

# Civil and Utilities Design Guidelines for Rail Transit Project

HARVEY L. BERLINER

The seemingly simple preparation of the civil and utilities drawings to be included in a set of transit facility construction contract documents requires designers who are familiar with transit design and reviewers who can look at a set of drawings and generate the proper comments. The information that needs to be contained within the civil and utilities drawings during both the preliminary and the detailed design stages is outlined in general terms. A guide for reviewers during a submission is provided, and their responsibilities are outlined. The designers and reviewers have performed their functions if the final drawings are properly coordinated and allow for efficient and correct construction.

It would take a book to recount all the problems that can arise during design and construction of a transit system. In that book many of the worst horror stories would begin apparently innocently: some minor drawing error or inconsistency was overlooked, only to emerge later as a major construction difficulty. Civil and utilities drawings in particular can become dangerously isolated from other types of drawings and can contain inconsistencies that hamper proper coordination. This paper is not the book of all that might go wrong but is a brief list of things that should be checked when reviewing civil and utilities drawings.

To visualize the problem more concretely consider the following scenario, which is not completely fictional. During the first review submission of drawings for a certain transit project, the reviewer found the civil and utilities drawings and the architectural and structural drawings to be oriented in opposite directions. When the reviewer requested that all drawings to be oriented in the same direction within the contract set, the designer replied that it was not unusual for a contract to have drawings with different orientations.

Later, when construction of the project was over budget and behind schedule, investigators traced the overruns and delays back to contract drawings poorly coordinated during design. Numerous change orders to correct the design deficiencies had delayed the contractor while the designer corrected the drawings. The "not unusual" inconsistency in drawing orientation had contributed to confusion and delay.

Such experiences show the hidden cost of poorly coordinated drawings: they can lead to confusion and misunderstanding, even when they are technically correct, and they may harbor actual undetected design errors. The goal of proper plan preparation is to minimize design errors before the final contract documents are advertised for bids. This is accomplished by proper coordination during design and indication of sufficient details on the drawings so that the contractor can understand and correctly build the project. Plan preparation depends on individual experience and back-

ground but must follow project guidelines to present the work consistently.

This paper outlines the typical civil and utilities drawings included in a rail transit contract, following the usual division of design into two phases: preliminary design and detailed design. The preliminary or 30 percent level study plans are prepared by a general consultant (GC) design team or by the transit authority and are then given to the detailed-design consultant (DDC) for completion. This paper describes what to include or verify during each phase for each group of drawings and what questions a reviewer must ask.

## PRELIMINARY DESIGN

The preliminary plans are the first time that the project is laid out at a scale where the problems and conflicts can be identified and possible solutions analyzed. They also provide the basis for

- A more precise identification of right-of-way (ROW) requirements.
- A good engineer's cost estimate.
- The short list of proposed DDCs who will be asked to prepare their proposals.
- The selected DDC who will develop the design.

The following types of civil plans are included with the preliminary design drawings:

1. Cover sheet and index of drawings.
2. Plan and profile drawings; these drawings include track plan and profiles giving the following information
  - Horizontal track alignment data with stationing (chainage).
  - Rail profiles.
  - Existing ground level.
  - Contract limits.
  - Station limits and platform centerline.
  - Significant design features.
3. General arrangement drawings; these drawings include a plan and section of important features along the route. The contents of these drawings vary according to whether the design is for a bored tunnel, cut-and-cover tunnel, aerial section, or at-grade section, but the drawings generally include:
  - Type of transit facility.
  - Basic layout of structures.
  - Type of drainage.
  - Type of foundation.
  - General information on existing structures.
  - Existing utility information and proposed utility diversions.
  - Typical sections.

Before finalizing these drawings they should be carefully reviewed to ensure that the following basic information is included:

1. Are the track horizontal curves, vertical curves, and super-elevations designed on the basis of the particular transit criteria? Review whether they satisfy the criteria.

2. Are streets and railroads designed on the basis of criteria for the different agencies involved with each?

3. If railroad tracks are involved, review the horizontal and vertical clearances between the transit facilities and the railroad tracks. Check the clearance requirements for that particular railroad. Check vertical clearances if the alignment crosses major streets.

4. Superimpose utility plans on the general arrangement drawings and determine whether any major utility relocation is required. Utility relocation should be kept to a minimum to avoid expensive and time-consuming relocation.

5. Review whether track horizontal and vertical curves are designed for the required design speed.

6. Review whether adequate sight distance is provided at street intersections.

7. Review whether typical sections, plans, profiles, and cross sections agree with each other.

During preliminary engineering accurate base mapping and existing utility mapping should be developed by the GC or transit authority. The base mapping provides the basis for many of the civil and utilities drawings throughout the design. Accurate existing utility maps are developed by

- Researching the as-built files of the affected municipalities and utility agencies.
- On-site investigation and survey.
- Digging exploratory bore holes in areas where it is necessary to know the exact location of underground utilities.

## DETAILED DESIGN DRAWINGS

The preliminary design drawings establish the guidelines that the DDC must follow to develop the detailed design plans. However it is also the DDC's responsibility to thoroughly check all the information on the preliminary drawings to ensure that they meet the established guidelines and criteria. Any inconsistencies should be referred back to the preliminary designer for clarification.

The first step in developing the detailed civil and utility plans is laying out the drawing sheets to the same scale and sheet layout. The architectural, structural, electrical, and mechanical disciplines use their own distinct scales and sheet layouts. However, the civil and utilities drawings and the architectural, structural, electrical, and mechanical drawings must be oriented in the same direction. Common orientation helps ensure proper review and coordination throughout the design and gives the contractor and the engineer's field representatives a better understanding of the contract.

The detailed design drawings are usually reviewed by the GC or the transit authority during three submissions of the design period. These submissions are

1. In-progress submission or about 60 percent design level.
2. Prefinal submission or about 90 percent design level.
3. Final submission or 100 percent design level.

Some 15 types of civil and utilities drawings contained within a set of contract documents are outlined below, along with the types of information generally included on each. The drawings are grouped in two sections, first civil (10 types of drawings) and then utilities (15 types of drawings).

## Civil Drawings

The civil drawings are the first plans that appear in the project set. These drawings lay out the project in total by defining

- Horizontal and vertical alignments.
- Grading, paving, and drainage requirements.
- ROW and easement needs.
- Traffic maintenance and traffic sign and marking requirements.

The civil drawings and a listing of what to include in each type of drawing are as follows:

1. Cover sheet, including contract title, contract number, contract description, and names of the DDC, GC, and transit authority.
2. Index of drawings. The drawing number and title in the index should be exactly the same as those in the title block of each drawing. Consecutively number each drawing and include the page number in the index.
  - Identify all major streets.
  - Show existing ground line on profiles.
  - Provide coordinate grid and indicate at least two sets of north and east coordinates on each drawing.
  - Provide the dimensions of typical sections of the transit alignment properly and describe their limits by stationing.
3. Alignment plans, plan and profile, and typical sections.
  - Show track horizontal alignment data and vertical curve elevations. Identify all horizontal curves by code numbers. Include data sheets listing coordinates and stationing for all control points.
  - Show profiles for all tracks. Indicate high and low points for all vertical curves.
  - Indicate the horizontal and vertical clearances between the trackway and critical structures.
  - Screen existing topography on the plan portion of plan and profile drawings.
  - Outline tunnel, aerial structure, station structure, entrances, vent shafts, cross passages, and major utility crossings.
  - Identify all major streets.
  - Show existing ground line on profiles.
  - Provide coordinate grid and indicate at least two sets of north and east coordinates on each drawing.
  - Dimension typical sections of the transit alignment properly and describe their limits by stationing.
4. Grading and paving (restoration) plans, profiles, details, and sections.
  - Show structure outlines, street lines, ROW lines, walls, sidewalks, ramps for handicapped individuals, curbs, medians, islands, alleys, drainage structures, fences, guard-rails, and other surface features to be constructed or to be affected by transit construction.
  - Dimension properly the driveways, access roadways, parking lots, and bus bays. Provide sufficient layout information

- and alignment data on the drawings for their constructibility.
- Indicate all dimensions and alignment data needed to define and locate features not identified elsewhere.
  - When the information is available, show (or reference other plans) type of pavement, curbs, and other details for areas to be paved, repaved, or restored.
  - Define clearly the areas to be constructed or restored; include a reasonable area outside the limits of excavation and include any areas affected by utilities restoration.
  - Show typical sections of highways, streets, parking lots, and bus bays. Thicknesses of pavement sections must be in accordance with local agency requirements.
5. Surface drainage plans, profiles, details, and sections. This information can be shown on the grading and paving plans depending on the complexity of the drainage system and whether the drawing scale will allow all information to be shown clearly on one drawing.
- Properly indicate structure outlines and street lines.
  - Show layout of new and relocated drainage facilities.
  - Indicate on plan drawings the sizes of pipes and culverts and direction of flow, types of channels and gutters, and types of structures.
  - Develop profiles for all drainage lines and coordinate them properly with the plan drawings. Show all other utility crossings and any pertinent structural features on the drainage profiles.
  - Develop sections and details at the locations necessary to properly define the surface drainage and sewer systems.
  - Check to ensure that the surface drainage design is coordinated with the facility roof and floor drainage.
  - Check to ensure that all aspects of the transit facilities are adequately protected against flooding.
6. Cross sections.
- Make certain that any cross sections required of the transit facilities, streets, driveways, access roadways, parking lots, and bus bays agree with the plans, typical sections, and profiles.
  - Indicate top-of-rail elevation for each transit section and pavement centerline (baseline) elevation for each roadway section.
  - Facilities on each drawing must be identified only once. This is done by the use of "Typ." to indicate typical facilities throughout a drawing.
7. ROW drawings.
- Indicate the existing ROW and the permanent and temporary easement lines, including all the coordinates that the contractor needs.
  - Coordinate any necessary changes in the easement lines with the GC or transit authority.
  - Identify ample contractor work sites on the drawings. If a potential work site lies outside the easement lines, indicate it as a potential work site to be arranged by the contractor.
8. Traffic maintenance plan, construction access, temporary parking lots, and detours.
- Develop plans indicating both existing traffic circulation and proposed circulation during construction.
  - If construction is to be performed in stages, outline in detail the traffic circulation for each stage. The traffic maintenance plan must be approved by the relevant agencies.
  - Detail any special construction access, temporary parking lots, or detours required for the contract.
9. Traffic signs and markings. Prepare plans of traffic signs, signaling, and pavement markings for each construction phase and for the final roadway layout.
10. Standard drawings. Prepare typical standard drawings in accordance with the details provided by the local agencies and the transit authority.

### Utilities Drawings

To save money and time, some engineers include the utility design work as part of the civil drawings. Because of the importance and complexity of the utility work involved with any rail transit project, the utility design must be shown on its own set of drawings and coordinated closely with the civil design. These drawings define the utility work in plan, detail, and, where appropriate, profile. The utility drawings and a list of what to include in each type of drawing are as follows:

1. Composite plan of existing utilities.
  - Include existing utilities drawings for the entire project.
  - Indicate the outline of the transit structure and the centerline of the track alignment with stationing.
2. Composite plan of utilities rearrangement.
  - Indicate the transit structure details and track centerline.
  - Indicate relocation schemes for all affected utilities. Whenever possible relocate utilities permanently.
  - Indicate the utilities to be abandoned in place and those to be properly supported in place. Show any new utility construction to be performed by either the contractor or agencies.
  - Check that there is sufficient room above the cut-and-cover construction to support the utilities during construction, including the related manholes and handholes.
  - Check that there is sufficient ROW for any permanent or temporary utilities relocated outside the construction area.
  - Indicate properly the interfaces between the building services and outside utilities. Coordinate the utility drawings with the electrical and mechanical drawings.
3. Composite cross sections. Indicate on cross sections the transit structure and the elevation of the top slab, the treatment method for each affected existing utility, and the locations of the proposed utilities. The cross sections must agree with the rearrangement drawings. If this information can be shown clearly and at proper locations on the civil cross sections, it is not necessary to have separate utility composite cross sections.
4. Utility profiles. Provide profiles for all gravity sewers and all utilities that cannot be constructed at a uniform depth below ground surface. Profiles should indicate the following:
  - The relevant portion of the transit structure, the top slab elevation, and the existing and finish grade lines.
  - The slope, elevation, and connection method of the proposed utility.
  - Sizes, materials, and other details necessary for construction.
  - Crossing utilities.
5. Utility details.
  - Develop details specific to the contract. Ensure that they

agree with the rearrangement plans and the profile drawings.

- Include standard drawings in accordance with the details provided by the utility agencies.

### Principles for Preparing All Civil and Utilities Drawings

Although each type of drawing has its own specific criteria, there are general principles applicable to all drawings. First, all drawings should be prepared in accordance with the drafting manual and computer-aided drafting and design (CADD) standards manual provided by either the GC or the transit authority. These manuals define the drafting standards to be used for all drawings. The other general principles are as follows:

- Indicate location in the titles of drawings whenever possible. Provide a key plan when applicable.

- Make all line work and lettering of sufficient size, weight, and clarity so that the half-size drawings can be read and scaled properly.

- Do not duplicate information in a set of documents. Use cross-referencing as required instead of making multiple copies in various locations. This will avoid confusion when a drawing must be changed.

- Review structural, architectural, electrical, and mechanical drawings regularly to ensure their agreement with the civil and utilities drawings. Such a type of review helps ensure proper coordination between disciplines.

### REVIEW OF SUBMITTALS

Reviewers on the staff of either the GC or the transit authority review each submittal from the DDC for compliance with the project criteria and to verify that the design is progressing in an orderly manner. The first submittal is very important because it is the first time the entire project is laid out and presented in a contract set. This is the time to steer the DDC in the right direction for the final bid documents.

The reviewer must answer the following questions positively when reviewing a set of documents:

- Are the plans easy to read and understand?
- Do the plans follow the criteria and guidelines specified in the drafting manual and CADD standards manual?
- Are the layouts of the drawings well planned on the basis of the space available on the sheets?
- Have the technical criteria of the transit project been followed, and does the design allow for safe and economical constructibility?
- Have previously agreed-upon review comments been incorporated into the next submittal of the contract documents?

- Can everything shown on the plans be accurately laid out by the contractor in the field?

- Have the proper standard details been included in the contract set?

- Have all the utility rearrangements been coordinated with the utility agencies, and has the constructibility of utilities been checked for both the temporary and the permanent facilities?

### CONCLUSIONS: GENERAL PRINCIPLES FOR CIVIL AND UTILITIES DRAWINGS

The care required to keep civil and utilities drawings accurate, up to date, and well coordinated with other contract drawings pays off in efficient construction. This payoff underlies all the specific rules listed in the paper. Thus the design and review process may be summed up in a few general principles.

- The preliminary drawings are developed by the GC or the transit authority, and these drawings are used by the DDC as the guidelines to develop the detailed design drawings.

- The detailed design drawings are developed to the criteria and guidelines specified in the project's drafting manual and CADD standards manual. This will ensure consistency among all the contracts being prepared for the project.

- It is the DDC's responsibility to coordinate the drawings from the different disciplines within the contract set, despite each discipline's tendency to worry about its own drawings and to forget to coordinate changes with other disciplines. It is usually the responsibility of the civil and utilities designers within the DDC and of reviewers within the GC or transit authority to ensure the cross-discipline coordination.

- The review process is very important because it ensures that the DDC has followed the technical criteria of the project and that the design allows for the constructibility of the contract. It is also recommended that independent constructibility peer reviews be performed at the conclusion of the preliminary design phase and during the prefinal submission review.

- Resolving problems during design reduces the need for resolving problems during construction. This is more cost-effective. Therefore before the drawings are signed, the designers and reviewers must verify that the contract set indicates sufficient details so that the contractor can construct the contract efficiently and correctly.

- The designers and reviewers should never compromise their values for the sake of completing the contract documents on a particular schedule. This is sometimes extremely difficult within the tight design schedule imposed by the owners. However it is extremely important that the contract documents be correct and free of errors. An extra day taken during design to ensure correctness and constructibility can save weeks during construction to correct design errors.

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