Shadow-cum-Material Vehicle:

Innovation for Enhancing Prevailing Work-Zone Safety Practices along Indian Highways

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Technical Session 3: Data-Driven Approaches to Road Safety for Forgiving Roads

05th February 2026

Content

Introduction

Accident Statistics

- 4.8 lakh road accidents
- 1.7 lakh fatalities

Work Zone Statistics

- 9,425 Crashes
- 3,904 Fatalities
- 8,246 Injuries

Source: (MoRTH, Road Accidents in India – 2023)

Reasons?

- **Insufficient Enforcement**
- **Poor Delineation**
- **Improper Traffic Management**
- **Low Compliances**

Present Safety Arrangement as per IRC

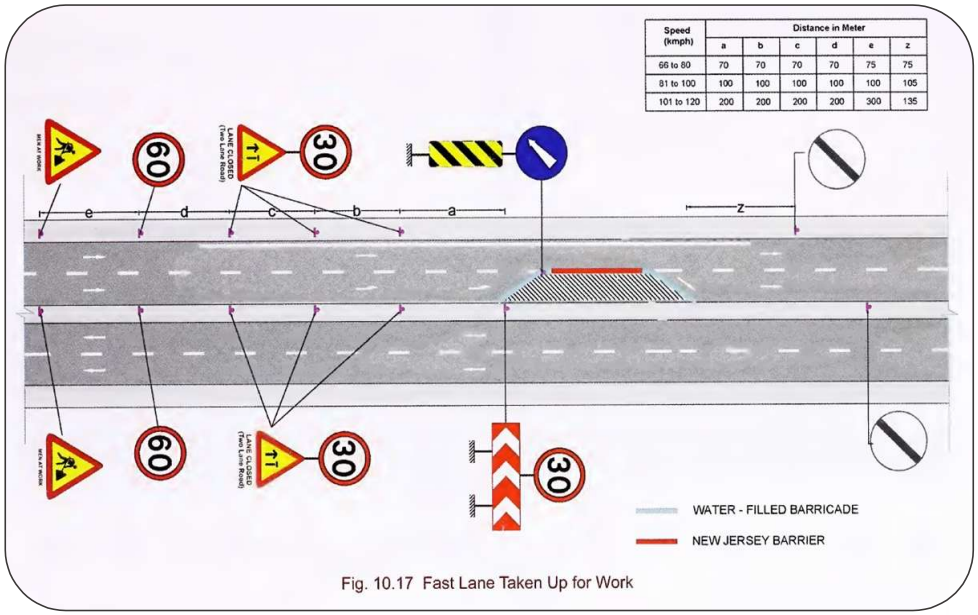
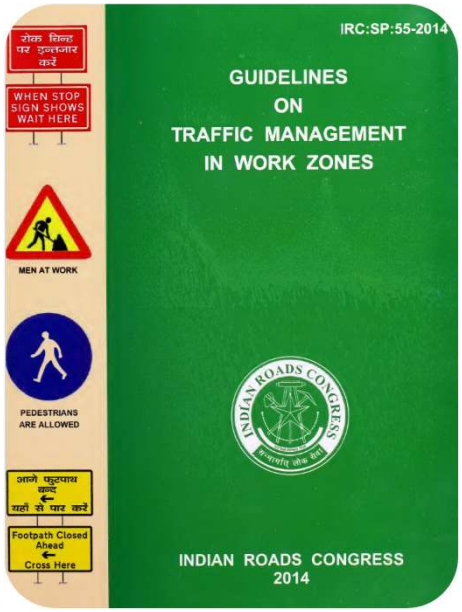


Fig. 10.17 Fast Lane Taken Up for Work



IRC: SP:55-2014
(Guidelines on Traffic Management in Work Zones)

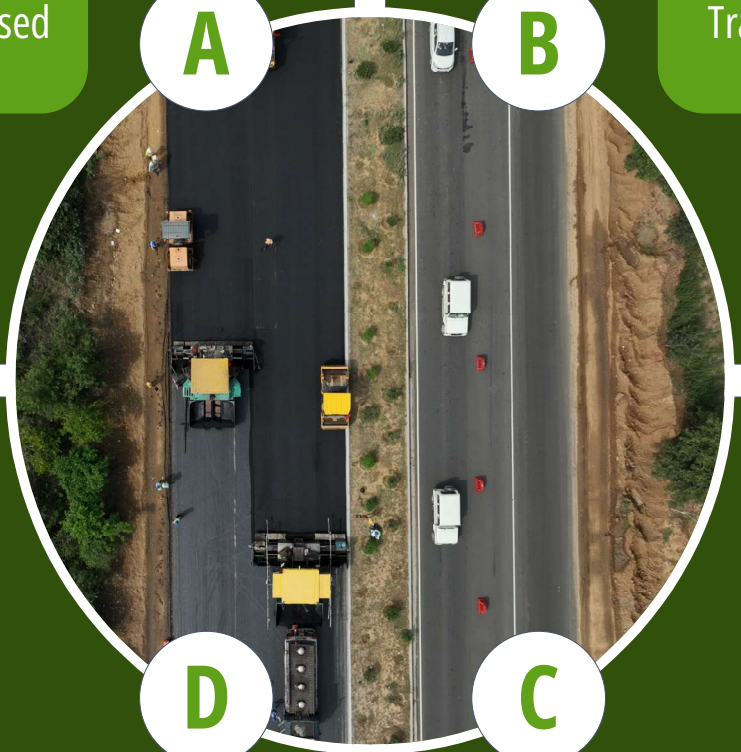
Current TMP Practices

- **IRC SP:55-2014 focus:** Prescribes static work-zone (Fast Lane Closure) layouts through defined placement of signs, cones, and barricades.
- The guidelines **primarily address** the configuration of work zones after full deployment of traffic control devices and shall be followed for static and semi-static work activities.
- Safety arrangements during transitional phases such as installation, adjustment, and removal of traffic management devices are **not specified**

IRC Challenges in Work Zone

A. Short–duration works are unaddressed

B. Traffic Management Set-up exposure



C. Absence of Activity based TMPs

D. Unsafe Equipment Logistics

International Standards: TMAs

Truck Mounted Attenuator (TMA) is a crash-absorption device mounted on a truck to protect road workers and approaching motorists by reducing the impact severity if a vehicle collides with a work-zone protection vehicle.

Advantage

- Provides strong impact protection in high-risk zones
- Reliable for mobile and short-duration work
- Safeguards both workers and approaching motorists
- Improves visibility and driver awareness

Challenges

- Worksites are too numerous in the Indian context.
- Limited budgets and fleet sizes restrict deployment.
- Equipment requires operations and maintenance.
- Imported equipment. Substantially high costs with maintenance challenges.

While TMAs are vital for high-exposure, high-risk sites, India also needs a ***scalable complementary solution*** - one that the Shadow-cum-Material Vehicle effectively provides by bridging operational and logistical gaps.

Basis for Developing the SCMV Concept

Existing Shadow Vehicle

Existing Material Carrying Vehicle

Challenges

- High-Risk Transition Phases
- Short-Duration & Mobile Works Gap
- Logistics & Sequencing Challenges
- Limited Applicability of Advanced Systems
- Need for Process-Oriented Safety

The SCMV is conceptualized to address these gaps by integrating shadow protection, organized material handling, and controlled withdrawal into a single, operationally feasible system.

Why both Vehicles Needs Integration?

Concept to Solution: Why SCMV?

SCMV improves operational safety where static layouts alone are insufficient

- Addresses **high-risk TMP transition phases** not explicitly covered in IRC: SP:55.
- Provides **continuous upstream protection** during set-up and dismantling
- Reduces **worker exposure to live traffic** in short-duration and mobile works
- Enables **systematic TMP deployment** through organized material handling
- Uses **commonly available project vehicles** with safety-oriented modifications
- Acts as a complementary measure not a replacement for TMAs

Concept - Stages

STAGE - 1

Upstream Shadow Protection (Set-up Phase)

- SCMV positioned upstream before any worker enters the carriageway
- High-visibility chevrons, retro-reflective panels, beacons, and message boards
- Establishes a **mobile protective buffer** between live traffic and workers

STAGE - 2

Organized & Sequential TMP Deployment

- Cones, signs, barricades stored in pre-defined sequence as per IRC layouts
- Direct unloading from vehicle minimizes random lane crossings
- Faster deployment = **shorter exposure duration**

STAGE - 3

Controlled Withdrawal & Safe Dismantling

- SCMV remains upstream until the **last TMP device is removed**
- Phased downstream withdrawal under continuous shadow protection
- Reduces rear-end and side-swipe risks during dismantling

Modified Prototype Shadow cum Material Vehicle Specification

LASB *(LED Arrow Sign Board)* Implementation Placement

Behind the Driver's Cabin

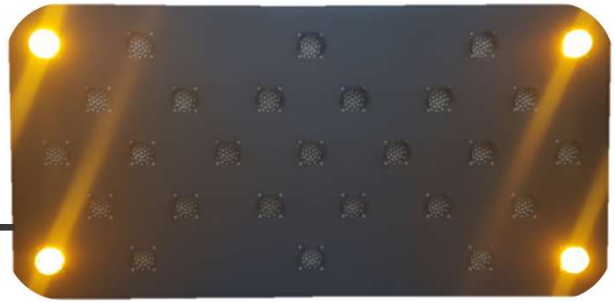
LASB Site Arrangement

LASB Light Modes

Pattern Flashing Rate:	
Four Corners	10 times on and 10 times off in 1 sec
Arrow Pattern	1 sec on 1 sec off

Working Modes

Four Corners



Continuous Left with Alternate four Corners

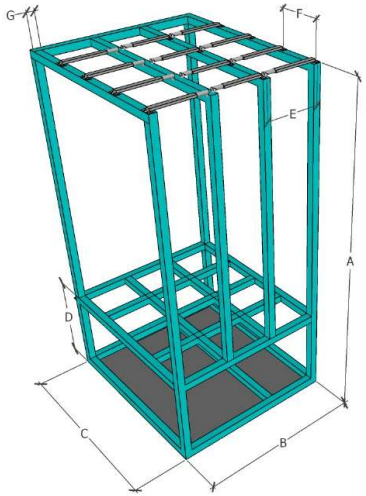
Continuous Right with Alternate four Corners

Both Sides Arrow with Alternate four Corners

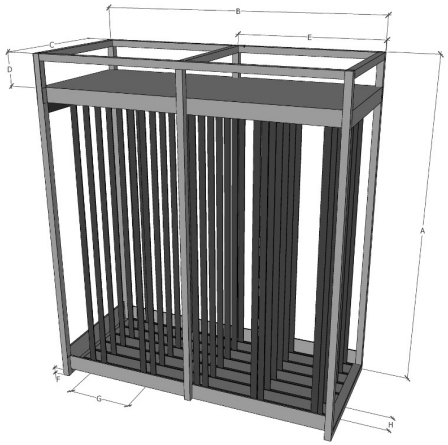
Modular Storage

Safety Cone Stand

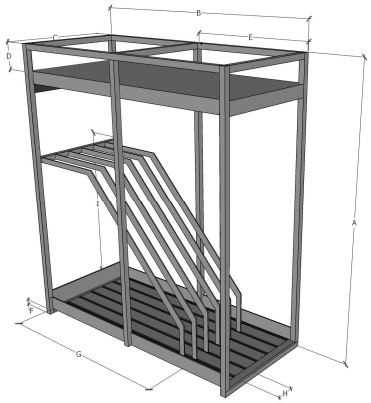
Tripod Stand



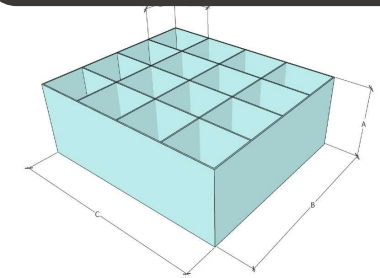
Signboard Stand - 1



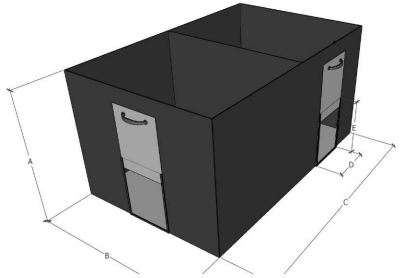
Signboard Stand - 2



Weight Stand



Material Box



Alignment with International Standards (AASHTO)

Closure/Exposure Condition	Examples of Typical Construction Maintenance Activities	Ranking*			
		Freeway	Non-Freeway		
			80 km/h [50 mph]	70 km/h [45 mph]	60 km/h [40 mph]
Mobile Activities					
No Formal Lane Closure					
Shadow vehicle for operation involving exposed personnel	Crack pouring, patching, utility work, striping, coning	A-1	A-2	A-3	A-4
Shadow vehicle for operation not involving exposed personnel	Sweeping, chemical spraying	E-1	E-2	E-3	E-4
No Formal Shoulder Closure					
Shadow vehicle for operation involving exposed personnel	Pavement repair, pavement marking, delineator repair	B-2	B-3	C-3	C-3
Barrier vehicle for operation not involving exposed personnel	Open excavation, temporarily exposed bridge pier	E-2	E-3	E-4	E-5
Stationary Activities					
Formal Lane Closure					
Barrier vehicle for operation involving exposed personnel	Pavement repair, pavement marking	B-2	B-3	C-4	D-5
Barrier vehicle for condition involving significant obstruction	Open excavation	E-2	E-3	E-4	E-5
Formal Shoulder Closure					
Barrier vehicle for operation involving exposed personnel	Pavement repair, pavement marking, guardrail repair	C-3	C-4	D-5	D-5
Barrier vehicle for condition involving significant obstruction	Open excavation	E-3	E-4	E-5	E-5

* The alphabetic ranking indicates the priority assigned to the use of a protective vehicle. The use of protective vehicles:

A—is very highly recommended
B—is highly recommended
C—is recommended
D—is desirable
E—may be justified on the basis of special conditions encountered on an individual project when an evaluation of the circumstances indicates that an impact with a protective vehicle is likely to result in less serious damage and injury than would impact with a working vehicle or the obstruction

* The numerical rank indicates the level of priority assigned to the use of a TMA on an assigned protective vehicle.

The use of a TMA under the defined conditions:

1— is very highly recommended
2—is highly recommended
3— is recommended
4—is desirable
5—may be justified on the basis of special conditions encountered on an individual project

For Shadow Vehicles Weighing 10 000 kg [22,000 lb] or More					
Operating Speed/Speed Limit[a]		Recommended Spacing[a]			
		Stationary Operation		Moving Operation[c]	
km/h	[mph]	m	[ft]	m	[ft]
Greater than 90	[Greater than 55]	45	[150]	52.5	[172]
70–90	[45–55]	30	[100]	45	[150]
Less than 70	[Less than 45]	22.5	[74]	30	[100]
For Shadow Vehicles Weighing Less than 10000 kg [22,000 lb] but Greater than 4500 kg[d] [9,900 lb]					
Operating Speed/Speed Limit[a]		Recommended Spacing[b]			
		Stationary Operation		Moving Operation[c]	
km/h	[mph]	m	[ft]	m	[ft]
Greater than 90	[Greater than 55]	52.5	[172]	67.5	[222]
70–90	[45–55]	37.5	[123]	52.5	[172]
Less than 70	[Less than 45]	30	[100]	30	[100]

Footnotes:
a) Should use operating speed if higher than posted speed limit.
b) Recommended spacing is distance between front of shadow vehicle and beginning of work area, that is, the first worker/operation/vehicle to be protected.
c) Distances are appropriate for shadow vehicle speeds up to 25 km/h [15.5 mph].
d) Shadow vehicles shall weigh 8000 kg to 9000 kg [17,600 to 19,800 lb] on all department construction projects.

Notes:
1. The heaviest shadow vehicle should be used to optimize protection of maintenance or construction workers. Because roll-ahead is minimized with heavier shadow vehicles, they can be placed closer to the work space to minimize the risk of vehicles cutting in ahead of the shadow vehicles.
2. The spacing distance is good with or without a TMA. A vehicle equipped with a TMA may move less than a truck not equipped with a TMA. However, the recommended spacing is conservative enough to allow the same spacing for a TMA versus a vehicle without a TMA.
3. Distances are intended as guidelines. However, engineering judgment should be used to alter distance to take into account traffic conditions, vehicle mix, sight distance, and other site conditions.

Problem

- Indian highways experience frequent short-duration and mobile works
- Full TMA deployment at every site is operationally challenging
- TMP set-up and dismantling remain high-risk phases

International Practice (AASHTO)

- AASHTO recognizes shadow vehicles and TMAs based on speed and exposure
- Shadow vehicles provide upstream buffering and visibility for mobile works
- Vehicle mass and spacing govern buffer protection requirements

SCMV Alignment

- SCMV operates as a shadow vehicle with enhanced conspicuity
- Suitable for urban roads and highway maintenance at 60–80 km/h
- Complements TMAs while extending protection to short-duration work phases

Risk Reduction Assessment (HIRA-Based Evidence)

The primary objective of the risk assessment is to evaluate the safety and effectiveness of using shadow vehicles (Without TMA) in dynamic work zones.

Likelihood (What is the probability that risk will happen)	Impact Severity (How severe the outcomes if the risk occurred)					
	Insignificant 1	Minor 2	Significant 3	Major 4	Severe 5
Almost Certain 5	Medium 5	High 10	Very High 15	Extreme 20	Extreme 25
Likely 4	Medium 4	Medium 8	High 12	Very High 16	Extreme 20
Moderate 3	Low 3	Medium 6	Medium 9	High 12	Very High 15
Unlikely 2	Very Low 2	Low 4	Medium 6	Medium 8	High 10
Rare 1	Very Low 1	Very Low 2	Low 3	Medium 4	Medium 5

Likelihood	
Rare	Unlikely to happen and/or have minor or negligible consequences
Unlikely	Possible to happen and/or to have moderate consequences
Moderate	Likely to happen and/or to have serious consequences
Likely	Almost sure to happen and/or to have major consequences
Almost certain	Sure to happen and/or have major consequences

Impact Severity	
Insignificant	Won't cause serious injuries or illnesses
Minor	Can cause injuries or illnesses, only to a mild extent
Significant	Can cause injuries that may require limited medical attention
Major	Can cause irreversible injuries that require medical attention
Severe	Can result in fatality

HIRA – Based Evidence

Without Shadow cum Material Vehicle

- TMP set-up and retrieval rated High Risk
- Risk scores typically **20–25** due to live traffic exposure

With Shadow cum Material Vehicle

- Controlled upstream shadowing and phased withdrawal
- Risk scores reduced to Medium–Low (**9–12**)

Key Outcomes

- The assessment outcomes indicate **potential for risk reduction during short-duration work phases**, warranting further structured evaluation.
- SCMV is considered a complementary safety measure and not a replacement for TMAs in high-risk or long-duration work zones.

These findings may be considered as preliminary evidence to support structured pilot studies and further technical evaluation for possible inclusion in future IRC guidelines, particularly for short-duration and mobile work zones.

Evidence based Impact

Risk related Impact

- Significantly reduces worker exposure to live traffic
- Minimizes chances of rear-end collisions
- Reduces multi-vehicle movement risk

Material related Impact

- Ensures uninterrupted material availability
- Improves response time
- Minimizes clutter and uncontrolled stops

Training related Impact

- Improves SOP compliance
- Enhances safety culture
- Simplifies training requirements

Field Performance & Operational Evidence

Observed Outcomes

Scale of Deployment	Traffic Interaction	Safety Indicator	Operational Efficiency	Exposure Reduction
SCMV implemented across 100+ highway work zones	Improved driver expectancy and speed moderation upstream	~25% reduction in rear-end near-miss incidents during mobile operations	30–40% reduction in TMP set-up and dismantling time	Shorter on-carriageway duration directly reduced worker exposure to live traffic

The above observations are indicative in nature, based on field deployments and internal monitoring. Outcomes may vary depending on site conditions, traffic characteristics, compliance levels, and operational controls.

Discussion & Way Forward

Limitations

- SCMV is **not a replacement** for TMAs in high-risk, long-duration, or expressway work zones.
- Best suited for **short-duration, mobile, and semi-static works** with trained operators.

Policy Direction

- Need for **national testing & certification facilities** for TMAs and shadow vehicles.
- Recommendation to integrate **AASHTO-style speed-based application guidance** in future IRC:SP:55 revisions.

CONCLUSION

✓ SCMV closes a critical safety gap in setup and removal phases.

✓ Provides a practical, scalable safety enhancement for India's highways and urban roads.

✓ Works best and SAFEST when used alongside TMAs and IRC-compliant controls.

THANK YOU

Safety Starts with ME