On 17th September 2011 the Train Driver and his Assistant had been killed on the spot, when the Indian build Class S11, No. 899, DEMU crashed with a closing-speed of about 37 kmph into the rear Observation Saloon Coach of a stationary Intercity Train at the station of Alawwa in Sri Lanka:
Just 6 weeks before the Alawwa rear-end collision the author had warned a Train Driver of the Class S11 DMU at Matara, after he had touched at Kogalla the 99 kmph mark, that in this Crash-unworthy Driver’s Cabin, manufactured out of Glass-Fiber/Polyester-Resin Laminate, he might sit on a “Death-Chair” in case of a collision with a heavy object, and that he “will be killed twice: First by the impact and second by the intruding debris and by the shattered pieces of the Glass-Fiber/Polyester-Resin Laminate and the burst Polycarbonate-Windscreen”.

Sitting on a “Death Chair” in Case of a Collision with a heavy Object

In a letter the author had informed the relevant Railway Authorities about the Crash-unworthiness outside any Crash-Norms of the Front Parts of the Indian build DMU without any sturdy Crash-Energy absorbing Front-Elements and without any Anti-Climber Modules to prevent that an object at collision might climb up and penetrate in the Driver’s cabin. A Glass-Fibre/Polyester-Resin Laminate can withstand in a certain extend a Compressive-Load, but cannot absorb or dissipate kinetic Crash-Energy. If a Compressive-Load exceeds the Stability of a Glass-Fibre/Polyester-Resin Laminate, the Compound will crack, and the stored energy will be released in an “Explosion” to shattered debris like shrapnel’s. This happened in Sri Lanka as predicted by the author at two Crashes of the Indian build DMU, Class S11.

Two years before the author had already raised his concerns at an Expo Rail Exhibition at Delhi, India, about the Crash-unworthiness, when he discussed with the designers of this rail-vehicle, who wanted to give the new DMU, originally engineered for the new Kashmir Valley Railway, a Bullet-Train like modern look of the “21th Century”.

For the RAIL 2012, Magazine by the Railway Engineers Association, Sri Lanka, Edition 03, July 2012, the author contributed a feature article on modern CRASH-ENERGY MANAGEMENT and on modern crashworthy front design-engineering for Rail-Cars, Power-Sets and Multiple-Unites in compliance with US and European Norms for the passive Driver’s Protection on Collisions; see below.

On 30th April 2014 another Indian build DMU, Class S11, No. 902, crashed at Pothuhera nose-to-nose with the Locomotive, Class M2, No. 570 “ALBERTA” of a stationary train; this
time at a higher closing speed. The M11 Front Part shattered explosively and disintegrated into pieces according to the same pattern as earlier at Alawwa:

![Disintegrated and shattered Class S11 Front Part at Alawwa](image1.jpg)

Crash at Pothuhera between S11 DMU, No. 902, and M2 Locomotive, No. 570

![Crash at Pothuhera between S11 DMU, No. 902, and M2 Locomotive, No. 570](image2.jpg)
At Pothuhera the hit M2 Locomotive climbed up and penetrated with its front nose into the driver’s cabin. The crash delineates a crash between “STEEL AND POLYMER-LAMINATE”.

Shattered Class S11 Front Part after Alawwa Crash; no Survival Zone for a Driver
The Train Driver, Assistant and Guard had learned from the previous Alawwa Crash, and they took refuge just before the crash in the engine room. In the crash-unworthy Driver’s Cabin and Guard’s Room they would have had no chance to survive. The Driver’s seat had been pushed through the wall into what had been before the Guard’s Room:

After the Crash: What had been once the Guard’s Room

Nobody will step into a car or drive a car in traffic with a Glass-Fibre/Polyester-Resin Laminate Front-Construct without any Crash-Energy absorbing Crumple Zone in front to protect the driver and passengers in the cabin in case of a collision! But the Train Drivers in Sri Lanka have to do so in this dangerous Indian DMU Cabin.

CRASH-ENERGY MANAGEMENT, Part II
MODERN CRASHWORTHY FRONT DESIGN-ENGINEERING FOR RAIL-CARS, POWER-SETS AND MULTIBLE UNITES IN COMPLIANCE WITH US AND EUROPEAN NORMS FOR THE PASSIVE DRIVER’S PROTECTION ON COLLISION WITH A HEAVY OBJECT

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The 17th September 2011 ALAWWA TRAIN CRASH raised the question about the driver’s safety in the S11 front cabin in case of a collision with a heavy object. The Indian build S11 Power Set or so-called DIESEL MULTIBLE UNITE (DEMU) collided with the rear of the Kandy Intercity at a speed of 37 kmph. The bulgy polymer-resin/glass-fibre laminate front part with its plastic polycarbonate windscreen collapsed, disintegrated and shattered into pieces allowing heavy objects to penetrate the cabin and crush the driver and his assistant to death:

ALAWWA COLLISION: Ill-fated S11 with disintegrated and shattered Polymer-Resin/Glass-Fibre Laminate Front

In August 2011 the author had informed the relevant authorities and loco drivers, that the polymer-resin laminate front bulge does not provide enough PASSIVE PROTECTION for the Driver in case of a collision with a heavy object, since there are no solid passive crash protection elements or skeletons behind the cladding. The S11 front is not fitted with a crumple element/zone absorbing crash-energy to prevent the destruction of the driver’s cabin. There are also no Anti-Climber Modules.

Material science experts know since decades, that it is not possible to fulfil the demands for CRASHWORTHINESS with polymer-resin/glass-fibre laminates alone without additional crash-energy absorbing elements or skeletons behind the polymer cladding. Polycarbonate windscreens are dangerous, because on high impact they might burst into sharp shrapnel’s.

Some modern double-cab locomotives and self propelled RAIL CARS, so-called MULTIBLE UNITES or POWER SETS, have the driver’s seat in the front cabin arranged. In single-cab locomotives the driver is better protected. The USA/Canada "DASH" type Class M4 locomotive, build by Alco-Bombardier in Canada, carries the passive crash protection chamber or "CRUMPLE ZONE" in the front. Some years back a M4 collided with a street roller with full speed at a level crossing near Balapitiya: Nothing happened to the driving crew and the cabin thanks the “Crash-Box” in front:

CLASS M4 with “DASH” Type Front Nose
Many railways worldwide have replaced locomotive hauled passenger trains by Rail Cars or Electric Multiple Unites resp. Diesel-electric Multiple Unites (EMUs resp. D(E)MUs). In England there are only two coach trains with conventional locomotive haulage left as sleeper trains from London to Scotland and Cornwall. All daytime running trains are served with EMUs or D(E)MUs. The same trend one finds in many other countries worldwide. This trend has triggered worldwide a boom for the railway rolling stock industries. Leading manufacturers for railcars are:

STADLER, SIEMENS, ALSTOM, ANASALDOBREDA, BOMBARDIER, TALBOT, VOSSLOH in Germany, France and Switzerland; TALGO SA-Spain; CAF (Compañía Auxiliar de Ferrocarriles SA-Spain); PESA BYDGOSZCZ SA Poland; SKODA TRANSPORTATION Czech Republic; CSR NANJING PUZHEM China; HITACHI RAIL EUROPE; HYUNDAI-ROTEM Korea; GENERAL ELECTRIC USA; TZV GREDELJ Croatia; METROVAGONMASH UDSSR.

After the good experience with the Hitachi build Power-Set S8, with German traction and compressed air brake technology, SLR has decided to bring more power-sets, so-called Diesel Multiple Unites, into service instead to procure new locomotives to haul coach trains.

The CRASHWORTHINESS FEATURES of a rail vehicle are intended to provide in event of a collision PASSIVE PROTECTION as well to the crew in the front cabin as to the passenger in the compartments. CRASHWORTHINESS STANDARDS are described as DESIGN STANDARDS and PERFORMANCE STANDARDS.

The American Crashworthiness Standards have been issued by the U.S. Department of Transportation’s Federal Rail Road Administration (FRA) and regulated by the American Public Transport Association (APTA). They include strength based requirements and CRASH-ENERGY MANAGEMENT equipments. The Association of American Rail Road’s (AAR) represents the interests of the freight operators, while the American Public Transport Association, APTA, represents the interests of the passenger rail road operators. In this concerted effort for PASSIVE STRUCTURAL SAFETY DESIGNS the drivers are represented by their Unions.

In USA there is a LOCOMOTIVE CRASHWORTHINESS WORKING GROUP of the Railway Safety Advisory Committee (RSAC) developing Locomotive Crashworthiness recommendations. This working group includes all segments of the railway community for a concerted effort in order to improve safety.

According the Federal Static Regulation U.S.CODE of FEDERAL REGULATION, CFR § 238.203.4, a passenger rail-car structure must be able to support a longitudinal STATIC COMPRESSION-LOAD of 3.56 Mega Newton (MN) without permanent deformation applied at the buffer level. According the FRA Collision Load Regulation 49CFR § 238.211 for the cab ends of a powered Multiple Unit the STRUCTURAL STRENGTH must be able to support longitudinal a COMPRESSION-FORCE LOAD without structural failure of 2.2 MN 762 mm above the top of the under frame.

The U.S. CRASH ENERGY MANAGEMENT REGULATIONS require that on collision the cabs should deform in a controlled fashion and retain for the driver a SURVIVAL ZONE. No acceleration more than 5g (1g= 9.8 m/sec²) should occur to the driver.

According the U.S. Standards the front part should be capable to absorb or dissipate the kinetic crash energy of 5 Mega Joule (MJ) by deformation or crumpling of the CRASH ELEMENTS.
Drivers in mono-cab locomotives like the W1, W3, M2, M4, M6 and M8 are better protected than in double-cab locomotives with front-cabins. Dual-cab locomotives like the M5 and M9 provide a better visibility. To bring the front parts in compliance with the Crash Stability norms is a challenge. The following picture delineates a new developed CRASHWORTHY front with crash elements in compliance with the U.S. Norm AAR S580 for a two-cab heavy haul locomotive build by General Electric, USA, for the European market:

The above mentioned Rail-Car Manufacturers follow nowadays the EUROPEAN CRASH NORM EN15227, the Railway Applications – Crashworthiness Requirements for Railway Vehicle Bodies of the European Committee for Standardization (CEN), elaborated 2007 and published 2008.

CRASHWORTHINESS is defined by the COMPRESSION-LOAD measured in MEGA Newton the Front Part can withstand without structural collapse and by the ABSORPTION of KINETIC CRASH-ENERGY measured in Mega Joule without deformation of the Driver’s cab survival module.

According EN15227 a Rail Vehicle can be regarded as CRASHWORTHY, if it can withstand the impact of a collision at 80 kmph with a heavy road vehicle without the collapse or disintegration of the driver’s SURVIVAL CELL. The front crew should have a chance to survive in a survival cell/zone/module. Before the driver’s Cabin collapses, the front structure should be able to dissipate on collision at least an energy of 1.5 Mega Joule (MJ), and the particular front zones should withstand together at least a compression-load of 2.5 MN, whereas the parts above the buffer- and coupler zones should withstand about 1.0 MN.

Demonstrations of the compliance with standards generally require either detailed numeric simulations by a LINEAR-ELASTIC-FINITE-ELEMENT ANALYSIS (FEM) or DESTRUCTIVE FIELD TESTING, best in combination of both. Expert for EN 15227 crashworthiness FEM simulations is INVENIO LITNER ENGINEERING, Halskertstr.3-5, D 477877 WILlich, Germany; www.fem-berechnung-simulation.de.

Above mentioned rail-car manufacturers undergo CRASH and BENDING-TESTS on test rigs/benches:
The picture shows the front crash structure of a STADLER Rail Car under test bending examination according EN15227 on a test-rig.

The car body is dimensioned to be stable up to a longitudinal compression-load of 3.0 MN. And the total crash-energy absorptions capacity is approx. 2.0 MJ. The energy can be dissipated by stepwise deformation of the skeleton over a length of 1300 mm. The following picture delineate crashworthy front structures and steel crash skeletons with crash-beams and a crash-board used by STADLER in compliance with EN 15227 for the first FLIRT generation:

The Crash-Concept for the third FLIRT Generation uses Front Crash-Modules and Crash-Boxes, so-called “Anti-Climbers”:
The front part of the ALSTOM designed Italian High Speed Rail Car Train AGV is able to absorb 4 to 6 MJ of kinetic energy in the crumple zone without deformation of the driver’s cabin. This is achieved by use of a three stage crumple structure called “MEGA”. The device was put through a series of trials on a test-bench calibrated to reproduce realistic crash conditions:

India has its own norms and standards issued by RDSO and RITES. The Srilankan Class S11 DMU, build by the Integral Coach Factory in Chennai, is a version of the new Indian D(E)MU generation build for the Kashmir Valley Railway, which is also nowadays in service in the Hyderabad region. It had been adopted for the Sri Lankan loading gauge and service conditions.

The synthetic POLYMER-COMPOSITE FRONT NOSE BULGE with the PLASTIC-POLYCARBONATE-GLASS WINDSCREEN should become the proud of India with its streamlined "21st century international look". But this “NOSE” has no Crash-Energy absorbing crumple elements and no solid skeleton, to deduct impact load towards the car body frame. This is a unique innovation, which failed in Sri Lanka at ALAWWA and POTHUHRA. Polymer-Resin/Glass-Fibre Laminates or Composites can withstand to a certain
extent a load, but since such synthetic materials break in a brittle way, they cannot dissipate energy by deflection, yielding or crumpling.

Nobody had asked the Indian manufacturer before, how much kinetic crash energy, measured in MJ, the front part can absorb or dissipate on collision without structural collapse of the driver’s cab module.

The Following CRASHWORTHINESS engineering features and elements are the latest trend:

<> To use stronger, broader solid Side-Beams or Side-Frames, firmly connected to the car body frame for the energy flow; the car under frame is the strongest element of a rail-vehicle.

<> To incorporate the Coupler and the Buffers into the energy dissipating concept.

<> To use energy absorbing Rubber Buffers with Crumple Zones/Chambers for energy absorption.

<> To reduce the Windscreen Size.

<> To arrange the windscreen at a higher level, and to draw it back from the front zone by shifting it more inside. By the remote arrangement of the windscreen the main Crash Surface of the middle part is enlarged and the windscreen (laminated safety train silicate glass), a weak point, retreated from the Crash-Zone.

Energy absorbing Crash-Buffers & Coupler, Stadler FLIRT

The picture of the DMU build in Russia by Metrovagonmash for Serbia as well of the EMU “REGIO-PANTER” build by Skoda in the Czech Republic delineate the new trend features. The crash buffers of latter vehicle with inbuilt deformation elements can absorb 840 kJ and the Scharfenberg coupler 750 kJ:

Metrovagonmash DMU for Serbia
The DMU on the next picture build by TZV GREDELJ in Croatia uses energy absorbing buffers with a Scharfenberg coupler mounted on an energy absorbing telescope. The same features are used by Siemens for the “DESIRO ML” series:

The front cabin of the S10, build by CSR China for Sri Lanka, has a similar crash protected windscreen arrangement with side beams:

In a 1 in 87 scale model design-study the author has build a Rail Car for the LANKA ECONO RAIL PROJECT – see http://www.drwngler.com – with CRASHWORTHY front structures incorporating all the mentioned features:

CSR, Nanjing Puzhen, China, has the intention to penetrate the lucrative European Rail-Car market with its Light Weight Rail-car build for Tunisia on the ALSTOM “LINT” concept with hydro mechanical transmission and with a MAN
Diesel power-pack of 500 kW under the floor of each compartment:

**CSR, Nanjing Puzhen, China, LRV for Tunisia**

The crashworthy front part of the PESA DMU LINK with its crash-energy absorbing buffer zone has a bulky appearance:

**PESA (Poland) LINK II DMU for Regional Traffic in Czechoslovakia**

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**Bibliography**

Conc. US Norms see:


Conc. European and UIC Norms see:


Expert for EN 15227 Crashworthiness FEM simulations:

INVENIO LITNER ENGINEERING, Halskertstr. 3-5; D47877 WILlich, Germany;
www.fem-berechnung-simulation.de