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TRUCK SIGNAL PRIORITY

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Why Truck Priority?

- Reduce the Cost of Goods Transportation
- Reduce Red Light Running
- Encourage Trucks to use specific Truck Routes
- Reduce Emission

Objectives

- Deliverables:
  - a prototype system demonstrating the concept,
  - a system evaluation to determine potential full-scale system benefits.

Outline

1. System for the detection and tracking of trucks using video sensors.
2. Evaluating different signal priority strategies using micro-simulation.

Video Sensors

- Video sensors have distinct advantages:
  - they are easy to install (or can be already installed),
  - they are inexpensive,
  - they can provide rich traffic description (e.g. road user tracking),
  - they can cover large areas,
  - they allow verification at any later stage.

Detecting and Tracking Trucks

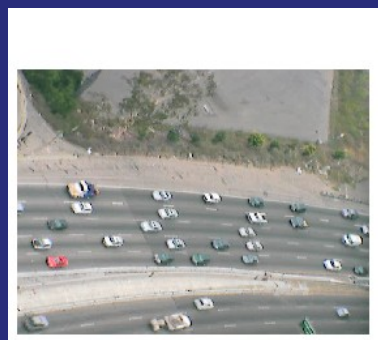
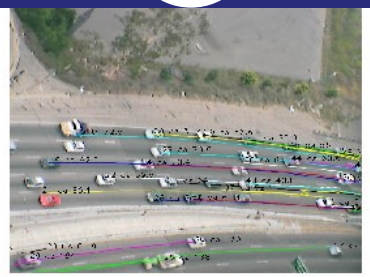
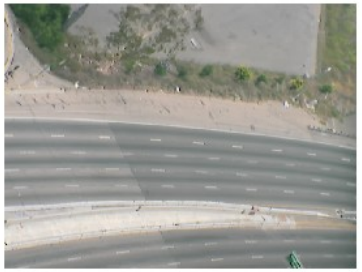


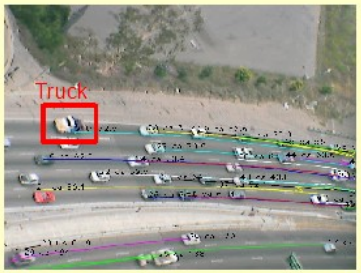
Image Sequence
+
Camera Calibration



Road User Trajectories

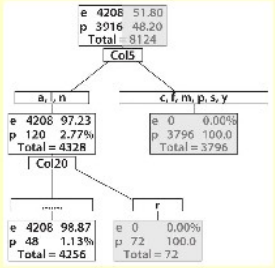


Background Model



Road User Classification

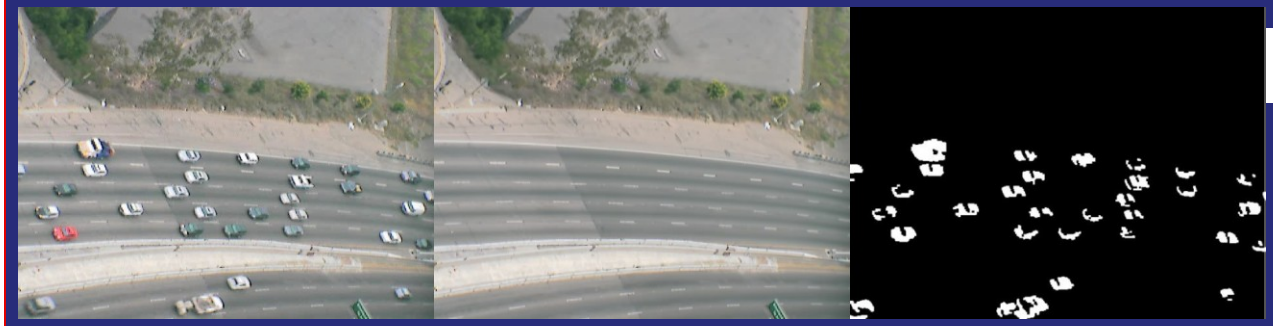
Labeled Truck Images



Truck Classifier

Learning to Identify Trucks

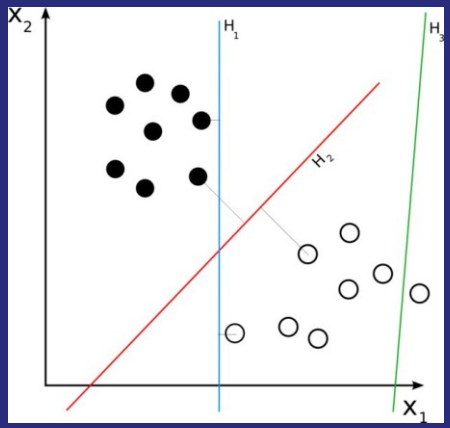
- Based on shape features extracted through background subtraction.



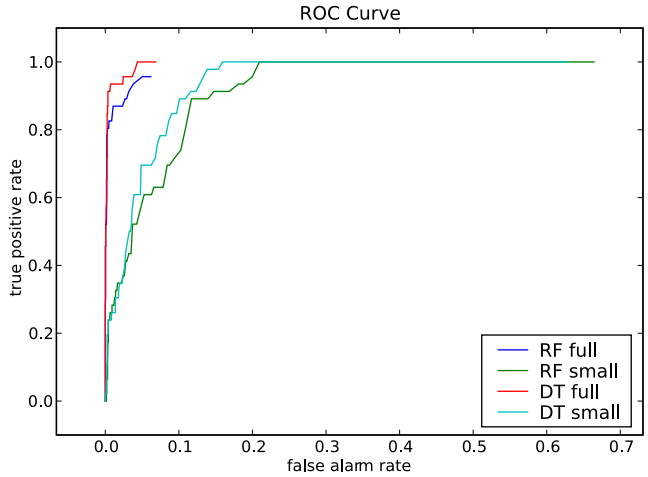
$$m_{p,q} = \iint f(x,y)\, x^p\, y^q\, dxdy$$

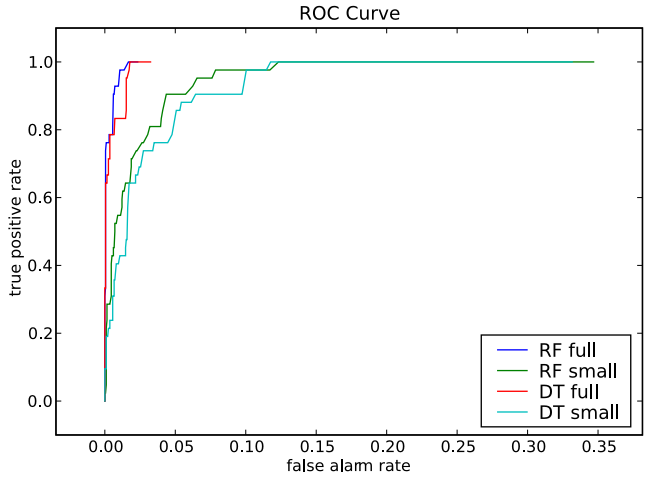
f(x,y)=1 if the pixel at (x,y) is in the foreground
0 if the pixel at (x,y) is in the background

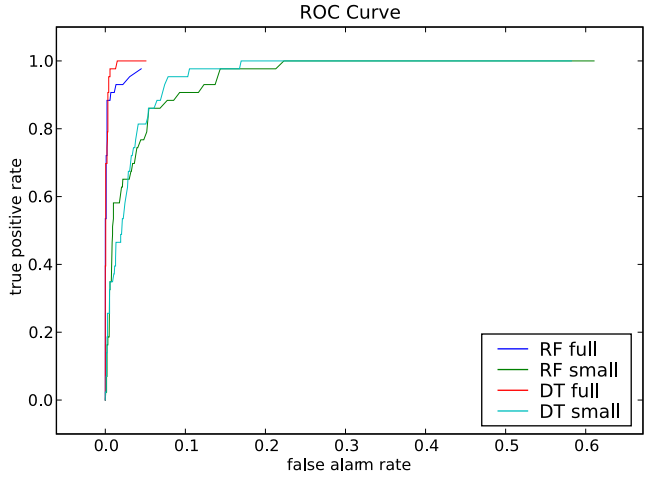
- Using machine learning to learn a binary classifier (truck vs. other road users).

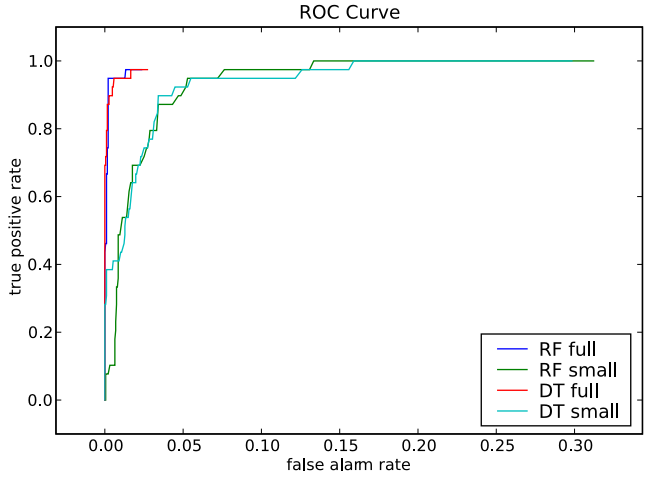


Experimental Results









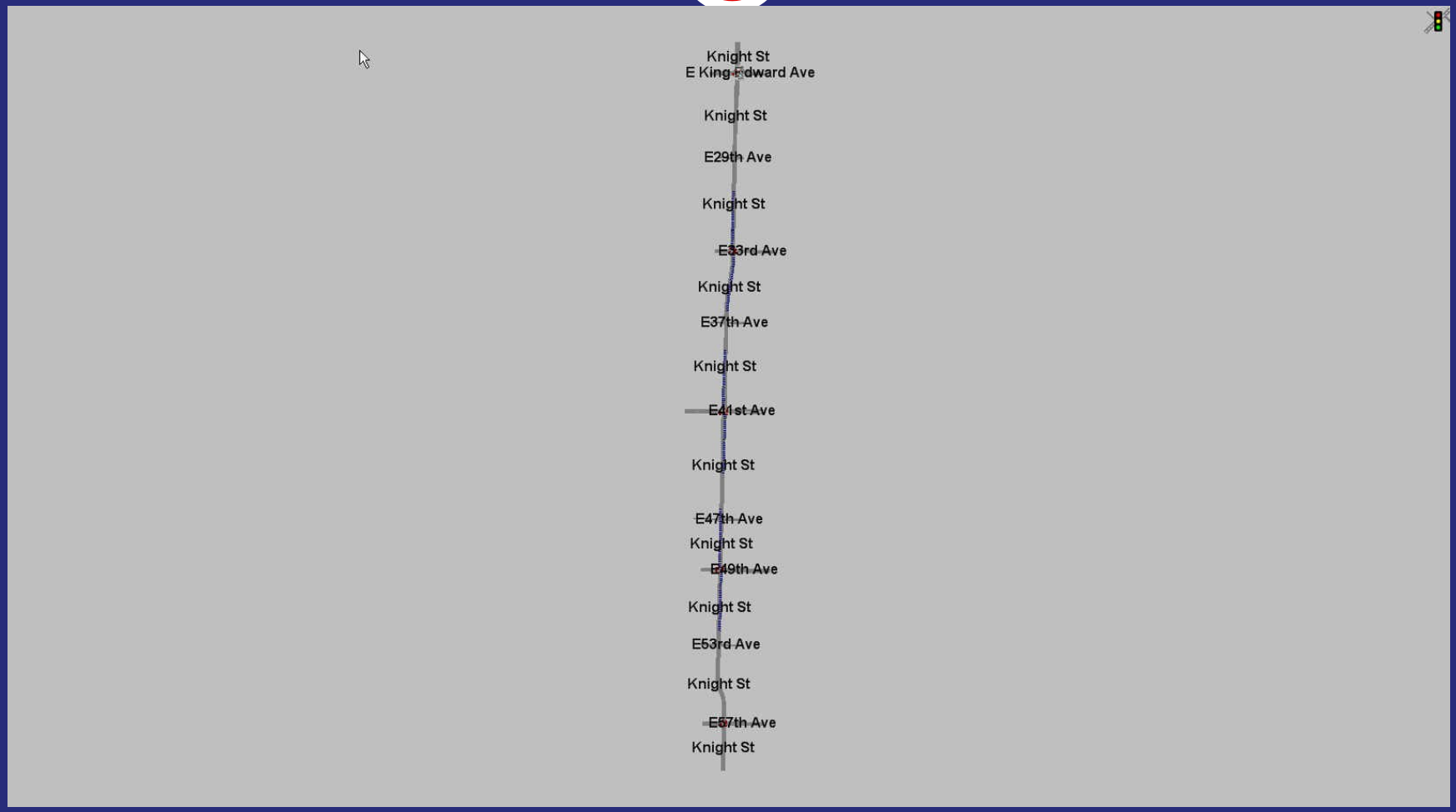
Experimental Results

- The recall for trucks reaches 78% to 95%, with a false alarm rate below the 0.5% value used for the system simulation.

Simulation Model

- Study Corridor
  - Knight Street (King Edward – 57th Ave)
    - Major Truck Route
    - 3 Intersections (2 Two phased, 1 Four phased)
- Simulation Software
  - Vissim
  - VisVap

Network


Knight St
E King Edward Ave
Knight St
E29th Ave
Knight St
E33rd Ave
Knight St
E37th Ave
Knight St
E41st Ave
Knight St
E47th Ave
Knight St
E49th Ave
Knight St
E53rd Ave
Knight St
E57th Ave
Knight St

TSP Strategy

- Green Extension
- Red Truncation

Conventional System

- No Prediction
- Two Detectors
  - Check-in: 50-100 m upstream of the intersection
  - Check-out: immediately after the intersection

Conventional System

- Shortcomings
  - Do not count in the travel time from a check-in detector to the intersection.
    - Opportunities for Green Extension can be missed.
  - A queue may extend beyond a check-in detector.
    - Do not call for red truncation sufficiently early to dissipate the queue.

Truck Detection

- Video Sensor
- Detect trucks from 300 meters.
- Continuously track trucks.
  - Simulated by normal detectors in 10 meter spacing.
- Consider the closest truck only.
  - The next truck will be considered after the closest truck checks out.

Detection Errors

- Missed Truck
  - 10% of trucks are assumed to be not classified as trucks.
- False Detection
  - 0.5% of non-truck road users are assumed to be classified as trucks.

Travel Time Prediction

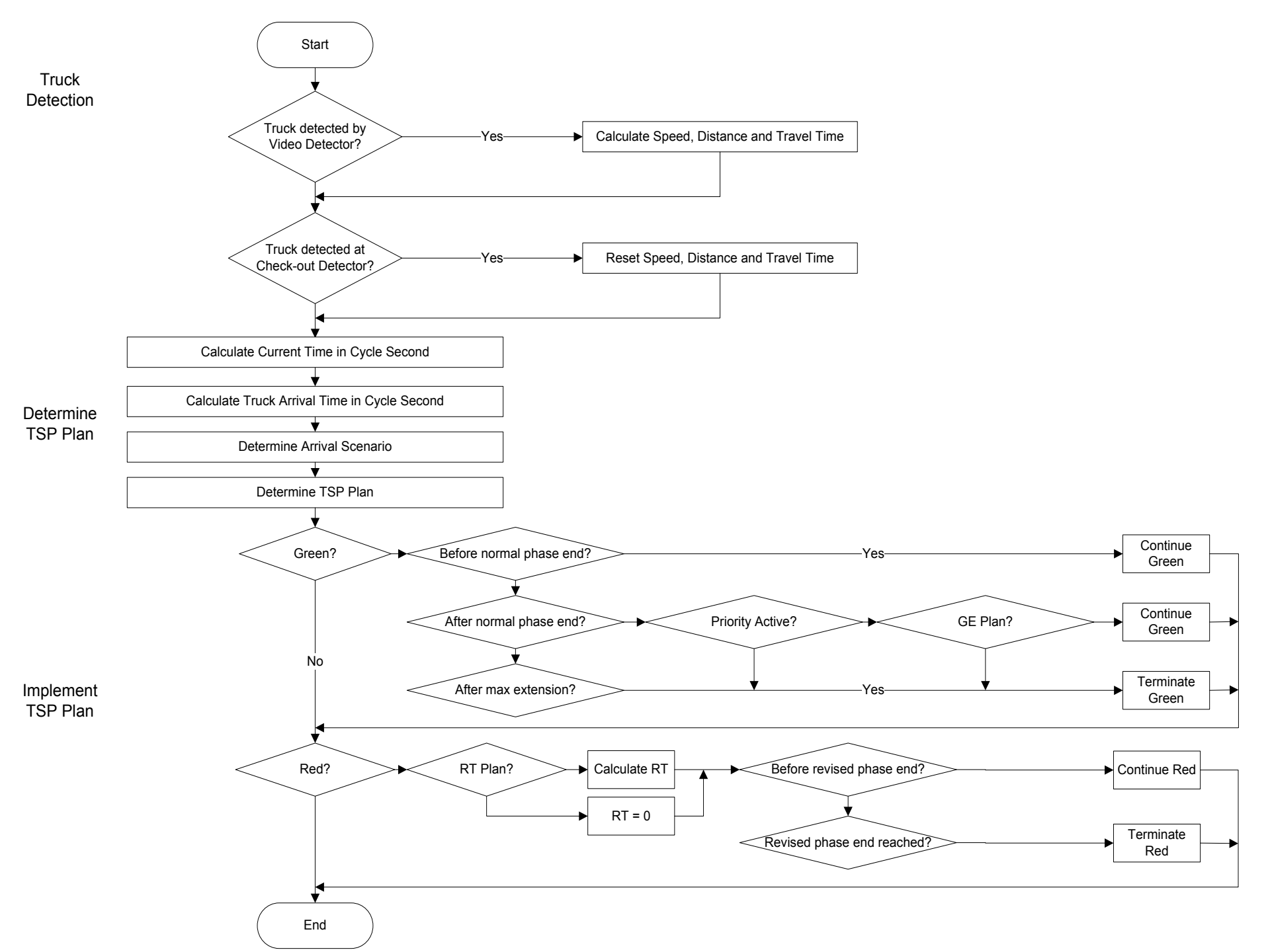
- Detect trucks from 300 meters ahead of an intersection and predict arrival time.
  - Travel Time = Distance / Speed
- Continuously track trucks and update prediction.

Green Extension

- Extend Green if a Truck will arrive within the Maximum Extension Limit.
- Cancel Green Extension if the truck will not arrive within the Limit according to Prediction Update
- Terminate when the truck checks out.

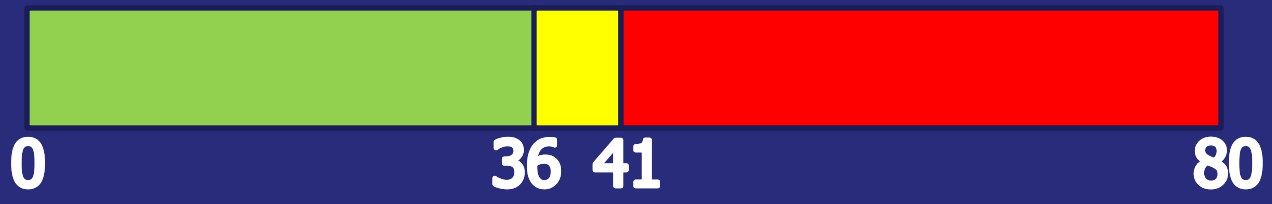
Red Truncation

- Truncate red if a truck will arrive after the maximum green extension Limit.
- Calculate queue dissipation time and start red truncation when required.


Truck Detection
Start
Truck detected by Video Detector?
Yes
Calculate Speed, Distance and Travel Time
Truck detected at Check-out Detector?
Yes
Reset Speed, Distance and Travel Time
Determine TSP Plan
Calculate Current Time in Cycle Second
Calculate Truck Arrival Time in Cycle Second
Determine Arrival Scenario
Determine TSP Plan
Implement TSP Plan
Green?
Before normal phase end?
Yes
Continue Green
After normal phase end?
Priority Active?
GE Plan?
Continue Green
No
After max extension?
Yes
Terminate Green
Red?
RT Plan?
Calculate RT
RT = 0
Before revised phase end?
Continue Red
Revised phase end reached?
Terminate Red
End

Example

- Intersection 7: Knight St. and 49th Ave.
- Signal Timing
  - 80 sec cycle length, 2 phases (Φ1 Truck phase)



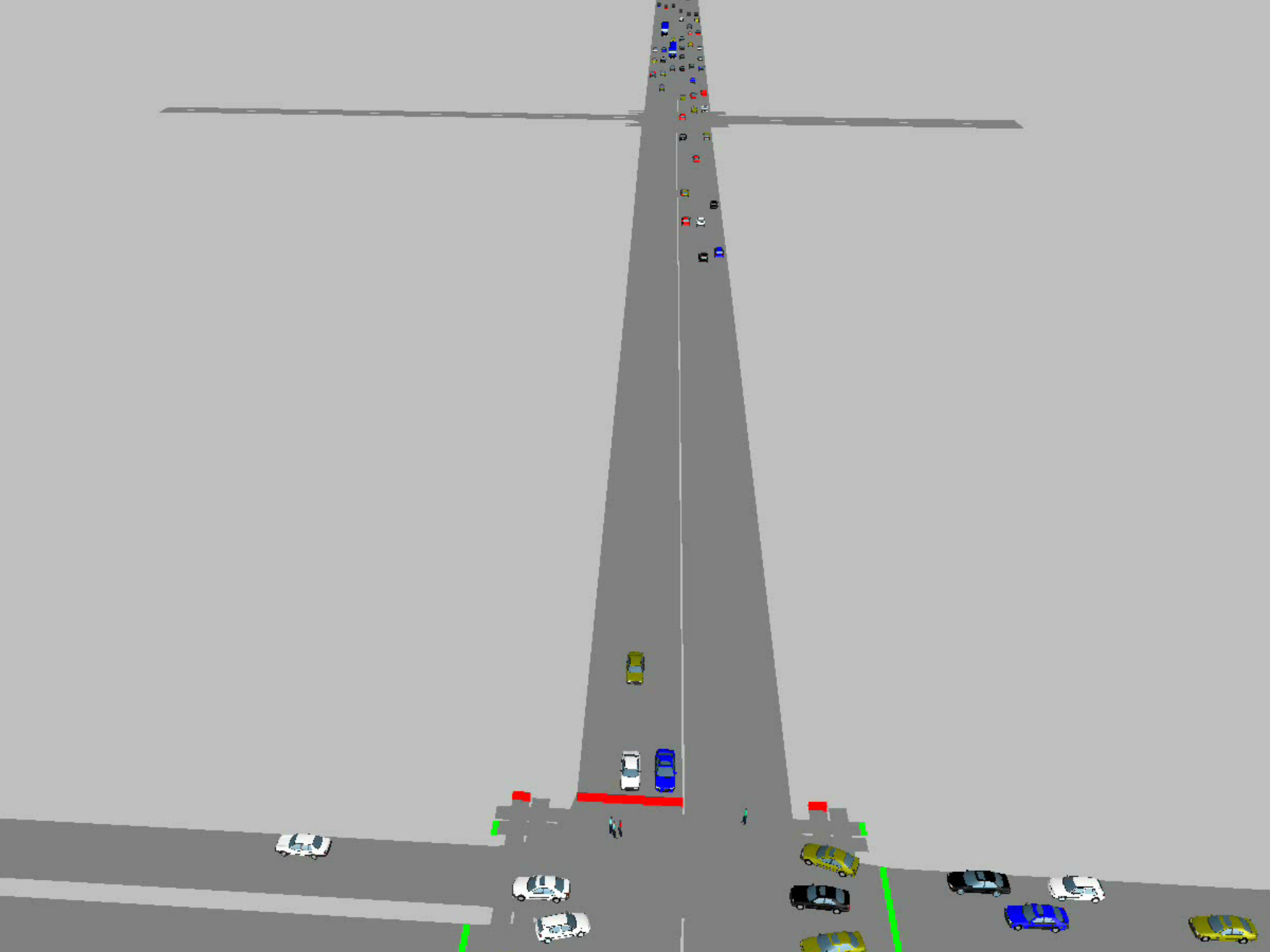
  - Maximum Green Extension: 15 sec
  - Maximum Red Truncation: 15 sec

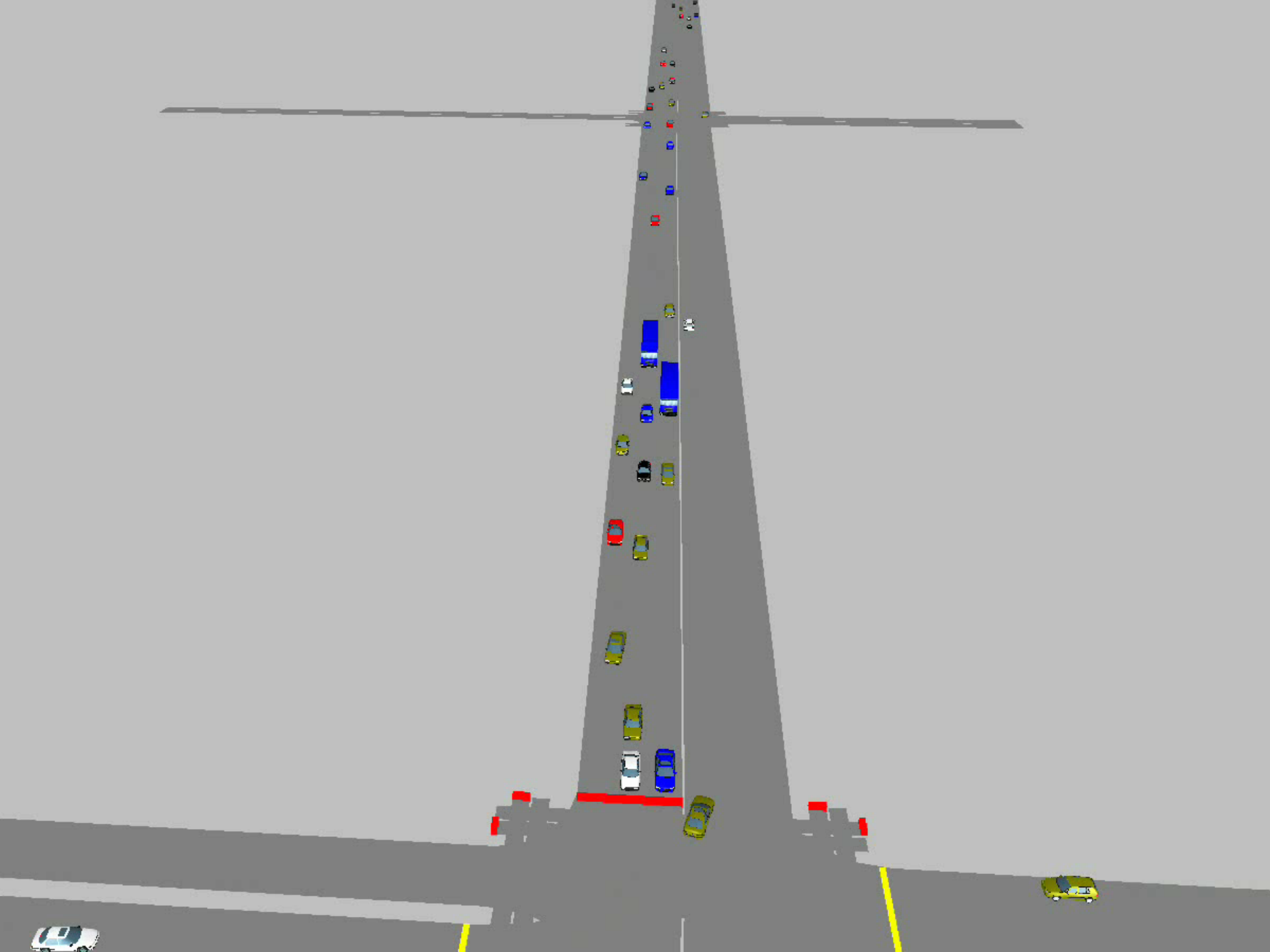
Example: Green Extension

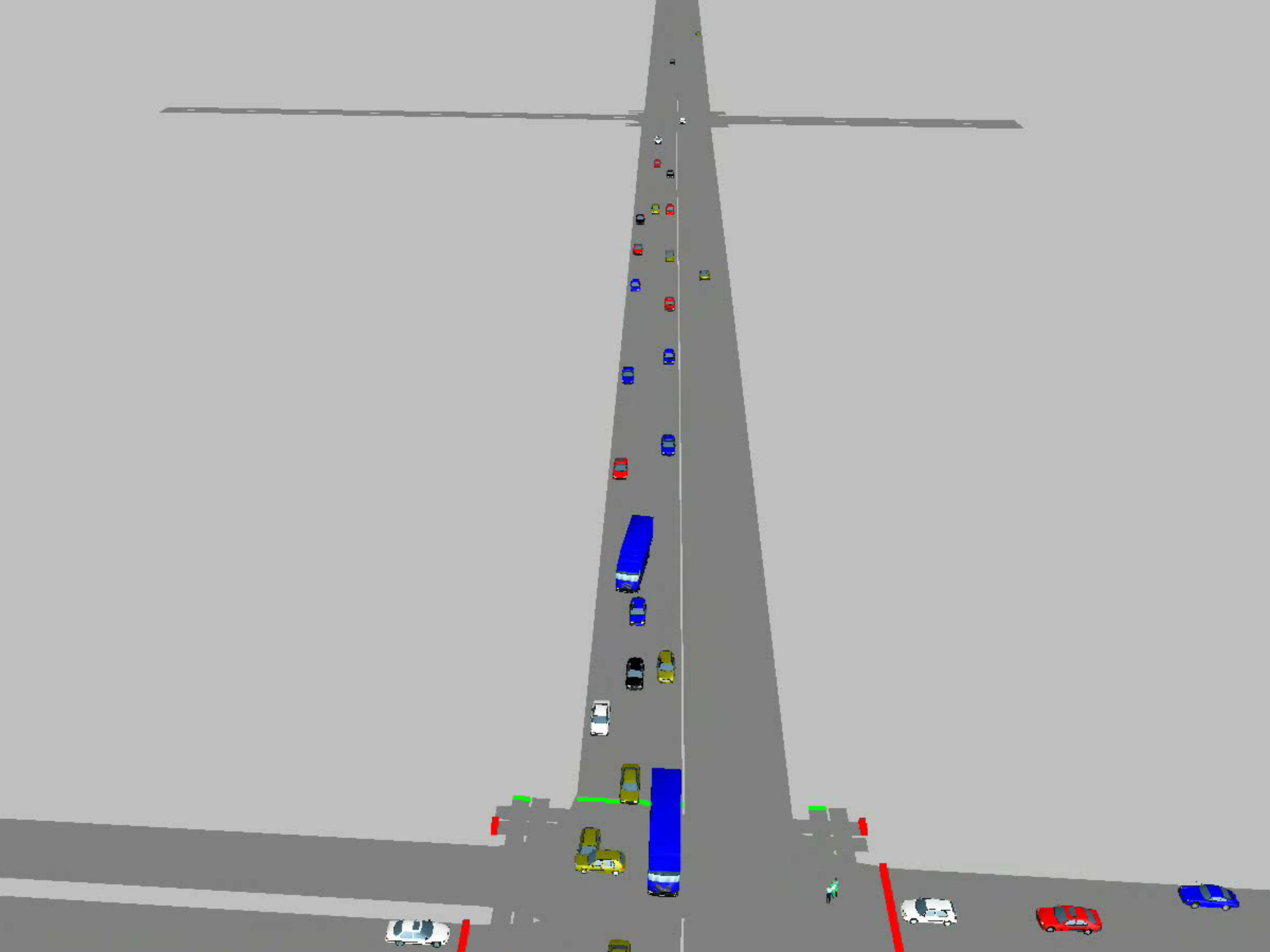
Sim Sec	Cycle Sec	Dist-ance	Travel Time	Event
561	0			Start of Green
588	27	290	19.0	Truck detected. 9 seconds to normal green end time.
597	36	160	10.9	Normal green end time. The truck is still 160 m away.
603	42	70	4.7	Conventional system would detect the truck 6 seconds after the normal green end time, only 5 seconds before arrival time.
608	47	0	0	The truck checks out and green end. Green was extended for 11 seconds.

Example: Red Truncation

Sim Sec	Cycle Sec	Dist-ance	Travel Time	Event
677	36			Start of Red
688	47	300	21.4	Truck detected. 25 seconds to normal red end time.
702	61	110	8.1	Red truncated for 9 seconds. The truck is still 110 m away.
704	63	80	6.2	Conventional system would detect the truck 2 seconds after the time to truncate red, only 6 seconds before arrival time.
707	66	50	5.4	Start of Green
713	72	0	0	The truck checks out after queue dissipation, 11 seconds after red truncation.







Base Case Condition

- Three lanes per direction
- AM Peak hour 8-9AM
- Volume
  - NB 1,304-1,466 vph
  - SB 665-1,058 vph
- Truck Volume
  - NB 47-51 vph
  - SB 26-42 vph
- Priority Lock: One Cycle Length

Travel Times

Direction	Section	Distance (m)	The Average Travel Time (sec)			The Average Travel Time Change (%)	
			No TkSP	Conventional TkSP	Advanced TkSP	Conventional TkSP	Advanced TkSP
NB	57th to 47th	1,060	92.5	94.1	89.0	1.67%	-3.81%
	47th to 37th	1,023	100.0	103.4	103.1	3.43%	**3.15%**
	37th to 29th	858	92.6	94.7	82.2	2.32%	-11.20%
	Total	2,941	285.1	292.2	274.4	**2.50%**	**-3.77%**
SB	29th to 37th	858	71.9	68.3	67.8	-5.00%	-5.66%
	37th to 47th	1,023	78.7	83.2	85.2	5.66%	**8.26%**
	47th to 57th	1,060	108.3	108.3	110.2	-0.04%	1.69%
	Total	2,941	258.9	259.8	263.2	0.32%	**1.65%**

Delay

Intersection		Approach	Average Delays and Volumes						Delay Change (%)	
			No TkSP		Conventional TkSP		Advanced TkSP		Conventional	Advanced
No.	Streets		Delay(s)	Volume	Delay(s)	Volume	Delay(s)	Volume	TkSP	TkSP
3	Knight and E33rd	NB	28.6	1,472	37.7	1,481	25.8	1,465	31.7%	-9.6%
		SB	10.5	709	9.0	710	9.4	710	-14.4%	-11.2%
		Knight St.	11.4	2,181	14.2	2,190	10.2	2,175	24.9%	-10.0%
		EB	17.5	663	15.6	663	18.6	666	-10.4%	6.6%
		WB	20.2	991	17.7	991	21.2	992	-12.1%	5.0%
		Cross Road	9.5	1,655	8.4	1,653	10.1	1,658	-11.5%	5.6%
		Total	21.2	3,836	23.5	3,843	20.3	3,833	10.8%	**-3.9%**
5	Knight and E41st	NB	27.9	1,595	32.3	1,597	30.3	1,584	15.7%	8.4%
		SB	9.0	899	13.3	901	13.0	901	47.6%	44.0%
		Knight St.	10.6	2,494	12.7	2,498	12.0	2,485	20.6%	13.7%
		EB	23.1	1,029	21.8	1,028	23.5	1,030	-5.4%	2.1%
		WB	28.9	1,380	27.4	1,377	29.7	1,379	-5.3%	2.6%
		Cross Road	13.2	2,409	12.5	2,405	13.5	2,409	-5.3%	2.4%
		Total	23.7	4,903	25.2	4,904	25.5	4,894	6.3%	**7.4%**
7	Knight and E49th	NB	19.5	1,586	22.0	1,584	17.1	1,590	12.7%	-12.5%
		SB	11.5	1,090	11.4	1,087	10.6	1,102	-1.1%	-7.4%
		Knight St.	8.1	2,676	8.8	2,671	7.2	2,692	8.8%	-11.1%
		EB	16.7	462	13.9	462	16.7	460	-16.8%	0.4%
		WB	17.8	1,033	15.8	1,034	18.2	1,031	-11.7%	2.0%
		Cross Road	8.7	1,494	7.6	1,495	8.9	1,491	-13.2%	1.5%
		Total	16.7	4,171	16.8	4,166	15.6	4,183	0.7%	**-6.4%**
Network Total			20.7	12,910	22.0	12,913	20.8	12,910	6.3%	**0.6%**

Performance for:
70% volume, 1% truck, No priority lock

Direction	Section	Distance (m)	The Average Travel Time (sec)		Change (%)
			No TSP	Advanced TSP	
NB	57th to 47th	1,060	89.7	81.5	-9.14%
	47th to 37th	1,023	99.6	97.2	-2.43%
	37th to 29th	858	84.7	70.2	-17.11%
	Total	2,941	273.9	248.8	**-9.16%**
SB	29th to 37th	858	69.2	64.8	-6.35%
	37th to 47th	1,023	81.8	80.3	-1.83%
	47th to 57th	1,060	98.5	102.1	3.63%
	Total	2,941	249.5	247.2	**-0.93%**

Conclusion

- Decrease HGV travel time.
- Do not increase all vehicle travel time when traffic volume is moderate to high.
- Performance is better when
  - traffic volume is less than that of peak hour;
  - truck volume is less than one in a cycle;
  - priority is not locked.

Further Study: Potential Improvement

- Gradual change of signal timing over 1-2 cycle.
  - Requires early detection and prediction.
  - Requires travel time prediction model for roadway sections in which there are multiple intersections.
    - Predict travel time including intersection delay
    - Use signal time data