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Occupational Safety and Health in Highway Maintenance Yards: an Approach Suitable to Face Special Criticalities

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On the request of Prosecutor Office, the Authors carried out a research work to define the extent of the Occupational Safety and Health - OS&H criticalities affecting the highway maintenance yards, in normal and special scenarios where hazardous freights are involved. The high number of work related accidents in maintenance/improvement yards, often characterized by dramatic Severity Rates, requires a special Risk Assessment and Management. The paper summarizes the results of a research leading to identify the main parameters directly or indirectly conditioning the design and safety of the highway maintenance yards. We developed a schematization of yard typologies and contexts, upon which a thorough Risk Assessment and Management becomes possible. Moreover, an original Accident Analysis Technique provided precious support to the study, filling the gaps of information on the Standards violations of some accident databases. Finally, the paper discusses some innovative Safety Control measures for different highway scenarios.

1. The context and OS&H problems in highway maintenance yards

The Italian Highway System covers more than 6000 km, with 1800 km of tunnels, bridges and viaducts. This involves the need of systematic maintenance and special interventions, due to the highly variable Italian climatic conditions, imposing additional wear to structures and materials of large part of the network. Additional deterioration factors, such as mean altitude a.s.l. and traffic load, affect some stretches: Table 1 summarizes the “total” and “heavy vehicles” traffic rates.

Table1: Italian highway Traffic rate (source Italian Association of Highway and Tunnel Companies - Aiscat)

Cumulative data January-March 2015 (millions of vehicles per km)					
Italian highway stretches (companies)	Total	Heavy vehicles	Italian highway stretches (companies)	Total	Heavy vehicles
Autostrade per l'Italia	9340.1	2307.4	Centro Padane	215.2	74.5
Traforo Monte Bianco	2.43	0.85	Brescia-Padova	1134	321.2
Traforo S.Bernardo	1.54	0.15	C.A.V.	369.3	95.6
R.A.V.	24.2	6.6	Brennero	959.8	284.2
S.I.T.A.F.	78.3	21.1	Autovie venete	521.3	169.1
S.A.V.	78.8	17.3	Autostrada dei fiori	240.7	63.2
A.TI.VA.	113.2	19.4	Aut.le della Cisa	136.3	41
Asti-Cuneo	29.6	7.1	S.A.L.T.	352.2	79.7
S.A.T.A.P. A 4	511	128.2	S.A.T.	38.7	8.5
S.A.T.A.P. A 21	426	147.7	Strada dei parchi	459.1	63.5
Torino-Savona	177.9	130.9	Tang.le di Napoli	221	18.3
Milano Serravalle- MI.Tang.li	320.9	65.7	Aut. Meridionali	353.3	32.8
Società di progetto BREBEMI	51.9	12.2	Consorzio Aut. Siciliane	330.4	52
Tang.le Esterna di Milano	4.5	1.0	Total	16491.7	4169.2

The presence of dangerous goods further increases the importance of maintenance and the criticality of the maintenance yards: dangerous goods are 10.5 % of the total transported freights, and 52 % travel by road (Italian Federchimica data). In Figure 1 (left) the dangerous goods circulating in the 28 EU countries in 2013. Eurostat data evidence a 8.4 % decrease of dangerous goods transportation on road in Italy, but the problem still remains concerning (approx. 7.000 t per kilometer), and a careful safety analysis of the traffic - yards interferences is still a priority.
From January 2008 to May 2013, 5562 non-fatal and 87 fatal accidents (the 1.5 % of the total) occurred in the Italian highway maintenance yards (source National Institute for Work Injury Insurance - Inail). In Figure 1 (right) the main causes of accidents in the Italian highway maintenance yards (from the same source).

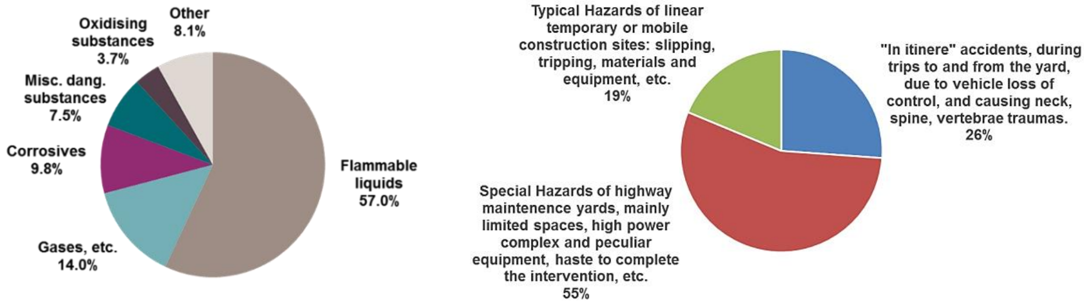

Figure 1: Dangerous goods circulating in the EU countries in 2013- source Eurostat (left); accidents typologies occurred in Italian highway maintenance yards (right).

A comparison between Italian and USA data from 2003 to 2007 (sources Occupational Safety and Health Administration - OSHA, and Census of Fatal Occupational Injuries - CFOI), confirmed the similarity in terms of hazard factors and criticalities of highway maintenance yards. Workers run over causes 50 % of the fatal accidents: run overs are due to equipment and vehicles belonging to the firm in charge of the site (54 %), or to other companies involved in the work (46 %) (Pegula, 2010). The Inail database provides no information on the accidents due to traffic - maintenance sites interference; according to the OSHA database the run overs of maintenance workers due to traffic amount to approx. 30 % of the total.
The Authors also referred to the National Statistical Institute - ISTAT and Italian Automobile Association - ACI data, to investigate the violations of the Traffic Laws, and the result is impressive: the total number of sanctioned violations in 2013 is more than 900,000 (560,000 for excessive speed, 35,000 general for reckless driving). No direct correlation is at present possible, but countermeasures are certainly necessary.
The OS&H situation resulting from the analysis of accident data demonstrates the general lacking Culture of Safety in terms of understanding of the interactions between cultural and contextual variables in a given scenario, and the effect they have on safety.

2. Risk Assessment and Management in highway maintenance yards

Risk can be defined (Borchiellini et al., 2015) as the potential of losing something of value: life, health, property or environment can be compromised by a given action, activity or inaction (whose probability can be estimated) involving a Hazard Factor which can cause the Unwanted Event and related losses.
Risk Assessment: the evaluation -pivotal to define a correct prioritization of Risk Management- of the levels of risk involved in a situation.
Risk Management: all the activities giving rise to the elimination / minimization of risks, through prevention (technical, organizational or procedural steps to reduce -and possibly set to zero- the frequency of occurrence or the contact factor), or protection (general or personal), to mitigate the severity of the possible damage.
An accurate Risk Assessment in complex situations, such the one under exam, requires a systematic approach, based on a rigorous schematization of the various contexts, scenarios and types of maintenance and improvement yards, to bring into evidence the problems which may be added to those typical of similar temporary or mobile construction sites (see Table 2).

Table 2: Highway maintenance yards: main parameters affecting the characteristics, design and safety (in addition to those typical of a similar temporary or mobile construction site)

parameter	typical criticalities	examples
type and characteristics of the yard	urgency, importance, extension, and duration of the activities;	emergency repairs or activities planned with no special haste; radical renovations and modifications;
	frequency of occurrence: exceptional/occasional/systematic;	parts maintenance due to accidents; pavement repair/renovation,...;
	position and evolution in space: stationary / mobile yards;	localized embankment maintenance; painting of lane markings;
	special yards;	not directly related to the highway normal use;
"internal" parameters	unique features of each situation;	in case of emergency repairs, the seasonal conditions can require different design approaches even for the same activity;
	available areas and special constraints, possible interference of contemporary activities;	the limited areas usually available can be further reduced, e.g. by overbridges; interference problems rise due to other yards, e.g. junctions,…;
	additional problems;	poor design in terms of maintainability, typical of the less recent stretches; equipment, materials and parts supplying, emergencies management,...;
"external" parameters	orographic & geomorphological characteristics, mean weather conditions, traffic load in general, and light / heavy traffic "seasonal" changes,..;	different traffic load, steeper stretches, straights and bend radii, windy conditions introduce criticalities in vehicle velocities, difference in speed between light - heavy vehicles, and modify the importance and frequency of maintenance and of interferences;
	peculiar site characteristics, such as tunnels, viaducts, etc..	interventions in tunnels can require special ventilation and fittings, criticalities from old linings,...;
	typologies of goods transported	dangerous goods traffic conditions the importance and criticality of the maintenance yards.

Every maintenance yard presents unique features, and requires a special Prevention through Design - PtD (National Institute for Occupational Safety and Health – NIOSH) approach for the Risk Management.

The proposed schematization, together with an in depth investigation of the intermediate and Root causes of the occurred accidents, can support the Risk Management phase, and contribute to identify the most suitable design for each special situation. The analysis of occurred accidents is still often limited to a general statistical approach, possibly involving subjective assumptions. Nevertheless, some innovative investigation techniques are nowadays available, among them the Computer-aided Cause Consequence for Prevention - CCCP technique (Luzzi et al., 2015), an original evolution from a combination of Fault Tree Analysis - FTA and Event Tree Analysis – ETA, based on the System approach (Reason, 2000). The CCCP approach provides help also in the discussion of the best control measures to interrupt the chain of causes of the event. Figure 2, from a real case, depicts the logical CCCP analysis flow, and provides an example of the achievable results.

ACTIVITY SECTOR F42 Construction – Highways, etc. CONSEQUENCE → 1 workers involved		NOTES: data resulting from Prosecutor Investigation	
A vehicle, hit by a van, loses control and runs over the flagman in a highway maintenance yard, set up to clean the highway signage. The event occurred overnight.			
	Accident causes chain	Possible corrective measures	
1	1 fatality	n.a.	IX
2	struck by a vehicle out of control	see II	VIII
3	loss of control of the involved vehicle due to rear-ending	n.a.	VII
4	poor working area signaling	see II	VI
5	unsafe signaling operation	see IV&II	V
RM	poor risk management	resulting from II, III & IV	RM
6	inadequate signage and lacks of signaling and protection systems of working area	work organization (safety lanes, traffic detour, etc.) with special reference to tasks assignment, and supervision	IV
7	improper worker IFT and working procedure	focused IFT and traffic vs yard interference analysis	III
8	lacking work organization, improper task assigned to the worker involved and poor supervision	temporary collective protection systems (e.g. barriers, Truck Mounted Attenuators, etc.)	II
9	poor Risk Assessment and Management, in particular entrusting unsuitable tasks to workers	adoption of Prevention through Design and Quality management approaches special for the yard	I

Figure 2: Results of the CCCP technique applied to a real event occurred in 2006.

Table 3 summarizes some possible Risk Management actions on the factors that can increase, in the case of highway maintenance yards, the Risks typical of similar temporary or mobile construction sites.

Table 3: Possible Risk Management actions to minimize the peculiar risks of highway maintenance yards

	factor	technical measures	other (organization & procedures)
Internal Risks	ED	emergency solutions special for the context;	special emergency procedures;
	FC	in typically limited areas, throughout analysis of the risk of interference and introduction of physical/non physical safety barriers;	introduction of strict work procedures; interruption of work in case of difficult environmental conditions (e.g. poor visibility);
	P	PtD approach special for the operation, including techniques, technologies and equipment selection, etc.;	special inspection and maintenance of equipment and fittings, special supervision and IFT (Information, Formation and Training);
	n	reduction to a minimum of the number of exposed workers, through a mechanization level as high as technically possible;	do;
External Risks	ED	collective protection systems (barriers, Truck Mounted Attenuators,…);	speed limits;
	FC	scheduling of the highway maintenance activities to minimize the need of interventions in critical traffic or weather conditions;	special organization of activities, shifts, and of trips to and from the yard;
	P	minimization of the number of highway maintenance interventions, through improved design choices and adoption of innovative materials and techniques;	safety lanes, traffic detour, speed limits, yard signage coherent with the general provisions of D.I. 04/03/2013, etc.;
	n	as suggested for the internal risk management;	as suggested for the internal risk management.

3. Some results of the research work

The safety of both workers and third parties, in general, and more so in the case of particularly risky and complex activities, imposes to consider both Safe Work Organization, and the Maximum Safety Technologically Achievable criteria. In coherence with the provisions of law (89/391 EEC Directive, enforced in Italy by D.Lgs.81/08), Article 6 General Obligations on employers, c.2. states: *"The employer shall implement the measures … necessary for the safety and health protection of workers, including prevention of occupational risks and provision of information and training, as well as provision of the necessary organization and means) on the basis of the following general prevention principles: … (e) adapting to technical progress".*
These criteria should be applied both to operations in the maintenance yard, and to the context in which the maintenance site is located. Asides from the well-known guidelines and good practices for the "normal" linear yards safety, and taken into account the contents of Table 3, the following pages discuss some examples of technological improvements on the safety of stretches and yards, which already proved effective abroad, and are finding growing use also in the Italy (EU Commission under the transport RTD programme, 1998).

3.1 Examples of new technologies to support the safety of highway and of the maintenance yard workers

3.1.1. Innovative materials and laying technologies for the highway pavement
Innovative materials and laying technologies for the pavements are nowadays available: this is a promising theme for study and research on bituminous binders, aggregates, additives and related products. The main targets are technical and economic efficiency, pavement duration, and environmental issues (Nösler, 2008).
Fiber or steel-net reinforced pavements, fiber reinforced asphalt-concrete flexible and high resistance pavements in Polymer modified Binders, and other solutions already provide in some cases important benefits in resistance to stresses induced by heavy vehicles (Abtahi et al., 2010; Yildirim, 2007), or reducing cracking and cracks propagation (Xu et al., 2010). Together with excellent surface characteristics, these advanced materials and technologies improve adherence, limit aquaplaning or splash & spray phenomena and degradation by deicing, and ensure good soundproofing. Their use for new highway stretches, or to replace the existing ones, can enhance the system availability, reducing the number of repair/renovation interventions, i.e. the need of maintenance yards. Hence, the FC value decreases, thanks to the increase of the Mean Time Between Failures - M.T.B.F. (Mean Time To Failure - M.T.T.F. + Mean Time To Repair - M.T.T.R.).
Even so, a preliminary Risk Analysis is essential, to define the expectable M.T.T.R. value, and make sure not to have introduced new hazard factors for the maintenance yard workers.

3.1.2. Technical improvements for the management of possible distributed traffic ⇆ yard interferences

In case of mobile linear yards, the usual segregation of the working areas from the traffic, based on Jersey barriers, involves that the progressive modification of the yard area makes also necessary the modification of the barriers layout. The traditional procedure (Figure 3 left) implies that the yard workers manually unfasten each module of the barrier, lift it up and move it to the new position by means of a crane; finally, it is necessary to reconnect the module to the already moved barrier. Workers and equipment operate in immediate proximity of the regular traffic; signage, light signals and flagman become necessary to draw the attention of the highway users. This operation is one of the most critical for the safety. The adoption of mechanized "Barrier Zippers" for Jersey barrier transfer (Rathbone, 2000) makes possible a significant Risk reduction for workers and users, see Figure 3 right; Table 4 summarizes the results of a Preliminary Hazard Analysis – PHA.

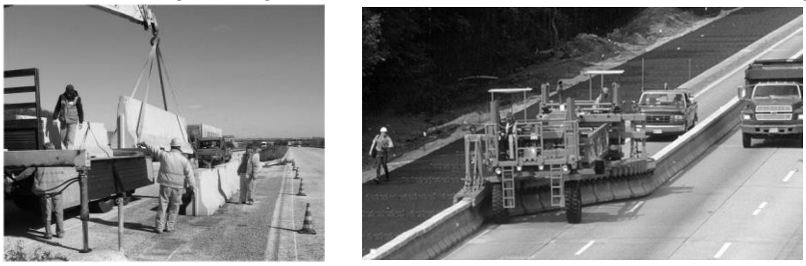

Figure 3: Barrier transfer: traditional procedure (left), mechanized "Barrier Zipper" technique (right).

Table 4: Extract of a Preliminary Hazard Analysis on traditional vs "Zipper" barrier movement activity

Hazard (traditional technique)	**Cause (1)**	**Risk reduction achieved by use of "Barrier Zipper"**	**Note**
workers and flagmen run over by vehicles unrelated to the yard;	regular traffic in proximity of the working areas;	limited exposure of the workers;	during the barrier tranfer with the "Barrier Zipper" technique, no workers operate in unprotected areas;
yard equipment struck by vehicles unrelated to the yard;	unprotected yard equipment and vehicles during the barrier tranfer;	minimization of unprotected yard equipment and vehicles;	the Barrier Transfer Machine is the sole equipment necessary, and operates safeguarded by the barrier already tranferred;
crushing;	handling of heavy loads;	hightly mechanized activity carried out from cabin and safe areas;	the "Barrier Zipper" does not imply manual operations such as unfastening/fastening of each module;
(follow)			

(1) some parameters typical of the Italian highway scenarios can further increase the Risk for both yard workers and users.

The Risk reduction possible through the adoption of the described solution results from:

- ✓ the reduction of P, thanks to the continuous barrier covering the whole length of the yard. The safety of drivers is also increased, thanks to the clarity of the situation;
- ✓ the reduction of FC, since the yard workers operate exclusively from the safe side of the barrier;
- ✓ the reduction of n, thanks to the mechanization of the system.

3.1.3. Technical improvements for the management of possible localized traffic ⇆ yard interferences

In case of stationary maintenance yards of limited extension and duration, where no Jersey barriers are present, the protection of the yard from vehicles irruption is possible by the positioning of obstacles of adequate size and mass (usually some heavy equipment or trucks). Such an improvised approach, even if effective to the purpose, can worsen the seriousness of the consequences for the impacting vehicle driver.

Some Truck Mounted Attenuators - TMA are now available, specially designed to improve the yard protection and reduce the collateral damages. Though occasional maintenance interventions are often carried out overnight, the critical number of fatal accidents due to the yard presence proves that lighting conditions (together with the weather ones) heavily influence the driver's perception of the yard area (Arditi et al., 2007). TMA devices can also contribute to enhance the yard identification and the anticipation of driver's reactions (Bham et al., 2010). Figure 4 shows the basic idea.

Figure 4: Truck Mounted Attenuator (left), and crash test results (right).

Granted that, in this case also, the discussed measures signaling the yard are necessary, the Risk reduction possible through the adoption of the TMAs results from the reduction of FC, since the possibility of irruption of vehicles out of control into the working area is limited; asides, the safety of drivers is increased.

4. Conclusion

The peculiarity of the highway maintenance yards requires a special Risk Assessment and Management, particularly relevant in the case of Italian scenarios, whose peculiar characteristics somehow increase the common temporary yard Risks. The research work made available some interesting results:

a. a through categorization of the different maintenance yards, of pivotal importance to define the different scenarios, and to identify the most suitable safety measures necessary in each situation;
b. a critical review and some practical examples of innovative techniques and technologies currently available, and of their possible effects on the total system efficiency (safety included);

More generally, the research work confirmed that at least in complex situations, among them the highway maintenance yards, the Risk Assessment and Management must be absolutely specific, and devoted to each situation requiring special Prevention through Design and Quality Management approaches. Moreover, also in these situations, the dissemination of the "Culture of Safety" can play a key role in the reduction of risks of workers and third parties.

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