2. ROADSIDE TOLL COLLECTION
2. ROADSIDE TOLL COLLECTION

Toll System Configuration
Cash Tolls
Electronic Toll Collection (ETC)
Violation Enforcement/Video Toll Collection Systems
2. ROADSIDE TOLL COLLECTION

Toll System Configuration

- **Open (barrier tolls)**
  - Tolls collected as vehicles pass a specific location (barrier) based on a classification schedule
  - Toll plazas usually are located on the mainline and at interchanges
  - Classifications by number of axels, weight, height, length, mass, etc.
2. ROADSIDE TOLL COLLECTION

Toll System Configuration

- Closed (mileage-based tolls)
  - Tickets issued at entry (manual or electronic)
  - Tolls computed by distance and classification
  - Payment paid or computed at exit location
2. ROADSIDE TOLL COLLECTION

Toll System Configuration

- **Cordon Line (area-based tolls)**
  - Priced entry into a restricted area
  - Usually computed by time of day

Stockholm

London

Singapore
2. ROADSIDE TOLL COLLECTION

Cash Tolls

- Manual Toll Collection
2. ROADSIDE TOLL COLLECTION

Cash Tolls
- Manual Toll Collection
2. ROADSIDE TOLL COLLECTION

Cash Tolls

- Machine Toll Collection
2. ROADSIDE TOLL COLLECTION

Cash Tolls

- Back Office Cash Operations & Security
2. ROADSIDE TOLL COLLECTION

Cash Tolls

“There is nothing worse than waiting in traffic … except waiting in traffic to pay a toll.”

Jim Ely
Former CEO, Florida Turnpike Enterprise

Past President, IBTTA
(International Bridge, Tunnel and Turnpike Association)
2. ROADSIDE TOLL COLLECTION

Cash Tolls

<table>
<thead>
<tr>
<th>Lane Type</th>
<th>Vehicles/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORT Lane</td>
<td>2100</td>
</tr>
<tr>
<td>Dedicated Mainline</td>
<td>1700</td>
</tr>
<tr>
<td>Dedicated Ramp</td>
<td>1300</td>
</tr>
<tr>
<td>Coin</td>
<td>500</td>
</tr>
<tr>
<td>Manual</td>
<td>400</td>
</tr>
<tr>
<td>Ticket – Entry</td>
<td>500</td>
</tr>
<tr>
<td>Ticket - Exit</td>
<td>250</td>
</tr>
</tbody>
</table>

Cash Collection
嵋Cumbersome嵋Labor Intensive嵋Expensive嵋Inefficient
2. ROADSIDE TOLL COLLECTION

Moving from Cash to Electronic Toll Collection

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- Customer Convenience and Throughput
- Lower Cost of Operation
2. **ROADSIDE TOLL COLLECTION**

**Electronic Toll Collection (ETC)**

- Vehicle Detector & Classifier
  - Laser Curtain or Pavement Loop
- Light Sensor
- Light
- Camera
- Integrated Roadside Unit
  - Lane Controllers
  - Readers/ICs
- On-Board Unit (OBU) aka Toll Tag or Transponder
- Read/Write Antenna
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Dedicated Short-Range Communication (DSRC)/Radio Frequency Identification (RFID)
  - ACTIVE: TDM Protocol
  - PASSIVE: 6C Protocol
  - PASSIVE: 6B Protocol
  - HOV/HOT & Switchable

900 MHz Range
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Dedicated Short-Range Communication (DSRC)/Radio Frequency Identification (RFID)

![Diagram of Overhead Gantry, Antenna/Transmitter, and Loop Detectors]
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Dedicated Short-Range Communication (DSRC)/Radio Frequency Identification (RFID)
2. ROADSIDE TOLL COLLECTION

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Electronic Toll Collection (ETC)

- Dedicated Short-Range Communication (DSRC)/Radio Frequency Identification (RFID)
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Dedicated Lanes (gated and/or free flow)
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Open Road Tolling (ORT) Lanes/All-Electronic Tolling (AET)

ORT and AET = Free Flow Tolling
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Violation Enforcement/Video Toll Collection Systems
  - License Plate Photography/Cameras

Plate Image Theory

- Color
- B/W (grayscale)
- Near Infrared
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Violation Enforcement/Video Toll Collection Systems
  - License Plate Photography/Cameras

Plate Image Reality

- Color
- B/W (grayscale)
- Near Infrared
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Violation Enforcement/Video Toll Collection Systems
  - License Plate Photography/Cameras
  - Automated and Manual Image Review

Plate Image Reality
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- **Violation Enforcement/Video Toll Collection Systems**
  - License Plate Photography/Cameras
  - Automated and Manual Image Review

- **Plate Elements**
  - Plate Number
  - Plate Type
  - State/Jurisdiction

Plate Image Reality
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Violation Enforcement/Video Toll Collection Systems
  - License Plate Photography/Cameras
  - Automated and Manual Image Review

Combination of:
  - Human Review
  - Machine Reading with Optical Character Recognition (OCR)
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Violation Enforcement/Video Toll Collection Systems
  - License Plate Photography/Cameras
  - Automated and Manual Image Review

Toll Image Review Systems combine **humans, hardware and software** to take advantage of the best capabilities that each brings to plate reading.

Machines can read certain plate styles and characters faster and more accurately if given high quality images to process (maximize cost effectiveness)

Humans can read all possible plate styles even with poor images or plate quality (minimize leakage)
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Violation Enforcement/Video Toll Collection Systems
  - License Plate Photography/Cameras
  - Automated and Manual Image Review

<table>
<thead>
<tr>
<th></th>
<th>Character Resolution</th>
<th>Image Contrast</th>
<th>Image Sharpness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Readable</td>
<td><img src="image1" alt="Character Resolution" /></td>
<td><img src="image2" alt="Image Contrast" /></td>
<td><img src="image3" alt="Image Sharpness" /></td>
</tr>
<tr>
<td>High Performance Machine Readable</td>
<td><img src="image4" alt="Character Resolution" /></td>
<td><img src="image5" alt="Image Contrast" /></td>
<td><img src="image6" alt="Image Sharpness" /></td>
</tr>
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</table>
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Machines can’t recognize this image ... but humans can.

- Human vision can perceive details that are not explicitly present in digital image data, there really is more to a picture than meets the eye.

- For Humans, a video image is a trigger that sets off a highly complex perceptual experience that is not well understood computationally.
2. ROADSIDE TOLL COLLECTION

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CAPTCHA
Completely Automated Public Test to Tell Computers and Humans Apart
Electronic Toll Collection (ETC)

- Optical Character Recognition (OCR)/Automatic License Plate Reading (ALPR)
  - OCRs Read Plate Number Characters
  - OCRs Recognize FONTS and SYNTAX that have been programmed
  - Many states use a distinct font, colors, and character positions

![Minnesotan license plate]

2. ROADSIDE TOLL COLLECTION
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- **Optical Character Recognition (OCR)/Automatic License Plate Reading (ALPR)**
  - ALPR systems that employ vehicle signature recognition (VSR) or “fingerprinting” create a digital “match” of the full image.
  - Fingerprinting can confirm the OCR read.

![Image of vehicle and license plate]

- **Information utilized by OCR**
  - OCR Result
  - Vehicle Pattern
  - Plate-Area Pattern (includes non-Plate info)

- **Vehicle Fingerprint & Match Result**
  - VSR uses much more information
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Optical Character Recognition (OCR)/Automatic License Plate Reading (ALPR)
  - ALPR systems that employ vehicle signature recognition (VSR) or “fingerprinting” create a digital “match” of the full image
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2. ROADSIDE TOLL COLLECTION

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![Image of ALPR systems with vehicle signatures highlighted]
2. ROADSIDE TOLL COLLECTION

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2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Double-Blind Manual Image Review Systems

Plate Image ➔ Human Review ➔ Human Review
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Double-Blind Manual Image Review Systems

Plate Image → Human Review → Match → Human Review
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

Double-Blind Manual Image Review Systems

Plate Image → Human Review → Match → Billing or Violation

Human Review → Match → Yes
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Double-Blind Manual Image Review Systems

![Flowchart Diagram](Diagram.png)
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Double-Blind Manual Image Review Systems

Plate Image

- Human Review
- Human Review

Match

- Yes: Billing or Violation
- No: Senior Human Review

Senior Human Review

Match

- Yes: Billing or Violation
- No: Human Review
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Double-Blind Manual Image Review Systems

- Plate Image
  - Human Review
  - Human Review
  - Match
  - Yes
    - Billing or Violation
  - No
    - Senior Human Review
      - Match
      - Yes
        - Billing or Violation
      - No
        - Rejection and/or Escalation to Manager
2. ROADSIDE TOLL COLLECTION

Electronic Toll Collection (ETC)

- Double-Blind Manual Image Review Systems

Plate Image

- Human Review
- OCR Output

Match

Yes → Billing or Violation

No → Senior Human Review

Match

Yes → Billing or Violation

No → Rejection and/or Escalation to Manager
2. ROADSIDE TOLL COLLECTION

Summary

- **Toll System Configuration**
  - Open (barrier tolls)
  - Closed (mileage-based tolls)

- **Cash Tolls**
  - Manual Toll Collection
  - Machine Toll Collection
  - Back Office Operations & Security

- **Electronic Toll Collection (ETC)**
  - Dedicated Short-Range Communication (DSRC)/Radio Frequency Identification (RFID)
  - Dedicated Lanes (gated and/or free flow)
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- **Violation Enforcement/Video Toll Collection Systems**
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Questions - Discussion