MARYLAND DEPARTMENT
OF TRANSPORTATION

STATE HIGHWAY
ADMINISTRATION

3D Engineered Model Guidance

January 2019

Contents

Summary / How to Use This Guide

The information contained in this guide is applicable in some way to all participants involved in the production of MDOT transportation projects, from planning through maintenance. To this end, the body of the guide mimics the project development process: Project Planning, Preliminary Design, Final Design, PS&E and Advertisement, Construction, and Maintenance and Asset Management.

There are specific questions called out at the start of each chapter that the reader should either ask or be able to answer. For example, at the start of the Preliminary Design chapter, one of the questions covers the level of survey that was completed during the project's planning phase. If the planning study used aerial photogrammetry for the alternatives analysis, more detailed surveys will be needed for the design stage.

Glossary of Terms used in the Guide

3D Engineered Model – a digital graphical representation consisting of x, y, and z coordinates of existing and proposed project elements that are tied to a defined coordinate system that communicates design intent and is useful for visualization, analysis, simulation, plans, specifications, cost estimating, and life-cycle asset management.

4D Engineered Model – a 3D engineered model that incorporates construction staging and scheduling elements.

5D Engineered Model – a 3D/4D engineered model that incorporates not only construction staging and scheduling elements, but budget and cost expenditure elements as well.

Automated Machine Guidance (AMG) – a process in which construction equipment is equipped with GPS or robotic total stations linked to site survey controls to determine positioning information that allows the operator to determine finish grades on-board with a higher level of precision.

Civil Integrated Management (CIM) – is the "collection, organization, and managed accessibility to accurate data and information related to a transportation facility including planning, environmental, surveying, design and construction, maintenance, asset management, and risk assessment".

Clash Detection – the process of identifying whether two or more objects occupy the same three-dimensional space or do not meet required offsets or clearance requirements. "Hard" clashes are those that occupy the same three-dimensional space, and "soft" clashes are those that fall within mandated minimum offsets, such as a sewer and water line within 10 feet of each other.

Digital Terrain Model (DTM) – is a digital topographic model of the earth's surface (existing DTM) or proposed work elements (proposed DTM) that can be manipulated through computer-aided design programs. All elements of the DTM are spatially related to one another in three-dimensions.

Global Navigation Satellite System (GNSS) – is a network of satellites that provide signals to ground receivers, which may use triangulation to calculate global position.

Global Positioning System (GPS) – is a subset of GNSS and refers to a specific network of satellites maintained by the United States government. A typical GPS system for survey and construction uses a base station unit, a mobile unit, and satellites to accurately locate objects using triangulation.

Light Detection and Ranging (LiDAR) – is a remote sensing method that uses light emanating from a pulsed laser to measure distance to objects. LiDAR data can be obtained from ground-based or aerial sources, using stationary or mobile units.

Point Cloud – is the term used to describe the millions of three-dimensional data points recorded through the use of LiDAR or laser scanning data collection. Post-processing software such as Leica Cyclone and TopoDot is used to extract the points needed for developing the existing DTM.

Subsurface Utility Engineering (SUE) – is a branch of engineering practice that involves managing certain risks associated with utility mapping at appropriate quality levels, utility coordination, utility relocation design and coordination, utility condition assessment, communication of utility data to concerned parties, utility relocation cost estimates, implementation of utility accommodation policies, and utility design.

Virtual Design and Construction (VDC) – is a term that is used to highlight the ability of the design engineer or contractor to make changes "on the fly". During design, geometric changes may be made to the model without making changes to plan sheets and cross sections. During construction, the contractor may update field conditions and green line revisions directly on the 3D model, speeding up the as-built plan process.

Additional Sources of Information

The American Association of State Highway and Transportation Officials (AASHTO) currently has free online training for its E-Affiliates that provides more information on 3D Engineered Models at https://training.transportation.org. The following courses are available in the 3D Engineered Models for Construction Series under the "Free Courses and Current Promotions" tab:

- 3D Engineered Models for Construction Series: Overview
- Introduction to 3D Engineered Models for Highway Transportation
- Surveying and 3D Engineered Models
- 3D Engineered Models in Highway Design
- Applications of 3D Engineered Models in Highway Construction and Quality Assurance

The FHWA maintains a clearinghouse of information related to 3D Engineered Models as part of its Every Day Counts program, including case studies, best practices, process guides from other states, webinars, and training. The address is https://www.fhwa.dot.gov/construction/3d/.

Introduction

The purpose of this manual is to provide guidance for planners, engineers, and designers as the Maryland Department of Transportation State Highway Administration (MDOT SHA) transitions from traditional 2D document-centric plan development and advertisement processes to an approach that uses 3D engineered models to convey project information. The Federal Highway Administration (FHWA) has identified 3D engineered models as an Every Day Counts innovation.

The key to successfully transitioning to this new approach lies in the recognition that this shift will likely impact or eliminate current 2D document-centric processes, and as a result, change the project development process as a whole. Approaching the transition as simply an improvement to current CADD processes decreases the chance to unlock the full capabilities that 3D engineered models can provide. However, if we embrace 3D engineered models and new or refined processes, we will discover better ways to convey project information to contractors, reducing project delivery time and cost.

3D Engineered Models offer capabilities that cannot be derived from a traditional 2D plan set, including visualization, analysis, animation, simulations, specifications, production estimates, and life-cycle asset management. From these enhanced capabilities several benefits arise - reduced project risk, improved project quality, expedited design and construction, and improved safety. 3D models can be rotated and tilted to provide views from any angle, can show clashes between design elements, improve the accuracy of quantity takeoffs, and be easily processed for use by construction equipment.

3D Engineered Models Defined

By simple definition, 3D Engineered Models are graphically accurate three-dimensional representations of any existing or proposed facility. They include ‘objects’ that are spatially coordinated within a given coordinate system or projection; in the case of MDOT SHA, the Maryland State Plane Coordinate System. In other words, by being represented both graphically and spatially accurate, 3D Engineered Models are digital representations of what exists or is proposed for construction. In essence, with this technology a project can be built in a computer before it is built in the field.

To an extent, 3D Engineered Models are already used in design. The existing digital terrain model (DTM) prepared by the Plats and Surveys Division (PSD) and the final merged DTM prepared by the design team serve as the basis for much of the information included in the 2D plan sheets and details. The horizontal alignment appears on Geometry Sheets, the vertical alignment on Roadway Profiles, and the roadway template is depicted in the Typical Sections and Cross Sections. The merged DTM is often provided as an “information only” supplement to the contract documents that the contractor can manipulate to create files in formats that are compatible with equipment that uses automated machine guidance (AMG) for grading, pavement placement, and other specialty services like placing curb and gutter and excavation for utilities and drainage pipes. Similar to cross-section sets, the 3D model is not included as part of the formal contract documents. The contractor assumes the risk in the event that the 3D model does not match the latest version of the contract plans.

> *The Contract Documents are the written documents and plans that define the roles, responsibilities, and scope of work under the construction contract, and are legally binding on the Owner, Contractor, and Subcontractors. On design-bid-build projects, the plans, specifications, schedule of prices, general provisions, and terms and conditions represent the contract documents. Cross-section plans, DTMs, and as-built plans are provided on an "information only" basis, placing the risk for their use on the contractor.*

The shift to solely using a complete, 3D Engineered Model as the contract documents in lieu of plans is not going to occur overnight. Utility companies, permitting agencies, and even other MDOT offices must change the way they prepare, review, and provide comments on projects at milestones; inventory as-built plans; and in the case of third party reviewers, may need to purchase design and/or enterprise management software. MDOT SHA project managers must coordinate the deliverables with each MDOT business unit or district office, local jurisdiction, utility company, permitting agency, and other project partners.

[As of this writing] Design engineers will still need to provide the following plans as traditional 2D plan sets, consistent with the requirements of the lead division or reviewing agency:

- Title Sheet
- General Notes
- Maintenance of Traffic Plans
- Stormwater Management Plans
- Erosion and Sediment Control Plans
- Traffic Signal Plans, Interconnect Plans, Communication and ITS Plans
- Structure / Culvert Plans
- Lighting Plans
- Signing and Marking Plans
- Utility Relocation Plans
- Landscape Architecture Plans

The 3D Engineered Model eliminates the need for Typical Sections, Geometry Sheets, Roadway Profiles, Grading Plans, Cross Sections, and several details that appear on Plan Sheets. The specifications and notes to contractor will need to clearly identify how each item in the 3D model will be measured and paid. For example, the Typical Section plans currently identify the areas where roadway and sidewalk removal will be included as part of the Class 2 Excavation on most urban and retrofit projects. It may be necessary to amend the current specifications to include project-specific work areas and limits that will be paid under each item.

3D Engineered Models vs. Current MDOT SHA Model Files

The current CADD standards use a series of model files (mXX) to delineate existing conditions, identify proposed features, and help coordinate the workflows of different divisions. Survey files are created in the 3D workspace, with the result being an mTO file and existing ground DTM surface. Most of the model files created in design are developed in the 2D workspace. Projects have also been developed partially or fully using the 3D capabilities of the current software and workspace: Design elements are developed in a mixture of 2D and 3D models. The 3D models representing those elements are usually created in a DTM by the design software but then displayed in 2D or 3D models.

The 3D Engineered Model will require that the designers work in the 3D Design workspace, using CADD design software and civil engineering tools to create baselines, profiles, templates/typical sections, site grading, roadway corridors and roadway drainage features. The software selected for use in creating the 3D Engineered Model allows engineers and designers to continue to function in a 2D environment while the software automatically creates the 3D models based upon their input. As part of this software, design data that was traditionally stored in external files (Coordinate Geometry, Terrain Models, Roadway Corridors, etc.) will now be created and maintained in the CADD files.

Current Design Data Containers (2D & 3D)		
RESPONSIBLE DIVISION	MODEL FILES	3D MODEL FEATURES
OHD - Plats and Surveys	mTO, mGR-E, mUT-E, mRW(2D)	“ExistTopo”.dtm, “ExistUtil”.dtm
OHD - Highway Design	mHA, mHD, mDD-P, mSH, mHP, mRW-P, mUT-P, mGR-P	“Grading”.dtm, “Pavement”.dtm, “PropUtil”.dtm, “Final”.dtm
OHD - Highway Hydraulics	mSW, mDA, mES, mGR-P	“SWMGrading”.dtm, “SWMSurface”.dtm (temporary and permanent)
Office of Structures	mBR	PropStructure.dtm, PropBuilding.dtm
Office of Traffic and Safety	mSN, mTP, mLT, mIC	PropUtil.dtm, PropSignMark.dtm
Office of Environmental Design	mLA	PropEnv.dtm

The current 2D design process relies heavily on cross sections generated at set intervals or “critical points” where driveways, side streets, utility crossings, and drainage courses tie in with the roadway alignment. Cross sections were created based upon existing and design data as it was stored in the DTM files. Anything not available in a DTM must be manually added to the cross sections. Cross sections are often manually modified to add existing and/or proposed drainage, to fine tune grading and to add other utilities (which are often placed on the cross-sections at an assumed depth).

With a 3D model centric process, cross sections are always a byproduct of the model and never manually modified. The cross sections are cut directly from the 3D Model CADD file. Grading is always achieved in the CAD models as part of a defining a final surface and all contours are a byproduct of the model. Drainage, utilities and any other 3D model elements are shown in their proper location to the greatest extent practicable on each cross section, no matter where it is cut on the alignment. The 3D model can contain other 3D elements, such as buildings or other structures which will also be represented in the cross sections.

3D Engineered Models and Other MDOT SHA Divisions

The MDOT SHA Project Development Process requires extensive coordination with other offices, each with its own workflow, and many of them require line and grade approval before they can get underway with developing construction plans.

Plans prepared by the Office of Structures (OOS) are developed using CADD, however structures are currently treated as standalone features in plan sets. While the plans *reference* the Maryland State Plane Coordinate System, the plans are not developed within a 3D engineered model. “Working points” are identified once the line, grade, and roadway typical sections are established that show where the structure ties in with the roadway approaches, as well as the centerline of bearing on piers and abutments. For the foreseeable future, bridge structures will likely still require 2D plans as MDOT SHA moves toward working exclusively in the 3D space. Footings and abutments may ultimately become part of the 3D model; however, the superstructure plans will remain as 2D. As a result, any changes to line and grade near the bridge structures will impact production schedules and finalizing the line and grade will still be an essential step in project development.

The Office of Traffic and Safety (OOTS) is responsible for the traffic signals, cantilever and overhead sign bridges, roadside signs, markings, lighting, and Intelligent Transportation System (ITS) hardware on state roadways. As of this writing, OOTS uses 2D plan sets to convey project information to contractors. The benefits of using 3D models would eliminate the guesswork as to where final elevations of signal and sign foundations should be placed, the proximity of ADA ramps to accessible pedestrian signals, coordinating sign locations with landscaping and lighting, and the ability to use the “drive-through” capabilities of 3D models to ensure that signs, lights, and signals are placed in their intended locations. Upon completion of the 30% plans, OHD coordinates with the District Office Traffic team and OOTS to prepare the Design Request (DR). At that time, OOTS makes the decision of whether the design will be completed by its forces or by the primary design consultant. The traffic design does not really start in earnest until after the Preliminary Investigation (PI) meeting at the 30% milestone, once the line and grade are finalized.

The Office of Environmental Design (OED) is responsible for ensuring that all MDOT SHA facilities and operations are in compliance with environmental laws, permits, regulations, and best management practices. OED will oversee wetlands and natural resource identification and delineation, performs quality control on the surveyed resources, provide oversight of minimization and mitigation measures that are included in designs, and also provide the landscape demolition and landscape architecture plans on projects.

The current Project Development Process really requires sign-off on line and grade prior to the work of other divisions can begin, which limits the ability to use the “on the fly” design change capabilities that 3D models could potentially provide.

The various MDOT SHA divisions will participate in the design and/or review and provide comments on the 3D model at each design milestone. Prior to initiating design, the OHD Project Manager must perform a quality control review of the existing surface to ensure that it is free of stray points that create dips or peaks in the surface, includes all of the information needed by each division to complete their design, and covers the project area. The existing utilities must also be checked against as-builts and information gathered from the field (Miss Utility markings, designation, etc.).

Responsibility Matrix for Design and Review

DIVISION	FIELD PI (30%)		SEMI-FINAL (65%)		FINAL (90%)		PS&E (100%)	
	DESIGN	REVIEW	DESIGN	REVIEW	DESIGN	REVIEW	DESIGN	REVIEW
OHD – Design	x	x	x	x	x	x	x	x
OHD – HHD	x	x	x	x	x	x	x	x
OHD – PSD		x		x		x		x
OHD - Utilities	x	x	x	x	x	x	x	x
District ESDT		x		x		x		x
District Traffic		x		x		x		x
District Right of Way		x		x		x		x
District Construction		x		x		x		x
District Utilities		x		x		x		x
OOTS - TEDD		x	x	x	x	x	x	x
OMT		x		x		x		x
OPPE - RIPD		x		x		x		x
OED	x	x	x	x	x	x	x	x

3D Engineered Models vs. 3D Visualization Models

When discussing 3D methods, it is important to understand the difference between 3D engineered models and 3D visualization models. 3D engineered models are the product of extensive survey, design, and coordination to develop a computerized model that accurately communicates the existing site conditions and the intent of the designer. The 3D engineered model can be used by the contractor to construct a project with increased accuracy in a shorter time frame. The information in a 3D engineered model can be used by a steel fabricator. On the other hand, a 3D visualization model is more closely associated with presentations and information provided to the public via websites and public information meetings. (Reeder & Nelson, 2015) 3D Visualization Models are not necessarily geometrically or geospatially accurate to engineering specifications.

The purpose of the 3D Visualization Model is to convey project information to a non-technical audience, like elected officials or citizens who may be directly impacted by the project. Visualization models often focus on the function and aesthetics, while the engineered model is used more as a tool for delivering the project. The current practice for developing 3D visualization is to render the design files developed in CADD and prepare a video drive-through using editing software. Using a spatially-correct 3D engineered model as the basis, however, allows for view manipulation from any point and at any angle without additional software.

3-D Engineered Models in Project Development

Planning

The use of 3D Engineered Models can help prioritize projects, program funding, and quantify long-range capital needs. Planning really covers both the long-range planning activities undertaken by the OPPE – Regional and Intermodal Planning Division and Capital Programs Divisions, as well as the corridor and project level planning undertaken by the Project Management Division.

Long-range planning often uses desktop-level GIS analyses and tools like the Highway Needs Inventory, coupled with cost-per-mile estimates to develop costs and potential impacts. Some DOTs, like the Utah Department of Transportation, are using mobile LiDAR to track pavement condition and provide ground-level survey information statewide. While the mobile LiDAR data may not be accurate enough for detailed engineering, its level is acceptable for alternatives development, impact assessment, and developing preliminary cost estimates for corridor projects in the six-year Consolidated Transportation Program.

At the corridor and project level, planning studies often require survey of a much larger area. It is typically more cost effective to use aerial photogrammetry coupled with mobile LiDAR data for areas that are obscured from view. The designer should convey to PSD the intended use of the needed data including the level of detail needed to analyze alternatives, and to limit the amount of re-work that would be required once the project gets into the detailed design stage. PSD would then determine the best method to collect the data.

Design

Ideally, the design engineer would have collaborated with the planning manager throughout the study and has an understanding of the project. It is important that the roadway designer understand the level of accuracy of the survey that was used during the planning stage. Mobile LiDAR provides accuracy up to about 0.2 feet, which is not recommended for designing features like ADA ramps, driveway tie-ins, or structure tie-ins. When scoping the design project, the designer must make sure that the survey is detailed or accurate enough for the work.

The designer should discuss the degree of underground utilities present, and the best method of creating the Existing Utility model, which should differentiate the utilities based upon SUE quality levels.

There are four recognized quality levels of underground utility information ranging from Quality Level (QL) D (the lowest level) to Quality Level A (the highest level). Each of the four quality levels is described as follows:

Quality Level D. QL-D is the most basic level of information for utility locations. It comes solely from existing utility records or verbal recollections, both typically unreliable sources. It may provide an overall "feel" for the congestion of utilities, but is often highly limited in terms of comprehensiveness and accuracy. QL-D is useful primarily for project planning and route selection activities.

Quality Level C. QL-C is probably the most commonly used level of information. It involves surveying visible utility facilities (e.g., manholes, valve boxes, etc.) and correlating this information with existing utility records (QL-D information). When using this information, it is not unusual to find that many underground utilities have been either omitted or erroneously plotted. Its usefulness, therefore, is primarily on rural projects where utilities are not prevalent, or are not too expensive to repair or relocate.

Quality Level B. QL-B involves the application of appropriate surface geophysical methods to determine the existence and horizontal position of virtually all utilities within the project limits. This activity is called "designating". The information obtained in this manner is surveyed to project control. It addresses problems caused by inaccurate utility records, abandoned or unrecorded facilities, and lost references. The proper selection and application of surface geophysical techniques for achieving QL-B data is critical. Information provided by QL-B can enable the accomplishment of preliminary engineering goals. Decisions regarding location of storm drainage systems, footers, foundations and other design features can be made to successfully avoid conflicts with existing utilities. Slight adjustments in design can produce substantial cost savings by eliminating utility relocations.

Quality Level A. QL-A, also known as "locating", is the highest level of accuracy presently available and involves the full use of the subsurface utility engineering services. It provides information for the precise plan and profile mapping of underground utilities through the nondestructive exposure of underground utilities, and also provides the type, size, condition, material and other characteristics of underground features. (FHWA-SUE, 2017)

For rural projects, there are few utilities within the roadway footprint, however on urban projects large ductbanks, service connections, water and gas mains, sewers, storm drains, and other utilities create a high likelihood of several clashes during design.

At the Field Preliminary Investigation meeting (30% milestone), the design has evolved to where there is an audited and approved existing conditions and existing utilities models, as well as the preliminary grading; roadway subgrade and pavement section; roadway drainage and ditch lines; conceptual stormwater management locations; preliminary type, size, and location of structures; estimated impacts to right of way easements; and anticipated environmental impacts. Many of these features will simply be “placeholders” in the 3D model, such as the structures and the SWM facilities. The proposed roadway baseline, horizontal and vertical alignments, and typical sections must be finalized at this time with the required clear zones, roadside grading, drainage ditches, and mitigation areas shown.

The 65% Semi-Final Review must include revisions to the surfaces included in the 30% review, as well as the proposed stormwater management grading, preliminary utility relocations and proposed new utilities, roadway drainage (including all inlets, pipes, and underdrains), and foundation information for overhead signs, structures, and traffic signal equipment. The primary purpose at this point is to identify any underground “clashes” that may exist between the proposed improvements and existing underground features. “Soft clashes” are those that fall within the recommended tolerances between utilities or between the proposed improvements and existing or proposed utilities. By the 90% review, all of the clashes identified in the 65% review should be addressed.

Construction/Advertisement

Contents of 3-D Engineered Models

Today's surveyors utilize sophisticated equipment such as robotic total stations, high-accuracy GPS units, digital levels, and laser scanners. To understand how 3D engineered models can incorporate the use of new survey technology, it is important to understand the capabilities of each piece of equipment, how it works, and the kind of data it collects. (Reeder & Nelson, 2015) Accordingly, it is important that planners, designers and engineers work closely with their surveying teams, not only at project inception but throughout the course of a project.

NEW SURVEY DATUMS ARE COMING! NAD83 and NAVD88, although still the official horizontal and vertical datums of the National Spatial Reference System (NSRS), have shortcomings and will be replaced in 2022. NAD83 is non-geocentric by about 2.2 meters, and NAVD88 is both biased (by about one-half meter) and tilted (about one-meter coast to coast) relative to the best global geoid models available today. These issues derive from the fact that both datums were defined using terrestrial survey techniques at passive geodetic survey marks that have deteriorated over time. The new reference frames will rely on GNSS and GPS, as well as an updated and time-tracked geoid model that will be more cost-effective and easier to maintain. (Source: NOAA National Geodetic Survey)

Digital terrain models are sometimes inaccurately used synonymously with surfaces when discussing existing and proposed feature models. A DTM is a representation of the ground surface for a specified area and it may include multiple surface layers and features such as subbase, subgrade, and pavement. Surfaces, on the other hand, typically only include a single ground surface or another surface such as pavement. (Reeder & Nelson, 2015) Thus, for existing conditions a DTM consisting of only a top surface will likely be sufficient for design. However when creating a 3D engineered model for the proposed design, the generation of additional surfaces for pavement base and sub base is typically an easy addition once the corresponding model component is created.

The two most important models designers require prior to initiating design are the Existing Topography and the Existing Utilities models. The Existing Topography model will primarily include the surface that represents the existing ground, but with fairly accurate as-built information the existing pavement surface, existing sidewalk and driveway surface, and existing aggregate base could all be included. Ideally, the Existing Utility model will include the best available information for underground water, sewer, telecommunication, fiberoptic, electric, and steam services. Existing storm drains, underdrains, traffic signal conduit and handboxes, and other information could be included if known.

The designer must coordinate with PSD to identify the level of accuracy required and discuss the most cost-effective method of gathering the base data. If laser scanning is used, the designer must be prepared to identify which items in the point cloud will be needed in the surface in order to reduce the amount of post-processing required. The more data points needed, the longer it will take to deliver the Existing Topography surface and larger file sizes may degrade computer performance. One of the benefits about having the scanned point cloud is that if additional survey points are needed later in design, they can be added with relative ease. For work on existing facilities, the designer should provide the as-built plans and identify any existing pipes, inlets, site features (wells, fences, porches, etc) that need to be included in the survey.

The designer must work closely with the OHD Utility Coordinator and the District Utility Engineer to secure as-builts and discuss the quality level required for the project. Resurfacing and sidewalk projects that do not have new drainage features may be able to use as-builts and the topography to locate utilities (QL-D), while projects with full depth reconstruction and drainage improvements may require other methods such as designation with pipe locators, ground-penetrating radar (GPR), or test pits to adequately locate all underground utilities in all three dimensions. Based on this information, the survey team/utility section will develop the Existing Utility model. The Existing Utility model will call out any abandoned utilities and will clearly show ownership data.

The Existing Right of Way model consists of property lines and easements that are overlaid onto the Existing Topography. It could also be used to show any mineral rights or underground easements, such as those for railway tunnels or subsurface utilities. Including the Existing Right of Way may allow the designer to quickly assess the benefits of providing retaining walls over graded slopes to tie in to existing properties.

The Proposed Roadway model is the most important when it comes to the design of the facility. It includes the roadway baseline, horizontal and vertical alignment, roadway sections and proposed grading, and roadside features such as ditches and swales. The model is broken out into several surfaces that will help the contractor expedite construction. As an example, the model will include a surface that shows the proposed grading that the contractor can convert into a LandXML or other file that is compatible with AMG equipment. The aggregate base and the pavement are each their own surface as well. Creating the pavement as its own surface allows for easier calculation of wedge and level courses, as well as the base and surface courses. It also allows the contractor to provide a more accurate amount of milling required for areas that are only to be resurfaced.

Current design software uses the approach of applying and sweeping templates (or assemblies / subassemblies) along horizontal and vertical control objects. Typically the software allows the user to alter template spacing or frequency; and from these 3 objects (horizontal, vertical and template) a surface can be generated by connecting the various 3d points on the template. Generally with tighter spacing between template applications, more points are generated. It is from these points that a 3D surface object is created and more points result in smoother surface. The following guidance is provided:

- Templates should be applied at all horizontal and vertical geometry critical points (PC, PT, PRC, PVC, PVT…)
- For preliminary design, the maximum template spacing should be 25 ft.
- For final design, the maximum template spacing should be 5 ft.
- Tighter spacing (<5 ft) should be used along horizontal and vertical curves; the smaller the radii the closer the spacing.

The Proposed Utility surface should include all of the new inlets, pipes, and underdrains for stormwater management and roadway drainage in addition to all of the relocated and new underground utility surfaces. Ideally, poles and guy wires would be located in this file as well. This surface is a “non-triangulated” surface as the features are either below or above ground.

Current design software provides functionality to create pipes, conduits and related subsurface structures as 3D objects called SUDA (Subsurface Utility Design and Analysis) cells, which can host not only geometric data but also engineering characteristics such as friction coefficients. Design software also provides the ability to dynamically link objects together and to organize objects into networks. Also, the design software may use parametric modeling whereby one definition of an object can be utilized for various depths of structures. These capabilities allow the designer to quickly and easily highlight and change all pipe, conduit and structure sizes. Additionally, drainage objects are able to attach to surfaces, so that if a surface is changed the attached drainage object location will also change.

The following guidance is provided:

- Utilize design software's modeling capabilities to model 3d pipes, conduits and related structures.
- Utilize conflict detection capabilities of the software to identify utility conflicts prior to the
- design reaching the field.

Additional Guidance and Considerations

- 3D technology can assist the design team with improving project communication, contract deliverables and quality assurance.
- The 3D engineered models provide unmatched graphic representation of a project to the public, the owner, and the affected property owners.
- The 3D engineered model takes the "picture is worth a thousand words" adage to a new level.
- 3D engineered models are used during all phases of a project and are capable of numerous benefits that are not possible with traditional 2D methods.
- 3D engineered models provide excellent project visualization for the lay person, which is ideal for public information and presentations.
- 3D engineered models offer enhanced Subsurface Utility Engineering (SUE) and conflict detection.
- 3D engineered models provide improved and expanded earthwork quantity calculations.
- The use of 3D engineered modeling has a major benefit during early design stages versus traditional 2D methods because 3D technologies can easily make alignment and profile modifications without the need to manually compute earthwork, right-of-way impacts, and other design elements.
- The 3D engineered model saves design time by allowing the information created during the preliminary design phase to be updated and efficiently used for final design purposes.
- The structural engineer's design can be incorporated into the 3D engineered model to help the roadway designer understand where to place utilities and how to grade the bridge berms.
- Hydraulic engineers can also benefit from the ability to incorporate the structural drawings into the 3D engineered model.
- Hydraulic engineers can use the model to accurately calculate the volume of unobstructed flow that can bypass the bridge structure.
- Hydraulic analysis can also be used to assist in calculating the buoyancy of structures that have the potential to be exposed to flooding conditions.

- Hydraulic information such as flood elevations can be incorporated into projects to assist designers in making sure the design functions according to the specification requirements.
- Geotechnical information can be incorporated into the 3D engineered model as well. Information obtained from soil borings can be implemented into the model that can include soil types, rock ledges, water tables, etc.
- The geotechnical information contained within the model can also be used to help designers determine where unsuitable soils may be encountered within the corridor.
- Some of the 3D modeling tools that are available to assist designers with engineering analysis include virtual drive-throughs, flyovers, parametric modeling, constructability analysis, sight distance calculations, traffic analysis, inclement weather analysis, and clash detection.
  - The virtual drive-through enables designers to identify any irregular bumps, dips, alignment errors, holes, or “busts” in the design model. This can also assist in sight distance reviews and checking for adequate signage.
  - These types of model animations can also help communicate design objectives to the public for informational meetings and demonstrations.
- Similar to a virtual drive-through of the corridor, flyovers can also be used in the design phase to facilitate engineering analysis.
- 3D engineered models provide designers with the ability to analyze the constructability of all aspects of the project prior to the model leaving the designer’s office.
- The 3D engineered model can show important items such as grading limits, vertical clearances, and utility conflicts that could create costly contract modifications if not identified prior to construction.
- The 3D engineered model can also be used to identify areas that may be difficult to construct such as utility installation in congested urban areas.
- 3D engineered models give designers the ability to quickly and accurately check driver sight distance and clear zones, which improves the safety of the traveling public.
- 3D engineered models can be used by designers to visualize traffic patterns and traffic flow.
- 3D engineered models assist the designer in analyzing how the corridor will function in inclement weather.
- New methods in 3D engineered models allow designers to simulate blowing snow and blizzard events in the design phase.
- One of the most important benefits of utilizing 3D engineered models is the level of quality assurance that can be performed during the design phase.
- 3D engineered models allow the designer to look at the project in isometric views at various angles to detect any surface irregularities such as “spikes” or “holes” that need to be corrected.
- 3D engineered models can adjust the horizontal and vertical exaggeration of elements to assist the designer in detecting errors.
- Unlike traditional 2D exaggeration tools, 3D engineered models allow the designer to exaggerate the entire surface to assist in detecting even the slightest errors in the model’s surface.
- Most errors that are detected during the QA/QC process can be quickly and easily corrected in the 3D engineered model prior to supplying the model to the client, owner, or contractor.

Works Cited

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