, approximation of their coordinates was performed by marking the intersection of the railway with the respective municipal polygon.

4. CARTOGRAPHIC FINDINGS AND DISCUSSION

4.1 Conception of the System and Location of the Lines

Constructing a national railroad system for the Philippine islands was first taken up by the Spanish government (Gonzalez, 1979). In compliance to the royal decree governing the granting of concessions to railway constructions, Engineer Eduardo Lopez Navarro published a general plan of railways for Luzon on 1876. After a few years of delay, the approved lines based on Lopez Navarro's report were announced in 1883. These were generally classified as the Lines of the North and the Lines of the South with respect to the location of Manila (McIntyre, 1907). The settlements on which the terminals were expected to be built and the general route description were stated in Lopez Navarro's report (summarized in Table 1 and illustrated in Figure 8).

Table 1. Planned Luzon railway lines as of 1876

General Line Classification	Terminals and General Route Description	Profitability, as reported by Lopez Navarro	Symbolization in Figure 8
Lines of the North	Manila to Dagupan by way of Tarlac	immediately commercially profitable	
	Dagupan to Laoag by way of the coast		
	San Fernando to Iba by way of Subic		
	Bigaa to Tuguegarao by way of Baliuag and Cabanatuan		
Lines of the South	Manila to Taal by way of Calamba	immediately commercially profitable	
	Calamba to Albay by way of Santa Cruz and Nueva Caceres		

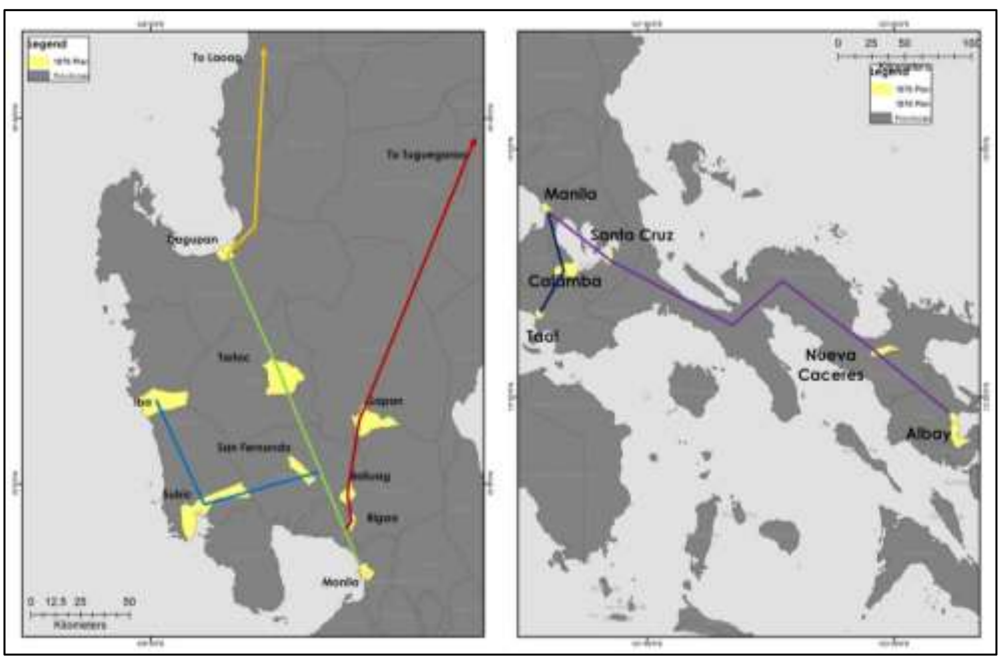

Figure 8. General plan of the rail system and localities traversed by the lines as of 1876

McIntyre (1907) noted that Lopez Navarro divided the lines into two classes. The first class were described as immediately profitable from an exclusively commercial standpoint. This group includes the Manila-Dagupan and the Manila-Taal lines. On the other hand, the Calamba-Santa Cruz, Dagupan-Laoag, and San Fernando-Subic lines were expected to barely cover running expenses over the first years of operation. Archival documents uncovered by the researchers to date do not provide figures and details of the potential profitability of the lines but reports mention that it is to facilitate the flow of goods across Luzon (Corpuz, 1999). The sections of the rail in central and northern Luzon were intended to provide means for transporting goods to and from the landlocked areas of Cabanatuan, and connect Luzon to the port of Dagupan in the province of Pangasinan (Gonzalez, 1979).

4.2 The Railway System over Time

Rail construction in the succeeding years adhered to the aforementioned general plan. The map series (Figures 9 through 12) shows a section of the railway system in Manila. There is a high level of known detail and accuracy of digitizing for this area. Note that the selected time periods are irregular since developments with the train system did not happen at a regular time interval. As far as the scope of historical Manila goes, the MRC experienced drastic growth during the time of the Commonwealth Government. As shown in Figure 11, a large branch of the railroads was decommissioned and abandoned during the Japanese occupation in the Philippines. The operation of this eastern branch would no longer be restored even after the war ended and the US military returned the ownership to the Filipinos.

Figure 9. Section of MRC in Manila mapped against streetcar (*tranvia*) lines and the urban area's built-up environment (1888-1905)

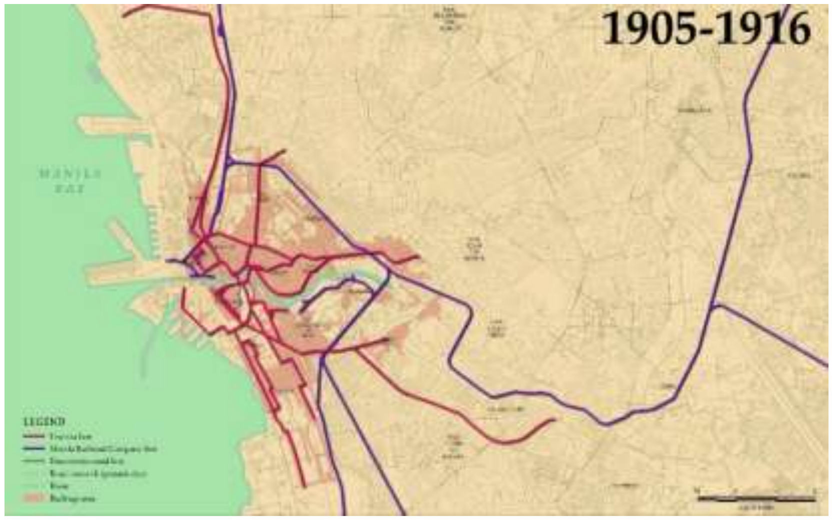

Figure 10. Section of MRC in Manila mapped against streetcar (*tranvia*) lines and the urban area's built-up environment (1905-1916)

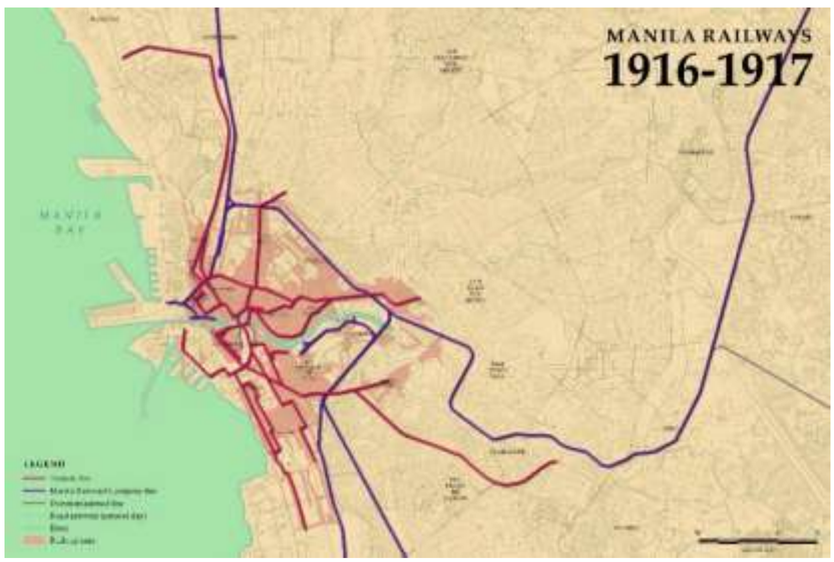

Figure 11. Section of MRC in Manila mapped against streetcar (*tranvia*) lines and the urban area's built-up environment (1916-1917)

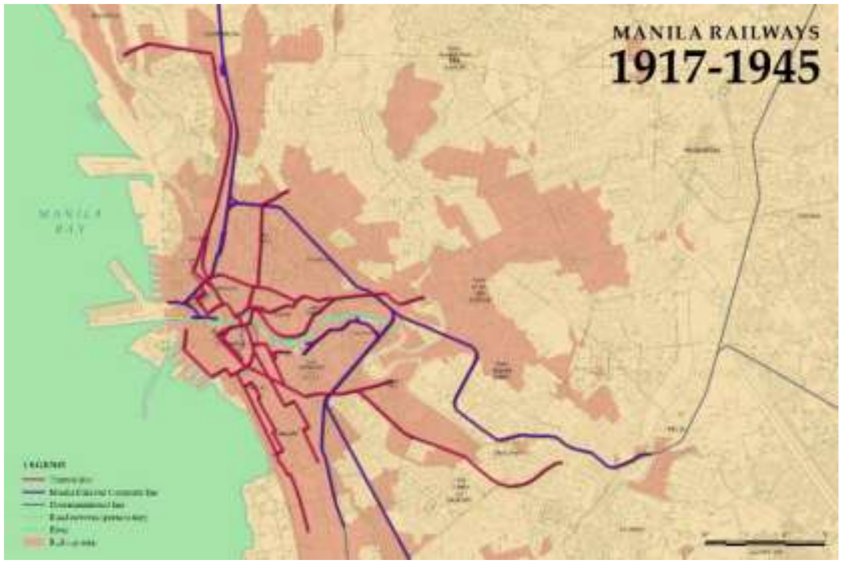

Figure 12. Section of MRC in Manila mapped against streetcar (*tranvia*) lines and the urban area's built-up environment (1917-1945)

Figure 13 shows a section of Luzon and the train system in 1908 and 1936, respectively. By 1908, about two decades after the first operational 45-km line from Manila to Bagbag, the railway length had increased to 106.87 kilometers, as estimated in GIS using a projected coordinate system. There were 27 stations at the time. It is notable that new stations had been constructed contiguously to these 27 initial towns by 1936. The main railway lines which branched out from Manila are illustrated in Figure 13.

The system's lines across Luzon, which peaked in 1936 in terms of length and density, is shown in Figure 14. The total railway length at this time is around 1,336.58 kilometers, roughly 30 times longer than its first operational length in 1891. The maps in Figure 13 through 15 were constructed by combining information from Corpuz (1999) and several documents from the *Biblioteca Digital Hispanica*. It can be seen that extensions which are generally oriented from east to west were constructed along the main lines. The list of nodes gathered from these travel guides and itineraries reveal key locations identified and deemed strategic by the train company to have stations.

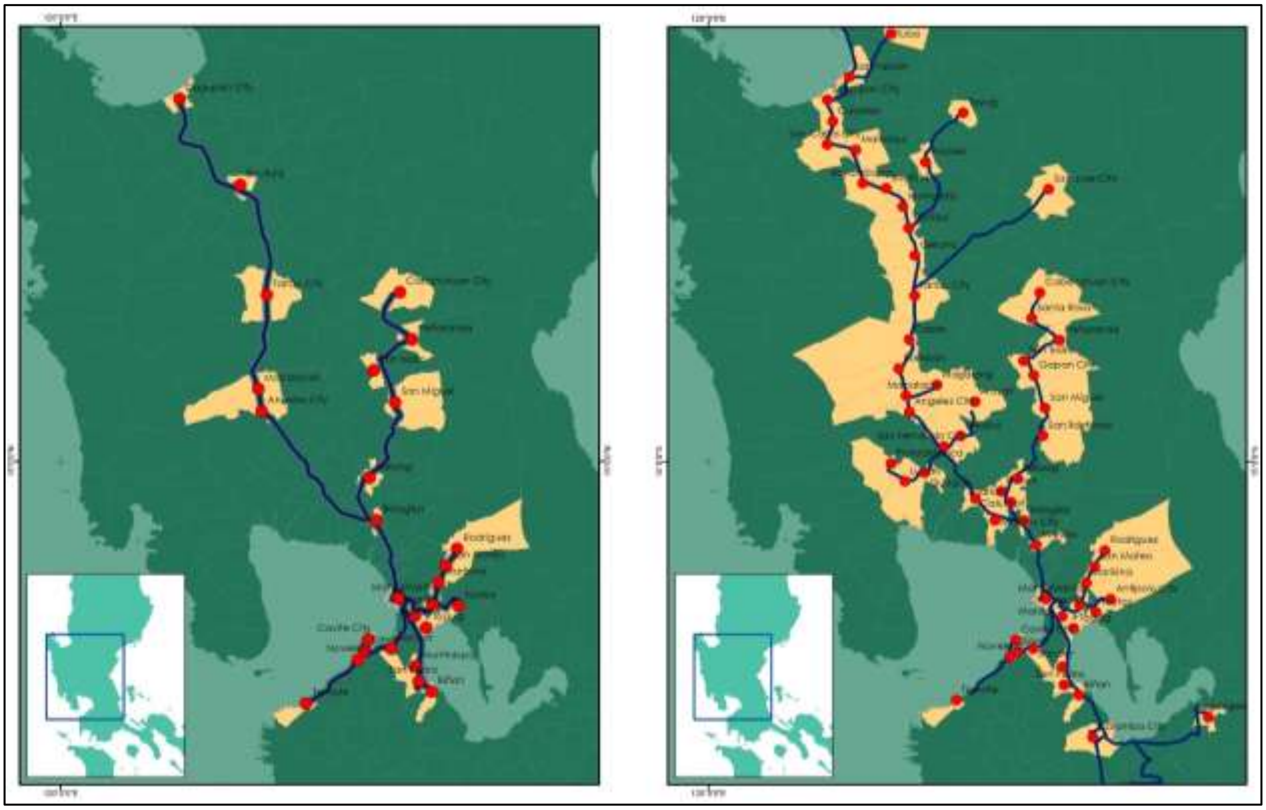

Figure 13. Map of the Manila Railroad Company lines and stations in 1908 and in 1936

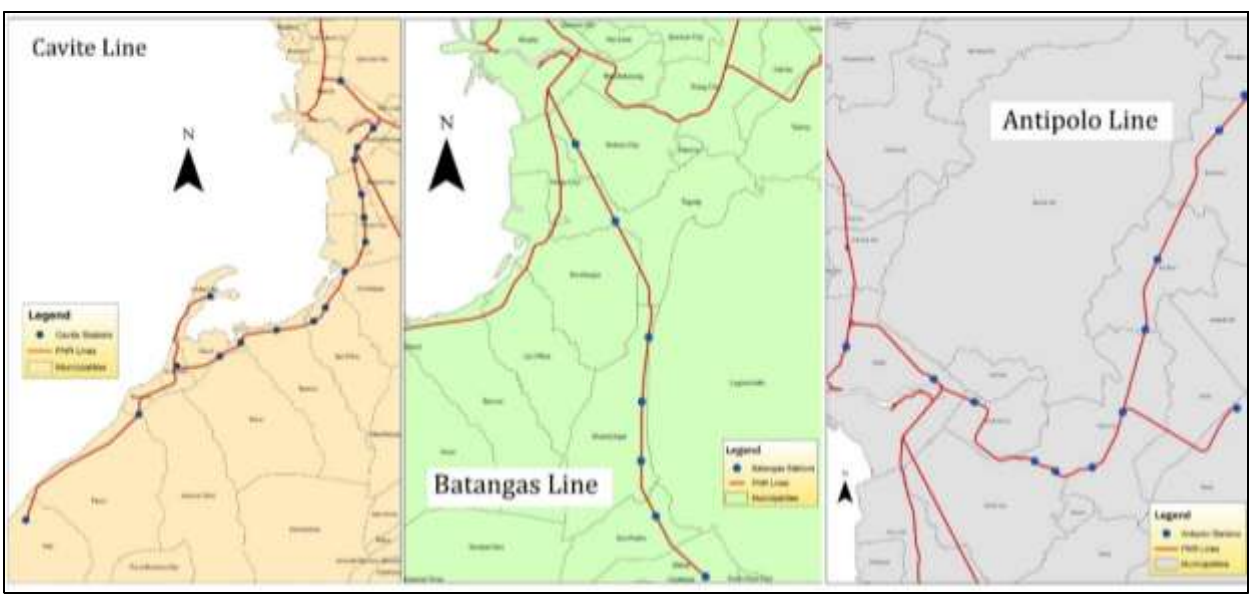

Figure 14. The main branches of the Manila Railroad Company system (1908)

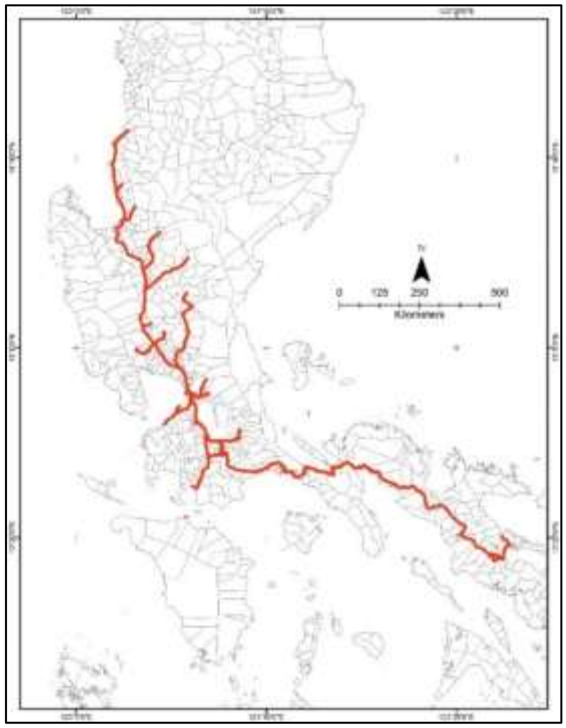

Figure 15. Manila Railroad Company system across Luzon in the late 1930s. The system was roughly 1,336 kilometers in length.

4.3 Population and the Rail

Population data was obtained from the US Bureau of Census and was inputted to the attribute table of municipal boundaries of the Philippines. The population for years 1903 and 1920, and the rail configuration of 1908 and 1936 (Figure 13) were chosen to approximate how the population changed coincidental with the development of the MRC system.

Using the quintile system for population interval classification and symbolization, the overlaid maps (Figure 16) highlight settlements which belong to the 20% most highly populated per time period. There are areas with no data from the census, or left blank across the map since these municipalities have not been established yet at the time period. Nevertheless, the top quintile municipalities generally coincide with the lines and stations when plotted in GIS. Such spatial pattern suggests that a positive correlation existed between the growth of population among settlements and the development of the railways.

It is of utmost importance to note that this procedure is taken to visually correlate the location of the rail and highly populated settlements. Municipalities north of Manila were chosen to be mapped because of the wide distribution of stations across the area, and because most settlements have census records. A more accurate correlation and temporal analysis by mapping can be performed if there is population data and corresponding rail map per year.

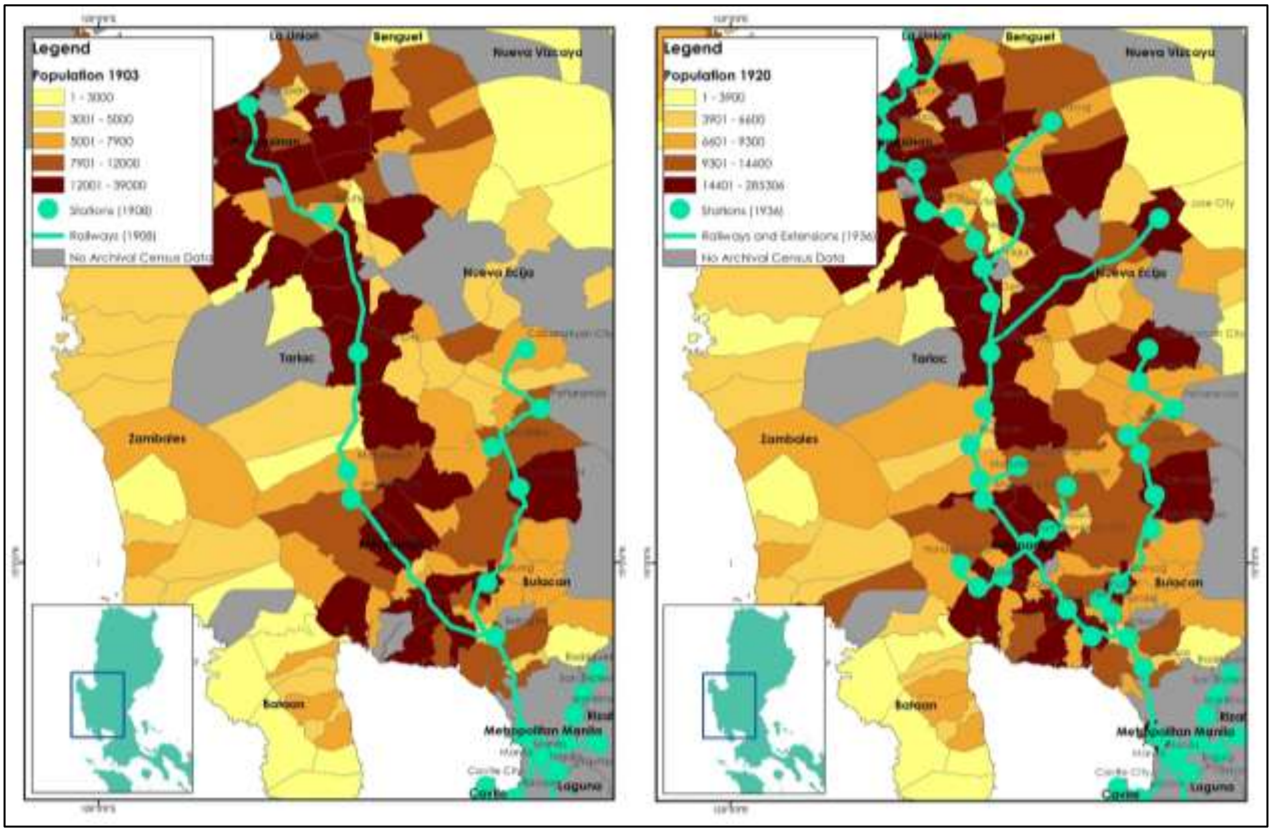

Figure 16. The MRC as of 1903 and 1920, overlaid with 1903 and 1920 population data respectively

5. 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.

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 changes of the Philippine railway system 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 and land use across Luzon. An accurate network analysis is not yet possible at this point because not all train stations have been mapped with maximum accuracy. It would also provide a better understanding of Manila's transport history if the evolution of the road network system in Luzon can be mapped alongside PNR.

Narratives from the Annual Report of the Municipal Board of Manila (Municipal Board of Manila, 1905) from 1905 through 1919 and handbooks such as *Manila and the Philippines* by the Philippines Company (1899) will serve as a goldmine of information on the specifications of the railway system as well as leads on which locations in Manila experienced consequent land use growth due to the transport system. However, it is possible that creating a geodatabase of land use development across Luzon will be a voluminous task. More archival documents and sources from various libraries must be pieced together to paint a more comprehensive feature. As such, the most viable indicator of development per locality are their respective populations over the years of operation of the first train system. Census data from the late 1800s to the 1900s may be needed for this endeavor. This may prove to be challenging due to the availability of historical census data from both the NAP and online libraries. In particular, most records explored from the American Bureau of Census are usually aggregated per province or per island for the Philippines.

Having mentioned land use growth, it will also be interesting to look at the relationship of the railway system not just with the population but to the physically built-up areas in Luzon. There have been few pioneering studies in the field of geographically correlating land use and transport development in the Philippines. For example, Damian and Mabazza (2016) mapped the expansion of urbanized areas and spread of concrete structures from Intramuros and the central business district of Old Manila to its suburbs in a radial pattern. This incidentally co-developed with the streetcar system. As for the case of the entire MRC, from its construction to the present-day, it will require access to more historical maps and text. One foreseeable challenge to this endeavor is the lack of datasets. It can be gleaned from experience that most archival maps and bundles in historical transport in the Philippines tend to be focused on Manila.

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