

GIS-Aided Production of Equipment Locator Maps for Metro Rail Maintenance and Support

by

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To my mother, Vera Quant

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List of Abbreviations

APTA	American Public Transportation Association
DDP	Data Driven Pages
FHA	Federal Highway Administration
FTA	Federal Transit Administration
GIS	Geographical Information Systems
HR	Heavy Rail
LR	Light Rail
MOW	Maintenance of Way
MS	Microsoft
NTD	National Transit Database
OCS	Overhead Catenary System
RELM	Rail Equipment Locator Map
ROC	Rail Operations Control
ROW	Right-of-Way
RTOS	Rail Transit Operations Supervisor
TP	Traction Power
TP	Traction Power
TPSS	Traction Power Substation
VBA	Visual Basic for Applications

Abstract

Many U.S. cities are expanding passenger rail transit to improve transportation system performance. This is particularly the case in Los Angeles and has presented specific challenges for Los Angeles Metro's rail maintenance, safety, and external emergency services personnel. Rail maintenance personnel require familiarity with the location of stations and a variety of rail equipment (crossing gates, power supply, signals, etc.) for routine maintenance and especially during emergency incidents. A common question asked by Metro field personnel is "Where is the equipment item located?"

Typically, answering this question would require prior field knowledge, engineering drawings, or computer systems, none of which may be available in an emergency. However, as part of a solution, a paper-based, pocket size Rail Equipment Locator Map (RELM) was developed for Metro's Traction Power department. While these maps proved useful, the development process presented challenges involving quality assurance, mapping and data management.

The goal of this study was to establish a viable development, production and maintenance methodology that would improve quality, require less development time while fitting Metro's current hardware/software environment. Combining Esri desktop geographic information system (GIS) tools including ArcGIS, ArcCatalog, ArcPy, MS Access local database management software, MS PowerPoint, and MS Visual Basic for Applications with partial automation, required less time to update the new RELM test product, while achieving format consistency, improved spatial accuracy, and reduced risk of errors. In the final analysis, the new methodology demonstrated a significant time based benefit-to-cost ratio improvement and should result in greater rail operations efficiency.

Chapter 1 Introduction

1.1 Overview of Los Angeles County Metropolitan Transportation Authority (Metro)

The Los Angeles County Metropolitan Transportation Authority (Metro) is among the 50 largest transit agencies in the United States (American Public Transportation Association (APTA) 2014, 8). Metro is responsible for a 1,513 square mile service area (NTD 2013), is actively involved in local and regional transit planning, design, construction, implementation, operation and maintenance of transportation services, and manages a \$36 billion transportation infrastructure program (Metro Source 2015). Table 1 provides a few facts about the organization.

Table 1 Metro organization profile. *Source:* Metro 2014, 2015

Name	Los Angeles County Metropolitan Transportation Authority (Metro)
Location	County of Los Angeles
Mission	Metro is responsible for the continuous improvement of an efficient and effective transportation system for Los Angeles County
Full Time Staff	9,302 (2015)
Total Program Expenses	\$4,995 million (FY2014)
Average Weekly Bus/Rail Boardings	1,352,499 (12/2014)

1.2 Metro Rail Transit Growth

Metro is among the nation's top transit agencies based on performance metrics (e.g., unlinked passenger trips, passenger miles) compiled annually by the Federal Transit Administration (FTA) and reported through the National Transit Database (NTD 2013). These findings, for example, Metro ranked third in unlinked passenger trips among more mature transit agencies such as New York City Transit and Chicago Transit Authority (APTA 2014). Metro's

growth mirrors national transportation trends, and reflects state and local demographics, economics and geographical characteristics (Metro 2009, 12-13; CTOD 2010, 13).

1.2.1. National Trends

Public transportation in the U.S. has grown significantly during the 50-year period between 1972-2012 (APTA 2014, 11). Reasons for this trend include federal, state, and local transportation investments, public-private partnerships, central city renewal efforts and the establishment of transit-oriented environments. Many urban areas are expanding or building new rail systems to improve transportation for their residents (Litman 2012).

It is important to distinguish between two common rail transit modes where cities, (like Los Angeles) are heavily investing. The first, Light Rail (LR), often operates alongside city traffic within designated areas defined as the Right-of-Way (ROW). The second, Heavy Rail (HR), provides greater passenger capacity than LR, typically maintains higher speeds between passenger stations when travelling along dedicated track constructed either below-ground (e.g., subways) or elevated track, above the streets and pedestrians (APTA 2014, 66).

While bus transit ridership has remained relatively stable, the combined HR and LR ridership has grown by about 52% over the past five decades (APTA 2014, 11). Figure 1 illustrates this growth trend for passenger travel. The trend for Heavy Rail (middle area band) indicates ridership growth from 1995-2012 following a four-year decline during 1992-1995. However, during the 1990s, Los Angeles celebrated the beginning of Light Rail service with the Blue Line in 1990, and Heavy Rail service in 1993 with the opening of the Metro Red Line subway (Metro 2015). A second portion of the Red Line opened in 1996, a third in 1999, and the final segment in 2000 (Metro 2015). Since 1993, ridership on Metro's rail systems has increased

annually. As a result of years of growth, Los Angeles has been included among the major U.S. LR / HR transit carriers.

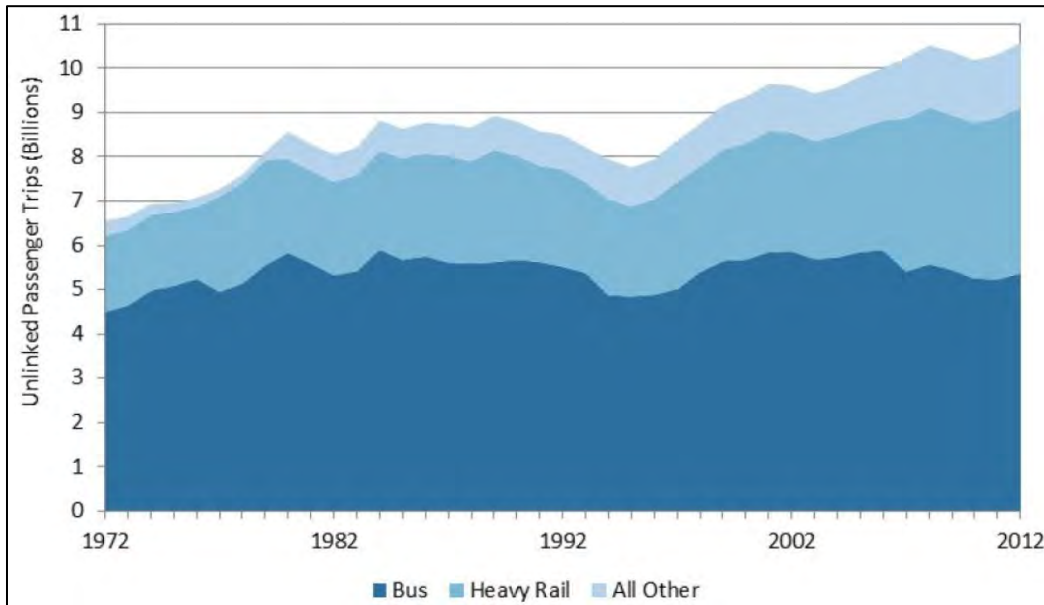


Figure 1 50-year trend of unlinked passenger trips. *Source:* APTA 2014, 11

1.3 Brief History of Rail Transit in Los Angeles County

The growth of rail transit in Los Angeles is embedded in Western U.S. expansion of settlers in search of land and opportunity. Regional and local growth was fueled by the discovery of gold in California in 1848, and completion of the first transcontinental railroad in 1869. Locally, the advent of the Red Car and the Los Angeles Union Station, (established in 1939 and recently celebrating a 75-year anniversary (Metro 2015)) were cornerstones of Los Angeles, Southern California rail transit.

1.3.1. Pacific Electric Red Car

The present Metro rail system, along with those lines planned or under construction, resembles portions of track laid down a century ago by early rail companies. The most legendary formed in 1899 when the Pacific Electric Railway Company (PE) filed for incorporation (LA

Times 1899, 16). Soon after, on July 4, 1902, the PE electric “Red Car” traveled from Los Angeles to Long Beach (Walker 2007). Through mergers and expansion, the rail system peaked by the mid-1920s. By that time, it operated through Los Angeles, Riverside, San Bernardino, and Orange Counties (Barret 2006, 3). An artist rendering of the early Red Car system in 1925 is illustrated in Figure 2.



Figure 2 Pacific Electric Railway Company rail network 1925. *Source:* Metro 2015

1.3.2. Metro Light Rail / Heavy Rail System

The era of the Red Car’s interurban rail transit ended with the last trip from Los Angeles to Long Beach in April 1961. It took 29 years until a similar passenger route resumed on July 15, 1990, when Metro opened the Blue Line (Fiore 1990). Figure 3 illustrates the present Metro rail system that resembles the core of its legendary Red Car predecessor.

The rail lines depicted in Figure 3 represent 23 years of growth, starting with the Blue Line (HR) (1990) that extends 22 miles, connecting downtown Los Angeles to Long Beach. The Blue Line opening was followed by Red/Purple Line (HR) subway (1993, 1996, 1999, 2000), Green Line (LR) (1995), Gold Line (LR) (2003, 2009), and Exposition Line (LR) (2012). Combined, these six rail lines provide Los Angeles county residents with 87 miles of rail transit (Metro 2014).

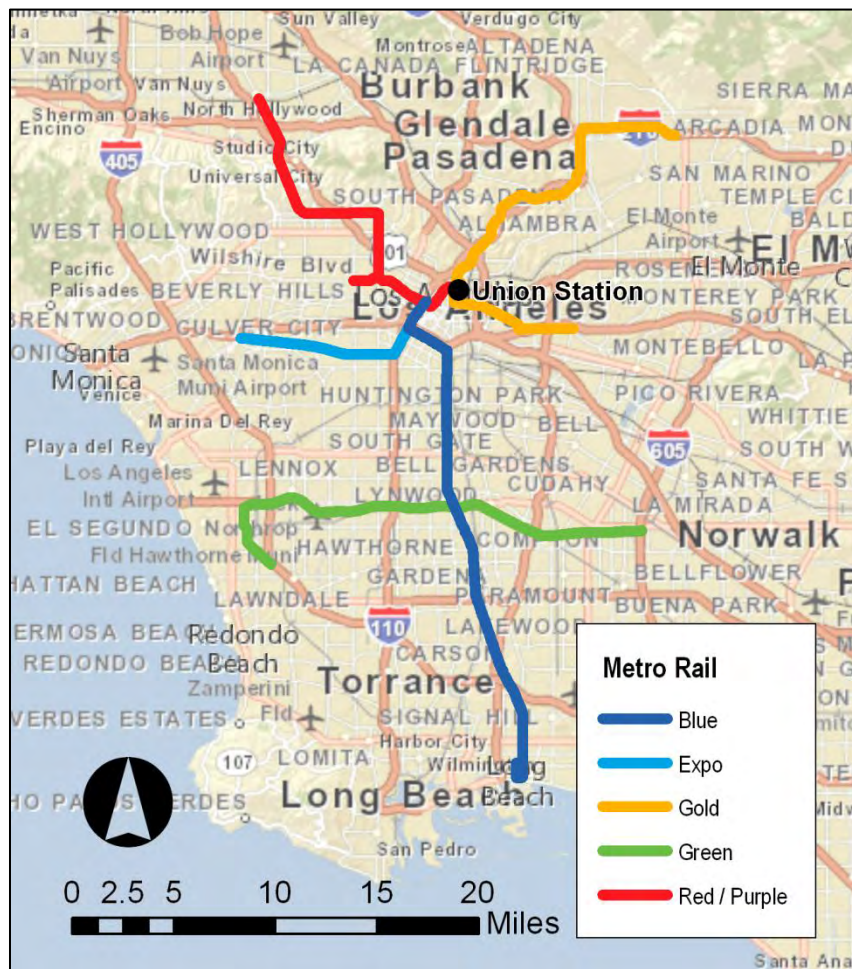


Figure 3 Active Los Angeles Metro rail system.
 Source: basemap: Esri 2015; rail lines: Metro 2012, 2014; Student 2015

1.4 Maintaining Metro’s Rail System

From the time a rail line is operational or placed into “Revenue Service,” it requires maintenance. The work performed by Rail Maintenance personnel is influenced by many factors, such as passenger usage, track mileage, and station design (e.g., below ground). The remaining sections discuss some key factors that affect maintenance and personnel.

1.4.1. Metro-Owned Right-of-Way

The Metro rail system extends through a diverse urban landscape and complex road infrastructure. All tracks are contained within the boundaries of the Right-of-Way (ROW) that is Metro’s responsibility. The ROW can “fly-over” streets, freeways, waterways, and intersect major streets, business driveways, pedestrian crosswalks, and neighborhood backyards. It is a controlled area, defined by fences, pedestrian gates, raised curbs, yellow street markings, railroad crossing gates, flashing lights and bells, and “No Trespassing” signs.

1.4.2. Street-Running Territory

When tracks are intertwined with street traffic and pedestrian crossings, it is considered “street-running territory.” Street-Running Territory is a segment of mainline tracks, where trains operate alongside vehicular traffic that is separated with medians (Metro 2014). At times, this separation is dangerously close to both vehicular traffic and pedestrians, with less than a few feet of clearance. These areas are highly vulnerable to an assortment of incidents resulting from collisions between trains and motor vehicles, trains and pedestrians, and automobiles with rail equipment (e.g., rail crossing gates). A significant part of the Metro Blue, Exposition, and Gold Lines are street-running, and present challenges for operators and motor vehicles all sharing busy streets. Examples of the street-running territory and hazards are exhibited in Figure 4.

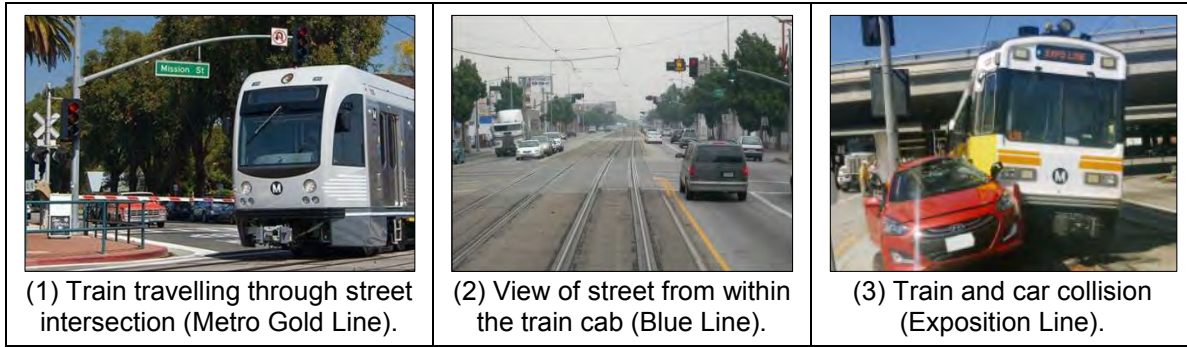


Figure 4 Example of street-running territory along Metro rail lines.

Source: (1-2) Metro staff; (3) Metro Source 2014

Some rail lines escape these dangers (to a greater degree) by operating trains below or above ground and, therefore, out of the path of vehicular traffic. Examples include HR systems in New York City and San Francisco, as well as Metro’s Red/Purple Line that operates below-ground. In addition, there are sections of Metro’s LR lines (e.g., Green, Gold) that operate on dedicated track within freeways.

1.4.3. Stations Above- and Below-Ground

Metro currently maintains 80 rail passenger stations among six rail lines (Metro 2014). This number will increase with current rail construction projects that include the Exposition Line extension, Gold Line Foothill extension, and Crenshaw / LAX Transit Line (Metro 2015). Rail passenger stations as well as track are typically categorized with respect to elevation. The term used to classify track elevation is “grade-level” and is grouped into three subcategories: (1) At-Grade (street level), (2) Above-Grade (above street level), and (3) Below-Grade (below street level). Figure 5 illustrates the number of Metro rail stations by grade-level.

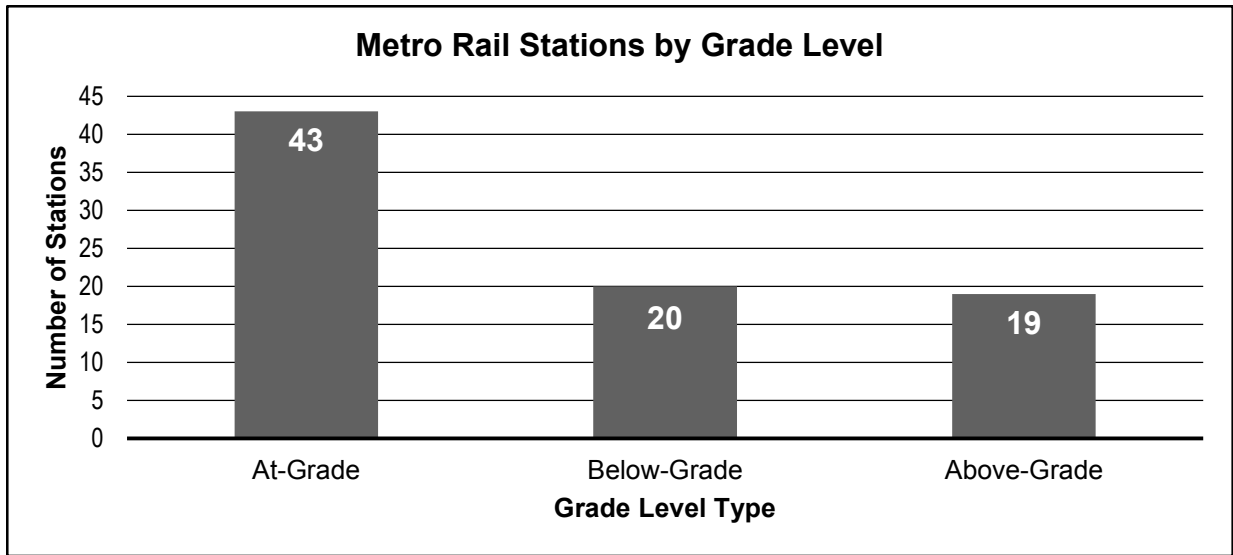


Figure 5 Number of Metro rail stations by grade-level. *Source:* Metro 2015, Student 2015

Figure 5 illustrates that most of Metro rail stations, 52%, are At-Grade level while the remaining stations are split between Below- (24%) and Above-Grade (23%). Two stations are included twice because they each service two or more rail lines with multiple grade-level passenger boarding platforms. The first example, Union Station services three rail lines, the Red/Purple Line subway is Below-Grade, and the Gold Line begins Above-Grade. The second is the Willowbrook/Rosa Parks station that has an At-Grade platform for the Blue Line and Above-Grade platform for the Green Line.

1.4.4. Fixed Equipment Locations

Most rail equipment and supporting infrastructure are stationary assets. For example, railroad track, crossing gates, signal cases, electrical power poles, and power buildings are seldom moved. However, in some cases, equipment is removed either as technology is upgraded or relocated to mitigate damage by moving it a few feet away from vehicular street traffic. When relocation is not possible, additional protective measures such as installing bollards or polls

around the equipment, are employed. An example of this approach is depicted in Figure 6 in response to vehicle damage.

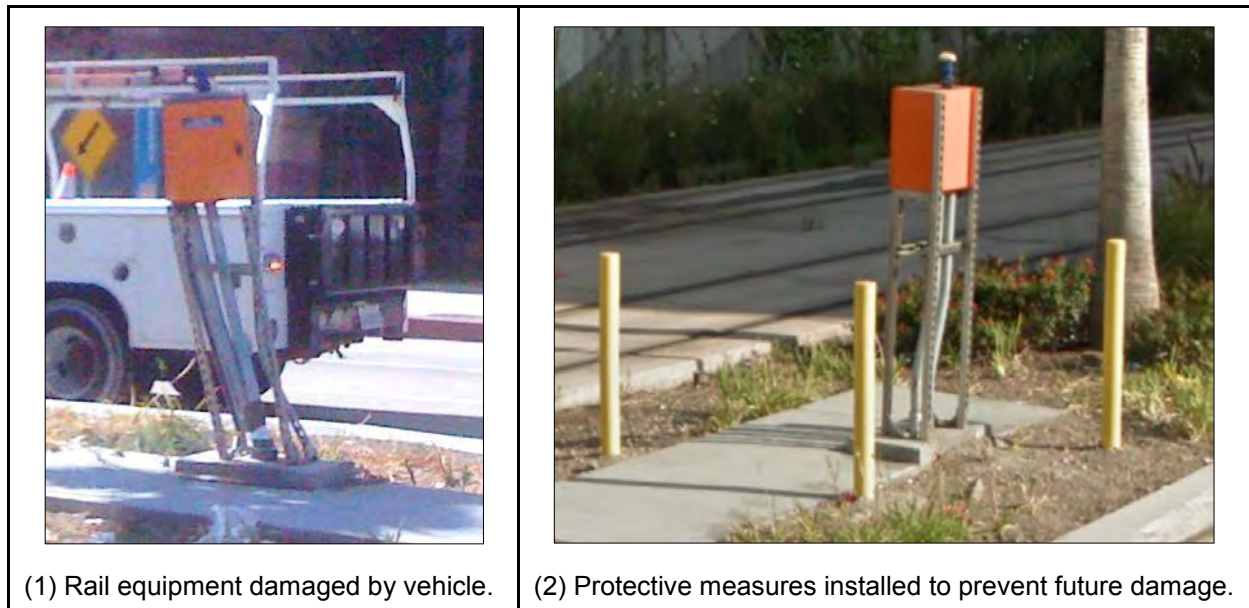


Figure 6 Equipment damaged by automobile and protective poles installed.

Source: (1) Metro staff 2012, (2) Google Maps 2014

1.4.5. Opaque Equipment Locations

Throughout the Metro rail system, there are areas where equipment is difficult to view from the street or is simply out of sight. Equipment may be located below-ground inside tunnels, above-ground on elevated track, or along a section of track that diverts from the street network and is accessible on foot or with specially designed vehicles.

1.4.6. Urgency of 24/7 Access

Maintaining a rail system is a 24-hour activity even when passenger rail service has ended for the day. Incidents along the ROW can occur at any time of the day, “24/7,” 365 days of the year. One operational difference between bus and rail operations is the ownership and responsibility for maintaining the ROW. The road networks that buses travel are the responsibility of the local city transportation department, while the rail ROW is maintained by

Metro. Metro maintains three work shifts to provide round-the-clock rail system maintenance and response to rail incidents.

With rail lines currently under construction and more being planned, maintaining Metro's rail system is ongoing. Incidents along the rail ROW can and do occur, thus it is imperative to have direct access to information regarding equipment location. Most pertinent is access to this operation equipment in a prompt, and at critical times, a life-saving response. In review of past implementation of operation methods, we will examine the challenges facing the Rail Maintenance of Way (MOW), Traction Power department and the tool this author developed to support personnel in the field.

Chapter 2 Background

2.1 Equipment Location Challenges

To properly maintain the rail line, rail maintenance personnel must perform scheduled routine maintenance on track equipment. Equipment (for this discussion) refers to railroad related technology that supports passenger train operations (e.g., track, switches, signals, crossing gates). Unscheduled maintenance often occurs from numerous causes, including malfunctions with equipment, natural disasters, collisions between rail vehicles and automobiles, and automobiles with track equipment (see Figure 7). In emergencies, locating the scene of an accident or an equipment problem with minimal delay is critical for field supervisors, maintenance crews, and emergency response personnel.



Natural causes	Human causes
	
(1) Damage to rail electrical cables from construction site caused by rain storm.	(2) Damage to rail track from collision between big rig truck and passenger truck.

Figure 7 Metro Rail Line incidents. *Source:* (1) Metro 2006, (2) Metro Source 2010

During a rail related emergency, Rail Maintenance personnel respond to the incident location based on prior experience, voice communications, hard copy maps, engineering drawings, or personal smart phones with mapping applications (e.g., Google Maps). Examples of two field scenarios are summarized to provide a perspective of issues involving equipment location. First, many times personnel are dispatched to an incident site while they are in the field

rather than from the maintenance yard. In this situation, personnel might not have supported maps or drawings with them. Another situation requires personnel to respond to equipment damaged from the effects of heavy rains and wind. In this situation, equipment was located in a brush area with the only access point through a dirt road that was not shown on the street maps. It was also difficult to determine where the best location was to set up a response center for the support crews.

2.1.1. Equipment Location and Street Addressing Limitations

In many industries, a postal address is utilized to locate equipment within the urban landscape. For example, a water main, fire hydrant, telephone pole, gas meter, or street lamp could use a parcel address. However, within the railroad industry, this approach is dubious because the majority of equipment is located within the track territory – the Right-of-Way. This is illustrated in Figure 8 where a section of the Metro Exposition Line is depicted using a street map, building outlines, street addresses, and a strip of matching aerial imagery. The Overhead Catenary System (OCS) pole located within the yellow circle is the item to locate. In this scenario, an address could only be assigned to the item as a reference based upon user selection criteria (e.g., closest address).

In Figure 8, the street address numbers 1660, 1658, 1667, and 1669 are all likely candidates based on their proximity. Alternatively, the street intersection could also be used to help with the location. Unfortunately, not all railroad equipment can be located using an address or intersection.

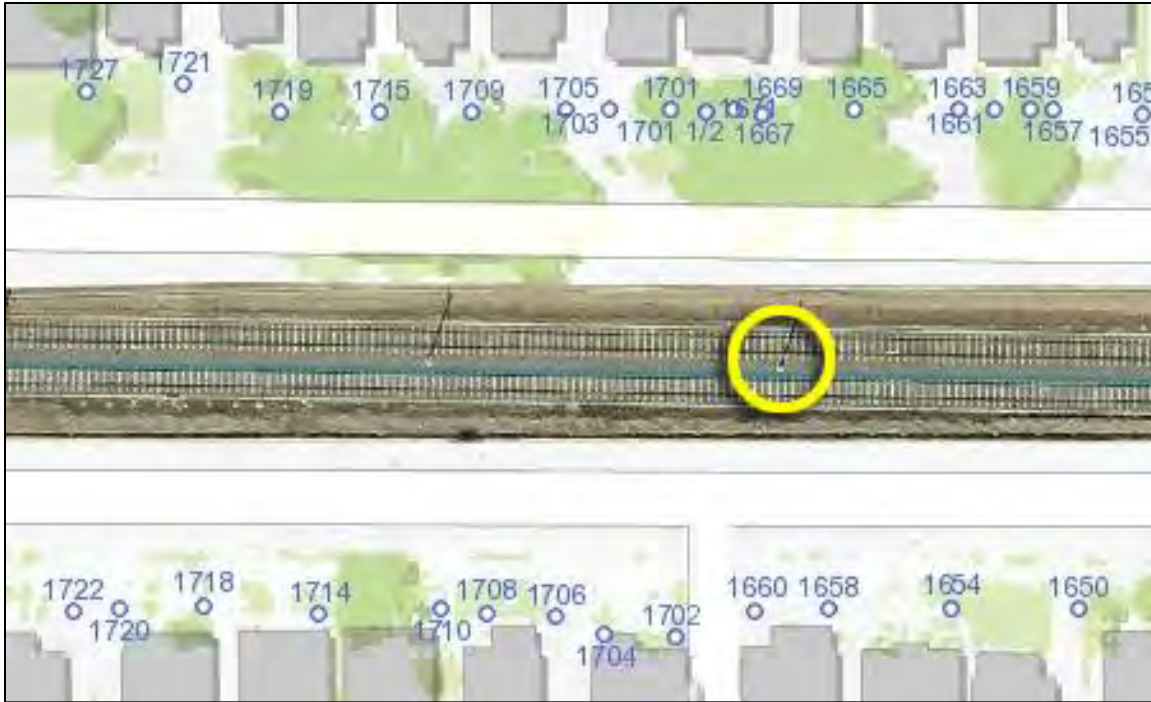


Figure 8 Track equipment located along street addresses. *Source:* street and building address: LA County GIS Viewer, Streets (2014); aerial imagery: Aerial 2014 – Preliminary

In Figure 9, a section of track (represented with a gold line) is displayed that is neither visible nor directly accessible from the street. This area cannot be associated to a particular street address and the closest street intersection is approximately a quarter of a mile away. Locating equipment in this area requires personnel to have prior knowledge or additional necessary information.



Figure 9 Metro Gold Line track diverts from street view between hillside trees. *Source:* aerial imagery: LA County GIS Viewer, Aerial 2014 – Preliminary; rail line: Metro 2014

Accessing equipment within this section of track takes longer because there are no close access points, a situation that forces Rail Maintenance personnel to walk a considerable distance to locate equipment. An example of an incident that occurred in this section of track is shown in Figure 10. The incident resulted from rain and high winds that caused tree branches to fall onto the electrical cables (OCS) and onto the tracks. In the photograph, a light rail train is shown waiting on the left track and on the right track two trucks (Hi-Rail vehicles) facing each other, that were used to repair the broken cables.



Figure 10 Traction Power personnel repairing Gold Line OCS cables with the aid of Hi-Rail vehicles. *Source:* Metro Source 2010

The incident shown in Figure 10 illustrates the challenges Rail Maintenance and Traction Power personnel experience when responding to electrical power incidents in hard to reach areas. This example demonstrates that it is not just one factor, but rather a combination of factors, that

produce the unique challenges. These include the track terrain, track elevation, automotive vehicle traffic, time of day (e.g., peak, off-peak), and weather conditions. Understanding these factors in relation to the equipment location can mitigate challenges experienced by personnel in-route to or arriving at the incident.

2.2 Traction Power Department Situation

Within Metro's Maintenance of Way (MOW), Traction Power (TP) department personnel raised questions pertaining to the location of Traction Power Substation (TPSS) equipment. The TP department had experienced an increase in trainees to maintain the current and expanding rail system. In addition, some TP personnel were transitioning between light and heavy rail lines with limited field location experience with the rail lines' TPSS equipment. Consequently, for some crew members, this lack of familiarity could result in longer travel times during routine maintenance or emergency response situations.

The TPSS buildings contain equipment that converts electrical power from the local utility company (e.g., Southern California Edison), and transfer electricity to the trains through the Overhead Catenary System (OCS). An example of a TPSS building is shown in Figure 11, followed by the OCS electrical cable system shown in Figure 12.

As the examples depict, the LR system support structures are interwoven into the urban landscape. As a result, the Traction Power personnel are confronted with an assortment of LR incidents that occur in street-running territory. Three incidents that are directly attributed to this environment include: (1) construction site damage, (2) vehicles on track, (3) vehicle collision with equipment (see Figure 13).



Figure 11 TPSS building (lower right) near the train tracks. *Source:* Wikimedia Commons 2015



Figure 12 OCS supplying electricity to the LR train. *Source:* Metro Source 2015

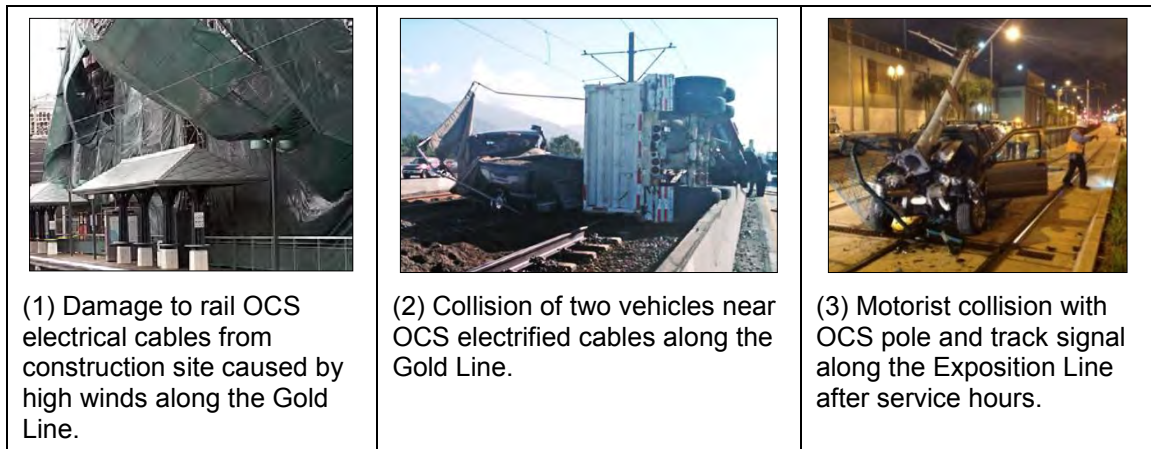


Figure 13 Traction Power related incidents.
Source: (1) Metro 2006; (2) Metro Source 2010, (3) 2013

Each incident displayed in Figure 13 required immediate response by Rail Maintenance personnel to support emergency responders and thereafter to restore normal transit service. In these incidents, personnel first have to remove electrical power to the immediate rail track to insure the safety of all persons involved.

Naturally, before the above incidents could be resolved, it was necessary to locate the related equipment. Some of these equipment-locating practices were discussed previously, while the following method is specifically applied to TPSS equipment. The approach is similar to following a telephone wire from a telephone pole and requires driving the maintenance vehicle on roads that are positioned closest to the rail track. The driver must then visually scan the track, looking for specific equipment. Nevertheless, the fact that, at times, this method has proven effective and some problem-solvers consider it acceptable, it is arguably hazardous, cost prohibitive, impractical under certain conditions (see Figure 9), and potentially detrimental during life threatening emergencies (see Figure 13).

As the TP department staffing levels grew to support rail system expansion, it was necessary to review current methods of locating equipment. It is beneficial to those involved

with rail maintenance to locate equipment safely and efficiently while expending minimal travel time under normal or adverse driving conditions. A solution that addressed the TP department's specific TPSS equipment location issue was required.

2.3 The Initial Locator Map Solution

During discussions surrounding the TPSS equipment with a fellow TP supervisor, one supervisor posed the following question to this author, "can you develop some maps?" This question initiated a project that culminated in the development of a pocket size Rail Equipment Locator Map (RELM). The first publication was the "Metro Blue Line Traction Power Substation (TPSS) Location Guide." Subsequently, additional TPSS locator maps were developed and published for the Exposition, Gold, and Green Line. An example of the TPSS locator map is depicted in Figure 14.

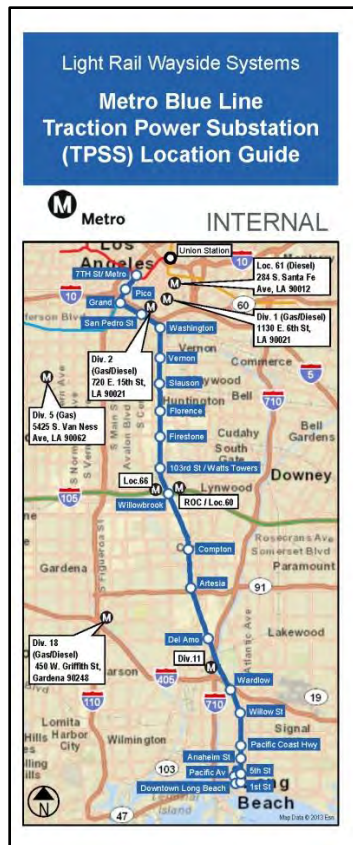


Figure 14 Metro Blue Line TPSS locator map. *Source:* Student 2015

2.4 User Response

Through review of map distribution quantities (see Figure 18) and user comments, the Traction Power department personnel, as well as outside department staff found the paper-based solution a useful reference for fieldwork. Some TP supervisors have kept the TPSS locator map (see Figure 15) on their desk, while others kept copies in their vehicles. A TP instructor began adding the locator map into the new TP trainee’s instruction binders. After the first two TPSS locator maps were published, one TP personnel commented, “Those maps have changed our world.” While this was an obvious exaggeration, nonetheless, well appreciated, it represented early evidence that this solution satisfied the user groups’ *initial* requirements.

During early draft reviews of the TPSS locator map, user feedback led to the creation of an additional RELM solution. The Rail Communications and Signal's department assistant managers requested a locator map specific to communication and signal equipment along the ROW (e.g., signal case, communication's cabinet). This was fitting because some equipment is co-located and addressed using a multi-departmental RELM guide. The first RELM publication in this series was the "Metro Blue Line Train Control and Communications Location Guide" (see Figure 16.)

2.4.1. Distribution

During the TPSS locator map development, a distribution site located outside the TP department was planned. Ultimately, a multi-slot distribution bin was installed outside the TP supervisor's office. This provided TP users a centralized location to collect all TPSS locator maps. A second distribution site was established outside the Signals department to store the multi-departmental Train Control and Communications locator map. A third location, established at the Rail Communications off-site facility offered both series of locator maps. The various distribution bins supporting each department is depicted in Figure 15, Figure 16, and Figure 17.



Figure 15 Traction Power department's TPSS Locator map distribution bin.
Source: Student 2015



Figure 16 Signal department's Train Control and Communication map distribution bin.
Source: Student 2015



Figure 17 Rail Communication’s map distribution area.

Source: Metro staff 2015

Once the TPSS locator maps were distributed, personnel from departments outside the TP group began requesting copies. For example, Rail Operations Control (ROC) department requested copies after reviewing early drafts. This group controls all train activity on the “mainline,” representing tracks outside the separate vehicle storage facilities (Metro 2010). The Rail Transportation Instruction manager emailed a set to Rail Instructors for training purposes. Another manager of Rail Operations emailed a set to 90 staff, including Rail Transit Operation Supervisors (RTOS). This is significant as RTOS personnel are dispatched daily to patrol rail transit regions.

Once a TPSS locator map was released, it was necessary to track distribution for monitoring inventory and updates. A distribution log was established to document this maintenance activity. The log collected revision number, date, quantity, distribution method (distribution bins, interoffice mail, email), format (paper, digital), and recipients (department,

group, or user). While considerable effort was involved in this activity, it is naive not to recognize that once materials are distributed, it is difficult to manage or monitor subsequent copies by users (Tulloch and Epstein 2002, 201). The results of this on-going activity are shown in Figure 18.

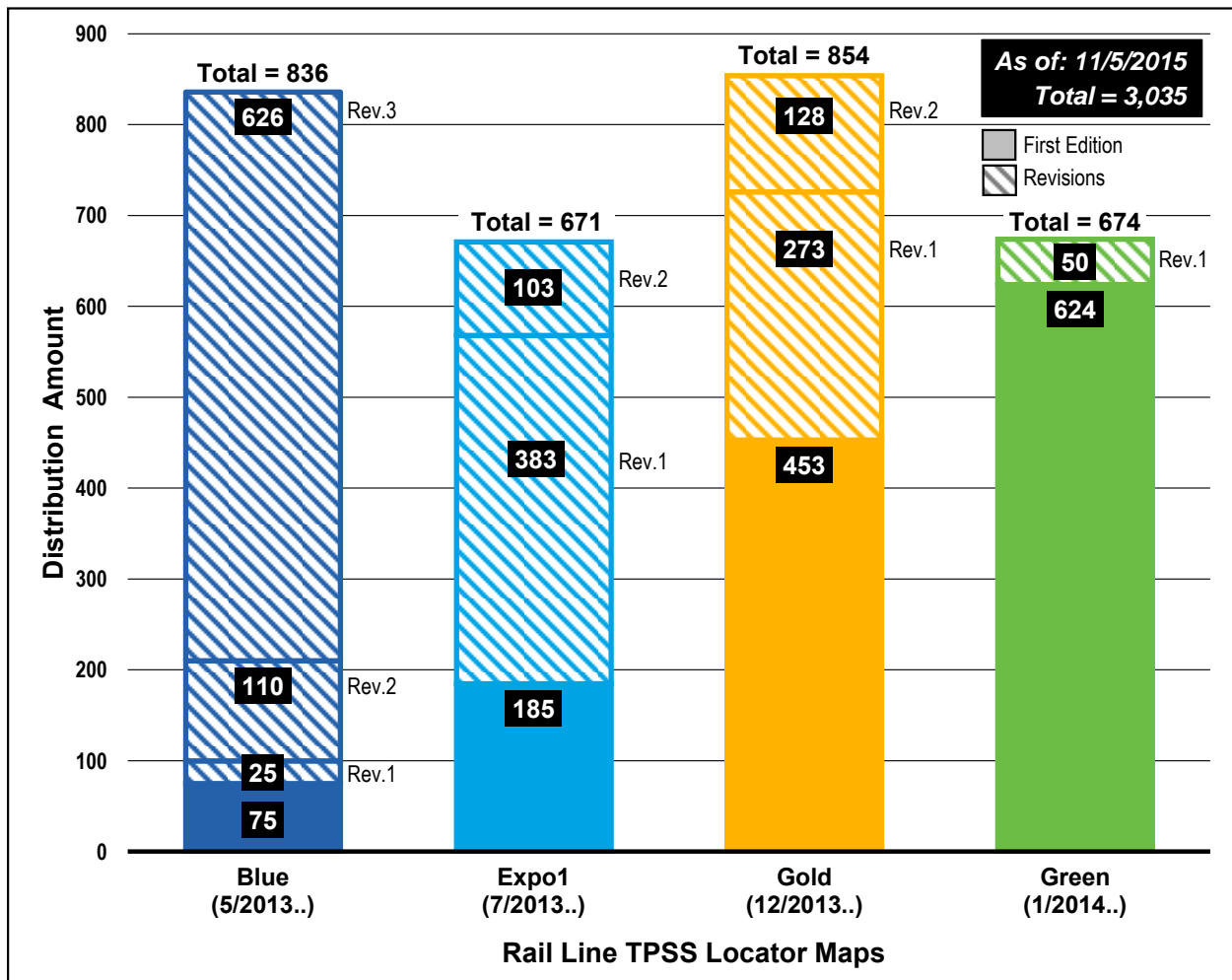


Figure 18 Traction Power Substation locator map distribution. *Source:* Student 2015

The distribution quantities presented in Figure 18 include personnel outside the TP department. While unanticipated, this validated the relevance of the content and functionality of the publication format, further proving that this form of communication media, specifically focusing on geographical information (Sui and Goodchild 2001, 388) is a valuable resource for

public transit agencies involved in rail operation. Encompassed in the TP supervisor's initial request and culminating with the last phase (maintenance), the locator maps represent an on-going activity stream supporting efforts by the GIS community (i.e., researchers, practitioners), and public agencies involved in identifying the tangible and intangible benefits of GIS technology (Tulloch and Epstein 2002, 203).

2.5 RELM Development Process

The initial locator map layout required a large amount of effort focused on solving the graphic design and production challenges. Once the design issues were addressed (e.g., page columns, standard symbology, font sizes, map frame size), and the development process had stabilized, the focus shifted to operation and maintenance. It is in the latter phases (operation and maintenance) that the bulk of benefits are anticipated and experienced (Tulloch 1999, 263). In practical terms, it is also where obstacles and deficiencies are encountered. The following sections explain this author's existing locator map development process and serves as a baseline methodology that this study set out to improve.

2.5.1. User Requirements

Beginning with the RELM project initiation, the primary audience for the TPSS locator maps were Traction Power personnel. Therefore, this represented a department-wide application supporting an on-going group activity (Tomlinson 2003, 35) that required the department managers, supervisors, and respective personnel to identify the necessary equipment information. The initial TPSS equipment data items were: (1) TPSS name; (2) address; (3) phone number (4) voltage; (5) utility company name; and (6) utility company identification number.

During draft reviews, a TP member requested that the highway network be clearly depicted on the TPSS locator map cover. The premise was that traveling between equipment

locations involves knowledge of the highway system, particularly one as complex as Los Angeles County. The request was immediately implemented, replacing the author's comparatively impractical cover design that included the rail line but omitted a vital underlying geographical feature – the road network.

In a related vehicle, travel issue TP personnel requested the identification of gas and diesel fueling locations. This is a well-known logistical concern when operating motor vehicles and especially during emergencies (Greene 2002, 54). Both requests clearly supported TP personnel's travel demands throughout Metro's rail network, and thereby addressed road accessibility/drive time (Radke, Johnson, and Baranyi 2013, 93) and fueling concerns.

After all the TPSS locator maps were in routine circulation, a request was submitted by another TP crew member (primary user). He explained that he transferred to the Light Rail (LR) line from the Heavy Rail (HR) line and wanted to know which light rail passenger stations had restroom facilities. In fact, the results of this particular data collection effort shown in Figure 19 reveal surprising results.

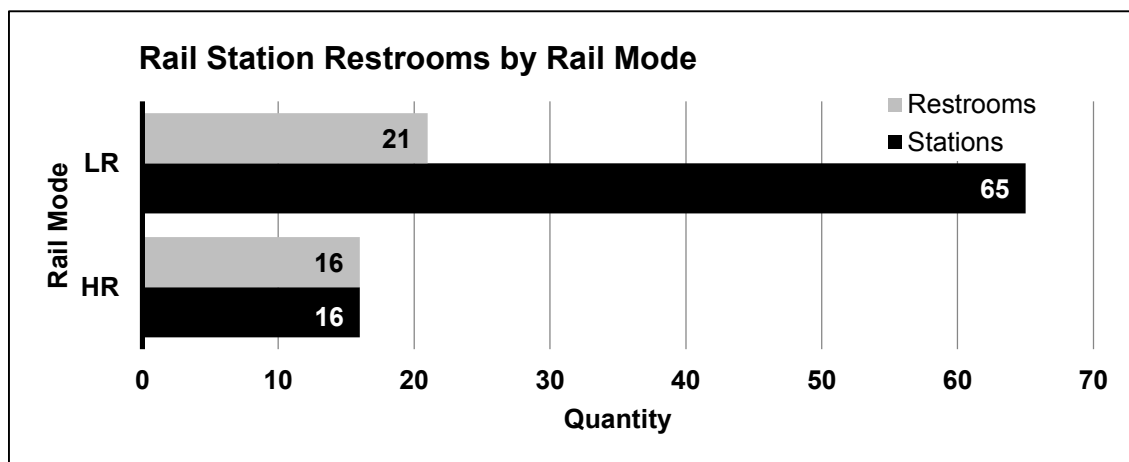


Figure 19 Comparison between staff restrooms at Light Rail (LR) and Heavy Rail (HR) passenger stations. *Source:* Metro 2014, Student 2014

The results shown in Figure 19 provided evidence that the TP personnel’s information request was warranted. The inquiry revealed that restrooms are located at all 16 heavy rail stations, compared to only 21 out of 65 (32%) of light rail stations.

To summarize the user request, from project initiation and through production, a compiled list of the TPSS locator map requirements is shown in Table 2. The list, arranged by project phase shows six items (1-5) were incorporated before the first publication release, two items (6-7) during the draft reviews, and three items (8-11) were identified after the first publication and later incorporated as revisions.

Table 2 TPSS map user requirements by development phase. *Source:* Student 2015

User Requirements	Initial Input (3/2013)	Draft Review (4-5/2013)	Post Publication (5/2013)
1. TPSS name	■		
2. TPSS address	■		
3. TPSS phone number	■		
4. TPSS power voltage	■		
5. Utility company name	■		
6. Equipment access path		■	
7. Highway map		■	
8. Utility company ID number (5/2013)			■
9. Fueling locations (6/2013)			■
10. Map symbol legend (12/2013)			■
11. Rail station restrooms (1/2014)			■

Typically, user requirements are identified during project definition (Tomlinson 2003, 49; Croswell 2009, 29) followed by draft reviews that may uncover additional requirements, thereby eliminating needless, post-publication revisions and costs. However, regardless of the project phase, user input is valuable and should not be underestimated.

2.5.2. Communication Media Review

Collecting and reviewing an assortment of primarily paper-based communication media influenced the RELM format. These were publicly accessible in distribution racks or available in digital format through the Internet (e.g., Metro.net). The subject matter targeted audiences interested in bus and rail transit, guides for locating apartments, campgrounds, restaurants, entertainment venues, and tourist attractions. These paper-based publications specifically incorporate and rely on maps to assist the user in determining the geographical location of an item.

Many of these publications utilize a brochure format that provide an assortment of map sizes and orientations. These publications benefited from the flexibility of the brochure format providing three or four panel folds to accommodate diverse requirements (Ryan and Conover 2004, 400). Brochures can be relatively small but fan out into fully opened sheets of paper. This delivery approach can maximize paper size and portability while minimizing the physical dimensions to fit within the limits of distribution bins or tabletops.

The brochures reviewed integrated text onto maps, based on a vector data model (Bolstad 2008, 32). They utilized graphics to represent cartographic symbols, leader lines, numbered labels, and a numbered index list. Additional characteristics considered were double sided printing, paperweight and opacity, colors, legibility (i.e., type family, style, size, color), and page size (e.g., letter, legal, tabloid, custom). A few examples of the communication media reviewed are exhibited in Figure 20, Figure 21, and Figure 22.

FEARNS'S 2013-2014 FREE MAP

San Antonio

Traveler Info Guide

VISITOR SERVICES VISITOR SERVICES SPORTS ATTRACTIONS
SIGHTSEEING WINE TASTING HELPFUL NUMBERS

1 The Alamo
216 Alamo Plaza
San Antonio
(210) 247-0212
thealamotrolle.com

2 The Buckhorn
318 East Houston
San Antonio
(210) 247-4000
buckhornmuseum.com

3 Charlie Wants a Burger
223 Losoya Street
San Antonio
(210) 227-0864
charliewantsaburger.com

4 City Sightseeing San Antonio
204 Alamo Plaza
San Antonio
(210) 224-8687
city-sightseeing.com

5 City Sightseeing Tours
321 Alamo Plaza
San Antonio
(210) 492-4144
citytoursinc.com

6 Paesanos Riverwalk
111 West Crockett Street
Suite 101
San Antonio
(210) 227-2782
paesanosriverwalk.com

7 Ripley's Believe It or Not!
301 Alamo Plaza
San Antonio
(210) 224-9299
sanantonio.ripleys.com

8 La Villita
418 Villita Street
San Antonio
(210) 207-8614
lavillita.com

9 Six Flags Fiesta Texas
17000 IH 10 West
San Antonio
(210) 697-5050
www.sixflags.com

10 Splashtown - San Antonio
3600 IH 35 North
San Antonio
(210) 227-1100
splashtownsa.com

11 Ripley's Haunted Adventure Tomb Raider/Guinness Museum
329 Alamo Plaza
San Antonio
(210) 226-2828
ripleys.com/phillips

12 Rio Rio Cantina
421 East Commerce Street
San Antonio
(210) 226-8490 or
(210) 226-8462
rrioriocantina.com

13 San Antonio Zoo
3903 North St. Mary's Street
San Antonio
(210) 734-7184
sazoo.org/zootennial

14 Schlitterbahn Waterpark
400 North Liberty Avenue
New Braunfels
(830) 625-2351
schlitterbahn.com

15 San Antonio & Beyond
317 Alamo Plaza
San Antonio
(210) 886-9991
SanAntonioAttractions.com

16 Snake Farm & Animal World
5640 IH 35 South
New Braunfels
(830) 608-9270
exoticanimalworld.com


17 ZDT's Amusement Park
1218 North Camp Street
Seguin
(830) 386-0151
zdamusement.com

18 Sunrise Over The Alamo
San Antonio, Texas


ADVERTISERS

visitor**tips**.com

Figure 20 Sample of a tourist guide with two scaled area maps. *Source:* Visitortips 2013


GOLD COUNTRY 

SIERRA CITY




Sierra Skies RV Park
 100 Carrier Circle | Sierra City, CA 96125
 (530) 862-1166 | kirbyranch@netzero.net
www.sierraskiesrvpark.com
 From I-80: Hwy 49 N to Grass Vly, L on Hwy 49 to Sierra City, R at Hayes St, L to park. From I-395 N: W on Hwy 70 to Hwy 49 S thru Loyalton to Sierra City, L on Hayes to park. Seasonal park on Yuba River. Fish, swim, gold pan. Nearby golf, dining. Phone hookups. Free WiFi hotspots. Open 5/1-10/31.
 S: 29 F: 29 MSL: 40

AUBURN




Auburn Gold Country RV Park
 3550 KOA Way | Auburn, CA 95602
 (530) 885-0990 | mgr@auburnrvpark.com
www.AuburnRVPark.com
 I-80 Exit Bell Rd go W. R on Hwy 49, R on Rock Creek Rd to KOA Way. In the heart of the Gold Country. Gold pan, mines, fish, whitewater rafting, golf course nearby. Call for more info.

DOBBINS




Lake Francis Resort
 13919 Lake Francis Rd | Dobbin, CA 95935
 (530) 692-1700 | info@lakefrancisrv.com
www.lakefrancisrv.com
 From Marysville 12 mi E on Rt 20, 12 mi N on Rt E21 (Marysville Rd), 7 mi E on Rt E20 (Marysville Rd) to Dobbins, ¼ mi S on Lk Francis Rd. Shade, fireplaces, cabins, group camping, clubhouse, pool, tennis, basketball, fishing hall w/fires, baseball, basketball.
 S: 57 F: 38 MSL: 40

OREGON HOUSE



Lake of the Springs RV Resort & Campground
 14152 French Rd | Oregon House, CA 95962
 (877) 947-6500 | info@lakeofthesprings.com
www.lakeofthesprings.com
 From Marysville 12 mi E on Rt 20, 12 mi N on Rt E21 (Marysville Rd), 7 mi E on Rt E20 (Marysville Rd) to Dobbins, ¼ mi S on Lk Francis Rd. Shade, fireplaces, cabins, group camping, clubhouse, pool, tennis, basketball, fishing hall w/fires, baseball, basketball.
 S: 54 F: 76 MSL: 40


MARYSVILLE



Collins Lake Recreation Area
 7530 Collins Lake Rd | Marysville, CA 95973
 (800) 286-0576 | info@collinslake.com
www.collinslake.com
 12 mi E of Marysville on Rt 20. A rare find!! Clean, Shaded lakefront recreation area. Hot showers, marina, store, great fishing & bass. Great fishing. Open 5/1-10/31.
 S: 333 F: 194 MSL: 40

Gently rolling hills studded with oak to pine trees with high hills and deep canyons.

GOLDCOUNTRY



Little towns nestled in the foothills along Highway 49, hidden like the nuggets of gold that brought many to the area; await you in California's Gold Country region. Walking in towns like **Jamestown** and **Nevada City**, that still boast the Old West architecture, will remind you of the rich history of the area. Kids of all ages will love to step back in time and visit **Columbia State Historic Park**, a living gold rush town.

Those that really like to explore the area they stay in won't be bored as the region has many winding trails to hike, bike or horseback ride, caverns to spelunk and native wildlife to watch. The region also boasts an abundance of lakes and rivers fed by Sierra runoff that offer many opportunities to go whitewater rafting, tubing, boating and fishing.

Yosemite National Park and all its stunning natural beauty lies within the regions borders as well and is a must see California landmark!

Calendar of Events

JANUARY
Wild & Scenic Film Festival

MARCH
Sonoma Celtic Fair
Mariposa Storytelling Festival

MAY
Calaveras County Fair & Frog Jubilee

JUNE
Nevada City Bicycle Club
Tuolumne Lumber Jubilee

JULY
Fire on the Mountain, T
California WorldFest, G

SEPTEMBER
Draft Horse Classic & Grass Valley Bluegrass in the Fog
Plymouth Blazer Hog BBQ Com
Mariposa

NOVEMBER
Mandarin Festival

Discover more about places to do at www.Camp-Cal.com



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The Old West Comes Alive!

Just a few hours from Sacramento - historic towns, antique, boutique amenities, independent art, live theater & more!

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 800-446-1333
www.YosemiteGoldCountry.com

Own A Motorhome?
WWW.FMCA.COM

No.	PARK NAME	FULL HOOKUPS	MAX AMPS	TENTERS WELCOME	PULL THRU AVAIL	LAUNDRY	STORE	CLUB ROOM	BIG HIG FRIENDLY	WiFi	CABLE TV HOOKUP	POOL	SPA
29	Sierra Skies RV Park	30	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
166	Sierra Skies RV Park	38	50	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
167	Lake Francis Resort	76	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
168	Lake of the Springs RV Resort & CG	194	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
169	Collins Lake Recreation Area	66	50	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
170	Auburn Gold Country RV Park	32	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
171	Camp Chiquita Campground	50	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
172	Camp Lotus	30	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
173	Ponderosa RV Resort & CG	40	50	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
174	Columbia Resort	329	50	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
175	Fair Horizons 49er Village RV Resort	80	50	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
176	Gold Country Campground Resort	34	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
177	Gold Strike Village	65	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
178	Angels Camp RV & Camping Resort	52	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
179	Sugar Pine RV Park	75	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Figure 21 Campsite guide with index and detail maps. Source: Camp-California 2015

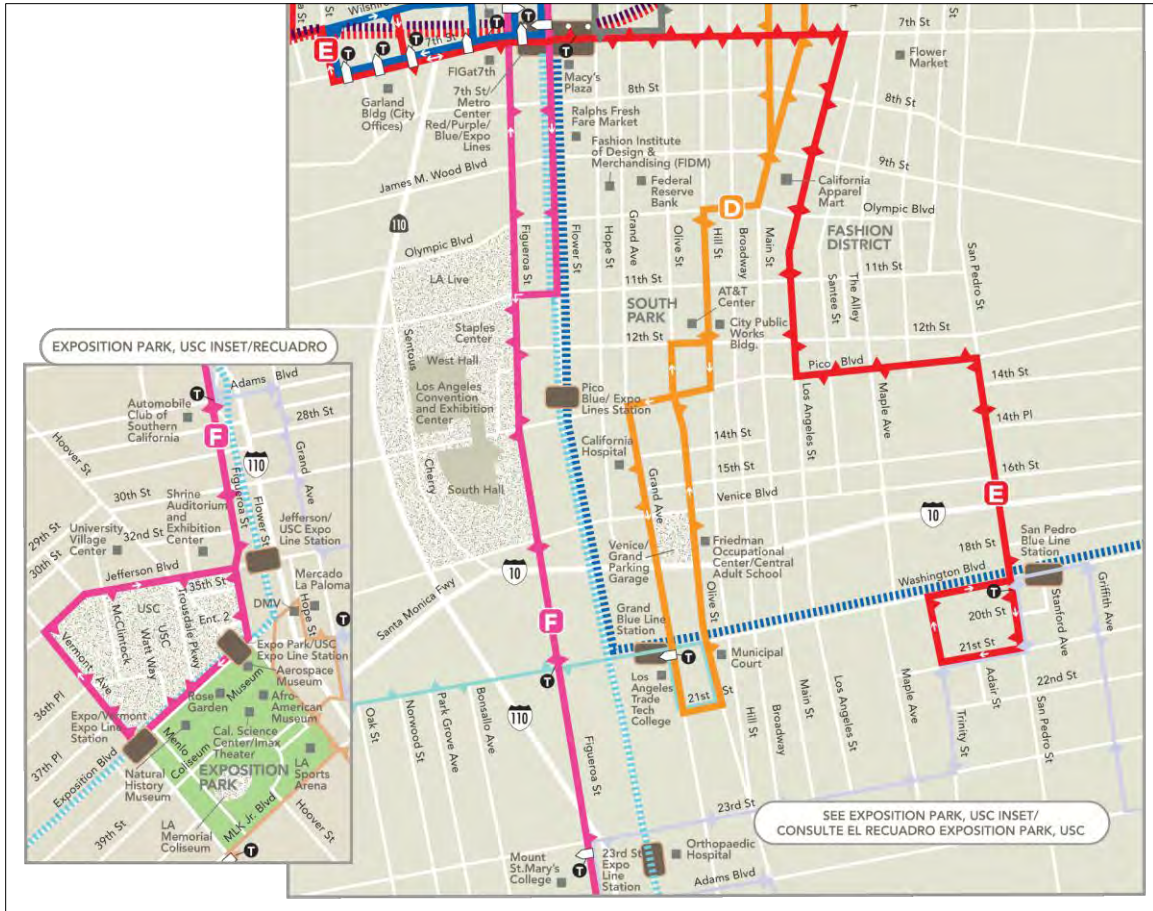


Figure 22 Shuttle bus route map with inset map. *Source:* LADOT Transit 2015

2.5.3. Page Layout

The page layout required that all necessary content would be incorporated within the printed page in a logical, legible, consistent, and cost effective manner. Steps involved to accomplish these objectives are discussed in the following sections.

2.5.3.1. Graphic Software Platform

Microsoft (MS) Office PowerPoint (ver. 2010) served as the software platform to produce the locator map layout. For many computer users, it is recognized as a presentation tool. However, for those restricted to Microsoft Office suite of applications, it is a formidable graphics and page layout accessory. An additional benefit from casual use is that it involves less training

relative to higher priced, sophisticated graphic software (e.g., Adobe Illustrator, InDesign, Coral Draw). As the page layout platform, PowerPoint provided the necessary tools to produce high quality, multipage layouts. Digital output and file transfer was accomplished using the built-in, industry standard Portable Document Format (PDF) print driver.

2.5.3.2. Components

The media review combined with user input played a significant influence in formulating the RELM page layout. The layout is arranged into three basic sections: (1) cover and highway map; (2) index list and index map; and (3) equipment information and detail map. The components of each section are shown in Figure 23 as identified with the red numbered circles.

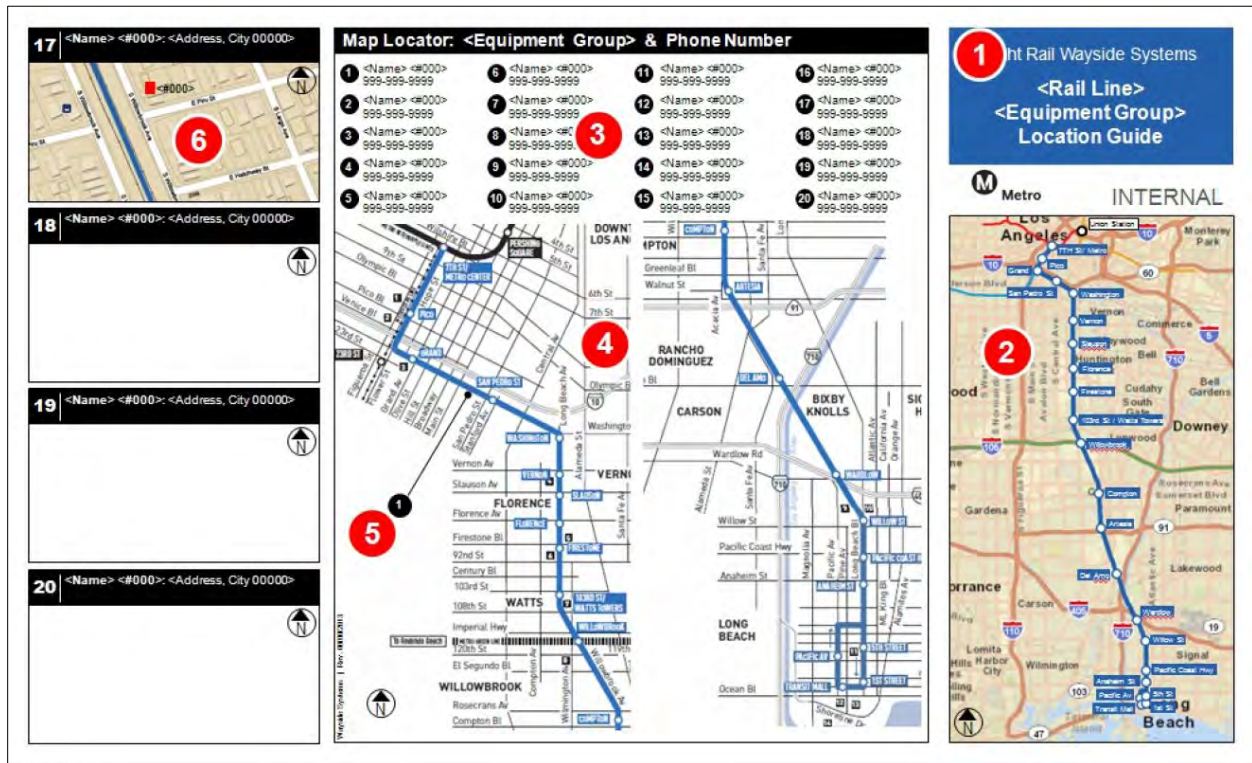


Figure 23 RELM layout and components. *Source:* Student 2013

The components are arranged in a logical order but follow the natural sequence: front, inside, and back panels of the brochure format (Ryan and Conover 2004, 401). The components identified in the RELM – TPSS locator map series are outlined in Table 3.

Table 3 RELM major components

Component	Function
1. Cover Title Block	Identifies the publication title and equipment group
2. Highway Map	Identifies the rail line, stations, fueling locations, and highway network
3. Equipment Index List	List equipment items with assigned index number
4. Equipment Index Map	Identifies the general location of the equipment items within the rail line
5. Equipment Index Number	Labels used to designate the equipment item number
6. Detail Equipment Map	Shows equipment information, location on the map, access path

2.5.3.3. Locator Map Elements

Making up the components of the locator maps are elements representing the pieces of textual and spatial information determined by the users. The maps present spatial information with the aid of cartographic elements representing the rail alignment, passenger stations, equipment, roads, labels, and map direction arrows. The basemap for each map is comprised of the roadway network and represented by lines (a cartographic technique for representing linear features). The roadways vary by line thickness, style, and color to delineate their functional classification (e.g., interstate, freeway, major, minor, local) (FHA 2013). The labels that identify roads are displayed or omitted based on the map scale which governs the degree of map generalization (Bolstad 2008, 130) and prioritizes the display of geographical features (Tomlinson 2003, 107). Table 4 lists textual and spatial elements of each component identified in Table 3 and illustrated in Figure 23.

In reviewing the element’s list contained in Table 4, it is important to recognize that some elements are repeated in each component. For example, rail lines are utilized in all components except Component (5). However, they do not function the same in each case. In Components (1)

and (3), it functions as textual data representing the rail line name (e.g., Blue Line), while functioning spatially in Components (2), (4), and (6) depicting the rail line alignment.

2.5.3.4. Detail Map Layout

It might be helpful to extend the explanation of elements by examining the detail equipment map Component (6) at two phases of development, during and after assembly. An illustrative example of a detail map is shown in Figure 24. This is followed by a conceptual view of the assembly process illustrated in Figure 25.

Table 4 RELM basic elements list

Component	Elements
1. Cover Title Block	<ol style="list-style-type: none"> 1. Department name 2. Rail line name 3. Equipment group/name 4. Agency name/logo 5. Distribution restrictions
2. Hwy Map	<ol style="list-style-type: none"> 1. Major highways (GIS basemap) 2. Rail lines 3. Rail passenger station 4. Location of vehicle re-fueling stations (e.g. gasoline/diesel) 5. North direction arrow 6. Map source credit
3. Equipment Index	<ol style="list-style-type: none"> 1. Equipment group title block 2. Equipment item name 3. Equipment index number 4. Equipment identification number (as required) 5. Equipment phone number (as required) 6. Rail line and rail operations control phone number
4. Equipment Index Map	<ol style="list-style-type: none"> 1. Rail lines 2. Rail passenger station 3. Street map with primary and secondary streets (sources: public timetable map or GIS basemap) 4. North direction arrow 5. Map source credit
5. Equipment Item Index Number	<ol style="list-style-type: none"> 1. Equipment item location symbol 2. Equipment index number (component #3) with leader line pointing to the equipment location

Table 3 RELM basic elements list (continued)

Component	Elements
6. Detail Equipment Location Map	<ol style="list-style-type: none"> 1. Equipment map index number 2. Equipment item name 3. Equipment identification number (as required) 4. Address (parcel address, approximate address, street intersection) 5. Detail street map with primary, secondary, and local street names and traffic direction arrows (GIS basemap) 6. Rail lines 7. Rail passenger station (as required) 8. Equipment item marker 9. Equipment item label 10. Access path arrow: start point and direction to identify access points (e.g., parking lot, rail station entrance, one way streets) 11. Traffic direction arrows (as required) 12. North direction arrow 13. Map source credit



Figure 24 Assembled detail map. *Source:* basemap: Google Map 2013; layout: Student 2013

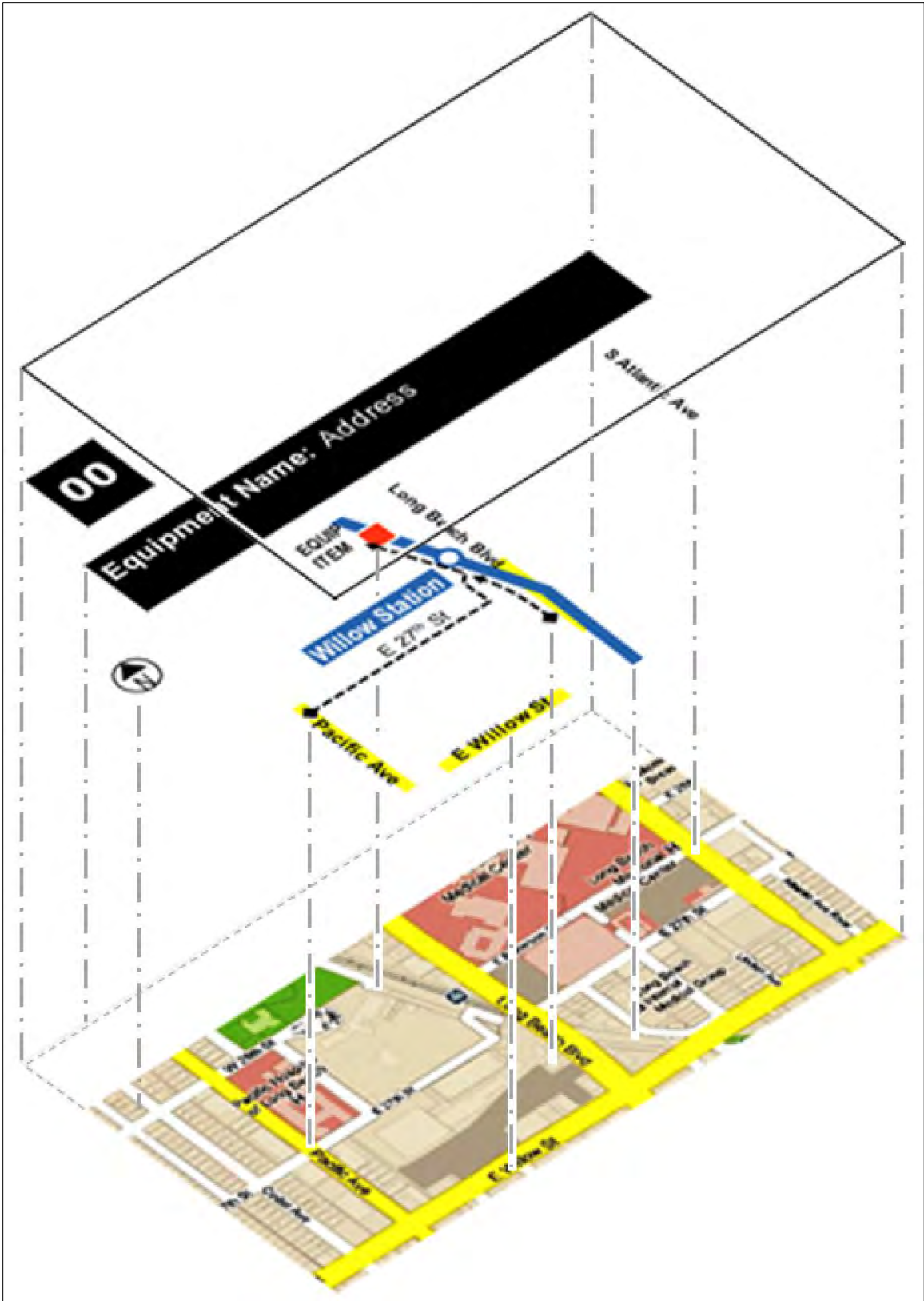


Figure 25 Detail map assembly process. *Source:* Student 2015

To understand how a detail map is assembled, Table 5 provides a standard set of steps and activities performed.

Table 5 General steps for developing the equipment detail map

Step	Activity description
1. Identify equipment location	<ul style="list-style-type: none"> • Review reference material to establish equipment location
2. Acquire basemap	<ul style="list-style-type: none"> • Open Google Maps map browser • Locate equipment area • Determine map extent and scale • Perform screen capture • Save image file (.jpg)
3. Import image into graphics software	<ul style="list-style-type: none"> • Import image graphic software work area
4. Adjust map color	<ul style="list-style-type: none"> • Adjust color based on the roadway content • Use graphic template (see google maps color setting)
5. Remove / hide embedded objects	<ul style="list-style-type: none"> • Hide irrelevant information in basemap using colored shapes • Group additional shapes and map image
6. Add primary elements	<ul style="list-style-type: none"> • Rail line • Rail station and label (if applicable) • Equipment item symbol and label
7. Create additional roads	<ul style="list-style-type: none"> • Street labels (if any basemap street labels are partially / completely hidden by elements, or outside the map frame)
8. Add access path	<ul style="list-style-type: none"> • Add access path as required
9. Add / create misc. graphics	<ul style="list-style-type: none"> • Based on review of reference materials (i.e., aerial imagery) • Traffic direction arrows (as required) • Interstate / highway route shields • Group map and elements
10. Add map index number block	<ul style="list-style-type: none"> • Add index number block • Enter index number based on equipment index list
11. Add map equipment description block	<ul style="list-style-type: none"> • Add description block • Enter information based on user requirements
12. Add detail map frame	<ul style="list-style-type: none"> • Add map frame
13. Add map source	<ul style="list-style-type: none"> • Add map source credit
14. Add north arrow	<ul style="list-style-type: none"> • Add north arrow • Group entire map block

2.5.4. Locator Map Development Template

To support the graphic artist and end user, two templates were developed. One contained reusable graphics, symbology and textual elements, while the other, served as a printing guide for the variety of users. The purpose and functional characteristics of each template are reviewed below.

2.5.4.1. Text / Graphics Template

As an internal company standard, MS PowerPoint was a plausible software platform; nonetheless, limitations with some features curtailed RELM development. For example, PowerPoint does not allow creating extensive text style libraries, found in MS Word and virtually indispensable for streamlining text formatting and imposing standardization. Additionally, PowerPoint has few options to create robust, shared, symbol libraries, found in MS Visio or Computer Aided Design (CAD) applications. Symbol libraries are indispensable for storing a set of reusable objects with unique properties (e.g., line style, thickness, color).

To address these and other drawbacks, a stand-alone PowerPoint file was created to store commonly used text styles, graphics, and cartographic conventions for features some of which include equipment item rail station, rail line, metro facility, restroom facility, access path, traffic direction, and north direction. A sample of the TPSS text/symbol template is shown in Figure 26.

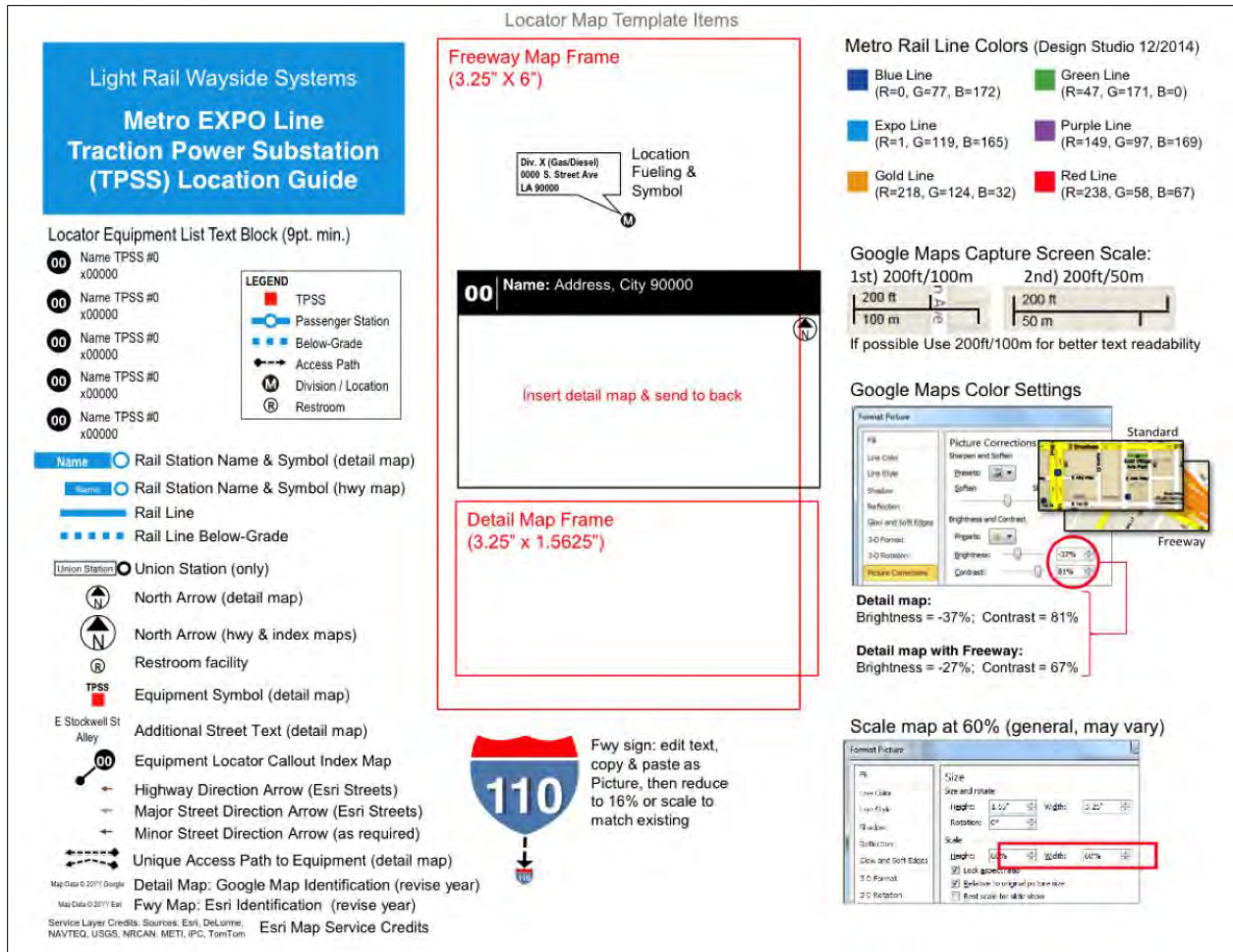


Figure 26 Sample TPSS locator map text/symbol template. *Source:* Student 2015

2.5.4.2. Printing Template

Primarily, the reproduction department (using high volume color copiers) handles the printing of TPSS locator maps. The users who have access to the TPSS locator map digital PDF files print these from their desktop computers to local color printers. In anticipation of user expectations, a printing template was specially designed to support the agency wide, high quality color copiers. This template displays steps for printing with the standard PDF reader software, Acrobat Reader that is routinely installed on all agency computers by the IT department. An example of the user orientated printing template is shown in Figure 27.

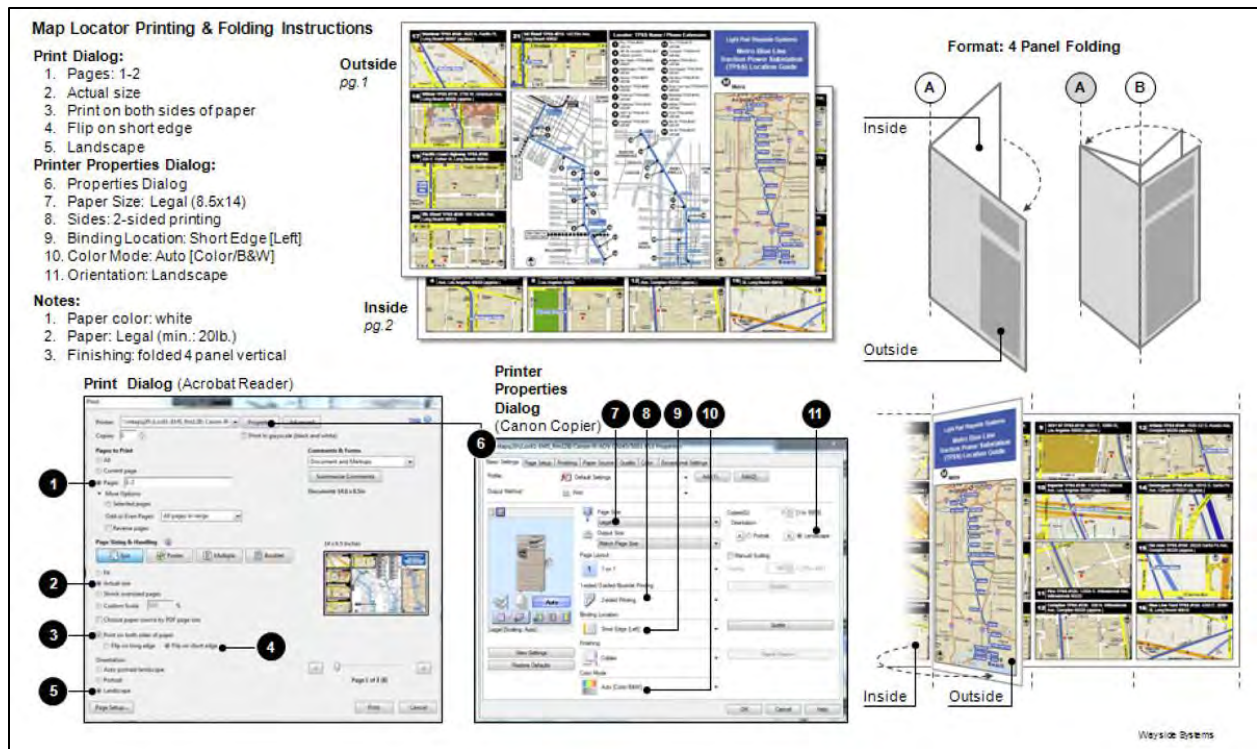


Figure 27 Sample printing instructions template. *Source:* N. Castellán, Student 2014

The text/symbol and printing templates were developed to address two concerns: reducing overall labor time by standardizing objects used on locator maps, and meeting the needs of support staff who will print digital versions using local office printers.

2.6 RELM Development Challenges

While the addition of the text/graphics template was implemented to improve locator map development, overall it remained a labor-intensive process with an assortment of challenges to overcome.

2.6.1. Merging Textual and Spatial Content

The contents of the locator map, discussed in Table 3, Table 4 and Figure 26 respectively, represent data pertaining to textual and spatial attribute information. An inherent but functional characteristic of the RELM is that some data elements appear in several places throughout the

textual and map content. Passenger station locations, for example, appear on the highway and index maps. In some cases, a passenger station appears in the detail map based on the equipment item location. Passenger station markers are represented with a graphic symbol and defined using a text label. Errors related to this data element may result from incorrect source data or data entry typographical errors (user blunders) (Bolstad, Gessler, and Lillesand 1990, 401) associated with the text label (e.g., misspelled station name) or spatial error associated with incorrect station marker placement.

As a precautionary measure, it is important to anticipate and avoid problems (Kulik and Weber 2001, 1), thereby mitigating risk from data elements that constitute a propensity to produce errors. The potential to duplicate errors based on element usage is a significant factor as a fundamental characteristic of the locator map format. Figure 28 illustrates the susceptibility to error in duplicated data elements.

The data elements listed in Figure 28 are identified numerically based on similarities between elements, and differentiated by functional type (e.g., textual, spatial). The usage analysis reveals that of the 20 elements listed, 12 (63%) are used at least twice and eight of these (66%) are used three times. Maintaining the accuracy of duplicate textual and spatial data on various scaled maps warrants extensive precautionary measures to eliminate errors in the locator maps.

2.6.2. Data and Quality Management Issues

The initial locator map layout required a large amount of effort focused on solving the graphic design and production challenges. Once the design issues were addressed, and the development process had stabilized, the focus shifted to operation and maintenance. It is in the latter phases that the bulk of benefits is anticipated and experienced (Tulloch 1999, 263). In

practical terms, it is also where obstacles and deficiencies are encountered. The following sections explain the existing locator map development issues that this study set out to improve.

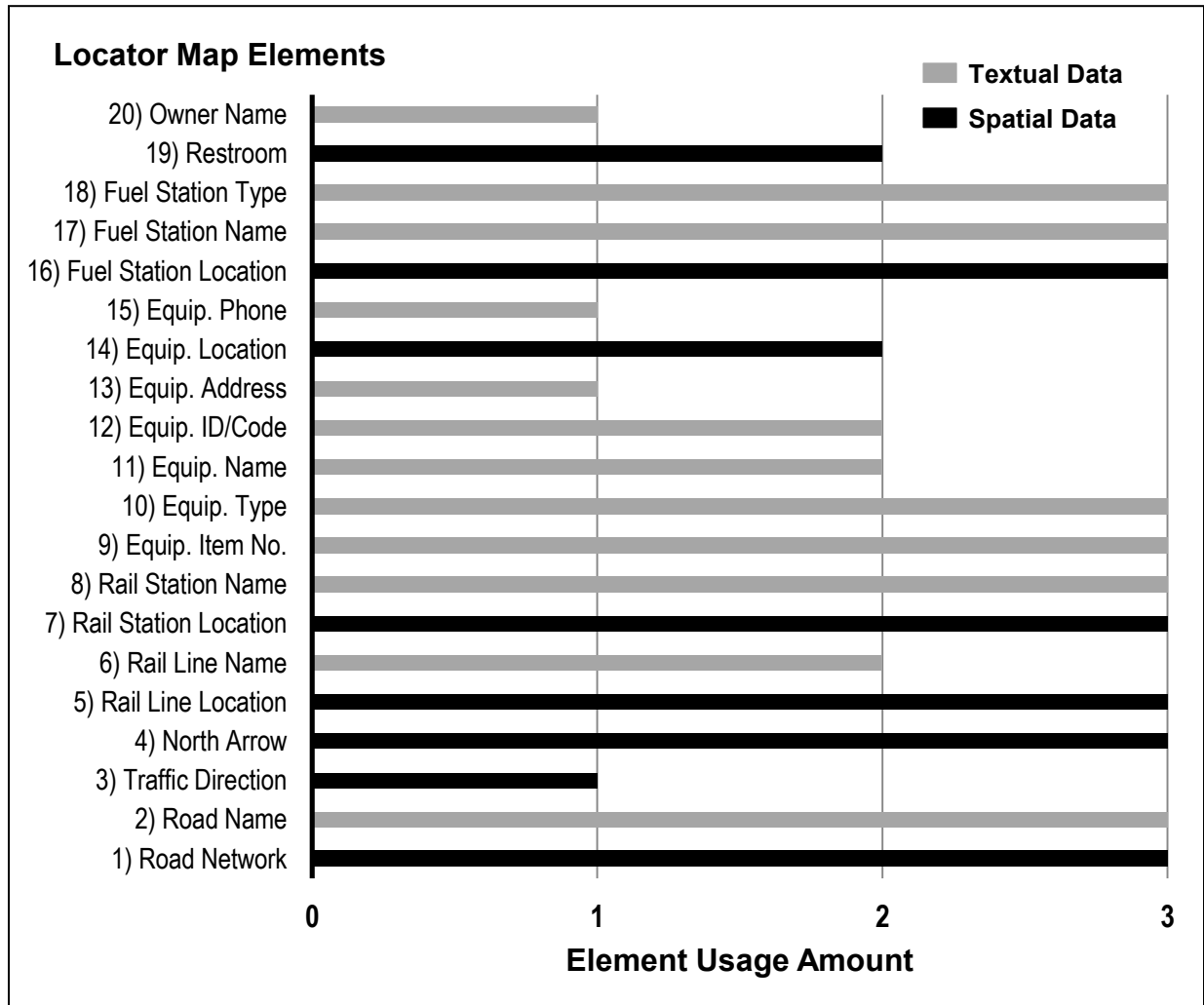


Figure 28 Locator map element usage. *Source:* Student 2015

2.6.2.1. Multiplicity of Association and Error Propagation

During the development of the first generation locator maps, data collection and storage was performed using MS Excel software. During the first edition, data was received from data suppliers in Excel files. Later each locator map utilized a separate worksheet within one Excel file to enter equipment information defined in the RELM element list. Working in Excel proved challenging without mechanisms available within a relational database environment to enhance

data integrity and manage data interrelationships resulting from the “multiplicity of association” (Tomlinson 2003, 140). To clarify, Tomlinson’s definition of association is, “the number of objects that can be associated with another object.” Managing data associations specific to the railroad domains logical linkages (72) requires a software solution designed to mitigate risk from error propagation by reducing redundancy yet improving data quality throughout the data stream process.

Passenger stations are a common data element within the locator maps and embrace the multiplicity of association concept. For example, a station performs a dual role: (1) an entry or exit point for passengers, and (2) at some stations, a transfer point between two or more rail lines. A graphic representation of these multiple associations is illustrated in Figure 29 using a section of Metro’s “Go Metro” map.



Figure 29 Single and multi-point transfer stations. *Source:* Metro 2015

The system map shown in Figure 29 differentiates station types cartographically using white outline, filled non-white color circles for single point stations, and black outline, filled white circles and shapes for transfer points. To interpret the impact these associations might have on the locator map, it was necessary to identify location, and quantify the number of associations between stations and rail lines. The results of this analysis are shown in Figure 30.

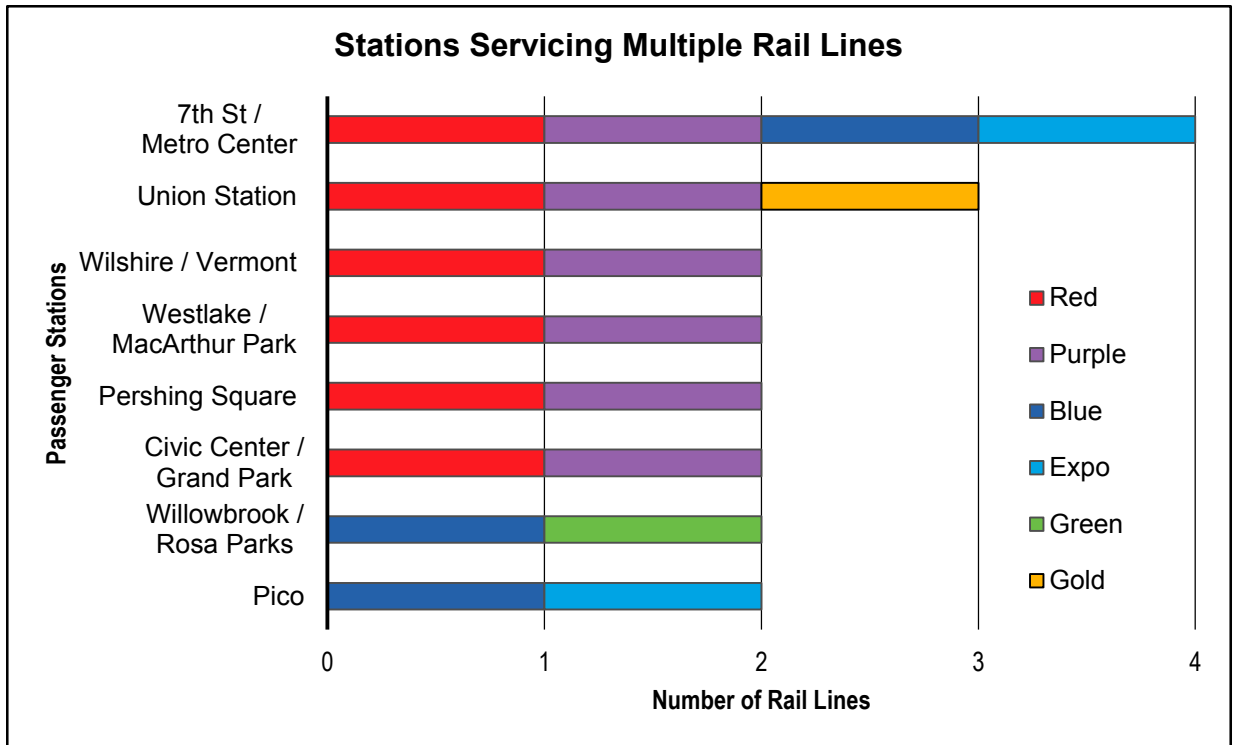


Figure 30 Rail passenger stations servicing multiple rail lines.
Source: Metro operational stations/rail lines, 5/1/2015, Student 2015

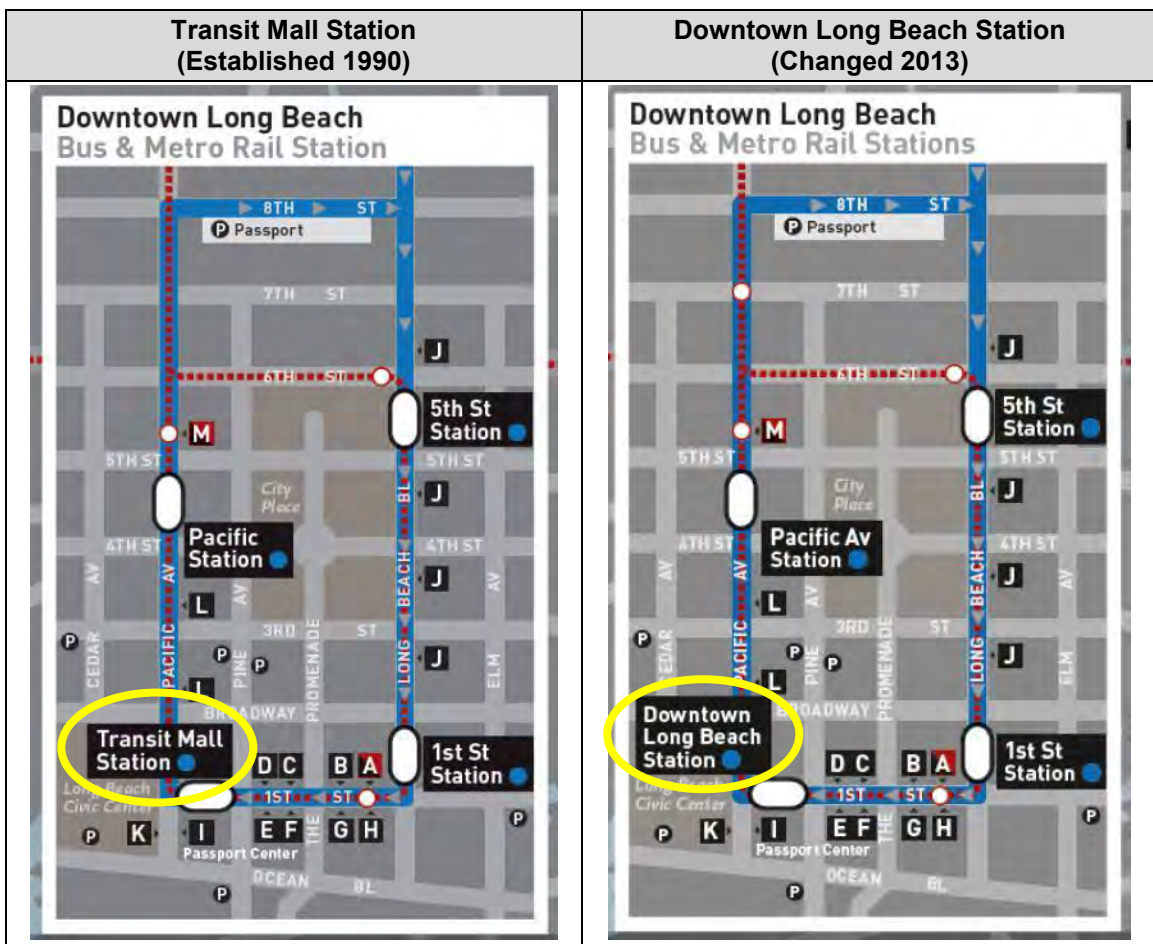
In Figure 30, the associations between eight stations and all Metro rail lines are shown. The 7th St/ Metro Center station serves four rail lines and must be identified within the relevant communication media (e.g., rail route schedules) for the Blue, Exposition, Purple, and Purple/Red Line. Similarly, with respect to the locator maps, 7th St/ Metro Center station is identified in the Blue and Exposition TPSS locator maps as well as the Blue Line Signals and Communications locator map. Therefore, based on the multiplicity of association between this station and four rail lines, a simple spelling error in the station's name could inadvertently transfer into other locator maps.

2.6.2.2. Passenger Station Name Changes

As with station name errors, "semantic accuracy" must also be considered (Wilson 2011, 6). Based on a common or agreed upon terminology, this refers to data about objects (Tomlinson

2003) and how well the geographical object is described (Wilson 2011, 6). For example, if a river channel is modified to facilitate shipping, it may be called a canal (Chomsky 2013), but without an appropriate text label, the distinction may not be clear. Moreover, station name labels must be distinct and name changes should be updated in all pertinent communication media. Neglecting this subsequent (or parallel task) will result in a referential error that is related to how it is identified (Tomlinson 2003, 59). This would create passenger confusion through exposure to conflicting materials. An example of this potential issue pertains to the name of a Blue Line station that was changed in 2013, 23 years after it opened (1990) as shown in Table 6.

Table 6 Blue Line Transit Mall station name change. *Source:* Metro 2013, 2015



The change was related to semantic accuracy, and did not “clearly or adequately reflect the identity of the destination and area context which is downtown Long Beach” (MTA Executive Management Committee 2013). Consequently, this change required the Blue Line TPSS locator map and Blue Line Signals and Communications locator maps to be revised and re-distributed.

One station name change after 23 years could be considered an uncommon occurrence, anomaly, or an unpredictable event (Crowell 2009, 91). However, based on a cursory review of various Metro documents, Figure 31 reveals a series of name changes throughout rail operation.

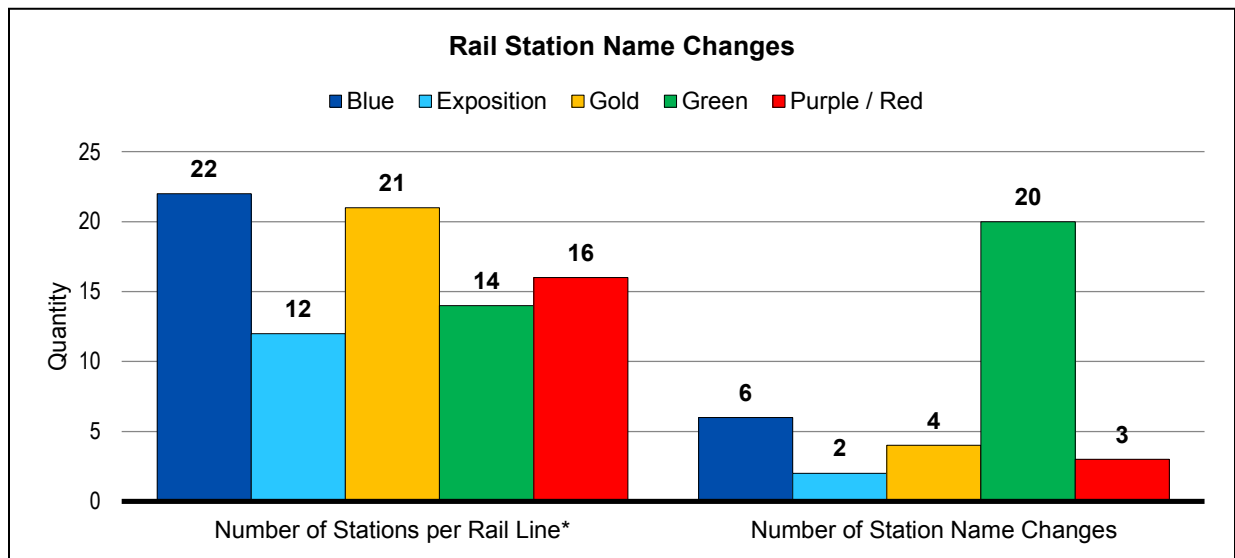


Figure 31: Rail station name changes.
 Source: Metro 1991, 1994, 1998, 2005, 2009, 2010, 2013

Regardless of the reason, Figure 31 demonstrates that station names are unpredictable dynamic data elements, (often subject to change over time), as opposed to the static, spatial elements they represent. In practical terms, if an incident occurs at a station whose name has changed, the public and first responders have no alternative but to refer to the posted name. Therefore, rail maintenance personnel must respond accordingly and become knowledgeable, in part, through locator map revisions. To effectively manage this semantic and data quality issue,

one requires an alternative data management strategy predicated on the appropriate data model (Tulloch 1999, 259), and reinforced through suitable data management software.

2.6.3. Addressing Paper Map Development Challenges

Taking into consideration the many challenges involved in producing the locator maps (e.g., TPSS, Communications/Signals), it was necessary to reevaluate the current development and maintenance approach. This involved reviewing both procedural and technology issues. These included, while not limited to: (1) Project Planning; (2) Data Management; (3) Quality Assurance (e.g., passenger stations on multiple scaled maps); and (5) Data Management Technology.

These factors and related outcomes provided the impetus to investigate an alternative development approach. The goal of this investigation was to establish a viable production and maintenance methodology that could reduce or eliminate some development steps while achieving higher positional accuracy, format consistency, reduced risk of errors, and ultimately contribute to greater rail operations efficiency.

2.7 Similar Work

2.7.1. The Medium of Paper Maps

Maps are a representation of spatial concepts. The oldest known discussion of land and irrigation rights was found on Babylonian clay tablets from 2500-2340 B.C. (CDLI 2013). During the Renaissance, maps were printed using carved wooden blocks then engraved on copper-plates. Fast forward hundreds of years and the modern maps were printed on paper that was lighter and easier to manage.

Paper map development and production, particularly the cartographic profession, became an academic field of study in the U.S. as early as 1900 (Slocum et. al 2009, 24). The teaching of

a graphic art course as a prerequisite to cartography was introduced by Paul Goode, charter member of the Association of American Geographers (AAG), in recognition of the fact that cartography involves lines, shapes, patterns, and must operate within the restrictions of the paper medium and the printing process (Slocum et. al 2009, 24). Restrictions related to paper and printing were echoed by George Jenks in his paper “An improved Curriculum for Cartographic Training at the College and University Level” (Jenks 1953, 317).

2.7.2. Transitioning to Digital Geographic Information

The issues related to map production were addressed in the 1960s by Roger Tomlinson, referred to as the “father of GIS” (Chrisman 2010; 2847-2849; Dangermond 2011, xiv). He began investigating the benefits of computer based mapping procedures in 1963 (Tomlinson 1988, 250). Based on challenges with map analysis, storage and retrieval at that time, Tomlinson identified two primary issues with paper maps:

“The first is that there are physical limits to the amount of descriptive data that can be stored and displayed on one map. To reduce such data to sensible graphic form, they must be classified and generalized. This often causes a loss of detail during the transition from a less- to a more- generalized form and the adoption of a cartographic model which may or may not fit the subsequent data analysis model. The second limitation is that data in a hardcopy map format has to be retrieved visually and manually.” (Tomlinson 1988, 250).

Tomlinson’s work with many academic and commercial professionals in the fields of image processing, printing, digital storage, and data management led to the many mapping programs of our time. These included Esri ArcGIS, GeoMedia, MapInfo, Idris, Manifold, AutoCAD Map, GRASS, MicroImages TNTmips, and ERADS (Tomlinson 1988, 257-258; Bolstad 2008, 15-18).

One of the more popular map products of the 20th century that eventually gained from Tomlinson’s work was The Thomas Brothers Map Books started in 1915. Located in San

Francisco, they produced paper maps of the city and later urban centers such as Los Angeles, Orange County, and San Diego. These spiral bound books contained four color, double-sided printed pages of cartographic representation of roads and places that were updated annually. For many years these books were utilized by public agencies (police, fire departments), as well as commercial businesses that focused on service and delivery (i.e. gas company, home appliance service) (Map Books 4 U 2015).

In the 1990's a Microsoft Windows based digital version of The Thomas Brothers Map Book was released. This provided users the ability to search by page number and grid, to create and save queries, and to import, and export data. Printing maps was possible using the standard software print options that included standard letter (8.5x11") and tabloid (11x17") paper sizes. In addition, the digital street layer was licensed to government agencies (e.g., Los Angeles METRO) for incorporation with GIS software (Esri ArcGIS) (Map Books 4 U 2015).

GIS is a "ubiquitous tool" (Bolstad 2008, 3) allowing the technology to expand to the local computer desktop and commercial mapping browsers (e.g., Map Quest, Bing, Google Maps). Currently, these have become one of the most widely available forms of public geographic media, offering customizable routes (Sui and Goodchild 2001, 388) for locating points-of-interest (POI). Individuals, institutions and commercial operations utilize these map browsers as a useful platform for locating places, equipment and supplement asset management records with the addition of geo-coordinates.

Chapter 3 Data and Methods

The existing set of locator maps have become a “routine part” (Rice and Rogers 1980, 500) of the day-to-day activity of the Traction Power department. However, the development issues discussed in Chapter 2 provided the impetus to improve the overall locator map development.

The following sections discuss the approach, including selection of the study area and equipment group, project work plan, data required, and methodology.

3.1 Study Area

The test case utilized the 8.6-mile Metro Exposition Line (EXPO) Phase 1, shown in Figure 32, as the subject area. The EXPO line began operation in April 2012 (Metro 2015). The line originates at the underground 7th Street/ Metro Center station located at the intersection of 7th St. and Flower St. in downtown Los Angeles, and heads south along the Harbor freeway. At the intersection of Flower St. and Exposition Blvd. (where it obtained the name), the line turns west and continues until it terminates at the Culver City Station at the intersection of Venice Blvd. and National Blvd.

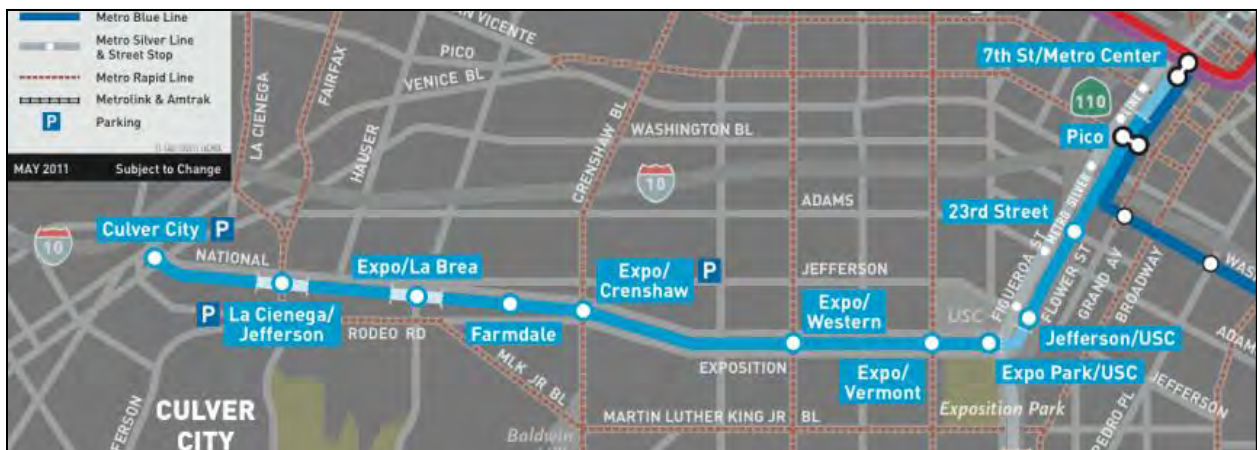


Figure 32 Metro Exposition Line Phase 1. *Source:* Metro 2012

3.2 Equipment Group

Railroad track signals were selected as the equipment group (instead of Traction Power Substation) for their unique characteristics. First, track signals are universally used for railroad operation, while Traction Power Substations are used only for electric powered rail transit. Second, the EXPO line operates primarily in street-running territory with the track signals equipment visible from the street. This makes them “visually” accessible outside of the Right-of-Way. A typical set of EXPO track signals is shown in Figure 33.



Figure 33 Sample of Exposition Line track signals. *Source:* Google Maps 3/2015

Finally, track signals are on or within close proximity to the train tracks because they function as a visual communication device by using colors, arrangement, and status (i.e. flashing, solid) to communicate with train operators. Consequently, they are generally positioned within 10 feet of the tracks to ensure visibility under adverse weather conditions. Traction Power Substations, on the other hand, may be located 100 to 500 feet away from the tracks. For these reasons, the Exposition Line signals equipment group was a more suitable candidate for this improvement test.

3.3 Project Workflow

Proceeding with a process improvement approach, required the development of a workflow that incorporated activities that could resolve existing process deficiencies. This meant documenting the activities that were involved in the existing locator maps.

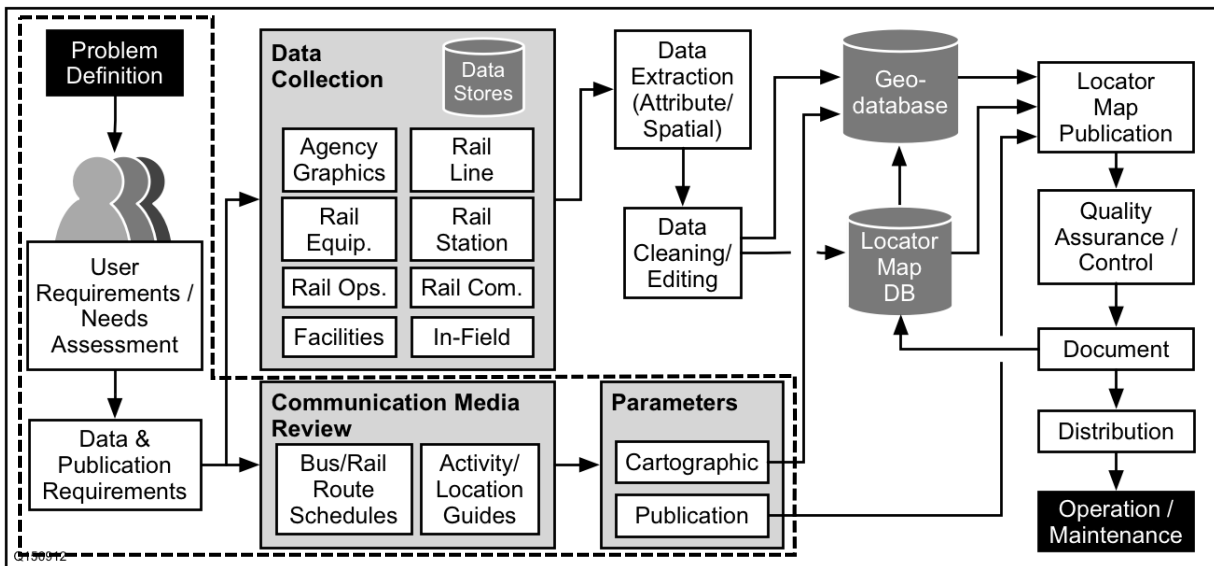


Figure 34 RELM improvement process workflow. *Source:* Student 2015

The process workflow for this study incorporated the RELM first generation development phases as shown within the dashed boundaries in Figure 34. The proposed workflow would require backward compatibility with existing locator maps. It was vital to maintain the existing locator map cartographic symbology while ensuring the ability to establish new symbols for the equipment group and track environment.

3.4 Data Requirements

Data requirements included an inventory of previous data usage and data pertinent for the study. It was also necessary to associate the data with the appropriate supplier or domain where that data was produced or used (Tulloch and Epstein 2002).

3.4.1. Data Formalization Process

The approach for identifying needed data involved consolidating data into a database (e.g., previous data, new data). Activities included identifying the previous data elements (see Table 4), identifying new data elements related to the track signals equipment group, and combining all data elements into one formal list using a data inventory system. This system would classify data according to its function (e.g., textual, spatial) and various characteristics (e.g., name, type, usage, source) (Tomlinson 2003, 49), and support subsequent development activities.

The creation of the data inventory system was implemented using desktop database software, FileMakerPro (ver. 12). The database produced variations of the following elements: “information product description (IPD)” (Tomlinson 2003, 49), “master input data list (MIDL)” (Tomlinson 2003, 83), “data theme description table” (Crowell 2009, 41), “layout checklist” (Peterson 2009, 17) and “preliminary logical model” (Allen and Coffey 2011, 3). Combining this information in a dynamic repository (as opposed to a static list) supported the development of the locator map database identified in the project workflow.

Following completion of the database implementation, previous and new data elements were entered into the system. Once the data entry and “transformation process” was completed, it was possible to begin “information utilization” (Obermeyer and Pinto 2008, 36). This utilization step was available at an earlier data collection stage with a broader scope of meaningful data. An entry screen used to classify data is shown in Figure 35.

The data entry screen shown in Figure 35 depicts the process for assigning the data element (e.g., Rail Station) with one of the data suppliers (e.g., Planning / GIS department). This task was necessary to direct the efforts in the following Data Collection phase. The information

generated from this process, presented in Table 7, displays data elements aligned with data supplier(s).

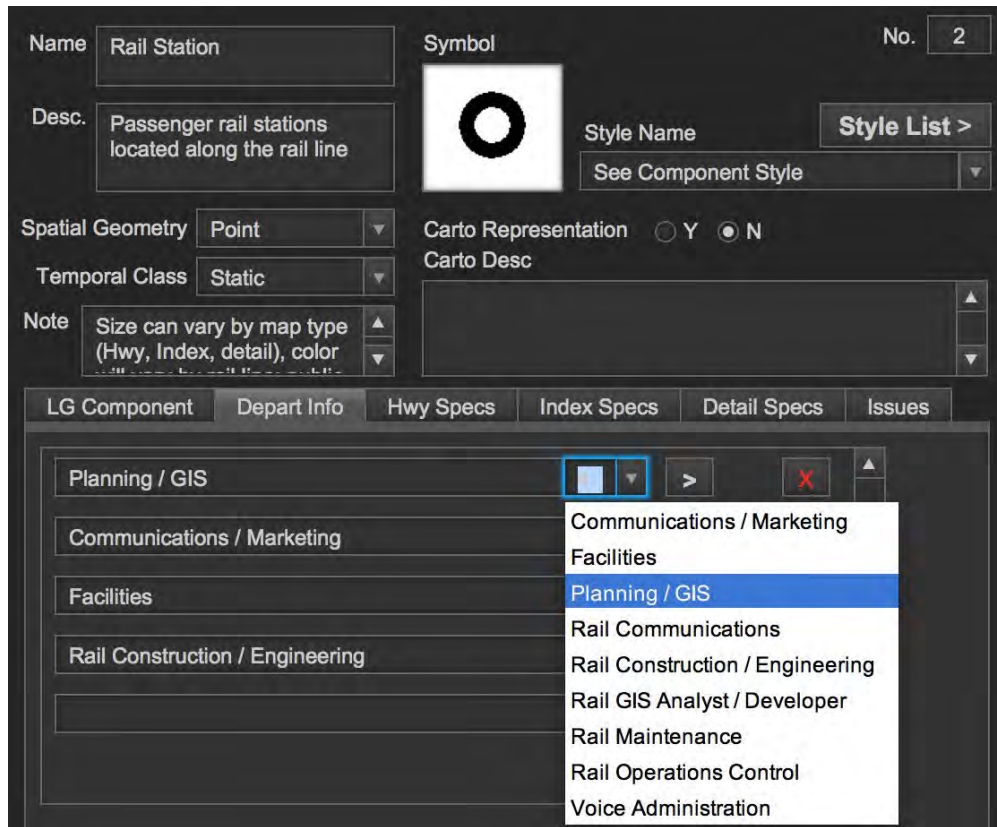


Figure 35 Data element and supplier association entry screen. *Source:* Student 2014

Table 7 Data elements associated to suppliers

Symbol	Element	¹ Rail C/E	² Rail Maint.	³ Rail Com.	⁴ ROC	⁵ Plng. / GIS	⁶ Comm. / Mrk.	⁷ Facilities	⁸ Voice Admin.
◆--->	Equipment Access Path		■						
■	Equipment Item	■	■	■	■				■
Ⓜ	Facility	■					■	■	
Portal	Portal Entrance	■			■				
—	Rail Line	■			■	■	■		
○	Rail Station	■				■	■	■	
Ⓜ	Restroom	■						■	

Suppliers: (1) Rail Construction/Engineering, (2) Rail Maintenance, (3) Rail Communications (2014), (4) Rail Operations Control, (5) Planning/GIS, (6) Communications/Marketing, (7) Facilities, (8) Voice Administration.

Table 7 also provides evidence that most data was derived from the efforts of multiple suppliers. It is worth noting that this is not a linear flow, nor universal to transit agencies, but rather is reflective of Metro's 2014 department processes and organizational setting (Tulloch 1990, 272; Ramasubramanian 1999, 365). Not shown in Table 7, but included in the data inventory system, are supplier responsibilities associated with the spatial data elements (e.g., rail line, passenger station). At various times, and subject to change, multiple suppliers may be involved in providing data or a derivative.

The following example demonstrates the involvement of multiple spatial data suppliers (identified by number in Table 7). The rail line and passenger stations are spatially depicted in engineering drawings (at design and construction phases) and maintained by the Rail Construction/Engineering department (1). The Planning/ GIS department (5) uses these engineering drawings, and in some cases, aerial imagery to construct the rail line and passenger station into a spatial attribute (Butler 2008, 12). The Communication and Marketing department (6) publishes the approved name of the rail line and stations on the public website. In addition, they establish the rail line colors used in communication media. The Facilities department (7) maintains and distributes a formal facilities list that includes station addresses. This example reiterates that supplier participation is complex and may not be easily recognized but is vital to locator map development and maintenance. Another pertinent information product derived from the data formalization process is shown in Table 8. This provides a listing of the spatial data (i.e., map components) used within the locator map.

Table 8 Spatial data elements typically required in map components

Symbol	Element	1 Hwy. Map	2 Index Map	3 Detail Map	Label	Scale Varies	Color Varies
	Equipment Access Path			■			
	Equipment Item - Detail			■	■		
	Equipment Item - Index		■		■		
	Facility	■	■	■	■		
	Highway Route Shield	■	■	■		■	
	Interstate Shield	■	■	■		■	
	North Arrow	■	■	■		■	
	Rail Line	■	■	■		■	■
	Rail Station	■	■	■	■	■	■
	Restroom		■	■			
*	Roads (basemap)	■	■	■	■	■	■
	Track Access Gates			■			
	Track Tunnel Portal Entrance			■	■		
	Traffic Direction Arrows			■			■

3.5 Data Collection

Based on the work performed during the Data Requirements phase, a listing of the departments responsible for necessary project data was developed. That list, which is shown in Table 9, identifies the source name, data type, supplier, and where it is located.

Table 9 Data collection list

Item	Data	Attribute/ Type	Supplier	Location
1.	Rail Line	Spatial (Line)	Pln./GIS	Metro.net: http://developer.metro.net/wp-content/uploads/2014/07/RailLines0614.zip
2.	Rail Station	Spatial (Point)	Pln./GIS	Metro: http://developer.metro.net/wp-content/uploads/2010/06/RailStations0715.zip
3.	Rail Station Name / Address	Text	Comm. / Marketing	Metro.net: http://www.metro.net/riding/maps/
4.	Restroom	Spatial (Point)	Facilities	Department contact: station restroom list

Table 9 Data collection list (continued)

Item	Data	Attribute/ Type	Supplier	Location
5.	Track Tunnel Portal	Spatial (Point)	Rail C/E ROC	Engineering drawing Department contact: designated name
6.	Track Access Gate	Spatial (Point)	GIS Analyst	LA County LAR-IAC4 http://egis3.lacounty.gov/siv/?Viewer=GISViewer field visit
7.	Equipment Item - Signals	Spatial (Point)	Rail Maint.	Department contact: signal equipment list
8.	Equipment Access Path	Spatial (Line)	Rail Maint.	Department contact: access points LA County LAR-IAC4 http://egis3.lacounty.gov/siv/?Viewer=GISViewer
9.	Facility	Text / Spatial (Point)	Facility	Metro intranet: facility list Metro.net: http://www.metro.net/about/filming-metro/facilities/
10.	Facility Fuel Type	Text	Facility	Department contact: fuel type list
11.	Places & Roads	Spatial	Esri	Esri World Street Map (basemap)
12.	Roads	Spatial (Line)	U.S. Census	Tiger 2013, California 06037, Roads http://www.census.gov/geo/maps-data/data/tiger-line.html

3.6 Methodology

3.6.1. Locator Map Desktop Database

A desktop database was developed to manage all related information and exchange data with the mapping software. The database, developed using Microsoft Access (ver. 2010) application, provided a relational database management system that served a multi-functional role. Activities performed, for example, included data import, data entry and editing, report output, and export to various formats (e.g., Excel, text). Figure 36 presents a conceptual design of the locator map database that includes primary and secondary data groups and/or data attributes.

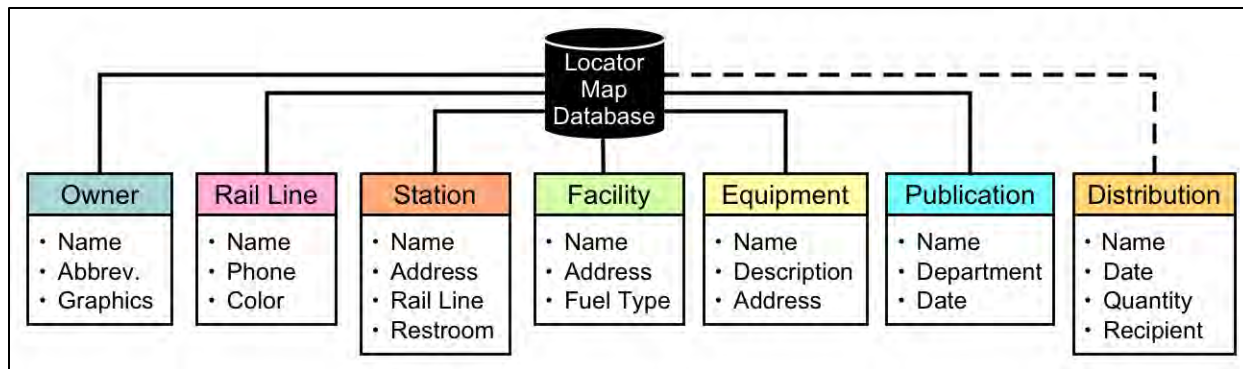


Figure 36 Locator map database conceptual design. *Source:* Student 2015

3.6.2. Determining the Locator Map Paper Size

The paper size options are based on Metro’s department wide color copiers. The standard, built-in paper trays are U.S. letter (8.5” x 11”), legal (8.5” x 14”), and tabloid (11” x 17”) paper. Determining the optimal paper size required taking into account the following factors: (1) the number of equipment items determines the *minimum* number of detail maps; (2) the space required for the equipment index list; (3) cover panel size; and (4) space required for the index map(s). To assist with this process, a paper size guide was developed and is shown in Table 10.

Table 10 Detail map paper size guide. *Source:* Student 2014

U.S. Paper Size	Letter (8.5x11")	Legal (8.5x14")	Tabloid (11x17")																																																					
Layout	<table border="1"> <tr><td>1:1</td><td>2:1</td><td>3:1</td></tr> <tr><td>1:2</td><td>2:2</td><td>3:2</td></tr> <tr><td>1:3</td><td>2:3</td><td>3:3</td></tr> <tr><td>1:4</td><td>2:4</td><td>3:4</td></tr> </table>	1:1	2:1	3:1	1:2	2:2	3:2	1:3	2:3	3:3	1:4	2:4	3:4	<table border="1"> <tr><td>1:1</td><td>2:1</td><td>3:1</td><td>4:1</td></tr> <tr><td>1:2</td><td>2:2</td><td>3:2</td><td>4:2</td></tr> <tr><td>1:3</td><td>2:3</td><td>3:3</td><td>4:3</td></tr> <tr><td>1:4</td><td>2:4</td><td>3:4</td><td>4:4</td></tr> </table>	1:1	2:1	3:1	4:1	1:2	2:2	3:2	4:2	1:3	2:3	3:3	4:3	1:4	2:4	3:4	4:4	<table border="1"> <tr><td>1:1</td><td>2:1</td><td>3:1</td><td>4:1</td><td>5:1</td></tr> <tr><td>1:2</td><td>2:2</td><td>3:2</td><td>4:2</td><td>5:2</td></tr> <tr><td>1:3</td><td>2:3</td><td>3:3</td><td>4:3</td><td>5:3</td></tr> <tr><td>1:4</td><td>2:4</td><td>3:4</td><td>4:4</td><td>5:4</td></tr> <tr><td>1:5</td><td>2:5</td><td>3:5</td><td>4:5</td><td>5:5</td></tr> </table>	1:1	2:1	3:1	4:1	5:1	1:2	2:2	3:2	4:2	5:2	1:3	2:3	3:3	4:3	5:3	1:4	2:4	3:4	4:4	5:4	1:5	2:5	3:5	4:5	5:5
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1:5	2:5	3:5	4:5	5:5																																																				
Columns	3	4	5																																																					
Rows	4	4	5																																																					
Detail Map Size	3.25"(w) x 1.9375"(h)	3.25"(w) x 1.9375"(h)	3.25"(w) x 1.9375"(h)																																																					
Detail Maps Per Page	12	16	25																																																					

Through review of the factors and the paper guide, a draft PowerPoint page layout was produced. This is one of the various reasons for using PowerPoint — it is multi-functional,

providing a page layout, print, file import and export environment (e.g., PDF, .jpg). The draft layout for the outside page (slide 1), and the inside page (slide 2) are shown in Figure 37 and Figure 38.



Figure 37 Draft layout page 1 outside. *Source:* Student 2014

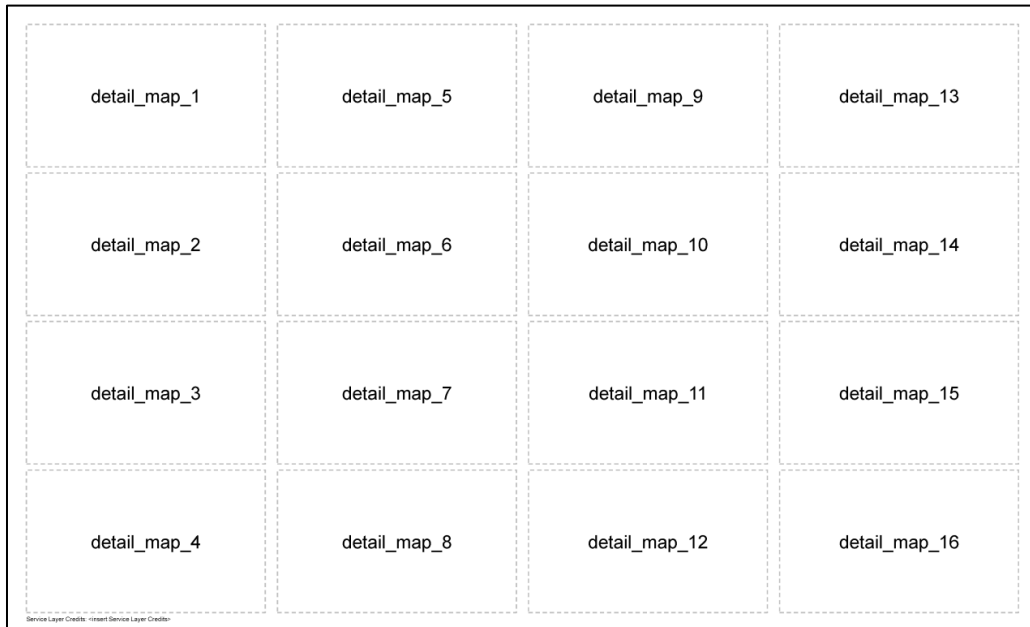


Figure 38 Draft layout page 2 inside. *Source:* Student 2014

Once the layout and the map sizes were determined, it was possible to begin development of the maps. The following sections examine the map development process.

3.6.3. Map Software and Basemaps

3.6.3.1. Software

The decision to utilize Esri ArcGIS Desktop, ArcMap (ver. 10.2) software for all map components was based on the premise that its usage would lead to an improvement in the map development process. Esri products, such as ArcGIS, ArcMap have been utilized within Metro for many years. Based on wide array of mapping tools, map output formats, programming platforms (e.g., Python, Visual Basic), and the current Metro user support model, ArcMap was a practical software platform.

3.6.3.2. Basemaps

The ArcGIS software basemaps used for all map components were Esri's World Street Map. One basemap insured features would remain cartographically consistent between three different map components that utilized different map scales. The World Street Map offered important features that included natural (i.e., forest, lakes, mountains) and human generated items (i.e., roads, traffic direction arrows, buildings, parks). In addition, there are a wide range of cached map scales that included street level detail at 1:5,000 and 1:10,000 in urban areas (Esri 2015). Moreover, the data used to construct the Esri basemap is updated twice a year (Esri 2015). Incorporating this basemap into the production of all maps advances consistency, legibility, and temporal accuracy.

3.6.4. Study Project Geodatabase

Through a careful review of the data collection list and review of existing locator maps, a geodatabase was developed to organize and manage spatial and tabular data. The geodatabase workspace was created within a Microsoft Windows XP operating environment. The physical design was implemented using Esri ArcCatalog (ver. 10.2.2) following the file based geodatabase procedure. Figure 39 provides the conceptual design of the geodatabase, including feature datasets, feature classes, and tabular data.

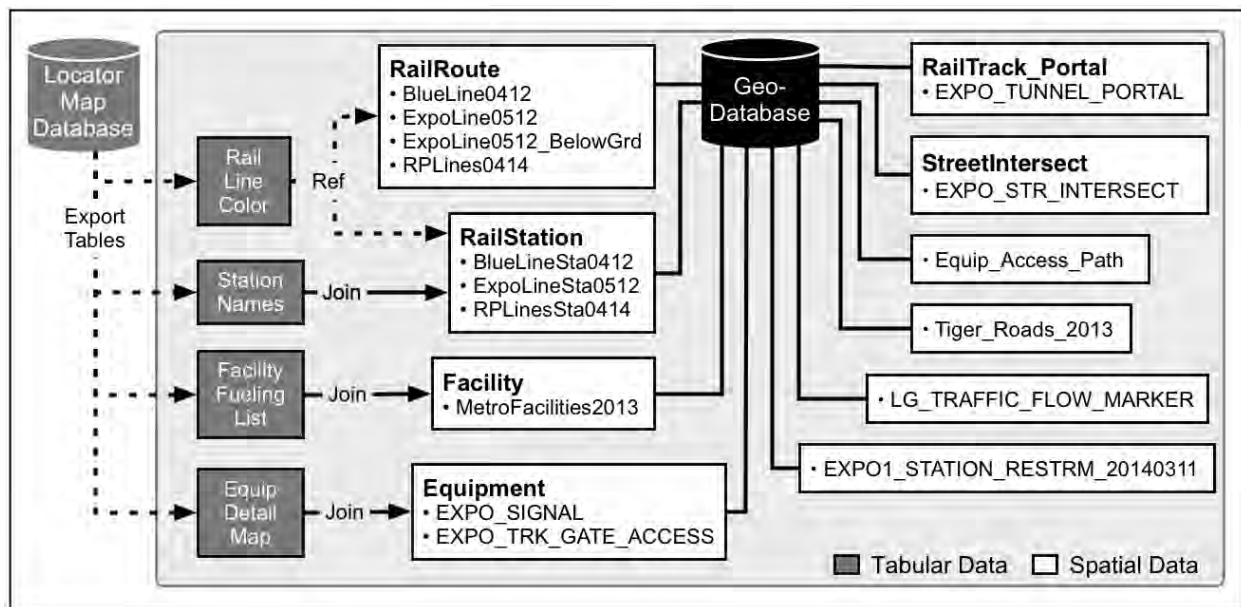


Figure 39 Locator map geodatabase conceptual design. *Source:* Student 2015

3.6.4.1. Data Loading

The data loading process involved various methods to incorporate data into the geodatabase. Depending on the data format (e.g., .shp, .xls), one of three methods was employed to convert data into spatial feature classes. These included (1) import existing spatial data (e.g., .shp, .kmz); (2) generate spatial data from existing x,y coordinates (tabular data); and (3) create spatial data within the mapping environment. The methods implemented for each item are listed in Table 11.

Table 11 Feature class development method

Item	Data (Feature Class)	Geometry Type	Method	Map Component		
				1 Hwy Map	2 Index Map	3 Detail Map
1.	Equipment Access Path	Line	3			■
2.	Equipment Item	Point	1		■	■
3.	Facility	Point	1	■	■	■
4.	Rail Line	Line	1	■	■	■
5.	Rail Station	Point	1	■	■	■
6.	Roads	Line	1	■	■	■
7.	Station Restroom	Point	1		■	■
8.	Track Access Gate	Point	3			■
9.	Track Tunnel Portal	Point	1		■	■

Methods: (1) Import existing; (2) Generate from x,y coordinates; (3) Create inside ArcGIS software

The non-spatial tabular data was the next dataset prepared for the geodatabase. This data was used for labeling features, as well as reference for defining feature characteristics. Tabular data was imported from a combination of tables within the locator map database.

3.6.5. Cartographic Symbol Library

An ArcMap symbol library was developed to function in a similar capacity as the PowerPoint symbol template. Symbols and relevant text labels had to match existing locator maps to be backward compatible. Second-generation symbology, those that did not exist prior to this study, was included in the new symbol library.

3.6.5.1. Creating Symbols

Re-creating existing symbols was based on symbol properties found in the PowerPoint template. Following this approach, symbols were developed using ArcMap's Symbol Property Editor with exact or similar properties. However, some symbols were developed during the layout of a specific map component. This was necessary, for example, for the traffic direction arrows that were designed during the detail map development phase, and utilized the unique cartographic representation feature. The development process was completed after symbols and

text labels were applied to the features they represent, evaluated, and revisions incorporated.

Figure 40 shows the style library categories and items developed for potential usage.

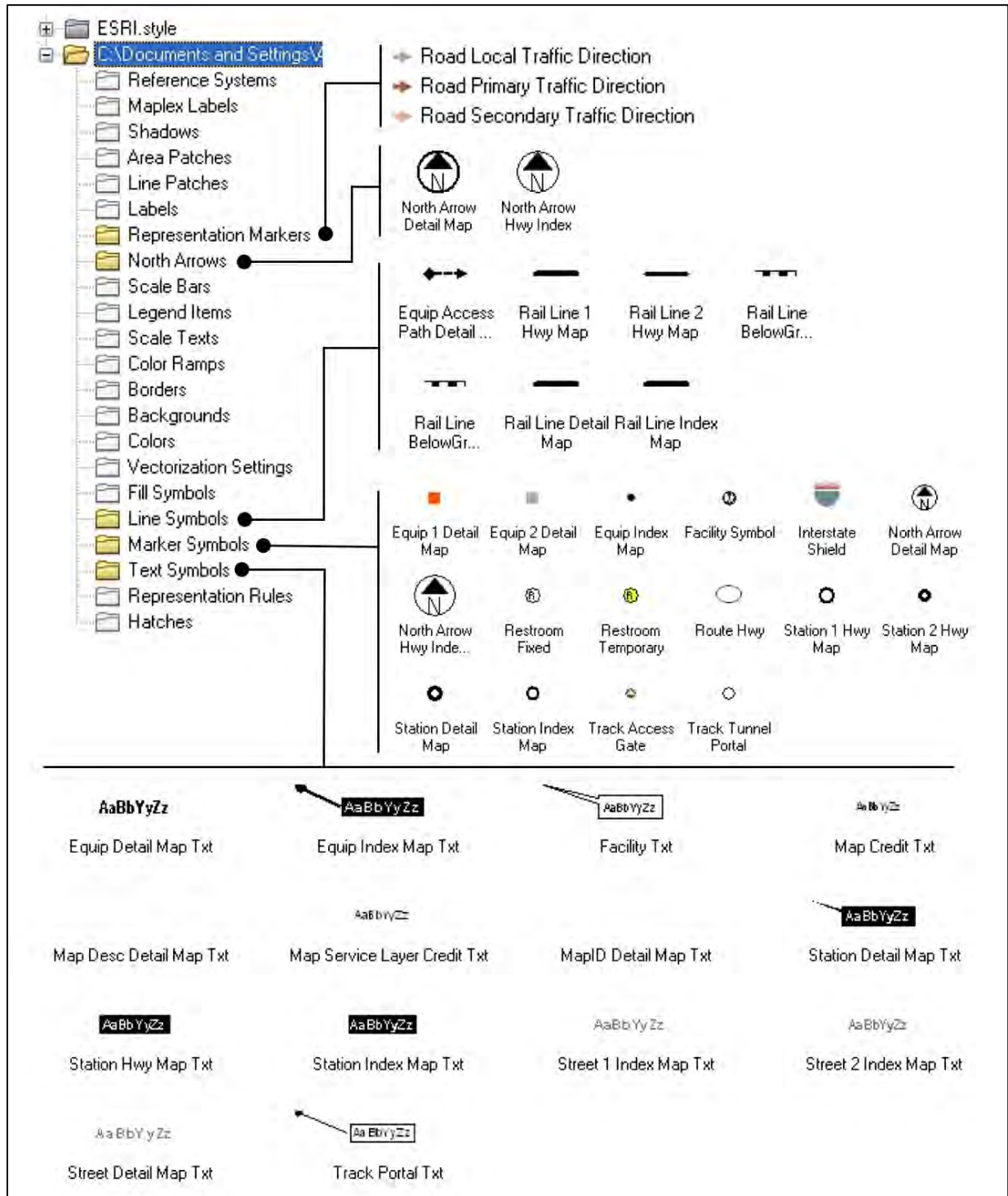


Figure 40 RELM project style library. *Source:* Student 2015

3.6.5.2. Naming Symbols

The names assigned to symbols and text labels were formulated using a more descriptive composite name format. The objective was to formulate functional names that associated subject matter (e.g., equipment) with the map component (e.g., detail map). While this might result in a longer name, the result required less time and effort to decipher than abbreviations, acronyms or unscrambling alphanumeric codes. In addition, some symbols and labels included a sequential numeric value to define two or more alternative versions. For example, the alternatives could represent different font sizes. However, these approaches were not applied to symbols that remained constant between all map components (e.g., facility).

3.6.6. Highway Map Development

Development of the highway map component integrated the products created in previous phases (e.g., data collection, geodatabase) joined together with an assortment of software specific map assembly procedures. While not all-inclusive, the general process included (1) create map file (.mxd); (2) establish page setup; (3) set paper size; (4) set layout orientation; (5) create map layer and define coordinate system; (6) create group layers; (7) add the basemap; (8) add feature classes and tabular data from the geodatabase; (9) establish labeling source; (10) create map layout view; (11) define data frame; and (12) prepare map and output. These steps would, in most cases, be applied in development of the index and detail maps.

After the general setup was completed, the symbology was applied to the features and textual labels. Labels were added manually using the labelling tool, which provided flexibility in determining the position. Figure 41 shows the highway map layout followed by Table 12 that provides a list of map elements and sources, and Table 13 that lists the library symbols utilized.

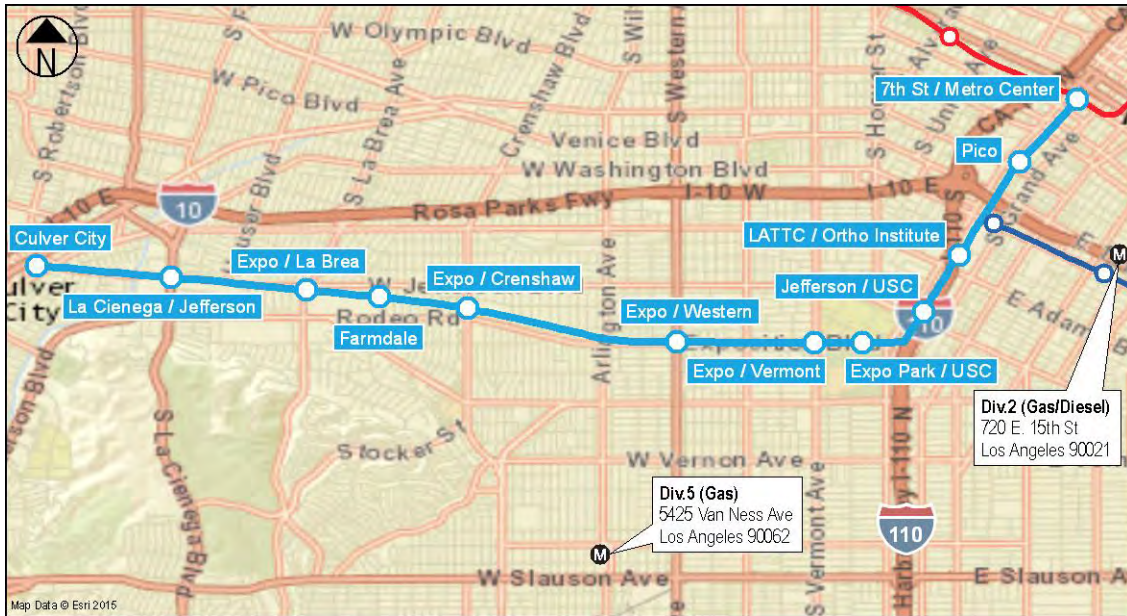






Figure 41 Highway map. *Source:* Student 2014

Table 12 Highway map elements

Item	Element Name	Description	Data Source	Code
1.	FACILITY NAME	Labels, manual placement	Tabular data; table join	Python: "<BOL>"+[FACILITY_FUELING_LIST.FacLGLabel]+"</BOL>"+'\n'+[FACILITY_FUELING_LIST.DeliveryAddr]+' \n'+ [FACILITY_FUELING_LIST.CityName] +" "+ [FACILITY_FUELING_LIST.ZipCode]
2.	HWY MAP	Map data frame	Esri World Street Map	Scale 1:105,000
3.	MAP CREDIT	Map source credit	Dynamic Text	Map Data © Esri <dyn type="date" format="yyyy"/>
4.	NORTH ARROW	North Arrow	Style library; manual placement	None
5.	SERVICE CREDITS	Service layer credit	Dynamic Text	Service Layer Credits: <dyn type="document" property="service layer credits" separator="\n" showLayerNames="false" layerNameSeparator="": "/>
6.	STATION NAME	Labels, manual placement	Tabular data; table join	Target Table:ExpoLineSta0512 Target Field:STOPNUMNEW Join Table:LGMap_StaName_Expo Join Field:AltRteStopNum None

Table 13 Highway map symbols and data source

Item	Symbol Name	Display	Description	Data Source
1.	Facility		Facility fueling locations	Feature = Facilities
2.	Rail Line		Rail lines (multiple)	Feature = RailRoute
3.	Rail Station		Passenger stations for multiple rail lines	Feature = RailStations
4.	Road Interstate Shield		Interstate Shield, as required	Style library; Basemap

3.6.7. Index Map

The index map component followed a similar setup process as the highway map, however, two maps were required with the equipment items. The map size was determined by following the draft layout that was two panels wide, where the combined height did not extend into equipment index list. Determining the map scale involved satisfying three conditions: (1) split the rail line where features were not duplicated between maps; (2) maintain the same scale between both; and, (3) include the primary freeway that extends along the alignment. Once all three conditions were achieved, to the degree possible, both map data frames were fixed, thereby locking the map scale. With no further adjustments possible, the map features were labeled. Figure 42 and Figure 43 show the two index maps followed by Table 14 that provides a listing of map elements and sources, as well as, Table 15 which lists the style library symbols utilized.

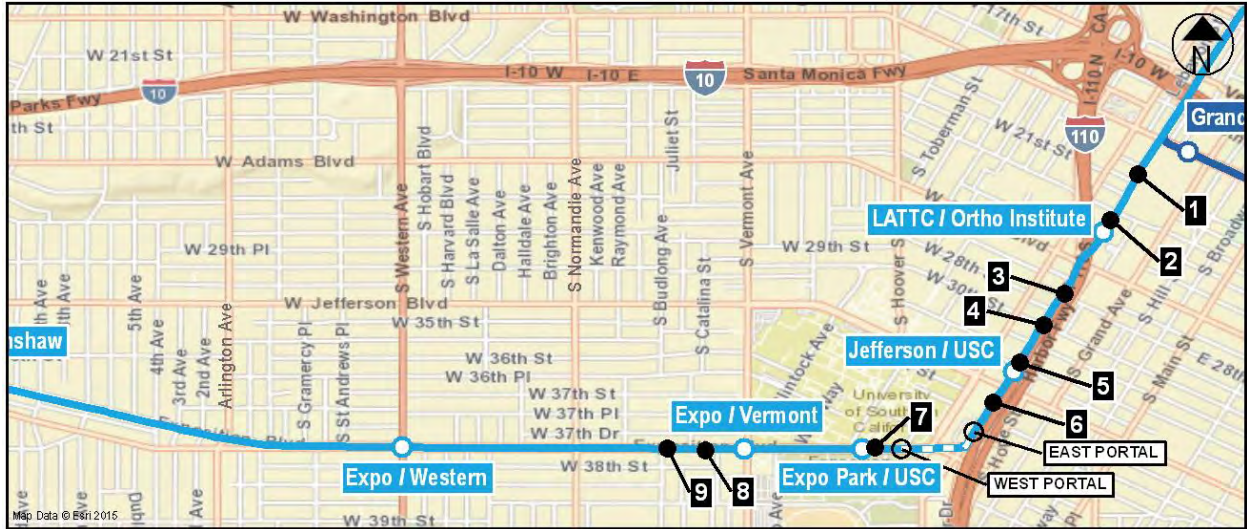


Figure 42 Index map 1 layout. *Source:* Student 2014

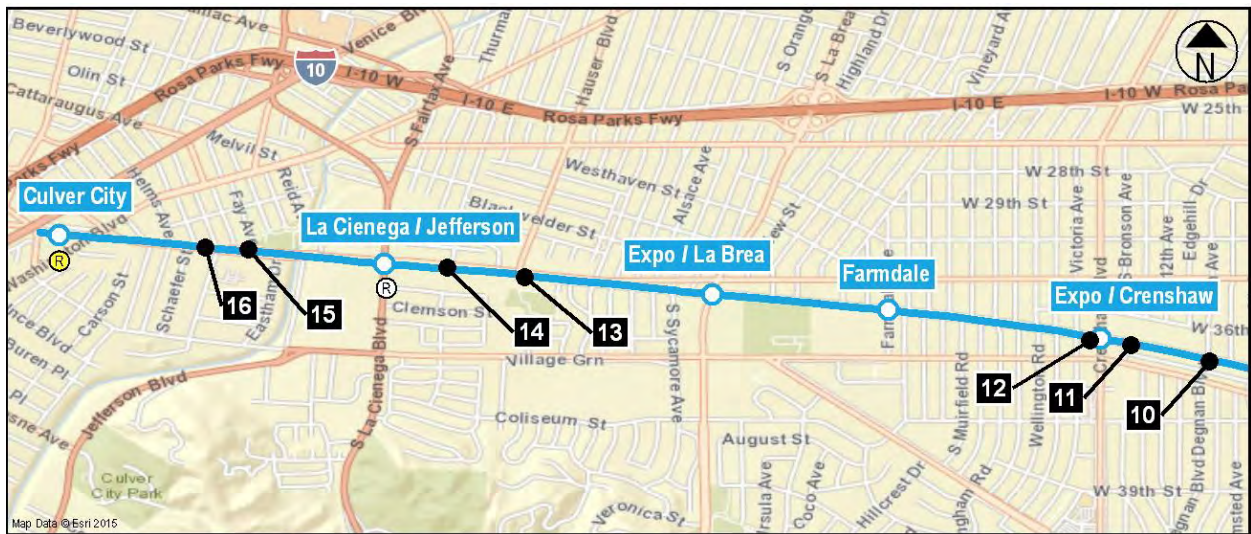


Figure 43 Index map 2 layout. *Source:* Student 2014










Table 14 Index map elements

Item	Element Name	Description	Data Source	Code
1.	IndexMap1, IndexMap2	Data frame	Esri World Street Map	Index Map 1 Scale: 1:42,000 Index Map 2 Scale: 1:43,269
2.	MAP CREDIT	Map source credit	Dynamic Text	Map Data © Esri <dyn type="date" format="yyyy"/>
3.	NORTH ARROW	North Arrow	Style library	None

Table 14 Index map elements (continued)

Item	Element Name	Description	Data Source	Code
4.	SERVICE CREDITS	Service layer credits	Dynamic Text	Service Layer Credits: <dyn type=""document"" property=""service layer credits"" separator=""\n"" showLayerNames=""false"" layerNameSeparator="" : ""/>
5.	STATION NAME	Labels, manual placement	Tabular data; table join	Target Table: ExpoLineSta0512 Target Field: STOPNUMNEW Join Table: LGMap_StaName_Expo Join Field: AltRteStopNum
6.	STREET LABELS	Labels, manual placement	Tabular data	Table: TIGER/Line Shapefile, 2013, Los Angeles County Field: FULLNAME

Table 15 Index map symbols and data source

Item	Symbol Name	Display	Description	Spatial Geometry	Data Source
1.	Equipment Index		Equipment item location	Point	Feature = Equipment
2.	Facility		Facility fueling locations	Point	Target Table: MetroFacilities2013 Target Field: FacID Join Table: FACILITY_FUELING_LIST Join Field: FacID
3.	Rail Line		Rail alignment	Line	Feature = RailRoute
4.	Rail Line Below-Grade		Rail alignment below-grade	Line	Feature = RailRoute / Below-Grade
5.	Rail Station		Passenger station	Point	Feature = RailStations
6.	Restroom Fixed		Staff restrooms located at passenger stations (Fixed, Temporary)	Point	Feature = RailStation_Restroom; Cartographic representation
7.	Restroom Temporary		Temporary staff restrooms available during construction	Point	Feature = RailStation_Restroom Cartographic representation
8.	Road Interstate Shield		Interstate Shield, as required	None	Style library; Basemap
9.	Track Tunnel Portal		Tunnel entrance	Point	Feature = RailTrack_Portal

3.6.8. Detail Maps Using Data Driven Pages

The equipment detail maps were unique, as they built upon the standard process used in the first two map components by incorporating the ArcMap Data Driven Pages (DDP) feature.

The DDP method allowed one map to serve as the display case for generating a series of maps, each with its own dynamic content.

Development began, as in previous maps, with the standard file initiation, page setup, and establishment of group layers and import of feature classes. The map data frame and map element dimensions originated from the detail map properties in the PowerPoint style template, and the paper size guide. Figure 44 shows the layout specifications for the detail map and map elements.

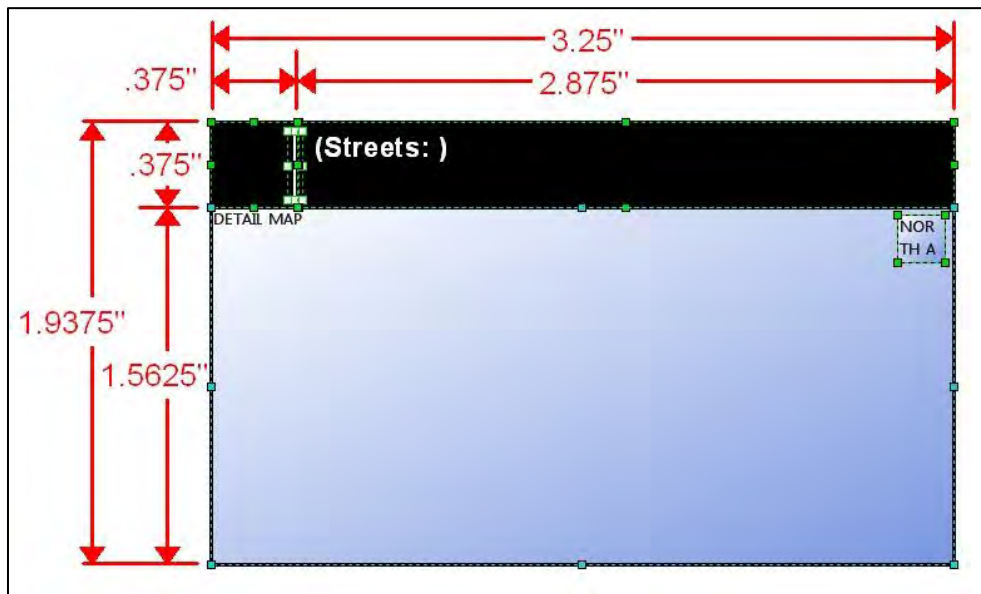


Figure 44 Detail map elements and specifications. *Source:* Student 2014

Before assembling the map content, it was necessary to activate the DDP feature by creating an index layer from the equipment feature. The equipment layer was joined with tabular data to generate the specific text for each detail map displaying the map elements (e.g., map id, map description) which correspond to the equipment index list that includes the number and equipment name.

Once the DDP feature was activated, it was possible to cycle through the maps using the data layout view, which allowed for the determination and placement of map content. Each item

was then evaluated in the layout view to resolve any unexpected placement issues. Figure 45 provides a snapshot of the development process. Table 16 provides a description of the elements, and Table 17 lists the symbols utilized.
















Figure 45 Feature comparison technique. *Source:* Student 2014

Table 16 Detail map elements

Item	Element Name	Description	Data Source	Code
1.	DETAIL MAP	Map data frame	Esri World Street Map	Page definition layer; center and maintain current scale (1:9000)
2.	DIVIDER	Vertical line separator	Graphic	None
3.	MAP CREDIT	Map source credit	Dynamic Text	Map Data © Esri <dyn type="date" format="yyyy"/>
4.	MAP DESC	(1) Equipment name; (2) equipment description; (3) street intersection	Table = LGEquipMap Field = MapEqName, MapEqDesc	<dyn type="page" property="attribute" field="LG_EXPOSIG_DETAIL_MAP.EQUIP_NAME" domainlookup="true" /> (Streets: <dyn type="page" property="attribute" field="LG_EXPOSIG_DETAIL_MAP.STR_INTERSECT" domainlookup="true" emptyStr="" />)
5.	MAPID	Map / equipment index number	Table = LGEquipMap Field = MapIndexNum	<dyn type="page" property="attribute" field="LG_EXPOSIG_DETAIL_MAP.MAPID" domainlookup="true"/>
6.	NORTH ARROW	North Arrow	Style Library	None
7.	STATION NAME	Labels, automatic placement	Tabular data; table join	Target Table: ExpoLineSta0512 Target Field: STOPNUMNEW Join Table: LGMap_StaName_Expo Join Field: AltRteStopNum
8.	STREET LABELS	Labels, manual placement	Tabular data	Table: TIGER/Line Shapefile, 2013, Los Angeles County Field: FULLNAMES

Table 17 Detail map style library symbols and data source

Item	Symbol Name	Display	Description	Spatial Geometry	Data Source
1.	Equipment		Equipment item	Point	Feature = Equipment
2.	Facility		Facility fueling locations	Point	Target Table: MetroFacilities2013 Target Field: FacID Join Table: FACILITY_FUELING_LIST Join Field: FacID
3.	Rail Line		Rail alignment	Line	Feature = RailRoute
4.	Rail Line Below-Grade		Rail alignment below-grade	Line	Feature = RailRoute / Below-Grade
5.	Rail Station		Passenger station	Point	Feature = RailStations
6.	Restroom Fixed		Fixed staff restrooms located at passenger stations	Point	Feature = RailStation_Restroom Cartographic representation
7.	Restroom Temporary		Temporary staff restrooms available during construction	Point	Feature = RailStation_Restroom Cartographic representation
8.	Road Interstate Shield		Interstate Shield, as required	None	Style library; Basemap
9.	Track Access Gate		Track access gates	Point	Feature = TRK_GATE_ACCESS
10.	Track Tunnel Portal		Track tunnel entrance	Point	Feature = RailTrack_Portal
11.	Traffic Direction Local Roads		Traffic direction along local roads	Point	Feature = TRAFFIC Cartographic representation
12.	Traffic Direction Primary Roads		Traffic direction along primary roads	Point	Feature = TRAFFIC Cartographic representation
13.	Traffic Direction Secondary Roads		Traffic direction along secondary roads	Point	Feature = TRAFFIC Cartographic representation

3.6.9. Map Output Using Python Script

Once all the map content was completed and reviewed on screen, it was necessary to review the maps in the output format as image files. Because of the iterative nature of the review process, automating the output was required, and the Python language was selected, tested, and modified to achieve the desired quality and format. The Python script was loaded into a Python window within ArcMap, and when executed, generated all 16-study maps into a predefined

directory awaiting the next study phase. Figure 46 shows the Python automation process flow used to export the detail maps.

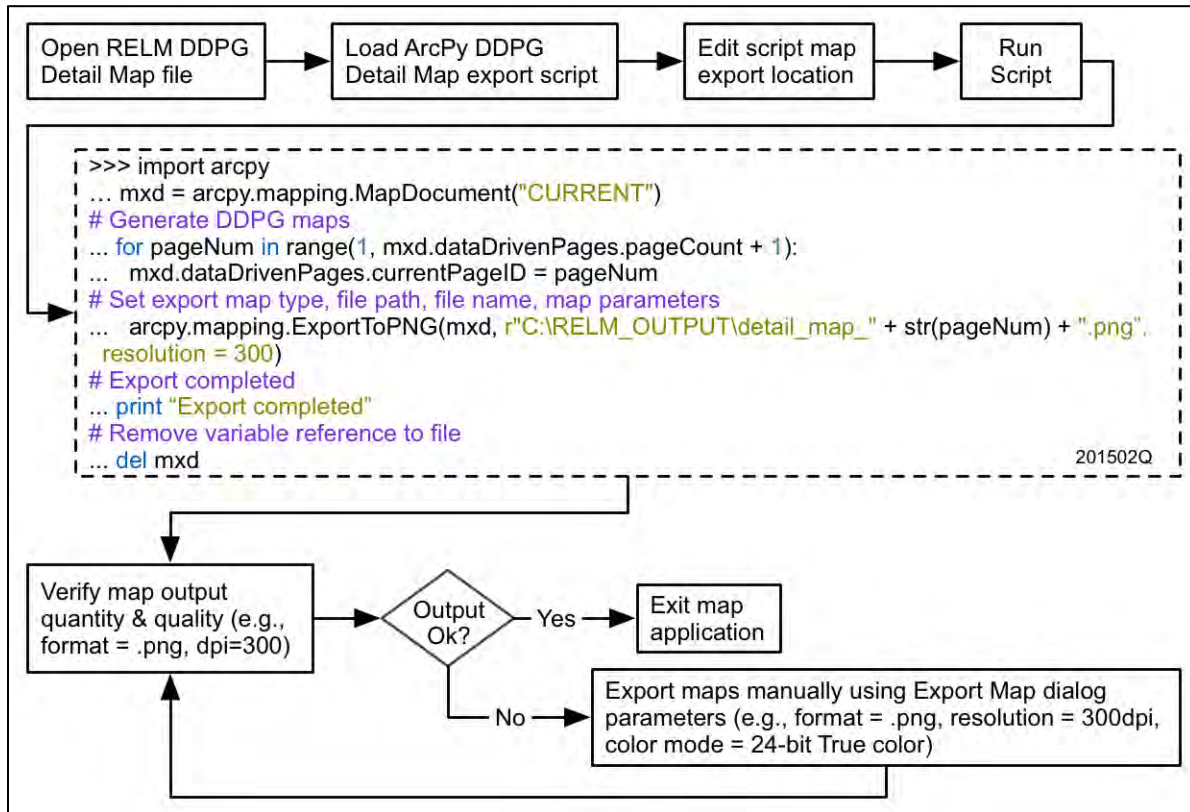


Figure 46 Python detail map export process flow. *Source:* Student 2014

3.6.10. Map Layout Incorporating PowerPoint Visual Basic for Applications

The previous process, [inserting and positioning the map image files (.jpg) within the PowerPoint slide], was now replaced with a semi-automated method. This next process employed Microsoft Office PowerPoint Visual Basic for Applications (VBA) that used a relatively small amount of VBA code per map, but required a significant amount of time and effort constructing the information to insert into the code. The following subsections outline the steps involved.

3.6.10.1. VBA Measurement Framework

It was necessary to understand the VBA environment, with particular attention given to defining object location within a page. In brief, the object’s coordinates originate from the top left corner of the page and are identified using “x,y” position (x= horizontal, y=vertical). In addition, the x,y values for the object location and page measurements are represented in “points” (pt.), rather than “inches” (in.). Therefore, establishing the conversion from inches to points was necessary. The conversion formula applied was one inch equaled to 72 points (1in = 72pt). However, the fractional representation of inches (e.g., 3-1/8”) must be converted to its decimal equivalent (e.g., 3.125”). The final formula would be represented as $72 \times 3.125 = 225\text{pt}$. This procedure was applied to each map component and explained in the following sections.

3.6.10.2. Highway Map VBA Code

The highway map is located on Slide 1 of the PowerPoint locator map file, referred to as the outside page. Determining the highway map position in the page layout involved four steps. First, the draft layout was used to determine the map’s top left corner coordinate in the cover panel (x=10.55in., y=2.27in.). Second, the x,y location is converted into points (759.6pt x 163.44pt). Third, using the map image file, the map’s dimensions were determined (3.1875in. x 5.875in.). Lastly, the conversion formula is applied to generate the value in points (229.5pt x 423pt) and inserted into the code. The resulting VBA code for the highway map is displayed in Table 18.

Table 18 VBA code for the highway map

Map Image	Code
Highway Map (hwymap.png)	<pre>Sub InsertHwyMap() 'Insert the Hwy Map into the cover panel (hwymap.png) With ActivePresentation.Slides(1).Shapes .AddShape(msoShapeRectangle, 759.6, 163.44, 229.5, 423).Fill _ .UserPicture "c:\GIS\RELM_OUTPUT\hwymap.png" End With End Sub</pre>

3.6.10.3. Index Maps VBA Code

Based on the page layout, the index map is located on slide 1 (outside page) along with the cover panel and highway map. Following the conversion procedure outlined above for the highway map, the page coordinates of each index map were established. A sample of the VBA code for top index map is displayed in Table 19.

Table 19 VBA code for index map #1

Map Image	Code
Index Map 1 (indexmap1.png)	<pre> Sub InsertIndexMap1() 'Insert the Index Map1 into the index panel (indexmap1.png) 'IndexMap1 size = 6.5w" x 2.75h" = 468w pts x 198h pts 'top left = 273.6 pt, top down = 176.4 pt With ActivePresentation.Slides(1).Shapes .AddShape(msoShapeRectangle, 273.6, 176.4, 468, 198).Fill _ .UserPicture "c:\GIS\RELM_OUTPUT\indexmap1.png" End With End Sub </pre>

3.6.10.4. Detail Map VBA Code

The detail maps begin on slide 2 (inside page), and continue to slide 1, (if required). The VBA code for each detail map position was determined by combining the page layout (see Figure 37, Figure 38) column and row coordinates (e.g., c1, r1) with the standard detail map dimensions (3.25" x 1.9375"). Using the detail map paper size guide, a detail map coordinate conversion matrix was developed for each column and row location. The column and row conversion matrix is listed in Table 20.

Table 20 Detail map page layout coordinate conversion matrix

Map#	Col	Row	Col X (inches)	Row Y (inches)	Col X, Row Y (points)	Detail Map (points)	Combined Detail Map Coordinates (points)
1	1	1	0.25	0.25	18,18	234,139.5	18,18,234,139.5
2	1	2	0.25	2.27	18,163.44	234,139.5	18,163.44,234,139.5
3	1	3	0.25	4.29	18,308.88	234,139.5	18,308.88,234,139.5
4	1	4	0.25	6.31	18,454.32	234,139.5	18,454.32,234,139.5
5	2	1	3.667	0.25	264.024,18	234,139.5	264.024,18,234,139.5
6	2	2	3.667	2.27	264.024,163.44	234,139.5	264.024,163.44,234,139.5
7	2	3	3.667	4.29	264.024,308.88	234,139.5	264.024,308.88,234,139.5
8	2	4	3.667	6.31	264.024,454.32	234,139.5	264.024,454.32,234,139.5
9	3	1	7.084	0.25	510.048,18	234,139.5	510.048,18,234,139.5
10	3	2	7.084	2.27	510.048,163.44	234,139.5	510.048,163.44,234,139.5
11	3	3	7.084	4.29	510.048,308.88	234,139.5	510.048,308.88,234,139.5
12	3	4	7.084	6.31	510.048,454.32	234,139.5	510.048,454.32,234,139.5
13	4	1	10.501	0.25	756.072,18	234,139.5	756.072,18,234,139.5
14	4	2	10.501	2.27	756.072,163.44	234,139.5	756.072,163.44,234,139.5
15	4	3	10.501	4.29	756.072,308.88	234,139.5	756.072,308.88,234,139.5
16	4	4	10.501	6.31	756.072,454.32	234,139.5	756.072,454.32,234,139.5

Referring to the “Combined detail map coordinates” column in Table 20, the coordinates were incorporated into the VBA code for each detail map number. A sample of the VBA code for one detail map is displayed in Table 21.

Table 21 Sample VBA code for detail map #1

Map	Code
Detail Map 1 (detail_map_1.png)	<pre> Sub InsertDetailMap1() 'Insert the Detail Map1 into slide2 c1r1 'top left = 18 pt, top down = 18 pt With ActivePresentation.Slides(2).Shapes .AddShape(msoShapeRectangle, 18, 18, 234, 139.5).Fill _ .UserPicture "c:\GIS\RELM_OUTPUT\detail_map_1.png" End With End Sub </pre>

Chapter 4 Results

The objective of this study was to develop a new locator map methodology that would be an improvement over the existing RELM development method. The new approach would have to contain an improvement in map element positional and textual accuracy, cartographic symbol consistency, require less production time, and reduce errors. The following sections discuss the extent to which these objectives were achieved.

4.1 Map Development and Automation

4.1.1. *Standardized Mapping Platform and Basemap*

Utilizing one map software platform, and particularly one basemap, ensured that features would remain cartographically consistent at various map scales and among the map components. This is important because a “map is a graphic,” (BCS 2008, 26) that represents features using points, lines, and areas, to transcribe geographical information into a language understood by a diverse audience. With the initial locator maps (see Figure 23), three map sources were used for each map component. These tri-visual mapping options resulted in a lack of consistency (BCS 2008, 31) producing conflicts between similar features (e.g., natural, human) such as the road type (e.g., interstate, highway), line color, background color, labeling (e.g., font style), and “noise”(elements that may visually distract or obstruct readability of the essential parts) (Wilson 2011, 40).

4.1.2. *Improvements Made to the Map Development Process*

4.1.2.1. Spatial and Textual Error Reduction

As discussed in Chapter 2, the goal of the maps is to offer an effective and accurate method of expeditiously finding TPSS equipment along the miles of track. Therefore, it is of the

utmost importance that the potential for errors is eliminated or at a minimum, reduced as much as possible.

Upon evaluating the initial run of the maps that were generated manually, three typical types of errors were found: duplicating elements that contain errors; inaccurate position of symbology, and typographical errors present in labels. It was hypothesized that automation would mitigate these issues and the pilot maps were updated via an automated process resulting in a 50% reduction in errors -- a significant accomplishment brought about by using geographical coordinates (spatial attributes) and textual attributes entered into the locator database. The key to the positive results is the ability to "share or reuse" information between maps automatically.

4.1.2.2. Labor Time Reduction

Labor time is typically used as a quantitative variable to evaluate labor costs, production costs, and monetary savings (tangible benefits). Benefits are realized through reduction in staff time, reduction in re-works, technological efficiency, or user training, improvement in process workflow (Tomlinson 2003, 187). Timed tests were performed in PowerPoint to represent the baseline process involved in the creation and placement of point, line, and textual labels. The tests were performed using the newly created test maps as background guide for the PowerPoint user to position the map elements. Three PowerPoint users were used representing beginner, intermediate and advanced skill levels. The results from these tests provided the basis of the benefit-costs analysis validating the map element quantity and labor time reduction.

Consider the following visual representation of the benefit-cost analysis based on the time samples shown in Figure 47. The bar graph provides a total development summary of the elements required compared to those automated per map component while the associated time expended and saved are shown in the pie chart.

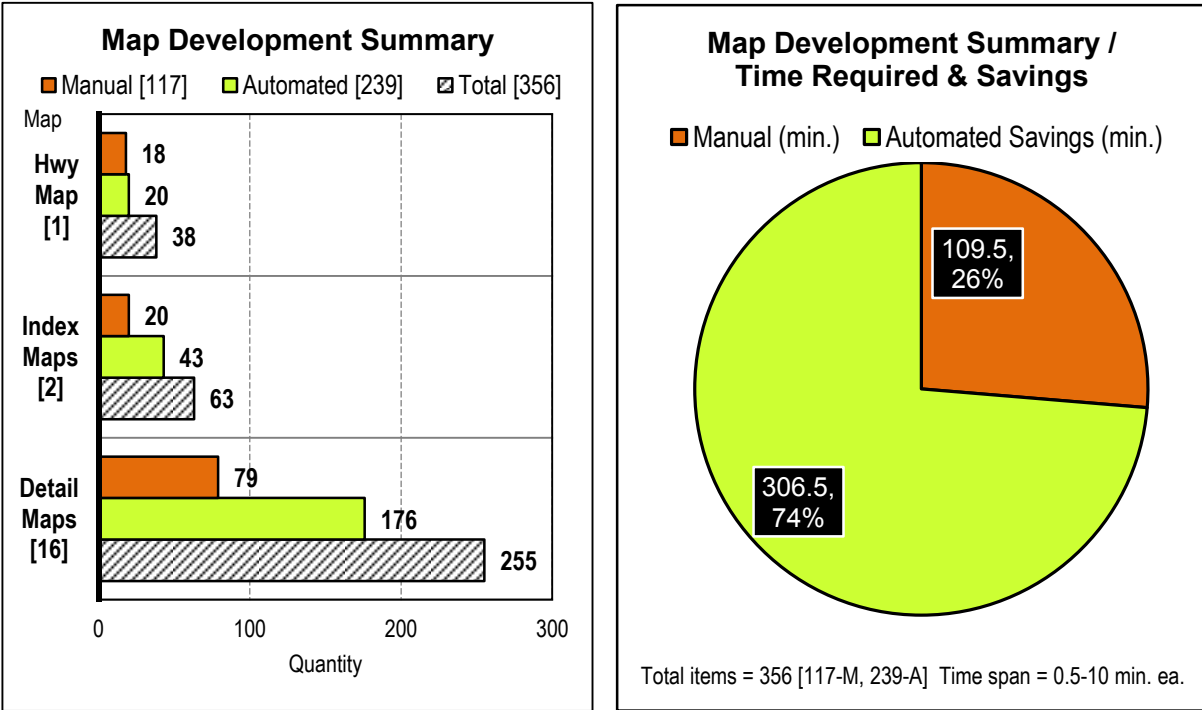


Figure 47 Map development benefit-cost summary comparison charts

Overall map element placement and labeling time savings were achieved in the development of each map component. Most of the time-consuming spatial data items had been developed before the project and were imported (see Table 11), therefore, generating immediate labor reduction and time avoidance savings. The station names, however, were added to the locator map database for data quality / quality control purposes. These textual attributes were exported back to the geodatabase and linked to the maps where the mapping software semi-automated the labeling of stations. The detail map elements based on ArcGIS Data Driven Pages generated the greatest time savings. This resulted from one map frame being used to generate 70% (176 of 255) of map elements contained in sixteen separate maps. The individual map elements, quantities required, and the amount of time saved for each are listed in Table 22.

Table 22 Map development by element benefit-cost evaluation summary

Elements	Map Component Usage			Total Items	Time Est. (min. each)	Manual combined with Automation		Automation Savings			See App. C Figure
	1. Hwy.	2. Index	3. Detail			Items	Time Tot.	Items	Time Tot.	%	
E1. Map Basemap	■	■	■	19	10	4	40	15	150.0	79%	71
E2. Rail Line Route Path	■	■	■	23	1	0	0	23	23.0	100%	72
E3. Rail Station Symbols	■	■	■	35	0.5	0	0	35	17.5	100%	73
E4. Rail Station Labels	■	■	■	32	1	12	12	20	20.0	63%	74
E5. Fuel Facility Symbols	■	■	■	2	0.5	0	0	2	1.0	100%	75
E6. Fuel Facility Labels	■	■	■	2	1.5	2	3	0	0.0	0%	76
E7. Highway Shield Symbols	■	■	■	8	1	7	7	1	1.0	13%	77
E8. North Arrow Symbols	■	■	■	19	0.5	4	2	15	7.5	79%	78
E9. Map Source Credit Labels	■	■	■	19	0.5	4	2	15	7.5	79%	79
E10. Equipment Symbols		■	■	32	0.5	0	0	32	16.0	100%	80
E11. Equipment Symbol Labels		■	■	25	0.5	9	4.5	16	8.0	64%	81
E12. Restroom Symbols		■	■	3	0.5	0	0	3	1.5	100%	82
E13. Street Name Labels		■	■	36	0.5	29	14.5	7	3.5	19%	83
E14. Track Portal Symbols		■	■	4	0.5	0	0	4	2.0	100%	84
E15. Track Portal Labels		■	■	4	0.5	0	0	4	2.0	100%	85
E16. Equipment Map ID. Labels			■	16	0.5	1	0.5	15	7.5	94%	86
E17. Equip. Name/Desc. Labels			■	16	2	1	2	15	30.0	94%	87
E18. Track Access Symbols			■	46	0.5	26	13	20	10.0	43%	88
E19. Traffic Direction Symbols			■	23	0.5	18	9	5	2.5	22%	89

By reviewing the three columns under the Automation Saving section in Table 22 most items exhibited a reduction in items created and time saved. The graph in Figure 48 depicts these savings through a comparison of the existing PowerPoint method and the new development process. The graph presents a cumulative time estimate of the map development process arranged by tasks (map component) and sub-task (map elements). See Appendix C for detailed benefit-cost results pertaining to each map element listed in Table 22.

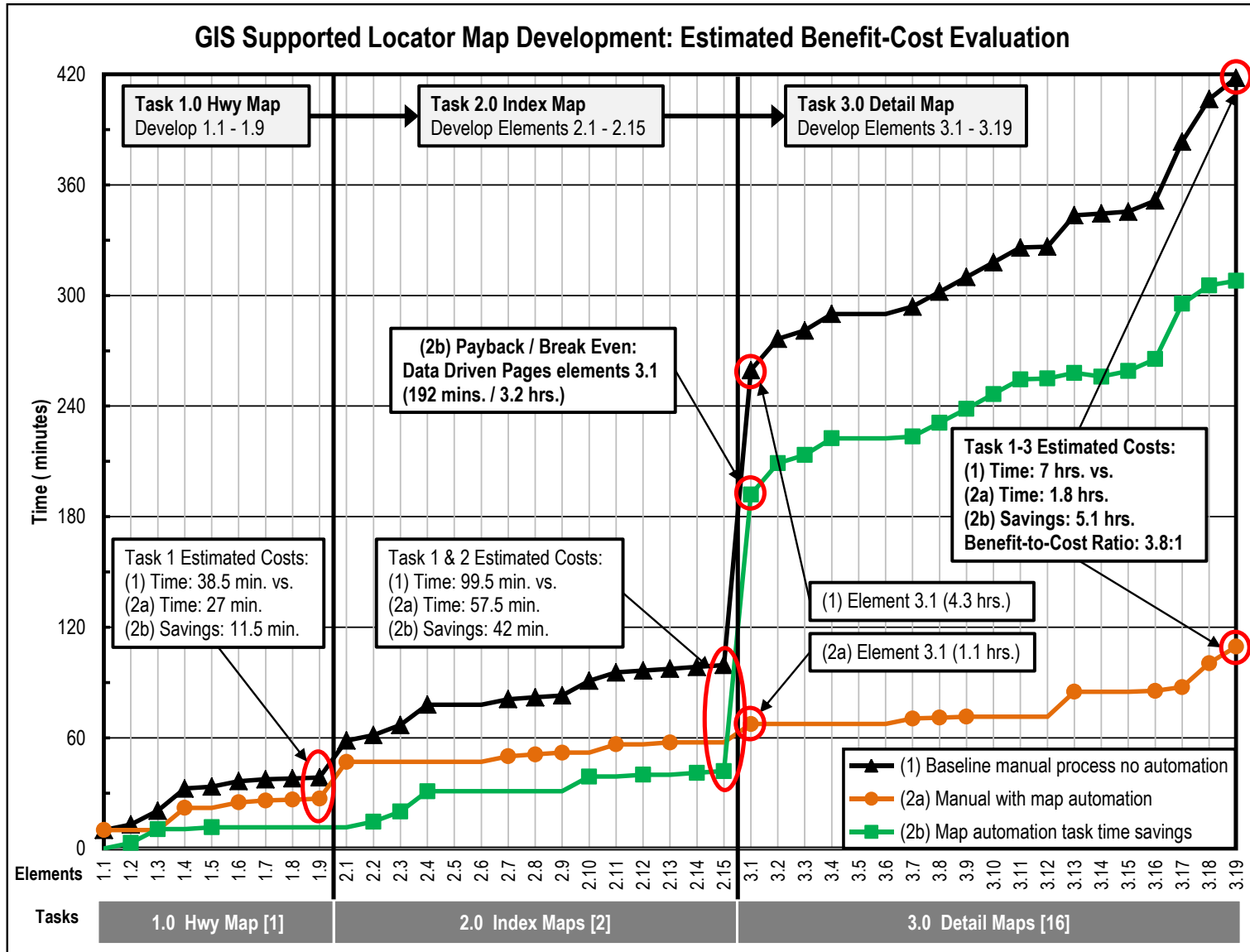


Figure 48 Benefit-Cost evaluation of baseline and map automation process

4.1.3. Geodatabase

The geodatabase provided a centralized spatial data management system for all study maps. The ability to retrieve all spatial and tabular data from one source meant that all maps would reference and display the same version. Conversely, they would possibly contain the same errors. However, the use of new methodology meant that once an error was discovered and the source data corrected, the change would be reflected in all maps once they were refreshed. In addition, each map file was based on the geodatabase structure (e.g., feature class name) which standardized data structure between map files.

4.1.4. Data Driven Pages

The ArcMap Data Driven Pages feature improved detail map development using one format to produce a series of maps. As a group, all maps were created using one map file, data frame, feature groups, and feature classes. Using the joined tabular data files provided a flexible method to produce various labeling formats. Independently, each map presented the specific equipment item information provided through joined tabular data.

4.1.5. Cartographic Consistency

The use of the newly formulated Style Library produced labels that were consistent between maps and required less time to set their characteristics. All existing locator maps utilized Esri ArcMap World Street Map basemap in the cover highway maps. Even though the rail line represented a spatial attribute rather than a hand drawn line, they did not share the same cartographic and labelling specifications. It is possible, as well, to incorporate the new library in all existing maps (backward compatibility) and future maps.

Another advantage using the library, is its ability to create a cartographic representation to support symbol consistency through user-defined rules. This feature was used for two

symbols: (1) traffic direction arrows, and (2) station restrooms. In both cases, rules simplified symbol selection based on an attribute containing user-defined terms representing the symbol. This method also maintained the symbol's characteristics, creating consistency between maps, as well as, throughout the map series.

Finally, similar to the PowerPoint style template which was developed as a stand-alone file (see Figure 26), the Style Library is also an independent file. An advantage of this strategy is portability. As a portable file, it can be shared among users, installed on multiple workstations, or placed on a shared drive for project reference. This allows team members involved in RELM development to produce similar looking maps while working more efficiently.

4.2 Desktop Database Integration

The development of the desktop database proved to be a lengthy process, one that resulted in a valuable information asset. This database incorporated tabular information from a variety of sources into a standard format. In synthesizing an array of information, there were logistical challenges that involved the data storage platform, static and dynamic data, temporal accuracy, digital data format (e.g., .xls, .docx, .PDF, .dbf), data integrity, and semantics. To resolve these issues, a variety of conversion techniques and quality assurance tests were performed before the information was usable.

Fortunately, from a maintenance standpoint, much of the information used in creating the maps could be considered static data, not expected to change in the near term. This is associated with major types of information, such as the rail line route, name, colors, station and facility location. Because regular updates rarely occur for these data items, database maintenance efforts are reduced.

4.3 PowerPoint Visual Basic for Applications (VBA)

Incorporating VBA code into the PowerPoint layout has automated the process for inserting finished ArcGIS detail maps, resulting in greater placement accuracy and efficiency. Automatically inserting the map images, with proper alignment, required a maximum of one second per map. Conversely, manually inserting each map into the layout, may take a minimum of one to two minutes depending on software experience.

The automated map insertion process for 19 maps (hwy, index, detail) resulted in a minimum timesaving of 1200% per map (1 sec. vs 120 secs. per map = total minimum time/cost savings of 38 mins.). The savings would increase if the code were to run as one routine that looped through and inserted all maps.

Chapter 5 Conclusion

5.1 Improved RELM Process

The RELM study provided evidence that the integration of various software applications can enhance the quality and the efficiency of the existing locator maps. The new process combined solutions that involved a combination of manual and semi-automated methods that were suited to the user, developer and production environment.

5.2 Locator Map Skillset Requirements

Developing the first generation of TPSS locator maps was initially envisioned as a graphic design project, requiring the skill set of a graphic artist. As a graphic arts project, the requirements involved are: (1) problem definition; (2) copy; (3) graphics; (4) color/bw; (5) typography; (6) paper size printing; (7) folding; (8) quantity; and (10) cost. Typically, the content would come from various suppliers providing textual and graphic content (e.g., logo, illustrations, photos, maps). With all input provided, the layout would be produced, reviewed, revised, approved, and printed. However, given the new proposed methodology, the graphic artist is no longer the only professional required.

The study has proposed a methodology that represents an improvement; it has incorporated an additional set of functional skills. For example, the development process implemented software typically utilized by individuals within specific departments. That said, the skillsets or experience required include's: (1) Graphic Artist; (2) GIS Analysis; (3) Database Developer; (4) Visual Basic Programmer; and (5) MS Office PowerPoint user. Going forward, the new challenge is to build the required organizational relationships to implement, operate, and maintain parts, or all of the proposed solution.

5.3 Future Work

5.3.1. Departmental Data Exchange

Having multiple groups of data suppliers requires communication among stakeholders in order to facilitate the exchange of information. It is feasible to access and incorporate map locator information on an “as-needed” basis with pre-established departmental agreements and data portals. However, it is preferable that relationships among internal data suppliers be formalized. For example, in the case of rail line and passenger station spatial data, the process for obtaining the latest data is available at one Internet website. This delivery system, established and maintained by one supplier, eliminates additional steps or variables. This type of delivery system is required for data such as fueling locations. An internal Intranet website (e.g., SharePoint) that posts fuel type and availability (active/not active) would streamline the current email/phone update procedure.

5.3.2. Extending Automation with Python

Maintaining the correct color of rail line and station features is required for consistency between locator maps and agency communication standards. Creating a colored symbol for each rail line and station was considered, but deemed impractical due to the number of options required per rail line and map component (e.g., route, station, below-grade). As an alternative solution, the color data was stored in the locator database and shared with the geodatabase (see Figure 36, and Figure 39), which in turn made it available to all map components.

A Python script can be applied to the color reference file in order to automate the color designation process. The color reference file could be joined to the feature attribute table (e.g., rail line, station) using the route identification number as the link. Based on joined attributes, the script would loop through the records transferring RGB color values to the appropriate feature

symbol. Automating the required color designation process could reduce color usage errors and time required, thereby making this step more efficient.

5.3.3. VBA Code Automation

5.3.3.1. Update Page Layout Elements

Further VBA code development can focus on automation of additional page layout elements. The cover panel and index map both contain elements that are manually inserted into the page or edited. These include the title block, agency/company logo, and locator map form number and revision date. This information would be exported as a text or Excel file from the locator map database, updating the locator map page elements.

5.3.3.2. Insert Detail Maps Based on Page Size

It is necessary to develop the VBA code for each page size. The page size used for this study was legal (8.5”x14”). A necessary VBA conversion matrix was designed to meet these requirements (see Table 20). To implement this automation solution with existing locator maps, a matrix will need to be developed for letter and tabloid paper. Once the complete set is available, they can be used to automatically generate the VBA code per page size. For example, a VBA code generator program could produce standard code that will insert common textual placeholders and map components. A narrative of the conceptual process flow for inserting the detail maps is shown in Figure 49.

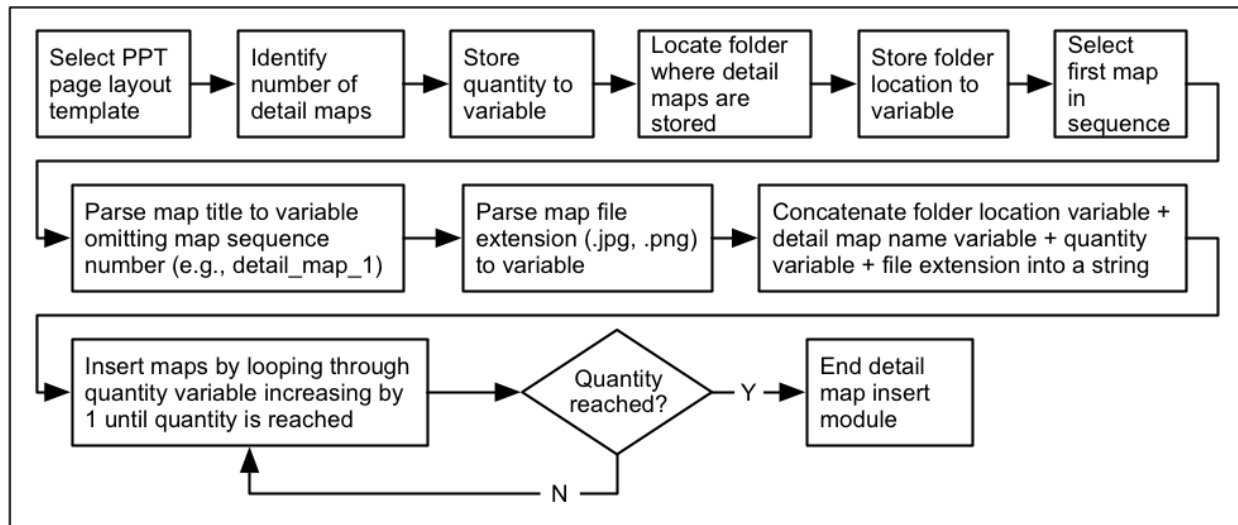


Figure 49 VBA conceptual flow chart based on page size. Source: Student 2015

5.3.4. Urban Rail Transit Partnership Pilot

The national public transit trends described in Chapter 1, particularly rail transit growth, provide a framework for discussing the RELM concept among rail transit agencies, which, at a minimum, could provide conceptual feedback. In addition, initiation of such dialogue through various industry platforms is an alternative. There are various transit publications and forums where discussions on a host of topics and practical innovations are explored. For example, the American Public Transportation Association (APTA) hosts an annual conference that draws national agency representatives. The topics are diverse, and could lead to a viable platform in which the RELM might find an interested audience, or a partner host of a pilot project.

5.4 Progress to Date

The first Rail Equipment Locator Map (RELM) was created by this author in March 2013 in response to a supervisor from the Traction Power department who was seeking assistance in locating traction power equipment along 87 miles of track across the county of Los Angeles. Two months later, after collecting information, surveying staff, and producing drafts, the maps

were distributed. While these maps were well received by staff inside and outside the Traction Power department, the eventual maintenance of each new or revised map publication reaffirmed issues inherent in the development process such as attribute and positional errors. Recognizing that the mapping software and methodology was inadequate, the improvement study was initiated in April 2013, a month prior to the first map's distribution.

Over the course of two and half years, this study progressed in parallel with department locator map development, distribution and maintenance. It involved investigating software tools and processes detailed in previous sections (and those not covered in this text) that have contributed to the proposed RELM solution. This package currently represents the combination of (1) MS Access desktop database; (2) Esri ArcGIS; (3) Python / ArcPy; (4) MS PowerPoint; and (5) MS Visual Basic, software that is utilized in varying degrees within Metro to perform business activities. As this new methodology is applied and tested with each version of the locator maps, the development, delivery options, and maintenance procedures will be enhanced, thereby benefiting rail maintenance personnel, the organization as well as the transit community.

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Appendix A: Assembled Exposition Phase 1 Track Signals Locator Map

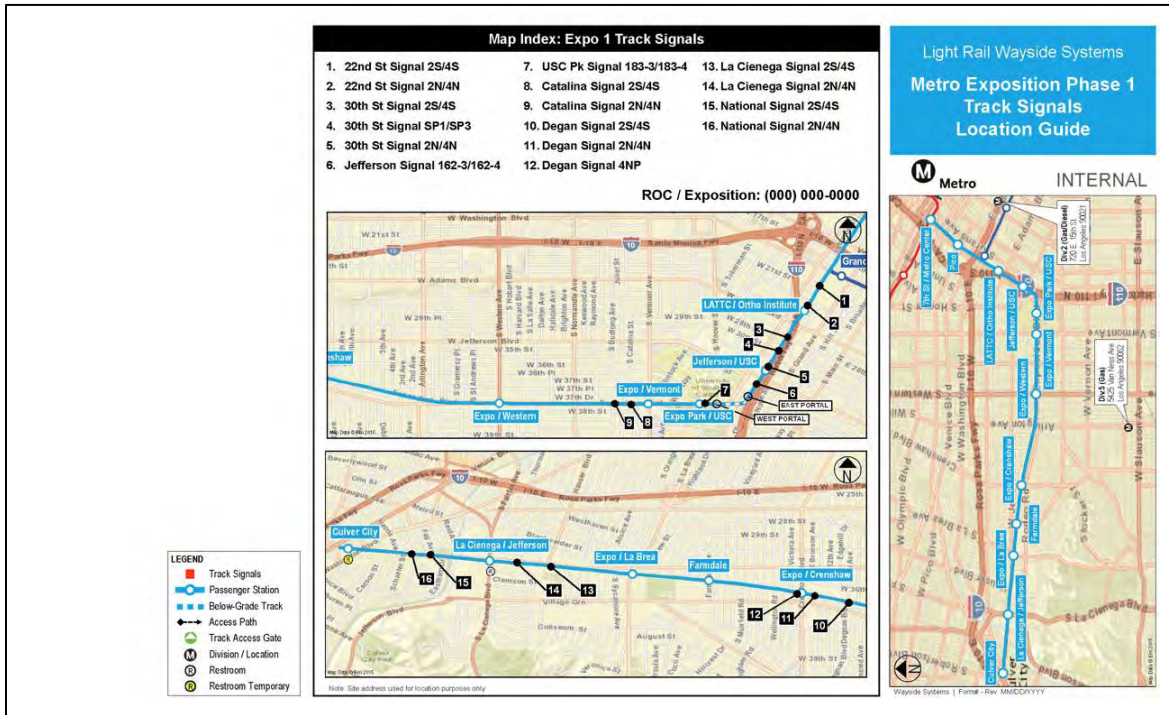


Figure 50 Outside page (PowerPoint slide 1)

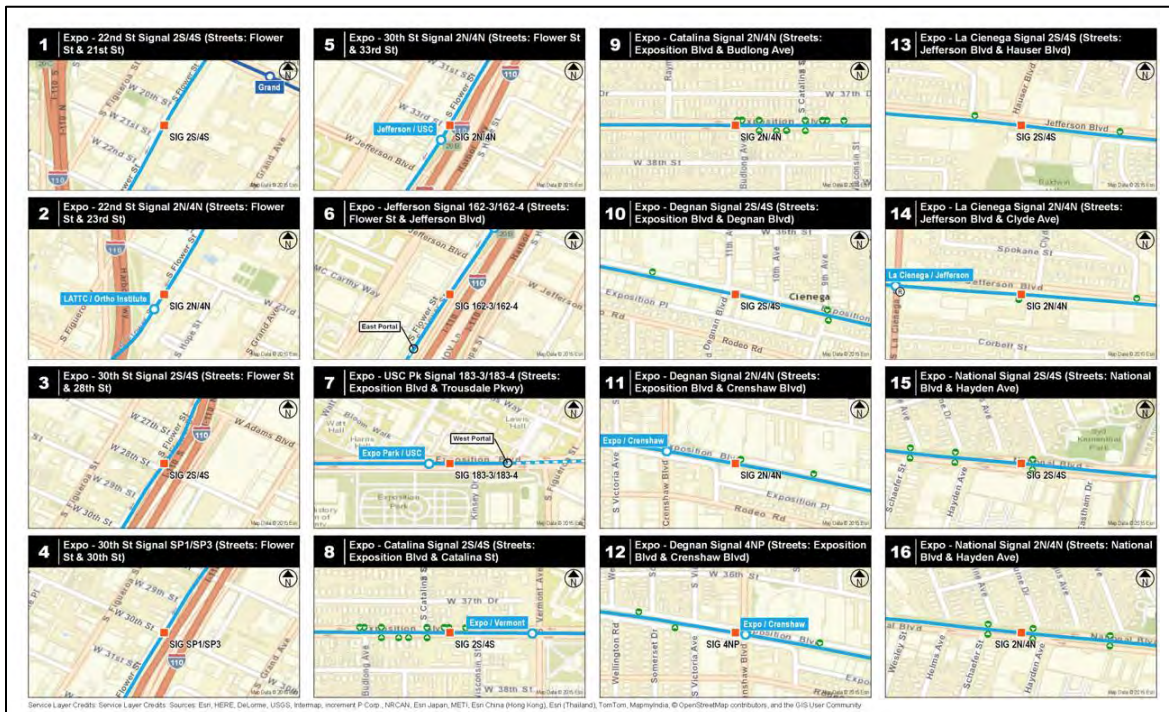


Figure 51 Inside page (PowerPoint slide 2)

Appendix B: Locator Maps With / Without Basemap

Review of additional map features displayed in maps to enhance equipment location.

B1. Highway Map

Highway maps may require highway interstate identification signs when partially obscured or outside the map boundaries. Map scale 1:105,000.

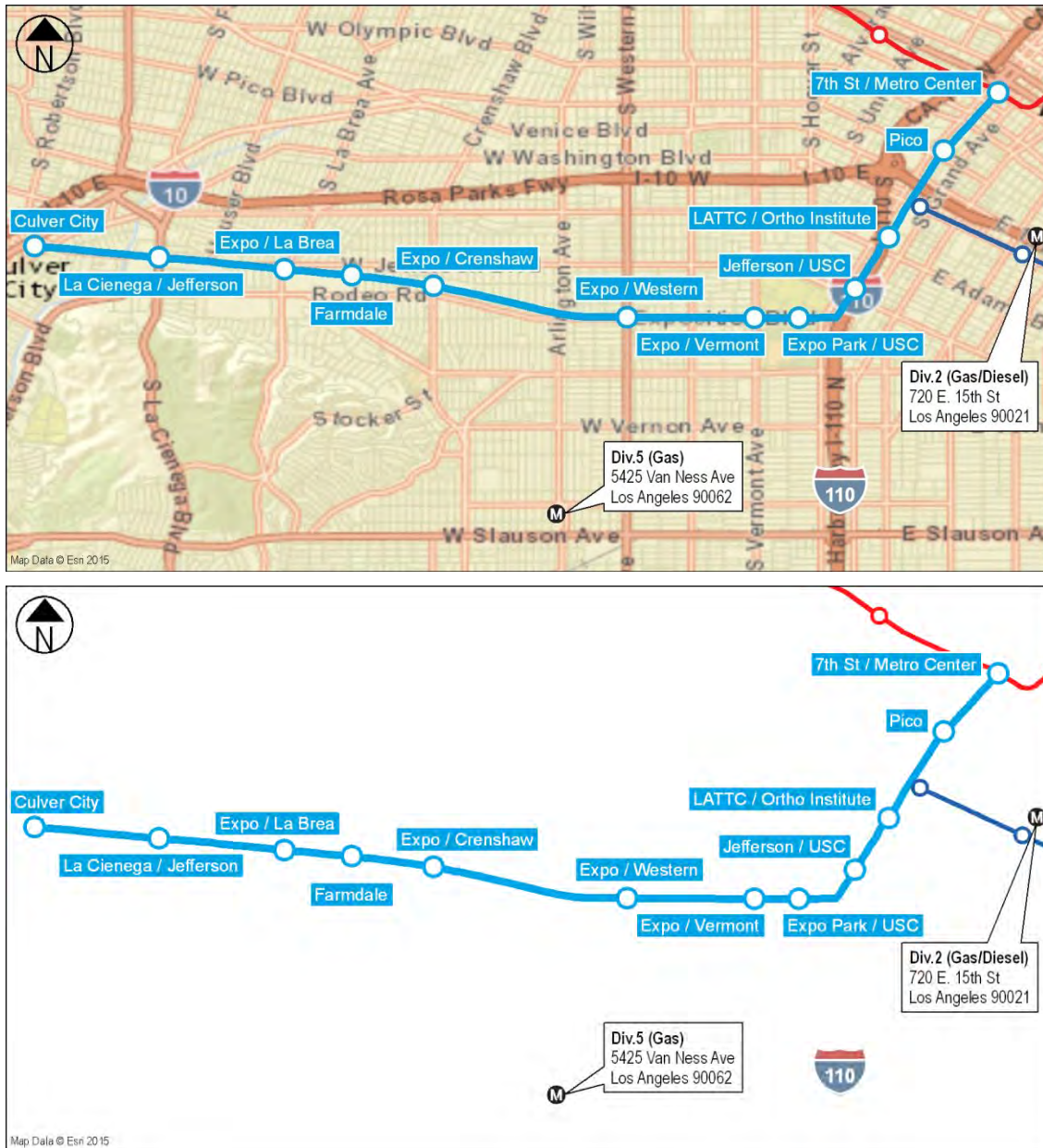


Figure 52 Highway map

B2. Index Maps

Index maps (1) and (2) required some additional elements such as street names and highway signs. Map scale (1) 1:42,000, (2) 1:43,269.

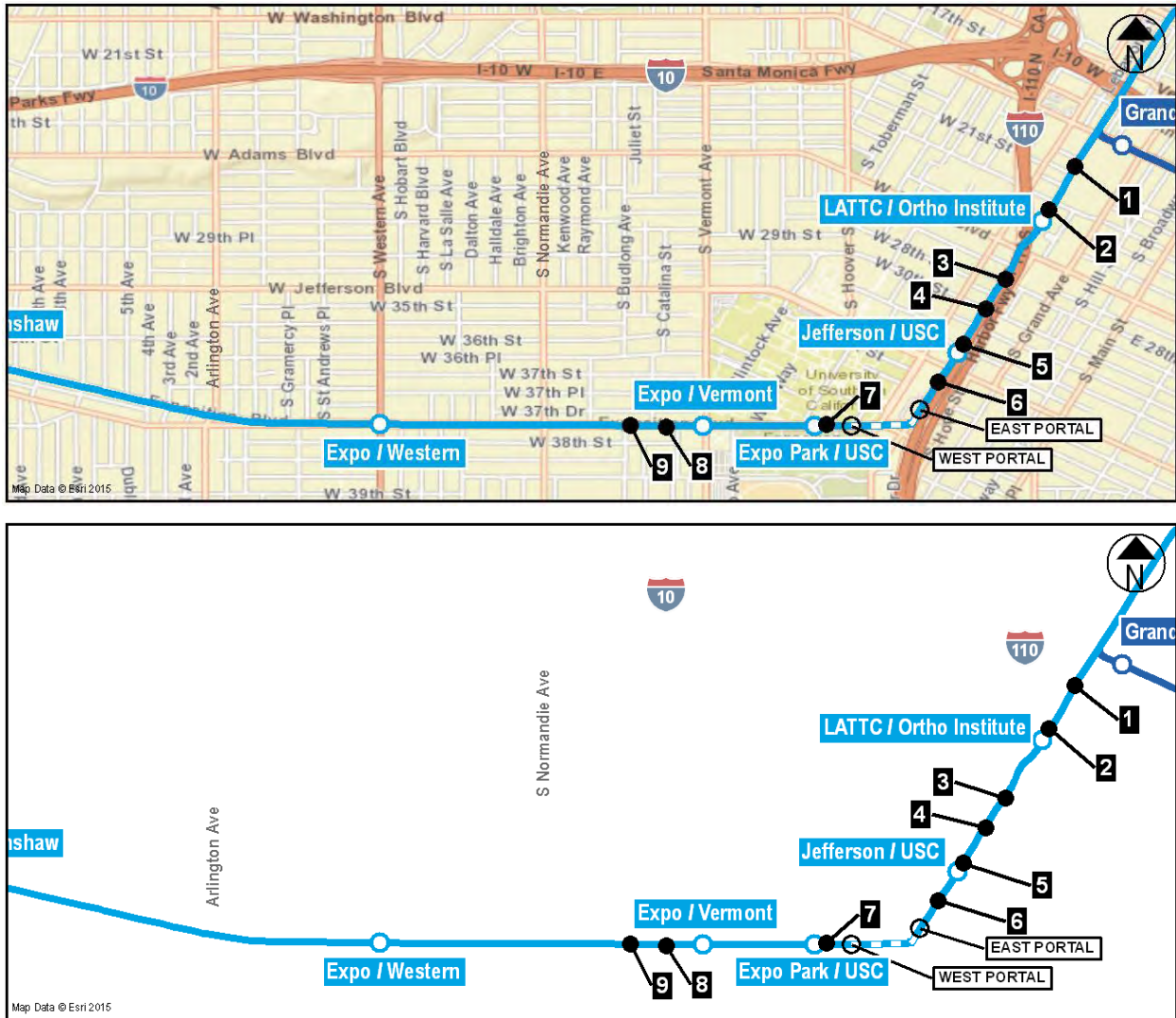


Figure 53 Index map 1

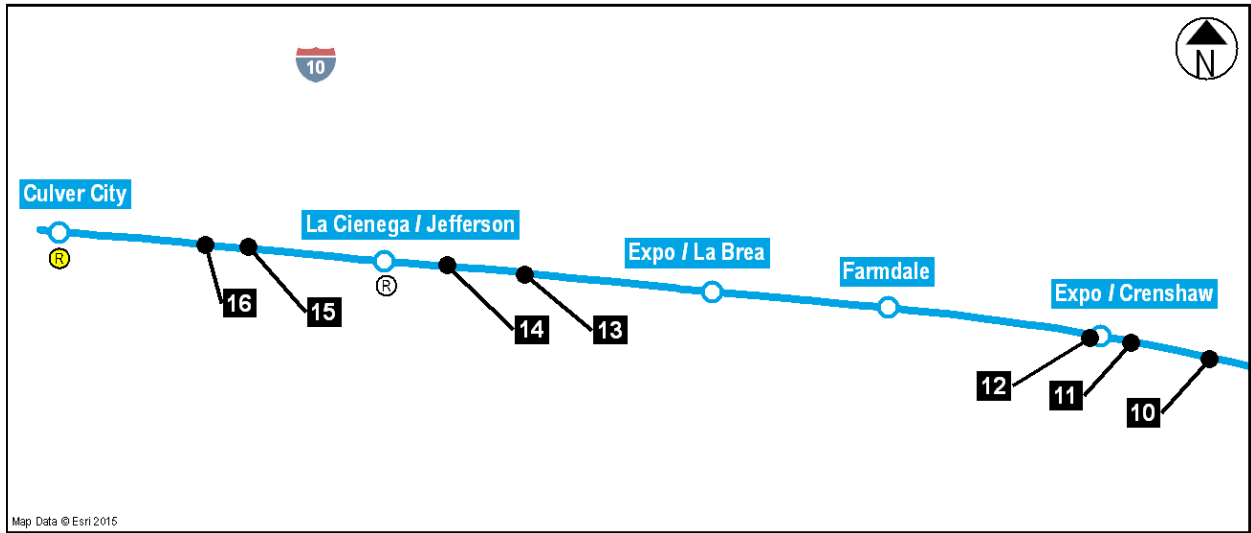


Figure 54 Index map 2

B3. Detail Maps

Detail maps usually required additional street names and traffic direction arrows. In some cases, the street name is visible in two maps. Map scale 1:9,000.



Figure 55 Detail map 1



Figure 56 Detail map 2



Figure 57 Detail map 3



Figure 58 Detail map 4



Figure 59 Detail map 5



Figure 60 Detail map 6

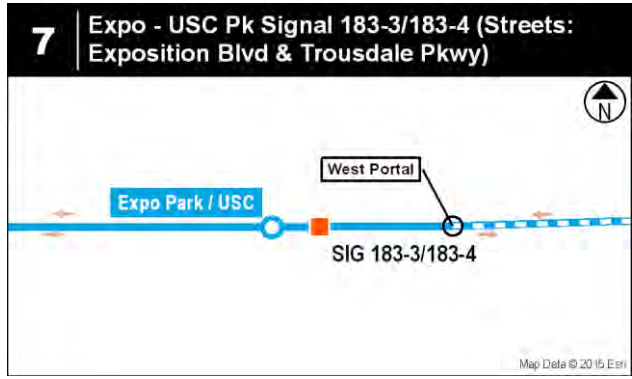
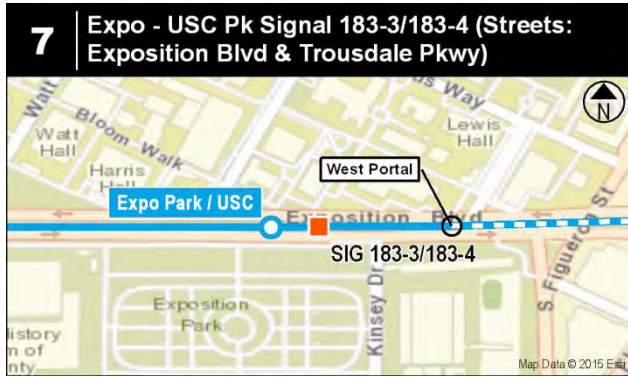


Figure 61 Detail map 7



Figure 62 Detail map 8



Figure 63 Detail map 9



Figure 64 Detail map 10



Figure 65 Detail map 11

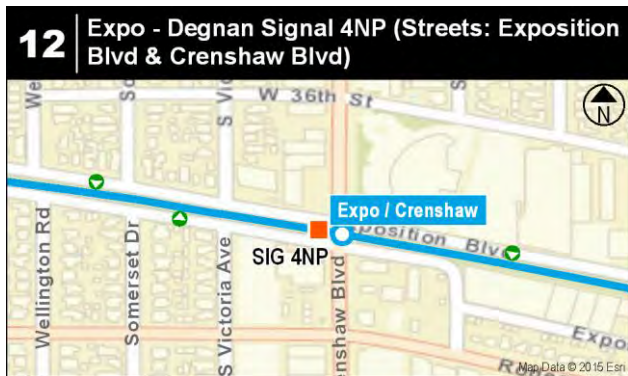


Figure 66 Detail map 12



Figure 67 Detail map 13



Figure 68 Detail map 14

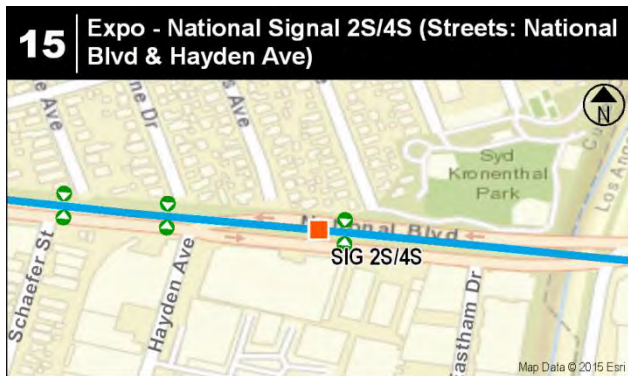


Figure 69 Detail map 15



Figure 70 Detail map 16

Appendix C: Map Development Benefit-Cost Evaluation

The benefit-cost evaluation charts for development of map elements 1-19 described in Table 22 are presented in the following figures.

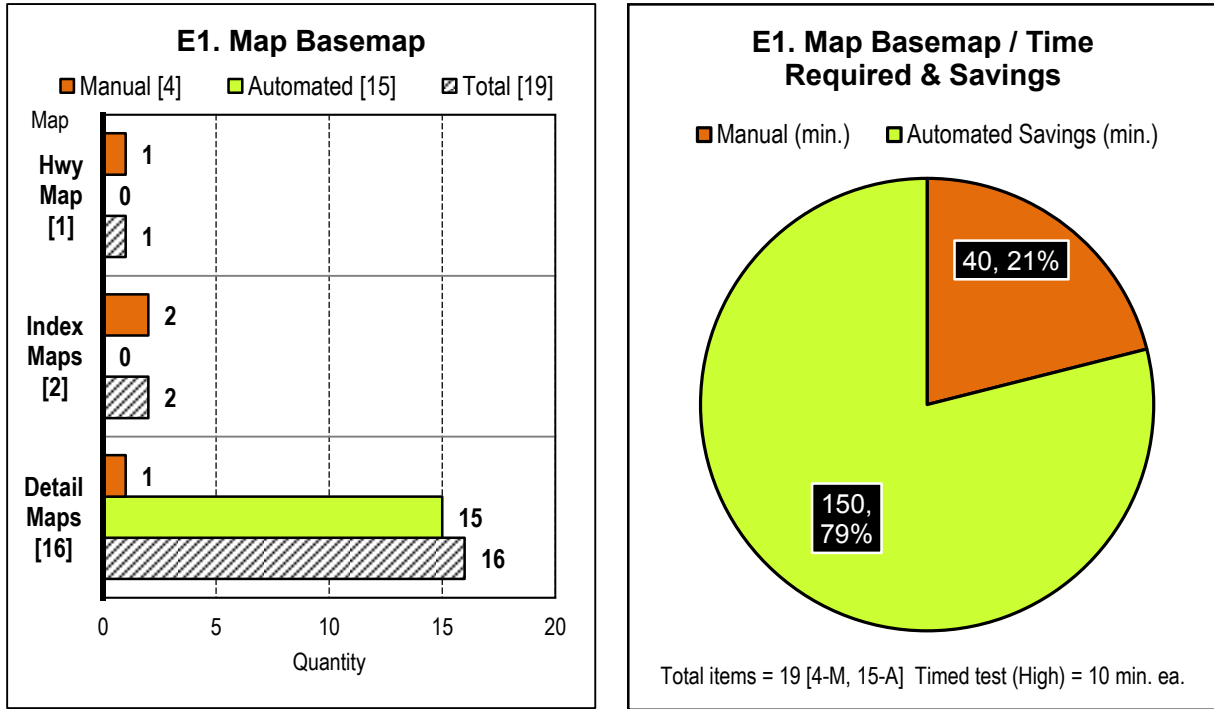


Figure 71 Element 1 Map basemap benefit-cost evaluation

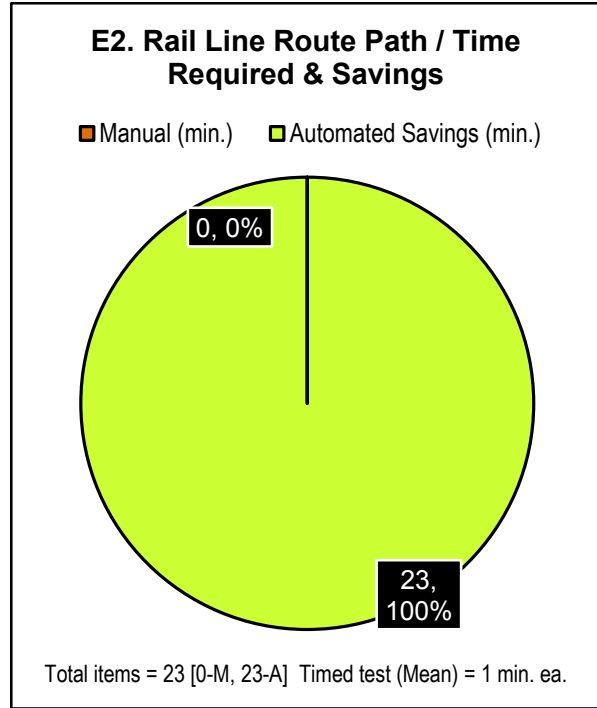
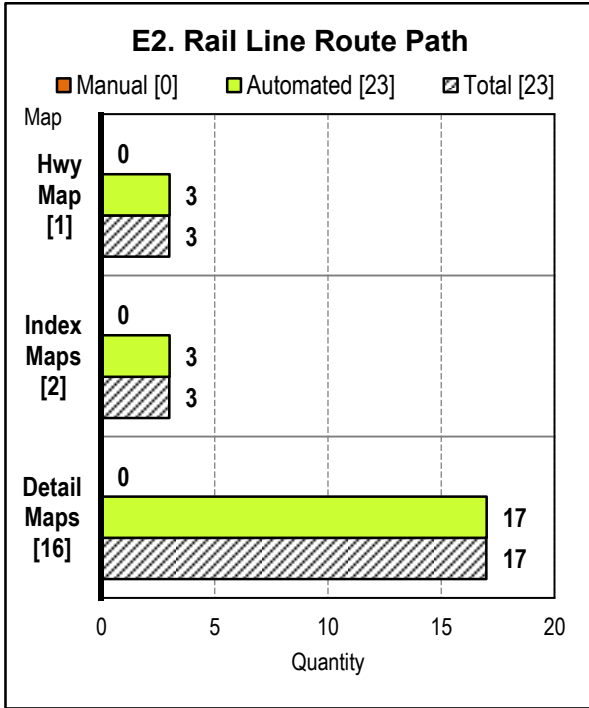


Figure 72 Element 2 Rail line route path benefit-cost evaluation

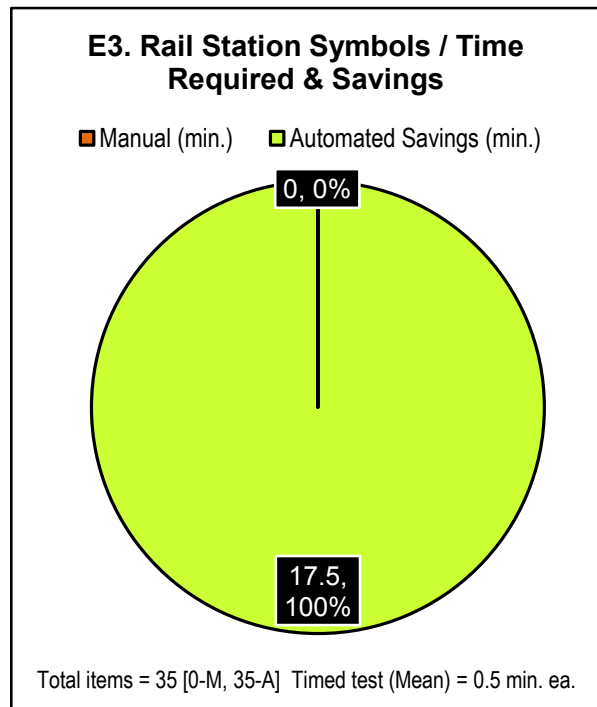
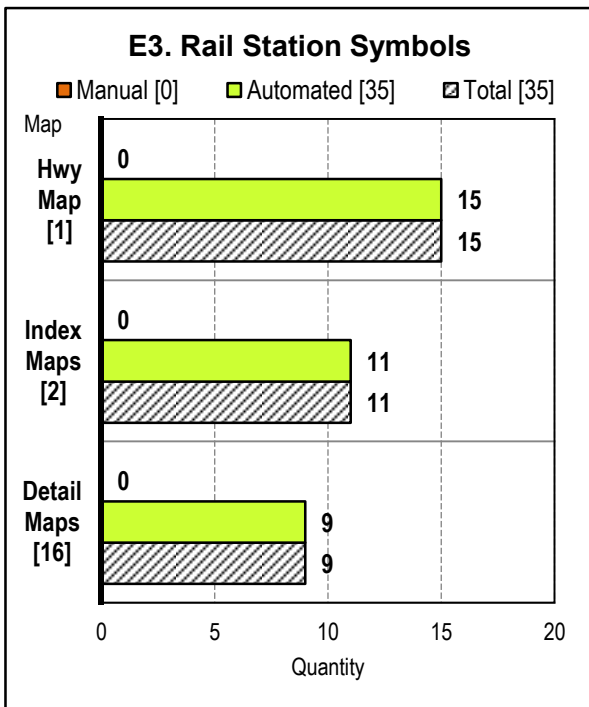


Figure 73 Element 3 Rail station symbols benefit-cost evaluation

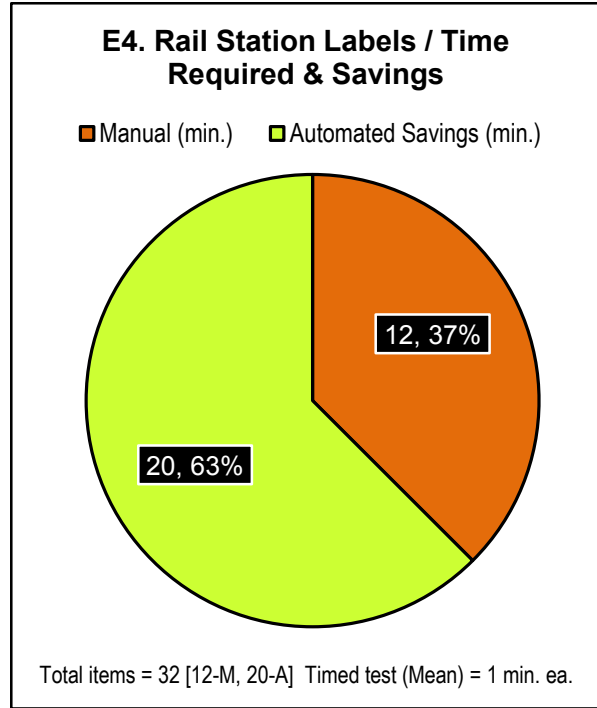
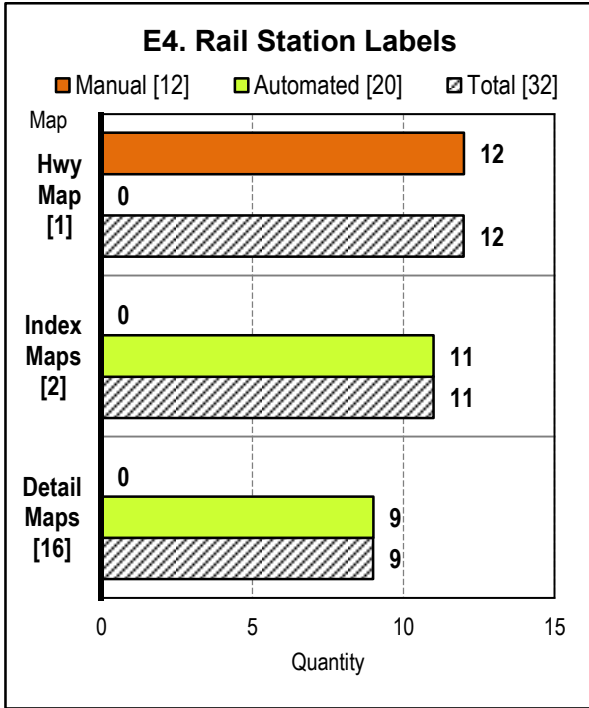


Figure 74 Element 4 Rail station labels benefit-cost evaluation

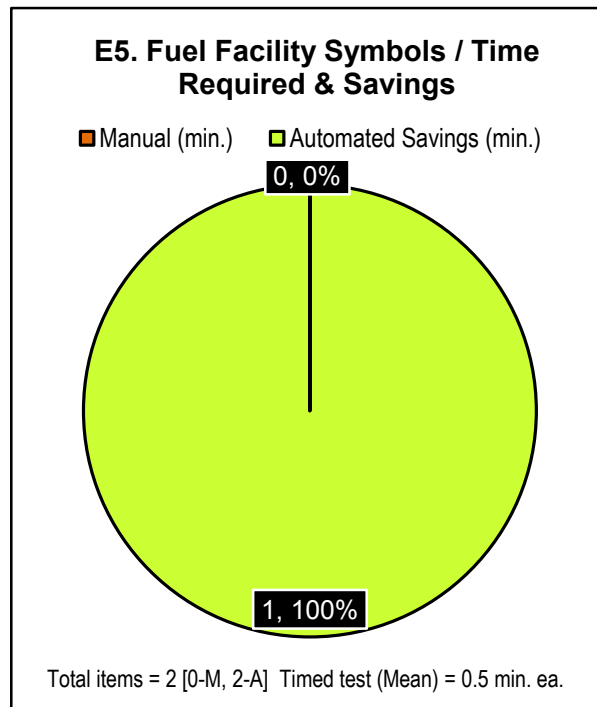
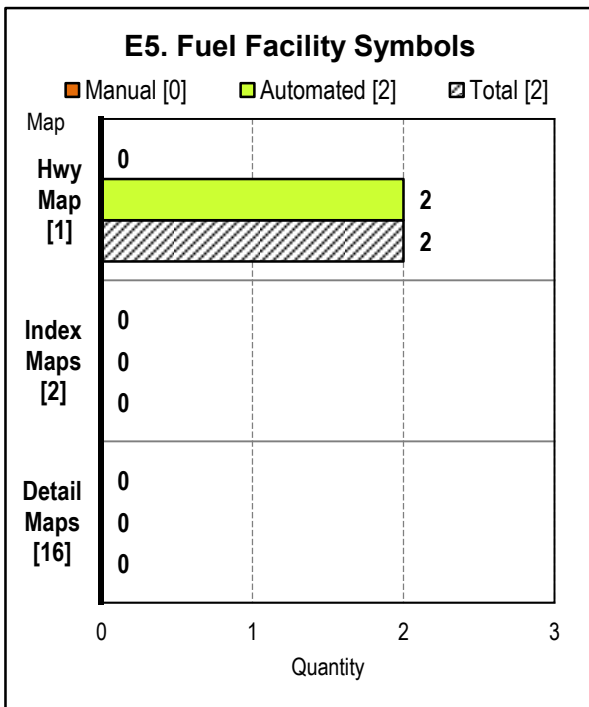


Figure 75 Element 5 Fuel facility symbols benefit-cost evaluation

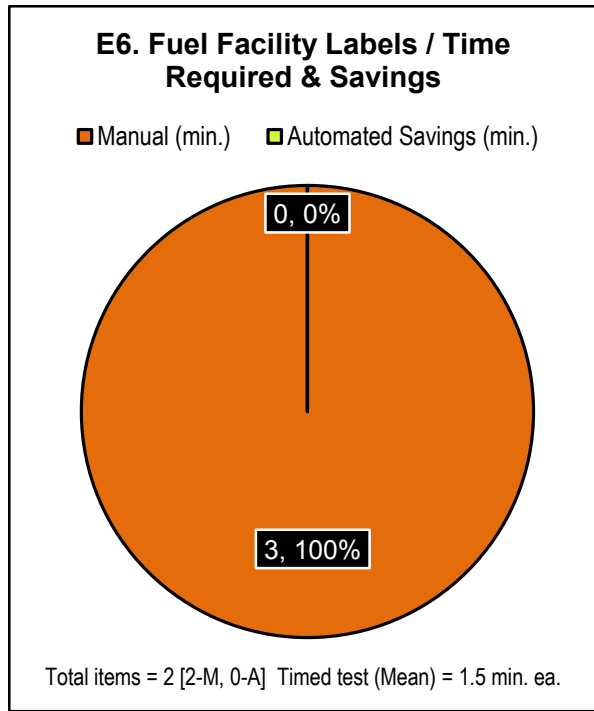
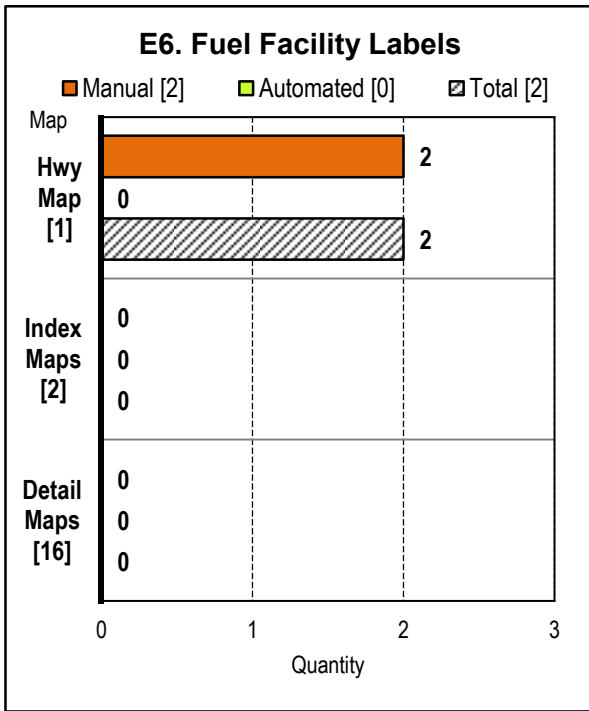


Figure 76 Element 6 Fuel facility labels benefit-cost evaluation

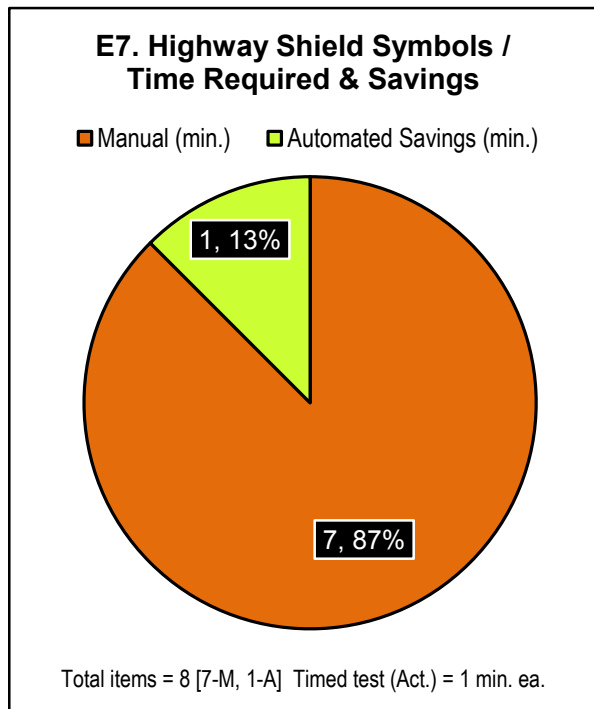
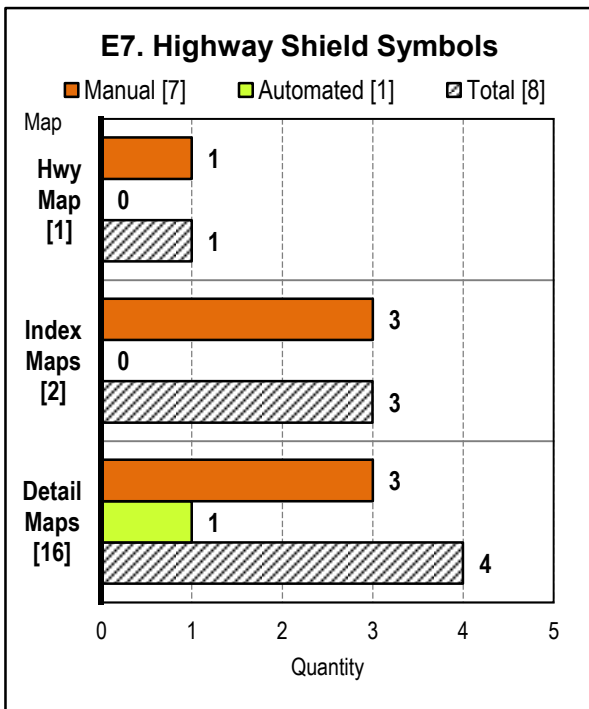


Figure 77 Element 7 Highway shield symbols benefit-cost evaluation

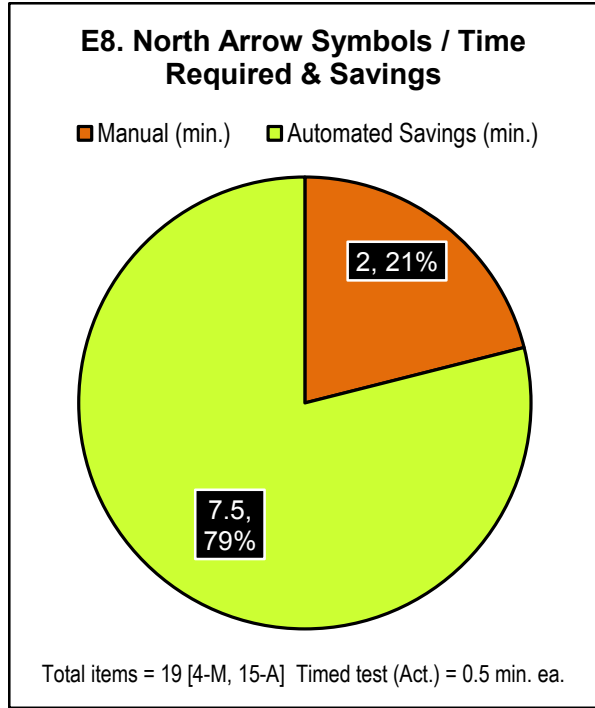
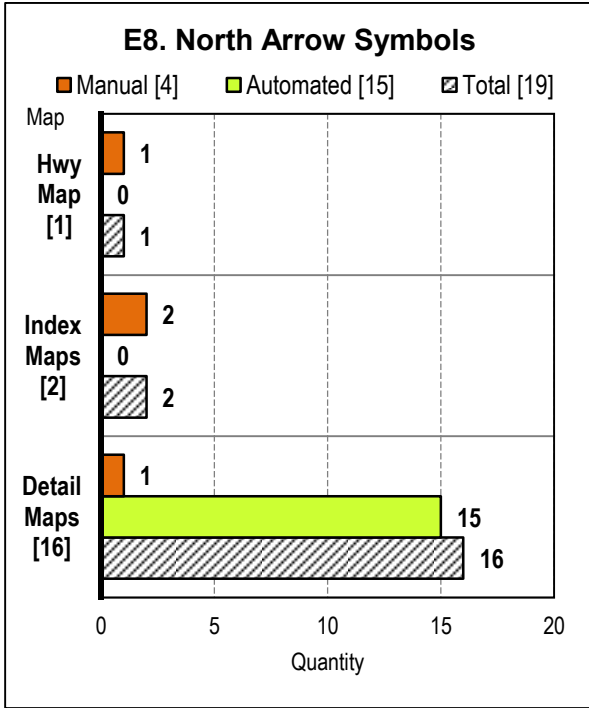


Figure 78 Element 8 North arrow symbols benefit-cost evaluation

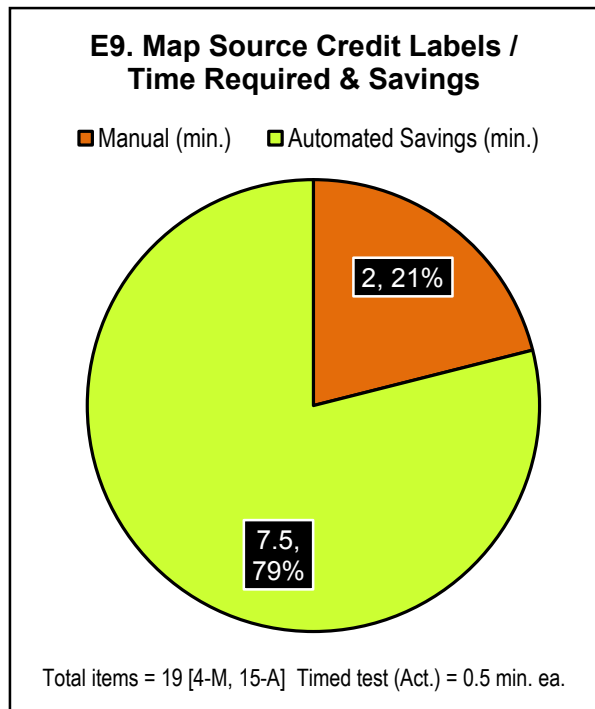
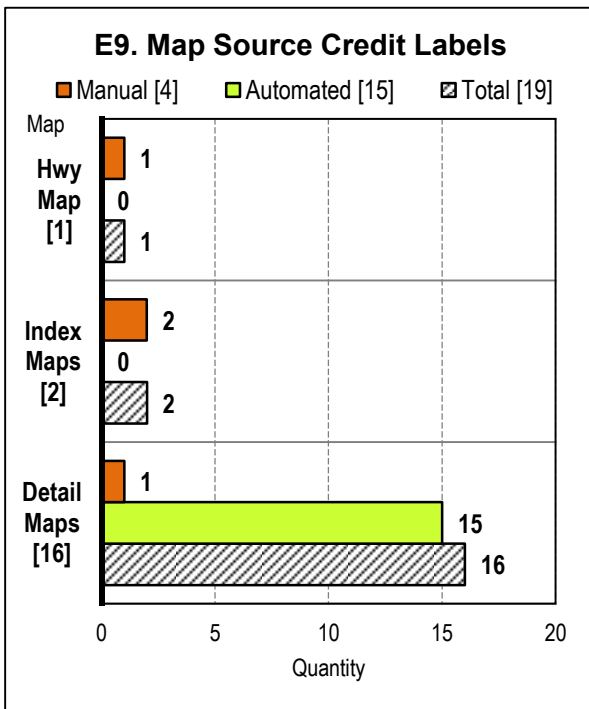


Figure 79 Element 9 Map source credit labels benefit-cost evaluation

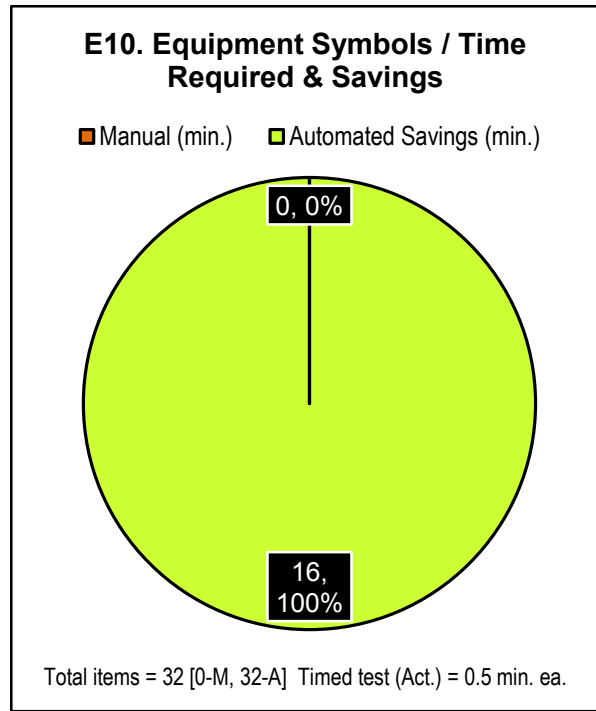
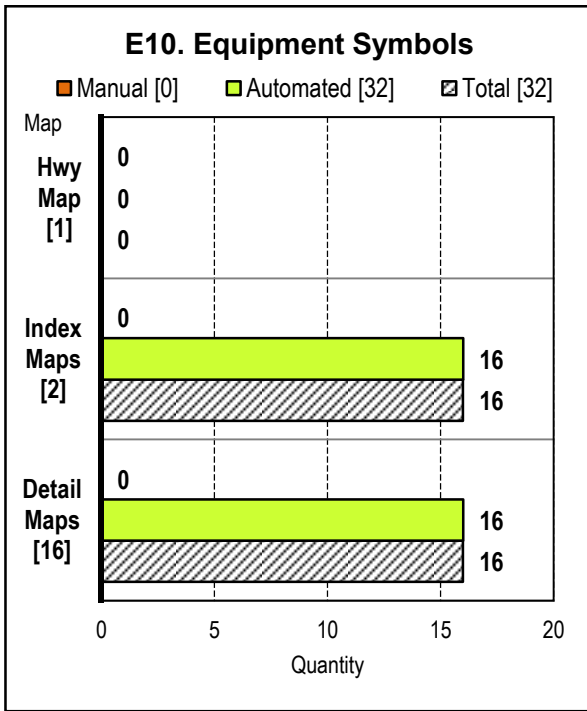


Figure 80 Element 10 Equipment symbols benefit-cost evaluation

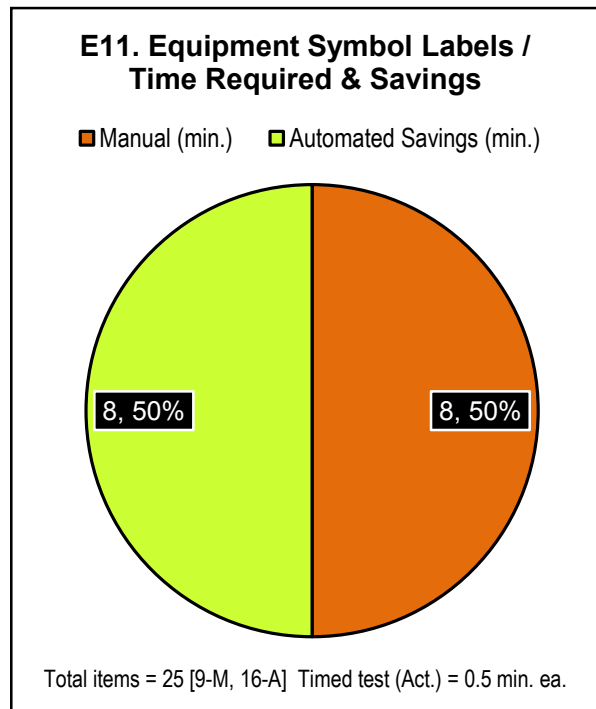
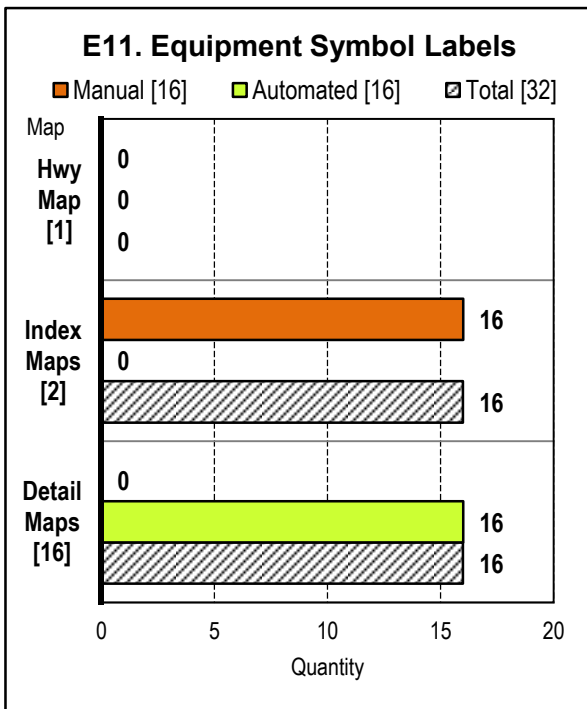


Figure 81 Element 11 Equipment symbol labels benefit-cost evaluation

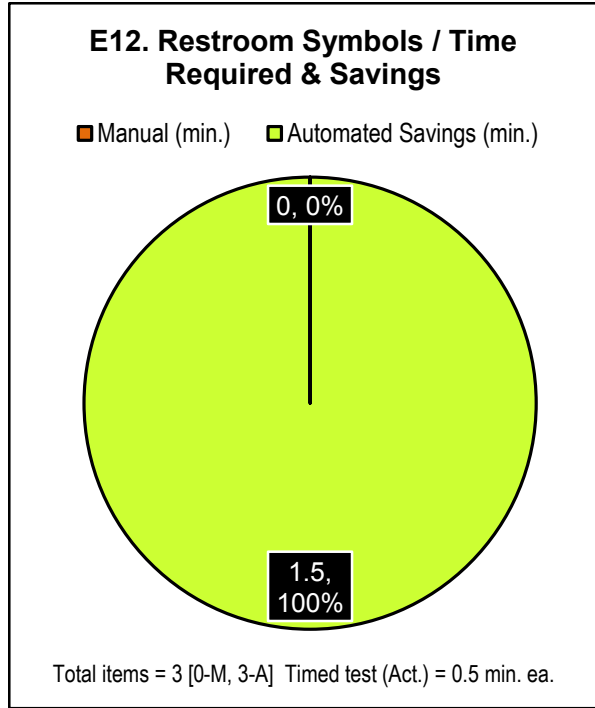
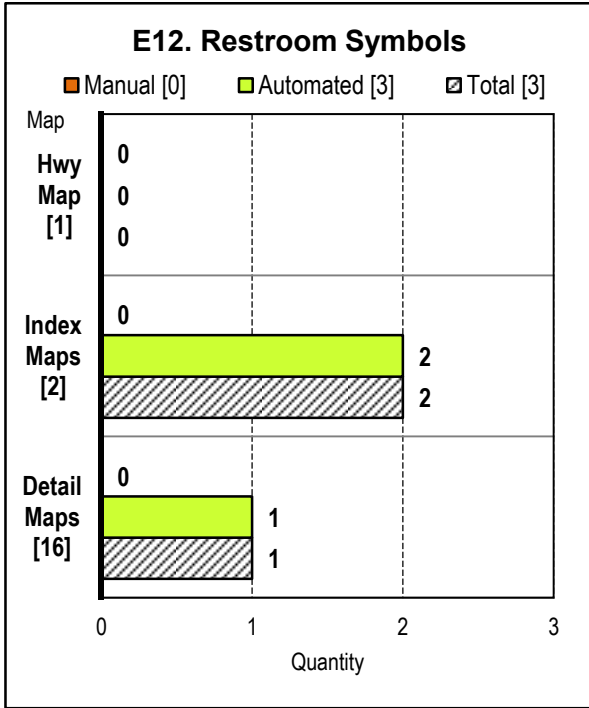


Figure 82 Element 12 Restroom symbols benefit-cost evaluation

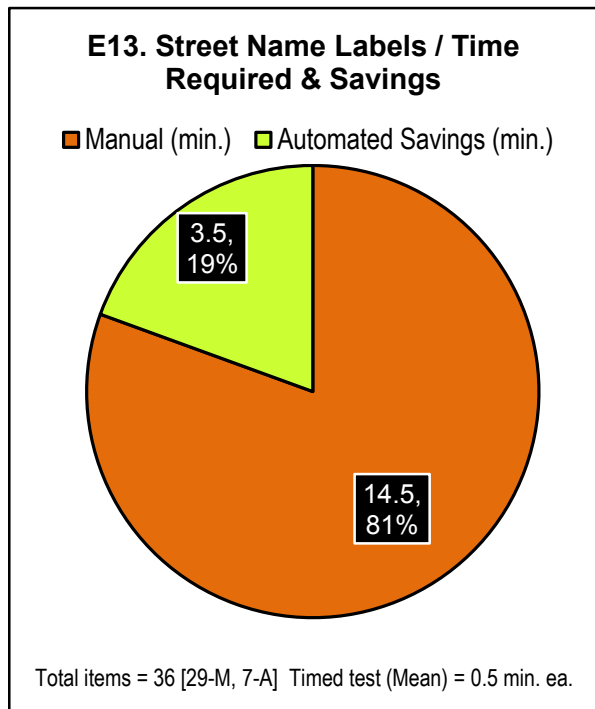
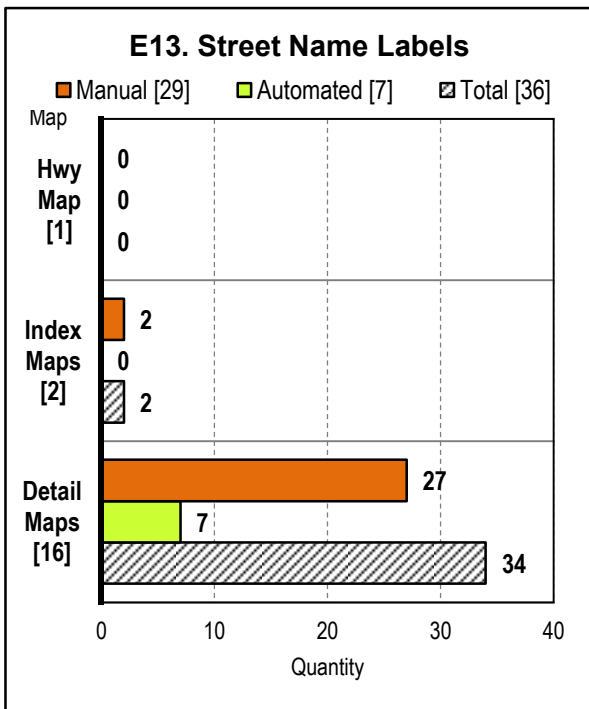


Figure 83 Element 13 Street name labels benefit-cost evaluation

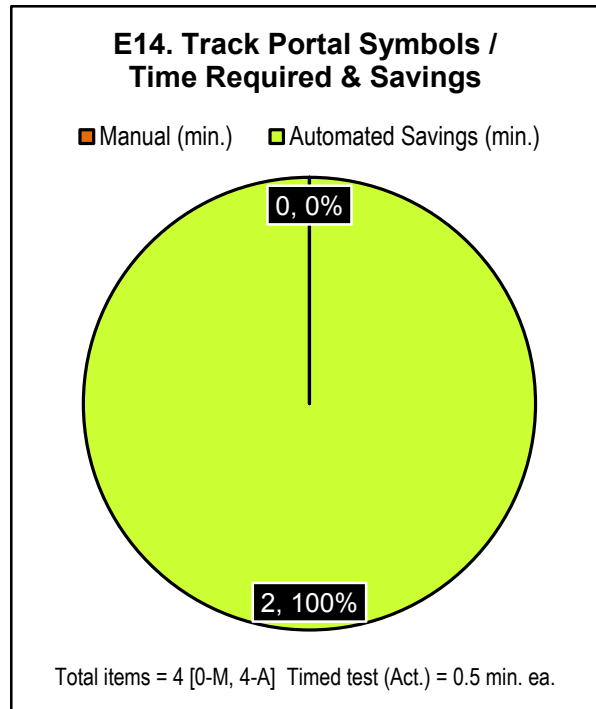
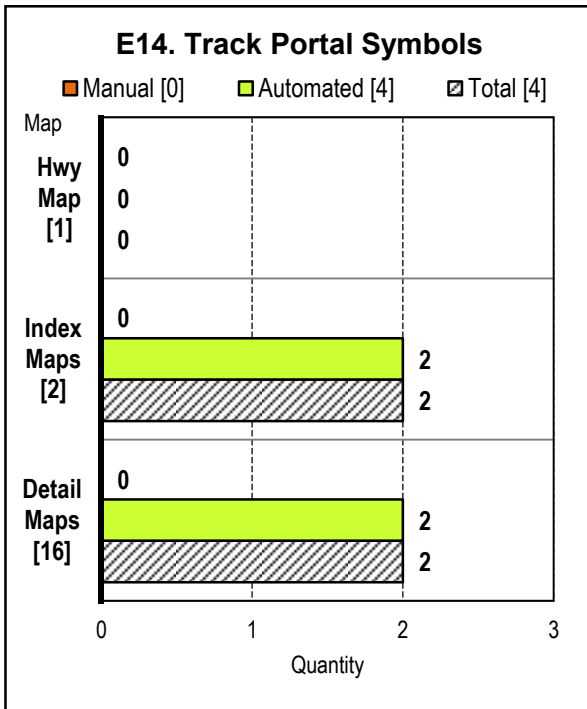


Figure 84 Element 14 Track Portal symbols benefit-cost evaluation

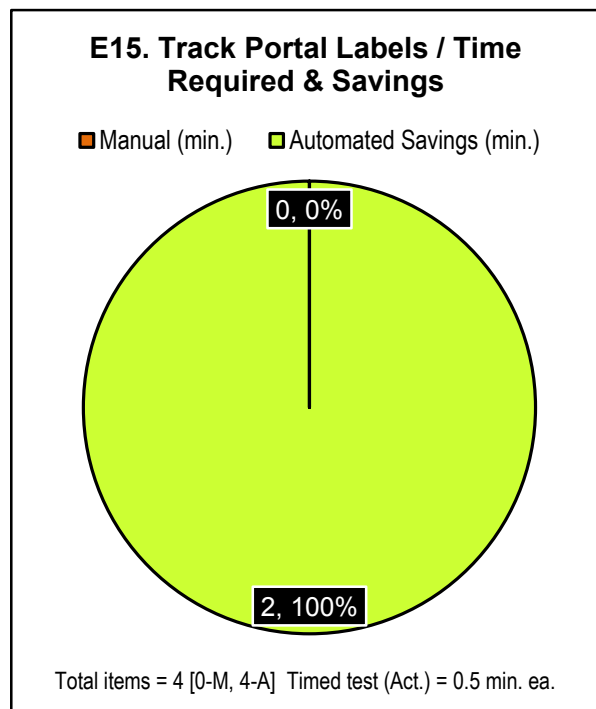
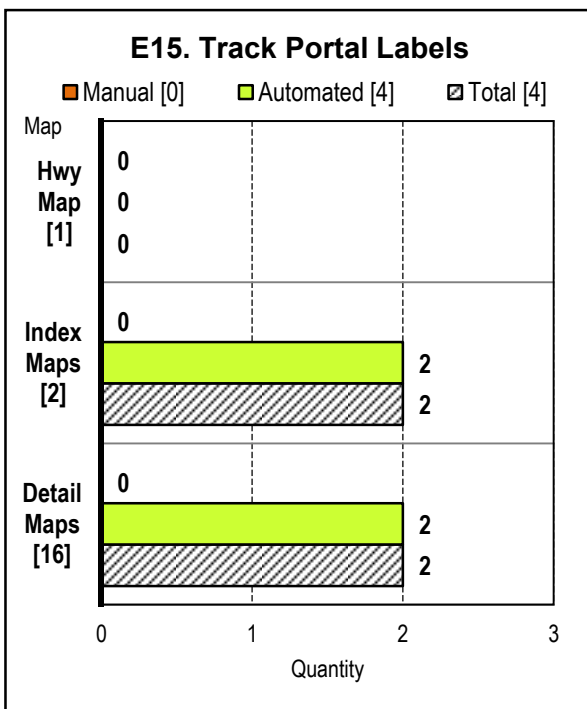


Figure 85 Element 15 Track Portal labels benefit-cost evaluation

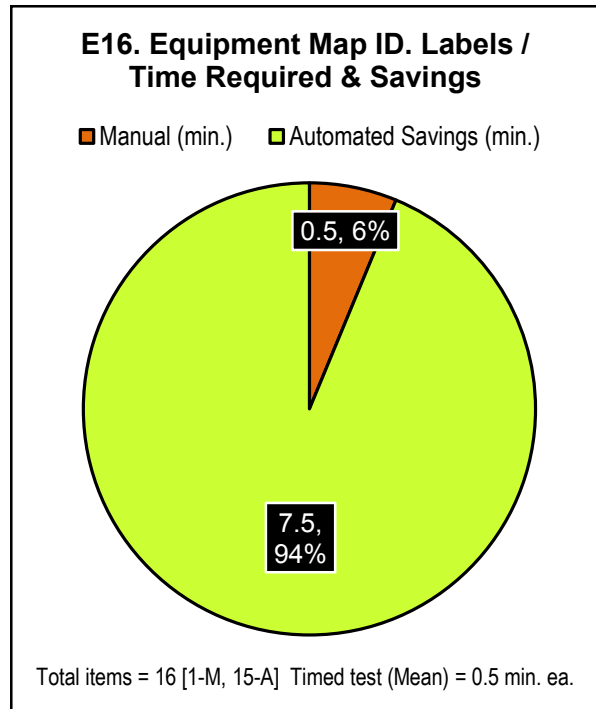
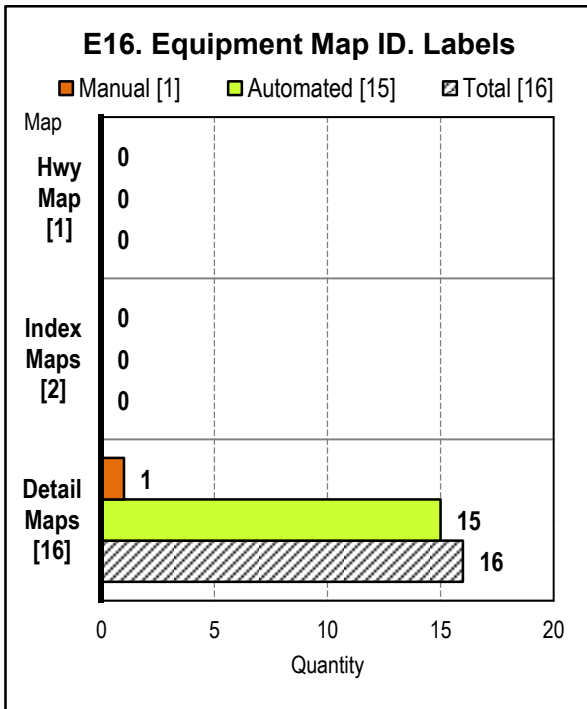


Figure 86 Element 16 Equipment Map ID labels benefit-cost evaluation

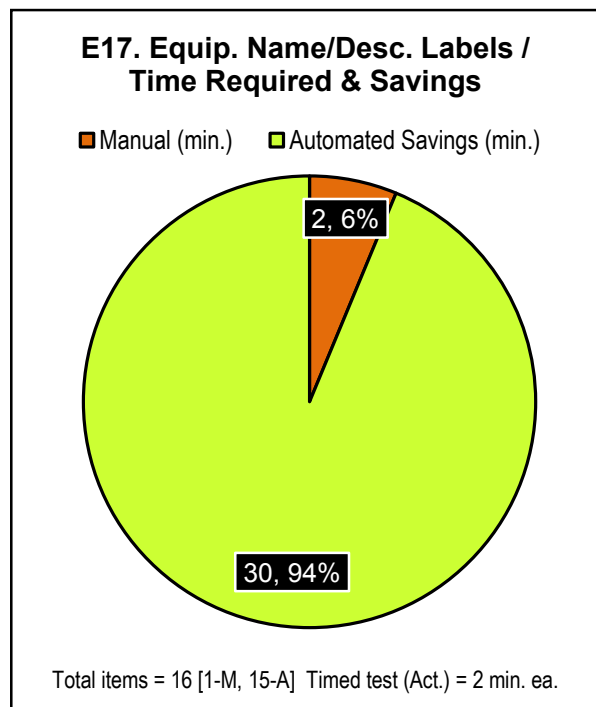
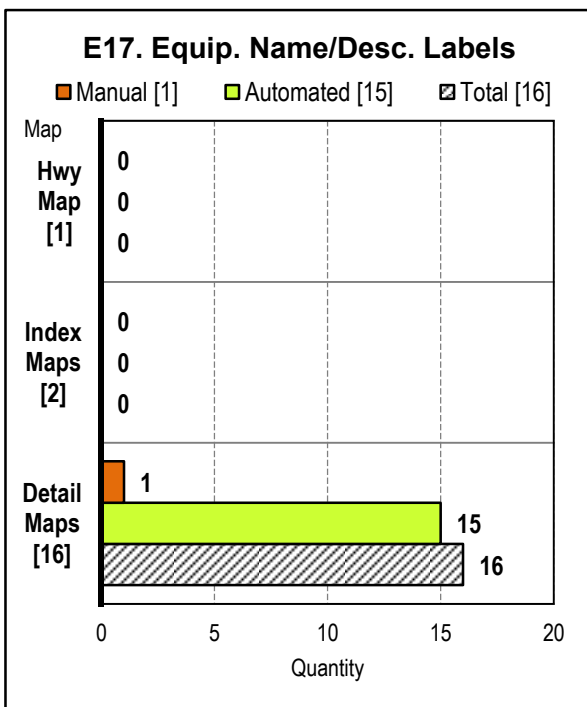


Figure 87 Element 17 Equip. name/desc. labels benefit-cost evaluation

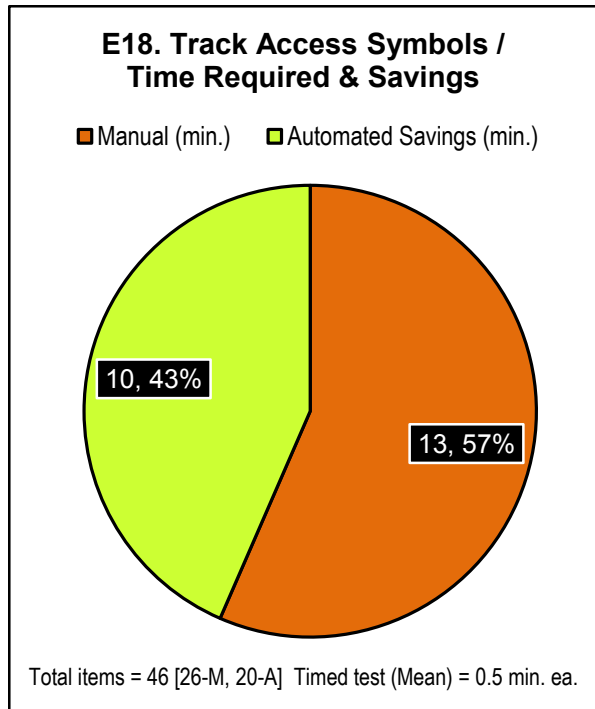
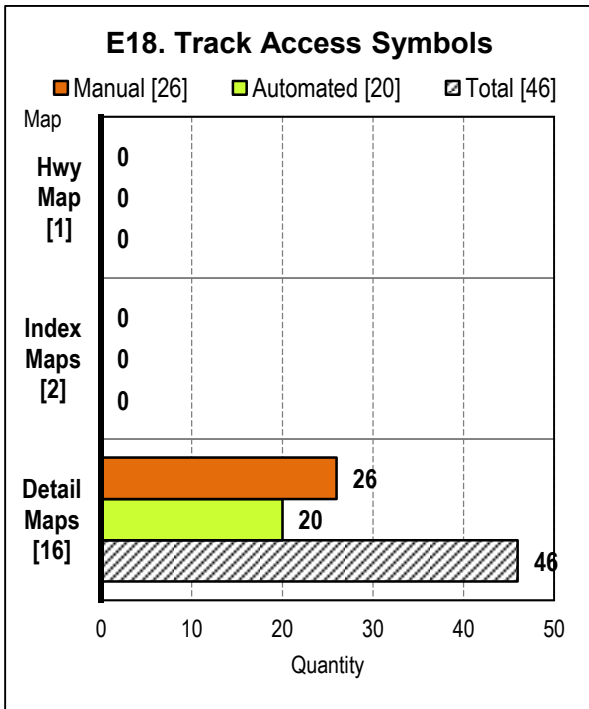


Figure 88 Element 18 Track Access symbols benefit-cost evaluation

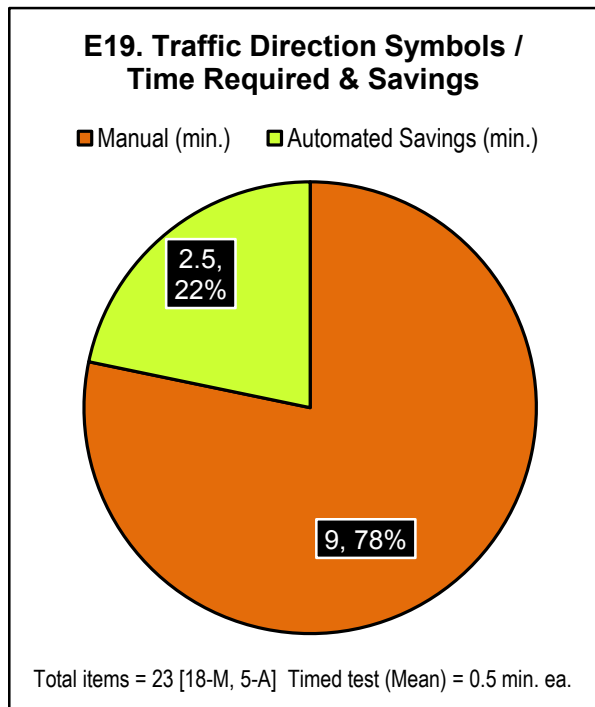
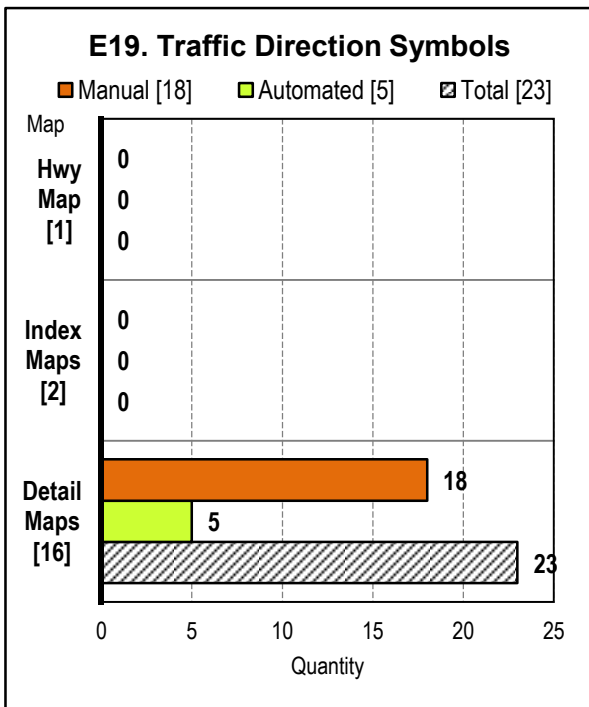


Figure 89 Element 19 Traffic direction symbols benefit-cost evaluation