Current Trends in Highway Design

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Computer Simulation of CA 224, Bautista Canyon
Overview of Today’s Topics

- FHWA and Federal Lands Highway
- Performance Oriented Design
- Context Sensitive Solutions
- FLH Approach to Project Delivery
- Visualization Techniques
- Geospatial Design and Construction
- Application of New Technologies

Monarch Pass, Colorado
Grading with 4-Horse Fresnos
Who is Federal Highway?

- Federal-aid Highway Programs
- Federal Lands Highway Programs
- Our Vital Few Priorities
  - Safety
  - Congestion Mitigation
  - Environmental Stewardship and Streamlining
- 52 Federal-aid Division Offices
- 3 Federal Lands Division Offices
- 4 Resource Center Offices
Why Federal Lands Highway?

- Provide public road access to and within Federal Lands
- Provide engineering and technical services to the Federal land management agencies (FLMAs) and the transportation community
- Implement transportation technology
- Provide training and technical support
Federal Lands Highway Facts

- Federal Lands are 30% of the land in US
- Travel - tourism is the third largest industry in the US and is the largest employer
- There are over 500,000 miles of Federal land management agency roads
- Recreation is growing at a rate of 5% annually
- FLH administers the oldest road program (1914 - Forest Highway Program)
FLH Partners/Customers

- National Park Service
- Forest Service
- Fish and Wildlife Service
- Bureau of Indian Affairs
- Department of Defense
FLH Partners/Customers (cont’d)

- Native American Tribal Governments
- Other Agencies – BLM, BOR, COE
- State DOT’s
- Local Governments – D.C., Towns, Counties
- FHWA Division Offices, Resource Center
Types of FLH Projects

- High Volume Urban Parkways
- Rural Parkways in National Parks
- Low Volume Rural Local Roads
- City Streets, Avenues, and Corridors
- Special-purpose Roads
- Scenic Overlooks and Parking Areas
- Pedestrian and Bicycle Facilities
- ATS: Alternative Transportation Systems
- ITS: Intelligent Transportation Systems
FLH’s Perspective:

- Long-standing partnerships with FLMA’s
  - Sensitivity to FLMA goals and values
  - Collaborative decision-making
  - Use expertise gained from partner agencies
  - Share complementary knowledge & skills

- National Perspective
  - Partner with many agencies and State DOT’s
  - Broad geographical coverage

- Able to accommodate other agency standards
- Partners expect delivery of value and quality
- Retain Federal stewardship responsibility
Data and Performance

- Quality data and tools needed for effective engagement of stakeholders and public
- Understanding the basis for design criteria results in a higher level of performance
- Facilities in sensitive environments face higher demands for performance
- Analysis, engineering, and construction all need to be accomplished with ever higher levels of thinking, performance and quality
Performance Oriented Geometric Design Analysis

- Current design practice bases criteria on conditions, not performance
  - Functional Classification
  - ADT
  - Urban/Rural
  - Design Speed

- Compares existing versus recommended
  - Does not quantitatively characterize future performance
  - Does not evaluate the driving task

- Output of analysis is simply dimensions, not performance indicators
Performance Oriented Geometric Design Analysis

- Future trends will be to base design criteria on performance measures
  - Safety performance/consistency
  - Operational performance/reliability
  - Infrastructure performance/sustainability
  - Driver performance/human factors

- Compares predicted versus what is needed
  - Accurate prediction tools to characterize future performance
  - Considers the driving task and experiential values

- Output of analysis is performance indicators to support increasingly difficult decisions
Interactive Highway Safety Design Model (IHSDM)

- Making Safety a Priority in Roadway Design
- Decision-support tool
- Five evaluation modules
  - Crash Prediction
  - Design Consistency
  - Intersection Review
  - Policy Review
  - Traffic Analysis

- Library of the research reports
Interactive Highway Safety Design Model (IHSDM)

- Quantitative analysis of expected safety and operational performance
- For two-lane rural highways
- Automated for CADD Design
- Compatible with GEOPAK and InRoads
CSS Approach

- Outcome satisfies the purpose and need
- Explores alternatives that equally address goals for safety, mobility, protection of the environment, and reflect community values
- Involves a collaborative, interdisciplinary approach, and effective use of resources
- Involves stakeholders, resource agencies and the public as a part of the design team
- Ensures that outcomes adequately address safety and mobility, and add long term value
Balanced Goals

- Mobility
- Safety
- Preserve Community Values
- Enhance the Natural Environment
Why Does FLH Emphasize Context Sensitive Solutions?

- Enables FLH to achieve its vision
- FLH Vision:
  Create the best transportation system **in balance with** the values of Federal and Tribal lands
FLH Approach to Delivery

- Facilitate early public involvement, integrated with scoping, to establish purpose and need
- Utilize an interagency, multi-disciplinary team based on identified needs, purpose and scope
- Maintain continuous communication and feedback among partners and stakeholders
- Collaborative decision-making with stakeholders
- Understand the context to guide alternatives which address mobility and safety needs
Recommended Practices

- Verify sound, factual basis for purpose and need
- Be flexible to consider alternative, corridor-specific design criteria that meets the need
- Understand basis for design criteria, and how it affects operational performance and safety risk
- Continuously adjust ever finer, the details that result in a more closer fit to the site conditions
- Follow proven processes that attend to the details affecting quality, across all disciplines
- Draw on lessons the road’s history can teach
CSS is Data-intensive

- Greater awareness/understanding of competing goals and values
- Knowledge of both the users’ needs and the affected community (context)
- Accurate traffic and crash data to identify safety and mobility needs
- Safety-conscious scoping is emphasized to assure deficiencies are recognized and goals are achieved
- Precise surveys and mapping are needed to best fit local conditions
Leverage the Technology

- State-of-the-art interactive highway design and CAD software for quality and productivity
- Continuously upgrade workstations, plotters, servers and network to utilize latest tools
- Maximize integration of geospatial data from all sources (GIS, web, satellite, terrestrial)
- Interchange and share data and design information across all technical disciplines
- Use the survey, mapping, terrain and design modeling from planning through construction
Highway Standards Used by FLH

- Generally... AASHTO Green Book
  “Policy on Geometric Design of Highways and Streets”
- Federal Land Agency Standards
- State or Local Design Standards
- Tribal Government Standards
CSS & Road Standards

- Purpose and Function of the Road
  - Arterial?
  - Collector?
  - Local?
  - Special-Purpose?

- Level of Traffic
  - ADT?
  - Seasonal?
  - Design Vehicle?

- Balance Design Speed & Roadway Width
  - With Purpose & Function of Road
  - With Mobility and Safety Needs
  - With Community & Environmental Values
FLH Design Techniques

Curvilinear Alignment

• Lie lightly on the land
• Follow existing contours
• Flowing alignment, varying views
• Coordination of horizontal and vertical
• Spiral transitions at ends of curves
• Consistent, self-enforcing design speed
• Iterative reviews to optimize alignment
Natchez Trace Parkway
Voyageurs National Park, Minnesota
Cherohala Skyway, North Carolina
National Scenic Byway
Roadside Features

- **Slope Treatments**
  - Rounded Top of Cut and Toe of Fill
  - Warping at Transitions to Cut and Fill
  - Roughening and Compounding
  - Rock Sculpting and Ledging
  - Landscape Planting with Native Species

- **Ditches**
  - Rounded, Vegetated
  - Masonry Lined (Stone or Brick)
  - Paved with Curbing

- **Aesthetic Curbs and Pedestrian Sidewalks**

- **Fences and Appurtenances which Blend**
Rock Sculpturing and Landscaping, Mt. Lemmon, AZ
Mountable Curbs, Baltimore-Washington Parkway, Maryland
Aesthetic Traffic Barriers

- Weathering Steel W-beam
- Etched Galvanized Steel W-beam
- Steel-backed Timber Beam Guardrail
- Steel-backed Timber Log Guardrail
- Simulated Stone Concrete Guardwall
- Natural Stone w/Concrete Core Wall
- Crash Tested and Approved
Skyline Drive, Shenandoah National Park, Virginia
Precast Artificial Stone Guardwall
Baltimore-Washington Parkway, Maryland
Typical Steel-Backed Timber Guardrail, Blue Ridge Parkway
Weathering Steel Guardrail,
George Washington Memorial Parkway, Virginia
Structures that Blend

- Bridges
  - Type, Span, Shape, Formwork, Finishing

- Culverts
  - Shape, Material, End Treatment

- Retaining Walls
  - Aesthetic Facing, Color, Texture

- Natural Materials
  - Accents, Veneers, Facades
Yosemite, California
Stone Masonry Arch, Blue Ridge Parkway
Forehand Hollow Bridge, Natchez Trace Parkway
Great Smoky Mountain National Park, Tennessee
Environmental Enhancements

- Adjust roadway location away from critical and sensitive areas
- Restore drainage to original stream channels
- Replace existing culverts with natural bottom culverts for fish passage
- Add crossing structures sized for wildlife
- Restore existing barren slopes with native trees, shrubs and grasses
- Restore hydrology to natural conditions
CSS Construction Techniques
Foothills Parkway, Tennessee
From Planning......... to Reality
Visualization Applications

- Similar to the State DOTs, primarily 2D photo-simulations for public involvement and Environmental Documents
- For major (high cost/high visibility) projects, 3D models, limited animation, VHS and CD-Rom
- Some use of web-based access
- Limited planning applications (GIS)
Why Use Visualization?

- Helps Context Sensitive Solutions
- Facilitates Involvement with Stakeholders and the Public
- Promotes Common Understanding
- Simulates the Proposed Facility
  - How it Looks (End Product)
  - How it Operates (Meets Needs)
Engineers Learn to Visualize in 2D

- Rod Guide
- Wireframe Model
- Cutting Plane Positioned on Solid Model
- Cut Section of Solid Model
Engineers Learn to Visualize in 2D
Stakeholders See Differently

- **Engineer:** Physical Requirements
  
  “End Product” “Meets Criteria”

- **Planner:** Needs and Goals

- **User:** How I Operate On It

- **Resident:** How It Affects Me

- **Community:** Sense of Place, Environ. Character, Heritage, Local Values

- **Owner:** Asset or Liability?
Users =
Communication Challenges

- Engineers Speak
  - Green Book
  - Typical Section
  - Pavement Materials
  - Design Speed
  - Crash Rate
  - Constructability
  - Plans and Profiles
  - Cross Sections

- Users Speak
  - Function, Fit
  - Space to Drive
  - Smoothness
  - Comfortable Speed
  - Feels Safe
  - Barricades, Delays
  - TV, Web, Pictures
  - Perspective Views
Form versus Function

- Need to illustrate more than what it will look like, but imply how it will work
- Need to convey contextual value of the project to the user and community
- Need to enable analysis + feedback
- Visualization is only as effective as the understanding and communication it generates for the user or stakeholder
Realism is Necessary – But Not Sufficient

- Conveys Purpose and Need of the Project
  - Shows what is Important? - User? - Community?
  - Safety? - Efficiency? - Environment?
- Reflects Credibility of Your Work
  - Is it Accurate? - Understandable? - Add Value?
- Tailors Information with Audience
  - Stakeholder: What the facility looks like
  - Community: What the facility changes
  - User: How well the facility works for me
Planning & Public Involvement Visualization Applications

- Project Scoping
  - Purpose & Function of Road
  - Describe and Evaluate Alternatives that address needs, issues, and values
- Public Involvement and Communication
- Partner and Stakeholder Participation
- Collaborative Decision-making
Levels of Public Involvement

- Influencing
- Calming
- Informing
- Consulting
- Partnering
- Collaborating
- Citizen Control

What Level Is Requested?
Levels of Interaction

- Imagination – The Engineer’s Vision
- Simulation – Show and Tell to Others
- Evaluation – Feedback, Preference, Ranking of Input from Others
- Analysis – Interactive communication, clarification, multi-attribute scoring, consensus-building, collaboration
Levels of Decision-making

- Expert-based
- Stakeholder-based
- Community-based

What Level Is Requested?
Where is Visualization Typically in the Process?

20% - 30% Phase
Visualization Technology

- **3D Perspective Views**
  - Intuitive and understandable
  - Capability within GEOPAK software

- **3D Model Navigation**
  - Requires a large 3D digital model
  - Enables any custom viewpoint
  - Degrades with close-up view
  - Limited fly-through and navigation capability without special software
Visualization Techniques

- **Photo Simulations**
  - Shows single location, or aspect of the project
  - Relatively simple, quick and inexpensive

- **360° Views**
  - Interactive, provides a context and scale
  - Requires 12 photos, carefully aligned
  - Requires Apple QuickTime Software

- **Animation**
  - Allows a comprehensive corridor tour
  - Provides a realistic video-like experience
  - Requires a large, rendered, digital “model”
Visualization Products

- Hardcopy Graphics Presentation
  - Exhibit boards and posters
  - Brochures and flyers
  - Graphics and charts

- Electronic Presentation Products
  - Slide Presentations
  - Video CDs and DVDs
  - Interactive CDs
  - Project Web Sites
Example – Guanella Pass

- Diverse Stakeholders and Issues:
  - 2 National Forests & CDOT
  - 3 Owners (2 Counties & Town)
  - National Historic & Mining District
  - Scenic Byway
  - Adjacent to Wilderness Area
  - Private Landowners and Businesses
  - Controversial Corridor Management, Preservation vs. Improved Access
Example – Guanella Pass

Visualization used in the DEIS to show:
- Mobility Needs
- Safety Needs
- Community Values
- Natural Environment
- Proposed Alternative Design Solutions
Alternatives in DEIS

- Rehabilitate vs. Reconstruct
- Paving vs. Gravel
- Alternative Surface Types
  - Gravel w/Magnesium Chloride
  - Stabilized Gravel w/Admixtures
  - Recycled Asphalt Pavement
  - Macadam (penetration treatment)
  - Pavement w/Coarse Chip Seal
Visualization Applications

- Photo-simulations (before & after) on exhibit boards at public meetings
- Continuous videotape loop played on TV at public meetings
- Interactive CD-Rom included in DEIS document (live video, narration, maps, photo-simulations, 360 views, and animations of alternatives)
- Website with materials from CD-Rom
Reconstruct w/Gravel
Reconstruct w/Macadam
360 Views (before & after)

Switchback 360 View Before

Switchback 360 View After

Georgetown 360 View Before

Georgetown 360 View After
Animation Excerpts from CD

Guanella Pass Movie Video Clip
How did Visualization add value?

- Identified true concerns
  - Rustic “backway” vs “parkway”
  - Impact of alternative alignments
- Need for aesthetic treatments
  - Retaining walls
  - Barrier rails
  - Curbs and ditches
- Showed the project could lay lightly
Example – Hoover Dam Bypass
Example – Hoover Dam Bypass (US 93 in AZ & NV)

- Diverse Stakeholders and Issues:
  - 2 State DOTs (owners)
  - BuRec, NPS, Hoover Dam, FHWA
  - National Historic Landmark
  - Adjacent Traditional Cultural Property
  - NAFTA Truck Route
  - Security of Hoover Dam
  - Safety, Congestion, Capacity Issues
Visualization Applications

- Photo-montage of alternative corridor alignments
- Photo Simulations (before & after) at public meetings and in EIS
- Interactive Split-screen animation
- Website with photo simulations and fly-through animation
HDB Animation

HDB Split-Screen Video

Building HDB River Bridge
How did Visualization add value?

- Corridor Selection
- Relationship to Hoover Dam
- Scale of Colorado River Bridge vs Hoover Dam
- Bridge Type Selection
- Proximity to Traditional Cultural Property Site
Example – Beartooth Highway
Beartooth Highway

Diverse Stakeholders and Issues:
- 3 National Forests
- 2 State DOTs (WY & MT)
- Maintained by NPS
- All-America Scenic Byway
- Adjacent to Wilderness Area
- Access to Yellowstone NP
- Endangered Species, Wetlands, Historic Resources, Alpine Tundra
Visualization Applications

- Photo Simulations (before & after) on exhibit boards at public meetings
- Continuous Videotape Loop played on TV/VCR at public meetings
- Interactive CD-Rom included in all DEIS copies (live video narration, maps, photo-simulations, 360 views, and animations of alternatives)
- Website with materials from CD-Rom
360 Views (before & after)

Beartooth Ravine 360 View Before

Beartooth Ravine 360 View After

Deadman’s Curve 360 View Before

Deadman’s Curve 360 View After
Animation Excerpts from CD

Beartooth Hwy Intro Video Clip

Beartooth Hwy Movie Video Clip
How did Visualization add value?

- Help resolve alternative alignment issues
  - Evaluation of new wetland impacts vs restoration opportunities
  - Illustrated pros/cons of alternative alignments vs perpetuation of existing alignment
- Bridge type selection
- Selection of aesthetic treatments
  - Retaining walls
  - Bridge rails design
  - Curbs and ditches
- Design major parking areas and pullouts
Emerging Technologies:

- Emersion in virtual real-time models
- Photo-realistic animation of surfaces, objects, vehicles, people, lighting
- Improved driving & crash simulation
- Analysis of traffic movement and operations in the virtual 3D model
- Integration of vehicle dynamics
- Interactive Web-based applications
Traffic Operations

- Traffic Simulation Software
  - CORSIM
  - VISSIM

- Visualization Application

Vissim Video 1

Vissim Video 2

www.fhwa-tsis.com
CAVE Virtual Environment
Design Virtual Environment

- Immersive, stereoscopic environment
- Walk-in or Head-mounted displays
- Accurate size and scale
- Multi-participant, collaborative design
- Easily navigable

EVL U of IL Video
DVE GATech Video
Stake-less Construction Technology
Mobile Digital Highway Measurements

TURNER-FAIRBANK
HIGHWAY RESEARCH CENTER

ADVANCED RESEARCH PROJECT
Measurement Needs

- Vegetation
- Roadside features
- Vehicle Traffic
- Contour/Terrain
- Lane Markings
- Edge of Roadway
- Right of Way
- Road Geometry
- Pavement Condition
Future Added Sensors

- Sound Intensity Pressure Device (SIPD)
- Ground Penetrating Radar (GPR)
- LIDAR
- Infrared Sign Retro-Reflectivity (IR)
- Downward facing Camera for Pavements
Sensors needed to obtain Roadway Super-Elevation

**Sensor**
- Infrared RetroReflectivity
- Stereoscopic Video
- Enhanced NDGPS
- DGPS
- Monoscopic Video
- Distance Measurement Instrument
- Temperature Gauge
- Optical trigger
- Scanning laser
- 1-D Accelerometer
- 3-D Accelerometer
- Profiling laser
- Texture laser
- Sound Intensity Pressure
- Ground Penetrating Radar

**Application**
- Hardware condition
- Hardware tracking
- Trajectory of vehicle
- Lane tracking
- Position of Hardware
- Linear Referencing
- Vertical Profile
- Horizontal Profile
- **Super-Elevation**
  - Lane Definition
  - Pavement Surface
  - Pavement thickness
  - Base
  - Sub-Base
  - Underground Hardware

**Phase I**
DHM DATA VIEWER

[Image of DHM data viewer interface with graphs and video player]

The DHM DATA VIEWER is a tool for viewing and analyzing data related to highway monitoring and infrastructure management. It features real-time video playback, trajectory and scanning laser data, and various graph options for elevation, slope, and profile analysis. The interface includes controls for playing and pausing the video, as well as adjusting settings such as color gain and layout options.
DHM STEREO IMAGING

LEFT CAMERA

RIGHT CAMERA
LANE ATTRIBUTES

- LANE MARKINGS
- LANE WIDTH
GPS RECEPTION

No. of Satellites:
- 3
- 4 & 5
- 6 & 7
- 8
- 9
# Integrated GPS and Inertial

## GPS Only

### Advantages
- High accuracy position & velocity
- Moderate accuracy orientation (using multiple antennas)

### Limitations
- Low bandwidth
- Satellite shading (dropouts)
- Slow ambiguity resolution

## Inertial Only

### Advantages
- Full 6 DOF solution
- High dynamic accuracy with broad bandwidth
- Self-contained (no dropouts)

### Limitations
- Solution errors grow over time

## Integrated Inertial/GPS/DMI

### Advantages
- All inertial and GPS advantages
- DMI constrains noise and drift, and adds robustness

### Limitations
- No significant limitations
# PHASE I APPLICATIONS

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<th>DATA ACQUISITION</th>
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<td>1</td>
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TYPES OF DATA

- VERTICAL AND HORIZONTAL ALIGNMENTS INCLUDING PC, PT, CURVE DATA
- SUPER ELEVATION
- LANE DEFINITION (MARKINGS AND EDGE)
- LINEAR REFERENCING
- ROADSIDE HARDWARE
- PAVEMENT SURFACE CONDITION
HIGHWAY GEOMETRICS

- HORIZONTAL ALIGNMENT
- VERTICAL ALIGNMENT
- SUPER-ELEVATION
Approximate PC = Point of Curvature and PT = Point of Tangency
Refined PC = Point of Curvature and PT = Point of Tangency
VERTICAL ALIGNMENT

DETAIL

MILES
Comparison with rod and level data over 2 miles
7 Runs Super-Imposed: Measured Precision = 0.02%
CROSS-SECTION SCANS

ELEVATION IN INCHES

OFFSET FROM CENTERLINE OF VEHICLE IN INCHES

POSITION OF GUARD RAIL
CROSS-SECTION SCANS

ELEVATION IN INCHES

OFFSET FROM CENTERLINE OF VEHICLE IN INCHES

EDGE OF CUT
CROSS-SECTION PLOTS

- ESTABLISHMENT OF A CONTROL LINE FOR LINEAR REFERENCING
- MERGE OF ELEVATIONS AND CROSS-SLOPES
- SUPERIMPOSED CROSS-SECTIONAL SCANS
Visualization

3-D RENDERING OF ROADWAY SURFACES
Superimpose Digital Imagery
Visualization

3-D RENDERING OF ROADWAY SURFACES
Superimpose Digital Imagery
Summary

- Federal Lands Highway uses
  - Performance oriented design and CSS
  - State of the art design technologies
- To deliver facilities which are
  - Technically feasible and responsible
  - In harmony with their environment
  - Reflect community and natural values
- That satisfy user and stakeholder needs
  - Safety
  - Mobility
For More Information

- NCHRP Report 480
- [WWW.ContextSensitiveSolutions.Org](http://WWW.ContextSensitiveSolutions.Org)
- [WWW.TRBVIS.Org](http://WWW.TRBVIS.Org)
Thank You

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Photo-simulation Techniques
Data Furnished By Designer

- GEOPAK .gpk File
- Tin File
- Alignment Centerline Name
- Proposed Cross-Sections
- Roadway Criteria Files
- Structures TSL Info
- Structures Criteria Files
Run 3D Cross-Sections
Apply Surface Texture Materials

Bridge

Roadway

Concrete
Apply Surface Texture Materials
Apply Lighting

Ray Trace Lighting
and Shadowing
Superimpose Photography
Photo Simulation Examples