WORLD

SAFETY JOURNAL

Volume IX/1-2001

2001

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Publisher: World Safety Organization, World Management Center.
Editorial Board: Dr. Brian B. Dubin WSO-CSS, Dr. Lon S. McDaniel WSO-CSE/CSS/CHMS/CSI(ML), Dr. Donald E. Rhodes WSO-CSE/CSSD/CHMS. The World Safety Journal (ISSN 1015-5589) is published by the World Safety Organization for its members and other interested individuals involved in environmental and occupational safety and health, security, public health, transportation safety, construction safety, safety education, and related professions. Copies are distributed to Missions of United Nations, libraries, WSO members, attendees of the conferences, seminars, etc. The information, data, comments, etc., contained in this publication, do not necessarily reflect the opinions of the WSO or its policies and programs. Data, articles, etc., offered in this publication, are provided only for informational purposes and the WSO is not responsible for the accuracy of content, data, etc., in this publication.

U.S. $5.00

World Safety Organization

Founded and incorporated in 1975 in Manila the Philippines

WSO Professional Certification Program opened in 1985 in U.S.A.

Reorganized in 1987 relocated to Missouri, U.S.A.

In 1987 WSO World Management Center established in Missouri, U.S.A.

WSO was granted Consultative Status Category II (NGO) to UN ECOSOC

WSO Publications:
World Safety Journal
ISSN 1015-5589

WSO News-Letter
ISSN 1070 311X

Conference Proceedings
ISSN 1022-1042

Conferences are held annually

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World Safety Organization

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Trains Accident Risk Management System
As Applied to Averting And Preventing Train Fire Accident

by: Mr. K.P. Ramalingam

Mr. Ramalingam retired from Indian Railways as an additional General Manager in 1982. All of his railway knowledge and experience is from his service since 1948 in the Indian Railways and deputation abroad. Mr. Ramalingam wishes to offer his expertise so gained, to the benefit of world railways, who want to improve safety and reliability. With over 30 years in railway service Mr. Ramalingam believes he has a lot of knowledge that can be shared.

INTRODUCTION: The Focus is on Train Fire Accidents. One may have an analysis of all types of fire accidents, as well as the results of experience on the various remedies that may have been applied to abate such incidence and the extent of relief or a degree of control that may have been practically achieved. It is not the intent of this paper to review or discuss the earlier treatment of the problem and its abatement. That the Train Fires continue to occur has reasons, and unless it is possible to generalize the source causes, the scope for finding a general solutions not feasible, and without such generalizations, a lasting and reliable and self regulating or controlling solutions can not be found. Thus fundamentally, it is the opinion and experience of the author, that any system of self protection resident in the object to be protected only can give reliable protection. It is not that such a system is infallible, but it is the optimum reliable. Nature has endowed all living forms with some kind of skill, and faculties to smell trouble to sense risks and guard against predators or even against the formidable forces of the elements of nature!

Thus, ARMS (acronym for "Accident Risk Management System") has a predictive approach to detect budding Risks by appropriate methods, and nip them in the bud, before they culminate into accidents. It is from this point of view that the Risk of Fire Accidents will be examined and solutions presented. ARMS will not be discussed, but separate papers on the new philosophy is appended, for a background information, since, other types of accidents have a contributing function for fire cases!

BROAD ANALYSIS OF TRAIN FIRES: In this analysis the following are assumed, as is to be expected or a seasonable: Under extant regulations for acceptance of materials for rail transport, spontaneously combustible and inflammable are either refused or special specifications exist for proper and reliable packaging and handling to prevent any risk of fire accident during transshipment, including nuclear wastes. Hence, every case of train fire, except cases of sabotage, that are wanton destruction and excluded from the definition of accidents, is a consequential event initiating a fire hazard that would be present even if combustible or inflammable commodities are not carried with the wagons empty or loaded with non-burning commodity.

ANALYSIS OF CAUSES FOR IGNITING COMBUSTIBLES/INFLAMMABLES: Materials that can burn to raise fire and flames carried by rail can be groups as;

1. Petroleum products generally carried in tank wagons
2. Coals, woods, bamboos, hay, cotton, plastics etc. in covered or open wagons
3. Explosives that will auto ignite when subjected to shock only

While in the first category a low energy spark can ignite the escaping vapor at top vents, the second category needs either the presence of a continued flame or only a brief exposure to a flame for sustained and increased intensity of fire of the commodity itself. The third category is self explanatory.

Passenger train fires are not omitted, but are covered by freight train analysis itself, except that the carrier deals with humans and other animals too. Investigations have revealed passengers carrying <u>inflammable</u> materials as personal luggage, also igniters like live cigarettes dropped either inadvertently or carelessly without extinguishing, and many other unauthorized and dangerous activities. Here again, it is a questions of discipline to strictly following the safety rules in rail travel. Barring this type of human neglect, the solutions covered by ARMS apply equally to Passenger Trains also.

PRIMARY CAUSES THAT INDUCE TRAIN FIRES: It is common knowledge and experience that the following Risks exist and can provide match stick ignition for Fire and Flames:

1. Steam and diesel engines can provide live cinders and sparkling soot with smoke
2. Electric traction drop molten copper from Catenary and high voltage spark
3. Train collisions are high energy impact or shock impulses to set off explosives
4. Side collisions provide friction welding temperatures to affect petroleum wagons
5. Derailments has a mixture of everything in random combinations

Thus, it will be logical to conclude, that if the ordinary train accidents are controlled as prescribed in ARMS concept, a very large part of the train fires can be averted or prevented automatically. The details are in the annexure, but summary remedial measures are mentioned below. The descending order of the magnitude of contribution can be mentioned as, Derailment, Collision, Live Sparks, and Friction Heat / Open Flame. These are discussed in this order further, indicating ARMS solutions.

MODE OF FIRE RISK INCIDENCE AND ARMS SOLUTIONS:

1. **DERAILMENT**: More than 80% of all accidents is contributed by derailment accidents. The phenomenon of derailment has been dealt in detail in the annexure. Reasons for derailments can be itemized as under.

   Track Defects generated and amplified by three piece square bogie design leading to unacceptable lateral oscillations and poor life of track and rolling stock components, particularly tire life, due to rapid wear of rail and flange.

   Rolling Stock design is principally damaging the track and get damaged in a vicious circle of mutual interaction and wear between the track and bogie. The rolling motion is not desirable either for stability or safety of inflammable liquid commodities as more vapor is generated than in normal operations.

   Collision of any type invariably results in derailment consequentially though!

ARMS REMEDIES ARE:

1. **Tracks:** ARMS equipment to detect all track defect locations and mark them for immediate rectification when they arise, as a first step. Consider improving track stability by progressive change over to ARMS design of ballast less track on pile-trestle foundations. It is a prefabricated design that can be assembled at site like a Bailey Bridge, to give an equivalent performance of track mounted directly on Girder Bridges, with a high level of track rigidity and no track defects in tangent with cross levels and maintenance free! There is a separate paper for this design. This is also economical. Lubricate the Rail through lubricating only 10% of rolling stock. Details are not relevant here but there is a separate paper on this.

2. **ROLLING STOCK:** ARMS modifications to bogies mentioned earlier; pendular suspension of body or bolster beam with meta center above center of gravity to improve stability and break resonant rolling at booked speeds. Hydraulic Damper type drag links for traction/braking on existing design of square bogies, candle type flange lubricators for 10% of all stock fit once, use type axle bearing temperature indicators that can be screw locked to axle boxes. Now mostly roller bearing are in use, but the system is suitable for plain bearings also. This is mentioned here because hot axles are responsible for axle breakage and so derailment.

Note: Axle bearing are damaged by several lateral oscillations on tracks damaged (cyclic wear) by squ bogies. Severe yard bumping shocks also add to bearing damages. With the elimination of square bo; problems and bumping, - through it is practically insignificant compared to lateral shocks from track caus and incidence of hot axles will be rare, fire in axle boxes eliminated and life of bearings greatly enhanc The friction losses in roller bearings is negligible to cause any serious temperature rise, and for hot axles occur, bearings should deteriorate beyond specifications and is difficult to determine in service and cost during overhauls. The tell-tale electronic device flashed LEDs, that can be noticed by driver and the gua with simple telescope or even a small TV unit with hand held monitor.

2. **COLLISIONS:** Collisions include grade crossing accidents. ARMS equipment are required on traction units c engines, at grade crossings and railway stations. Collisions result in high impulse shocks and consequen derailments. These have been mentioned for derailment. Details of equipment, principle of operations ar described in the annexure papers. ARMS averts and prevents all types of collisions, - head-on, rear-end, sid collisions at fouling marks for infringement of moving dimensions, and yard shunting errors. On traffic lines, the incidence of collisions is in the order of 5% to 10% on various systems. However, since collisions cause derailments, it is contributive to risk of fire accidents. While there may be combustible goods in freight traffic, fires in passenger trains are from battery source largely.

3. **DIRECT SPARK OR FLAME:** Steam engine using coal are practically extinct, and diesel engine contributing for throwing sparklers is insignificant. However, incidence of copper melting under very severe sparking between traction wires or ground are many. The author has been able to demonstrate the phenomenon at will, to prove creating such terrorizing and roaring Standing Arc Flames and dropping of copper globules. This phenomenon is due to incorrect design lay out of the overlap spans in 25 KV AC Traction systems, and due to engine negotiating section Insulators in 1500 V DC traction when the contact wire ahead is isolated for any operating or maintenance demands. The problem is easy of rectification, as it is only correcting the schematic to suppress arcing automatically.

Even under normal running, there have been cases of direct flash over from the contact wire to the steam locomotive chimney, due to presence of smoke and ionized status of effluent gases and steam. Similar phenomenon is also observed for diesel engines. But incidence at the locomotive does not affect the safety of wagons behind, as the feeder trips and no one can notice this easily, or correlate it with feeder tripping, as it calls for special investigations and study. However, in the case of steam and diesels, safety is not jeopardized, as the traction wires are directly connected to ground on a flash over. In contrast, in Electric traction, the arc is sustained by the locomotive drawing power through the stationary arc at the overlaps, after the pantograph has left the overlap zone without being affected. There is no direct ground return. If any maintenance is done in an isolated section, and if a train is admitted by some mistake, (it actually happened, and the author studied the problem and found the solution with safety), there is a very great danger of anyone on the track to be electrocuted, as the rail potential exceeds safety limits. Nothing happens to the electric locomotive whatsoever!

4. **CONCLUSIONS:** Fire accidents can be controlled on the basis of ARMS principles. ARMS equipped zones can be practically free from fire accidents, as well as other types of accidents, since fire accidents are only consequential, given that goods do not inflame automatically. Spill of hazardous materials like petroleum products, spread fire and is not restricted to train damages. Environmental pollution and contamination from pollutant goods and nuclear wastes spreading leakage of radioactive material more important to consider, as the time factor for restoring human safety is costlier and time consuming to achieve with confidence.

5. **RECOMMENDATIONS:**
   1. Initiate a study of the new methodology and verify the same by computer simulation or even practically in parts on any well equipped laboratory railway models.
   2. Make field experiments, that is simple and does not call for any major investment in time or money.

3. Implement the scheme on a pilot scale in a zone for both dry runs for establishing reliability and deriving final standard specification for performance, to enable fast execution, and maintenance either by the railway or contractors.
4. ARMS is totally a software design, and implementations needs only well proven hardware like the computer, and input output peripherals. Data is merely inputs of actual or real time feed from sensing devices, that are all readily available, leaving only integration engineering to be done. Consisting of both software and hardware modules, manufacture in bulk at any speed by any number of reputed firms who will not only manufacture but also install and maintain them is a great asset for safety insurance.

In sum, averting and preventing fire and environmental pollution control arising from railways carrying hazardous goods, is a spill over benefit from adopting Accident Risk Management to the more worrisome collisions, grade crossing crashes, and derailments. ARMS study finds that these are very closely interrelated but manifestation is deceptively independent. Human error does not play any significant role in precipitating accidents, if it is conceded that responsibilities entrusted or defined to a worker is commensurate with the technical aids provided, and does not stretch to the limit the average faculties of a person to execute his task with out serious strain or failure of this stamina or mental or physical fatigue.

Late Pandit Nehru, the first Prime Minister of India, had once said that, "There is nothing so good it can not be improved". This motto is boldly displayed on the entrance arch at the entrance gate to Chittaranjan Locomotive Works of Indian Railways! Modern science and technology has grown in leaps and bounds proving this maxim already found in nature, that we call evolution. It is also dynamics and dynamics is life! ARMS is no exception, but one has to work for it. Following laws of nature, assures far greater reliability than isolated sophistication, and working against nature, whereby simplicity is sacrificed for complexity. Problems of pollution is a consequence of concentration while the same component materials was never a hazard when widely dispersed, as is observed with factory, human or other wastes including nuclear. Thus waste recovery and dispersal has assumed a great importance in pollution abatement at a very great cost, just for dispersal after concentration!

ARMS with its idea rooted in the concept of self protection, only reflects the reflex motor nerve systems in all life forms, merely for survival. It is innate and resident in the object to be protected, it is involuntary and impulsive and automatic. The system is normally dormant but instantly active when a risk is sensed in the nascent state, to protect even if the object is in sleeping or in non-conscious mode. Prevention of accidents is only for survival. Save Accidents. Save Lives. Save Assets.

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TRAINS ACCIDENT RISK MANAGEMENT SYSTEM

by: K.P. Ramalingam

Summary Report On:

Analysis of the phenomenon of derailment identification and detecting derailment risks performance specification of arms modules arms data collection and processing principles.

ACCIDENT RISK MANAGEMENT SYSTEM

Preface from the author: I have taken up the discussion on RAILWAY ACCIDENTS **focusing first** on the most prevalent and least resolved problem of DERAILMENTS that accounts for over 80% of all types of train accidents embracing collision, grade crossing crash, derailment, and fire. Other categories are far less and incidence of vandalism or sabotage fall outside the classification of accidents being wanton damage by humans and largely governed by Law and Order violators. The treatment is limited to technical aspects of design, manufacture, maintenance and operation of a railway network, and for which technical solutions are needed.

Railway is as much an industry as any other. Hence, being an activity involving man machine co-ordination in various modes is naturally beset with Risk of error and failure of some degree, due to inadequate design, undue wear and tear, loss of adequate control in operation and mutual interaction or co-ordination at man-machine interface. Thus, UNUSUAL OCCURRENCES are syndrome signals at perceptible levels of the incongruity or disturbances in the harmonious working of the system entity and if overlooked or not properly diagnosed and remedied, lead to performance failures, breakdown or **accident**. These phenomena follow the laws of nature in precipitating poor life of components or accidents. Statistical analysis, if properly done by stages will help to diagnose the primary root cause for the risk generator, whereupon, correct solutions can be determined for successful abatement of accidents.

I have, presented only a new approach to the analysis and understanding of the problem of DERAILMENT in this paper, and left the solutions or remedies to another paper, following. I am sure, designers, manufacturers, and railway transport managers will have many comments, questions and suggestions to express, and these require to be answered or clarified too, after exposition of the new philosophy of approach to problem recognition. The appropriate solutions are then only consequences and validity checked by the principle of demonstrability with consistent repeatability in the laboratory and field!

In the context of the existing void for effective remedies to satisfactorily control DERAILMENT, the discussions should throw up useful clues to orient research and development to enhance railway operating reliability and confidence of railway patrons. It is evident that bulk transport not only of freight but also passengers is becoming more and more important with the air corridors becoming congested and the rapid growth of new cities reducing point to point distances for air travel, thereby justifying fast development of fast trains or High Speed Trains! I look forward to hear the RAILWAY EXPERTS in design, manufacture, construction, operation , and maintenance.

OBJECTIVE

The principal aim of this paper is to present a new approach to the study of DERAILMENT of trains as a GENERALIZATION of the PHENOMENON for the application of a novel safe system based on ACCIDENT RISK SENSING even in the early stages of its inception and development to take PREVENTIVE measures, - say, nip it in the bud, by way of both timely restoration of safety parameters, as well as evolve necessary primary CORRECTIVE measures, to totally ELIMINATE the ORIGINAL RISK SOURCE OF CAUSE, and thereby IMPROVE RELIABILITY OF THE SYSTEM ENTITY. Such means do not exist now, with the result, the pervasive track and rolling stock defects lead to UNACCEPTABLE LEVELS OF DERAILMENT INCIDENCE. It can be said that the accident counts actually an INDEX OF PROBABILITY that precipitate these accidents as a NATURAL PHENOMENON! One can imagine what should be the magnitude of various DEFECTS AND DEFICIENCIES of all related parameters, which by combination of RISK FACTORS can cause an accident.

ACCIDENT ANALYSIS:

The railways controlled by government or privately managed, has NO INFLUENCE in the RELIABILITY OF PERFORMANCE as has been experienced in all the previous decades, and it is necessary to look a the PROBLEM OF DERAILMENTS by studying nature, where all life forms are forced with ENVIRONMENTAL RISKS of VARIOUS TYPES AND DEGREES! Thus, one finds that in NATURE, means and methods have evolved automatically to be able to survive against all types of risks not only from predators but also from risks caused by vagaries of elements in nature! Such kind of evolution OR RELIABLE AND INTRINSIC SELF PROTECTION for kindling a thought in the minds of modern Humans seems imperative! Accident Risk Management initiates such introspection to find out why the world's railways have not been able to evolve a "Total Trains Prevention/Protection System" for so long, after the production of the First Stephenson's Steam Locomotive hauled Train over 170 years ago! Modern designs of high speed trains have also suffered a few derailment accidents. Surely investigations have pinned down reasons for the chance error that had crept in. That will not suppress the present day experience of over 80% of all accidents that are contributed by DERAILMENTS! The new analysis is to understand this strange phenomenon of derailment that has posed a challenge to all RAILWAY EXPERTS to solve!!

BASIS FOR THE NEW CONCEPT:

Every new concept is evolved from its predecessor, and so is this, called ARMS an acronym for Accident Risk Management System. By definition, it is **RISK**, - a prelude to any imminent or immanent and possible hazard, is continuously monitored for automatic *Self protection through prevention function.* While this paper explains only the "How and Why" of derailment phenomenon, risk identification, detection and remedial steps are dealt in the second paper. Third paper describes the field equipment required for implementing the ARMS.. Finally, the forth paper describes interpretation of field data for research study for component design and system configuration like track structure, rolling resistance and stability of vehicle from the point of view of enhancing reliability and life of all parts.

The author was a special mission (1969-1970) to solve the riddle of very high rate of failures of 25kV AC electric locomotives, that suffered also derailment accidents like other rolling stock in the severe gradient sections of the Bengal - Bihar iron ore and coal belt, in India. The problems were defined and dealt with as high propensity for derailments, incidence of hot axles, premature failure of axle roller bearings, and very poor life of track and rolling stock bogie components practically crippling the traffic in the MOST DENSELY WORKED TRAFFIC ZONE OF INDIAN RAILWAYS WITH THE HIGHEST REVENUE EARNINGS! I felt, that the age-old practice of studying the details of component failures, - rails, sleepers, track fittings and similarly for engines, wagons and coaches and deciding remedies was like anodyne treatment for apparent syndromes and leaving the original core cause untouched! Thus, these problems that were experienced with increased propensity since mid-fifties and treated with different methods in the next nearly TWENTY YEARS did not show any semblance of any relief what so ever! Since, this was the triggering point for serious thinking and subsequent study and more field experiments, some relevant details are included.

STATISTICS:

This paper does not require any statistical support only to prove that derailment is a serious problem! It is one of established fact. Special type of statistical DATA will be self generated by the new system logic. It will be dealt while discussing ARMS in a separate devoted third paper. Existing statistical reporting by railways and government are not useful for the purpose of this paper beyond establishing that DERAILMENT is yet an important and serious problem. There is no clear understanding for making a generalizing postulate and needs urgent attention TODAY! However, a brief reference will be made only to highlight the National Financial loss implication in railway operation. Hence, *if any figures are mentioned they are indicative of the magnitude, but does not purport to be quotations of any official reports from any agency or quarter!*

REFERENCES:

The following references are alluded for deriving any related statistical or descriptive information, if the reader desires to have any specific requirement in connection with train accidents in general and derailment cases in particular. There are many more than what is mentioned here, but the author has chosen to list some from his data sources. For instance, the accident statistics given by Indian Railways, is based on the practice of giving some selected data, and say, for derailments, that do not affect main line traffic are not included, but the figures have influence on understanding risk of derailment phenomenon and determine the correct solution!

1. Railway Safety Statistics: www.hse.gov.uk/railwaay/rsb9798.htm
2. Rail Watch: www.rialwatch.org/sum.htm
3. Association of American Rail-roads: *Railroad Facts*
4. Indian Railways Year Book: 1997 - 1998 issued by Ministry of Railways, Gov. of India

PHENOMENON OF DERAILMENT

CONVENTIONAL EXPLANATION OF DERAILMENT:

The Phenomenon of Derailment is an accident. Conventionally, all investigations focus on finding the mechanism of derailment. This turns out into incriminating the last failed component, (or weakest chain in the link), of the track structure or on the first vehicle that is suspected, - no one knows, to have derailed. Thus a perusal of all old reports from the day Railway Transport was commercially introduced, will reveal that there are as many causes as there are derailments that are not consequential events, - such as side collision on a turn-out. Hence, investigators generally examine the design adequacy for strength, or abnormal wear and tear for the material properties, and possible Human error as a cause in poor maintenance or operating error. Sabotage and vandalism are beyond the scope of survey here. While the details of recommendations are not identical, statistics are classified something like the list indicated below.

DERAILMENT	**LOCATION**	**CAUSE**	**VANDALISM/SABOTAGE**
Passenger	Mid-Section	Railway Staff Fault	
Freight	Station Zone	Failure of Others	*(Not considered as an Accident)*
		Technical Failure	

TECHNICAL CAUSES FOR DERAILMENT:

Based on technical investigation reports, the causes are classified like the following:

6. Sharp Wheel Flange
7. Gaping Switch Tongue
8. Over-speed
9. Burst Wheel Tire
10. Axle Broken
11. Vehicle Spring Failure
12. Reversing on Spring Points
13. Broken Rail / Fish-plate
14. Damaged / Failed Sleeper
15. Excessive Track Defect, - (Twist / Slack / etc.)
16. Spread Gauge / Buckling etc. on Long / Continuous welded rail sections
17. Train Parting, etc.

Correspondingly different types of repair/replacement remedies are recommended, *but none to prevent future incidence of derailment.*

ARMS CONCEPT ON DERAILMENT:

- The new ARMS concept consider, those twelve categories mentioned above are only consequential intermediate

Defects, failures, or damages, while the primary or root cause is generally occult.

- Even the primary or root cause may be indeterminate, like the chicken or egg first research and it will be necessary to find the primordial source for the anomaly!

- It is often found that every component supporting smooth running, rail, flange etc., develops a local vicious cycle of mutual destruction of mating parts in a process of feed back amplification at a particular frequency of operation, that can be generally easily located and remedied to break the cycle or largely ameliorate it.

- Between the first source cause and the final tragedy component that results in derailment, there are many derailment risk contributing components. Every one of these component requires adequate energy input to precipitate an accident collectively. On level tracks it represents about 1Kg/t - 2.5 Kg/t traction energy loss!

- Ultimately, all this wasteful energy has to come from the train engine or gravity potential on long falling gradients, where loads are in favor of gradient.

- Unless the primary causes are eliminated progressively, they will act like viruses of sorts, the accidents will keep happening as a balance between repair/rehabilitation efforts and the level of accident risk arising. The probability need not be calculated, as it is as accurate as weather forecast! However it can be done after setting up a data base for the consumption of spares for some of the most critical components that are easy of recognition for any type of vehicle or track, which two are the only ones involved in derailments. Thus this information when carefully monitored can guide in controlling the derailment risks. This data can be correlated with incidence of derailment for each type of vehicle, for each zone of similar traffic pattern and terrain and similar track design etc.

In practice such fuss is not required, if the ARMS REMEDIES ARE IMPLEMENTED. This remedy as will be seen further is simple in prescription, easy of procurement, fast in implementation and economical in the ultimate operation!

3. AN ILLUSTRATIVE CASE STUDY ON DERAILMENT:

The author fist exposed the new concept of Risk Analysis adopted in his investigation during 1969 - 1970, and also demonstrated the same to the Railway Administrative Heads, (who are Experts in their own field of specialization). Forum discussions were, hence, based on actual field experience of the DIFFERENT POINT OF VIEW FOR A NEW ANGLE OF PERCEPTION! Further presentation in this paper is devoted to analyze and explain the mystery of THE PHENOMENON OF DERAILMENT. Since, other problems and failures are also linked to derailment, brief references will be made to point to vicious cycles of feedback amplification greatly increasing propensity for derailment.

The case study relates to investigations and experiments and demonstration in the field mentioned in the Introduction. *A very brief summary of the report submitted to the Railway Board and duly accepted after a long time monitoring is given below. The investigations, experiments, and subsequent development of the theory of derailment and remedial measures are entirely of the author and no one else was associated in the investigations at any time before the results were verified and accepted!* The summary is split into different phases indicating the significance of each phase.

PHASE I:

I. Indian Railways introduced during the fifties a new design of three piece cast steel short wheel base bogies for special bottom side discharge type wagons for transporting iron and other mineral ores. With a maximum carrying capacity of 90 t (tonnes), it works on long steep gradients of 1%. The maximum running speed potential was 90 kph. These special wagons were designated as BOBS type. Axle spacing of 1860 mm was chosen to negotiate sharp curves. The entire load was on a center Bearing with King-Pin anchor on a load beam. Side bearers had 10 mm gaps equally on each side.

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2. Experiencing high incidence of hot boxes and DERAILMENTS even while working at much lower speeds, and thinking that plain journal friction bearings was the cause, it was decided to change over to roller bearings. The problem continued unabated, with extended failures of springs, very heavy rolling motion and lateral oscillations provoking damages and wear of center buffer couplers, etc.

3. While the wagon wheels developed very fast flange wear, track rails developed cyclic pattern of gauge face wear on alternate rail heads, with a wave length of about 25 M, which corresponded to the Indian standard 52 Kg. Short rails with fish plate joints and supported on wooden sleepers and heavy ballast cushion. This phenomenon is know as cyclic wear of rails on Indian Railways. The track damages through spread gauge, unacceptable levels of defects line slack packing, effect of center binding and damages to sleepers, slackening of spikes, tilting up-turning and twisting of rails etc., rendered track maintenance almost impossible absorbing heavy labor and materials.

4. The change in axle spacing did not accompany any modification to tire profile, flange angle, or to standards of rail-wheel clearances prescribed for the earlier standard for 3200 mm spacing of axles. This variation in the track-bogie co-relation dimensions has its influence on the relative geometry for infringement in the moving dimensions that has implications on dynamic characteristics of track-flange forces, different modes of oscillations, and overall stability, reliability, safety and smooth performance. The increase in the initial skew running on shorter axle spacing, that increases Bogie skew angle with rapid flange wear become a major cause for high frequency of derailments, unreliability and operating costs. There are other reasons too, discussed later, but these contributed to initiate and work as catalytic agents to influence even other normal earlier proven designs of vehicles and bogies, infecting otherwise good stock and tracks, - a spreading virus.

EFFECT OF HIGH SKEW OF SQUAR BOGIE OVER POINTS AND CROSSINGS:

The main effect is creating risk conditions for derailment. Briefly itemized, these are;

1. Turnout tongue rail gapes when flange thrust is high beyond stopper blocks.
2. Wheel gauge increases due to flange gauge face hitting wing rail flared ends.
3. Spread Wheel gauge added to flange wear helps riding nose point at crossings.

NOTE: This design of CO-CO bogie has a short wheel base of only 1706 mm between axles 1 & 2. This pacing is even smaller than that of Jessops design for BOBS wagons of three piece cast steel bogie. It causes serious lateral impact forces at the flare ends of wing rails, not only due to high skew configuration from high rail-flange clearances when new and enhanced with were in service, but also due to higher initial gaps between axle-box and Horn Cheek Guides.

INFLUENCE OF TIRE PROFILE ON DERAILMENT:

The major considerations for designing wheel tire profile has all along been;

1. Reduce lateral accelerations within limits, by using tread taper and gravity control
2. Limit lateral excursion of wheels within limits, by limiting rail-flange clearance
3. Achieve smooth running with good linear guidance, limiting wheel eccentricity, and thereby reduce risk of derailment to the minimum.

4. CURRENT METHOD OF INVESTIGATIONS AND CONCLUSIONS:

In the current method of technical investigation into derailment, all the attention is focused on material failure to determine design, manufacture, maintenance adequacy and all possible human error factors are examined. The conclusions are therefore like;

1. Material defect calls for improving specification and inspection.
2. Human error recommends better training and monitoring.

This applies to all the failed components noticed on track and vehicle. Human error is generally associated with operating or control systems. Since such investigations are made only on the results of a derailment accident, the recommendations do not naturally encompass genesis of risk for derailment. Hence, there has been no effort to detect risk prone abnormalities, except that of human experience and intuition ideas.

5. THEORY OF ENTITY IN ARMS METHOD OF ANALYSIS:

The new ARMS considers;

1. Rail-Wheel is an entity, and the goodness factor depends on the harmonious working of the associated environmental systems like the track infrastructure, rolling stock, and control or operating system that includes human control.
2. In a large railway network, there are components that may be inherently defective, develop weakness due to different degrees of wear and tear in use or abuse. These locations become origin for seeding risk development.
3. The controlling environments mentioned above are mutually interactive in the common performance objective of transportation.
4. Consequently, every primary risk location transfers the problem signals either by conduction or by induction, taking the energy needs for risk transfer from the train engine or tap the potential or gravity energy or falling grades.
5. Because of the abundance of traction energy available to feed fault, the magnitude of defects grow and spreads like a virus infection.
6. In the conventional investigations, the apparent derailment syndrome, are given only anodyne treatment looking at it as the cause for derailment.
7. Thus maintenance or rehabilitation cost increases, while the prime disease is left scot-free to continue to precipitate derailment risks all the time.
8. The ARM's method, on the other hand TRACES SYNDROME SIGNALS TO IDENTIFY THE PRIMARY RISK SOURCE AND ALL PRESCRIPTIONS ARE DIRECTED TO ELIMINATE THE PRIMARY SOURCE CAUSE.

6. ARMS CONCLUSIONS ON DERAILMENT STATISTICS:

It will be evident from all railway statistics that propensity for derailment depend on the following factors that can be controlled by ARMS remedies;

1. The design of bogies to assure skew angle is limited 0.33 Deg. When tier is new and re-profiling carried out at the maximum worn level of 1.0 Deg.
2. The wheel tread taper should match rail incline of 1/20 and not 1/40 that will cause hollow wear and also <u>rapidly decrease flange angle.</u>
3. Flange angle when new can be 60 - 65 Deg, that will increase to 70 - 75 Deg. With skew angle controlled flange wear will become normal
4. Wheel-Gauge face of tier flange should not touch flare end of wing/guard or check rail no nearer that at least 1 M away from throat of rail gap and the flare extension should have a slope not more than 5% to reduce lateral shock and acceleration of wheel to be insignificant.
5. Incidence of bogie distortion in goods yard due to hard shunting operations.
6. The rate of risk arising for various causes depends on the population of defective or damaged vehicles and number of serious track defects. This is normally a gradual variation with much of the arising being compensated by repairs and maintenance. However, when a large number of old stock are replaced at a time due to rolling stock programs, there is a step change and statistics will be improved. This does not reflect in any improvement per se!

8. RECOMMENDATIONS:

The subject of derailments will be complete with, two other papers. This paper was limited to discussions on how derailment occurs. This new approach was to focus studying risk arising rather than explain the last stage intricate details of the mechanical phenomenon of derailment.

The other papers deal with remedial steps in detail for implementation of ARMS Derailment Abatement Measures and evolving Statistical Data Based Risk Management methods.

Controlling Derailment Risk Means Preventing Derailment Accidents.

NO PROTECTION IS POSSIBLE AGAINST DERAILMENT.
PREVENTION IS THE ONLY CURE
BY RISK MANAGEMENT

Notes: THE PHENOMENON OF TRAIN DERAILMENT

1 - Important parameters for Track Maintenance: INDIAN RAILWAYS

a. Limits to wear on Tongue Rail:

- Vertical Wear 6mm
- Lateral wear 13 - 15 mm below stock rail 8 mm for 52 Kg/90R

b. Curve parameters:

- Radius of Curve: R=125 c/v, where radius is in meters (c-cord length in meters v-versine in mm) 1 degree curve on 30.5 M cord length has 1750 m radius & v-2.2 mm

c. Rail level and gauge: 1676 mm

- Rail level reference on curves in from inner rail
- Gauge BG on tangent level track up to 400 M radius 1676 - 3mm
- Gauge on curves with less than 400 M radius (>4,4 degrees) 1676 + -5mm
- Cant gradient transition, limited to 1/360 or 2.8mm/meter
- Rate of cant deficiency limit change at speeds say is 35mm/sec
- Center to center of rail heads for transitioned curves is 1750 mm
- Safe speed on BG curves is v(kph) = 0.27 R(C_a + C_b)
- Theoretical Cant C = 1750 (1676 + rail width 50 mm) V^2 127 R
- Max. Cant for A,B,C routes is limited to 165 mm
- Future High speed standards raised to 185 mm
- For Group D & E routes 140 mm
- Max. Cant deficiency in Gr. A&B >100kph 100 mm, others 75 mm
- Max. Cant excess is limited on BG to 75 mm

d. Curve Compensation:

- Normal rule for a curve of radius R 70/R% or 700 R mm/M

1. Track Defect Parameters:

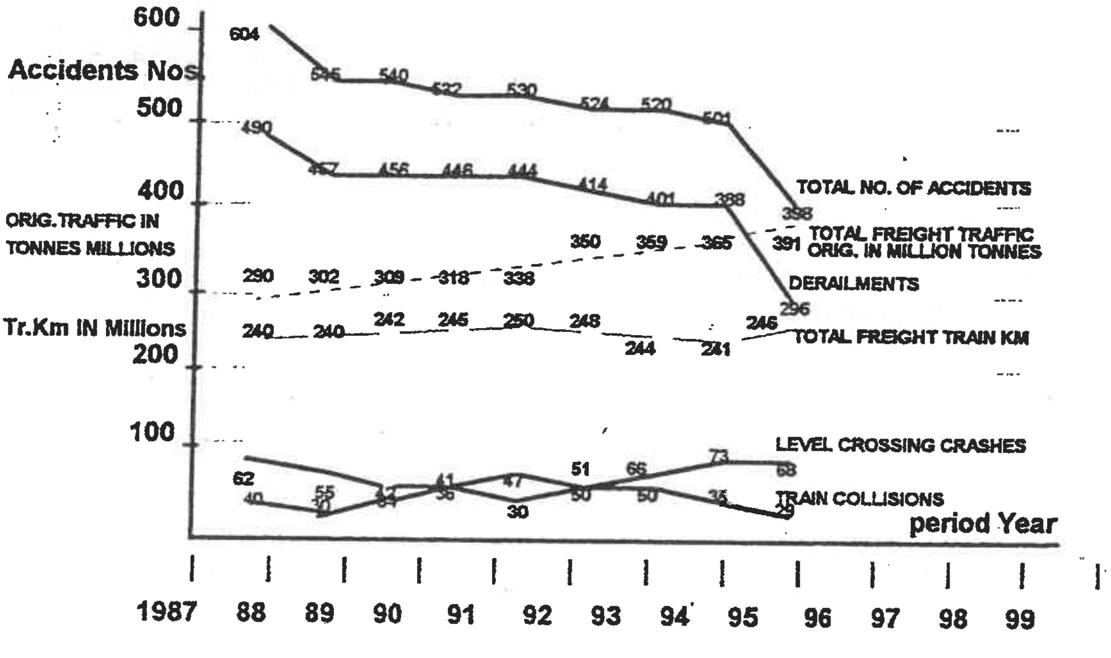
- Unevenness over 3.6 M chord for Gr. A 6 mm
- Unevenness over 3.6 M chord for Gr. 6-10 mm
- Unevenness over 3.6 M chord for Gr. C 10-15 mm
- Unevenness over 3.6 M chord for Gr. D > 15 mm

2. Twist over 3.6 M

- Gr. A Routes 0-5 mm
- Gr. B 5-7.5 mm
- Gr. C 7.5-10 mm
- Gr. D > 10 mm

3. Track Gauge
   - A ±3 mm
   - B 3-5 mm
   - C > 6 mm
4. Track Alignment On 7.2 M chord
   - A 3 mm versine
   - B 3-5 mm versine
   - C > 5 mm versine
5. Rail vertical wear limited to 13 mm to avoid Flange hitting fishplate
6. Lateral gauge face wear for BG A&B Gr. 8 mm and C&D GR. 10 mm

LARGE SCALE REPLACEMENT OF OLD WAGONS AND ITS INFLUENCE ON RELIABILITY BY INDUCTION OF NEW DESIGNS OF ROLLING STOCK



Graph Indicating The Train Accidents For the Period April 1988 to April 1996

NOTES: PROPENSITY FOR DERAILMENT ACCIDENTS:

. The author had submitted his first report of 1969-70 correlating the performance of the square bogies of BOBS and other special purpose wagons WIT c-snub type bogies. Since mid fifties, cyclic wear of rails were observed more in captive circuits where such wagons and tracks sustained many types of component damages not only to the good stock but the cyclically worn rails and infected also the other wise good coaching stock running in the same section. BOBS stock is small and are due retirement and replacement.

2. BOX (N) and similar wagons with 2000 mm axle spacing, the bogies need modifications to remove the design defects. Now over 50,000 such special wagons are in use, and the fleet increases progressively.

3. It will be evident from the above graphs that the higher incidence of derailments and increased maintenance of rolling stock coincide with the induction of the special types of bogie wagons including the CRT 4-wheelers. Specific wheel loads and average operating speeds have remained the same

ACCIDENT RISK MANAGEMENT SYSTEM FOR IDENTIFICATION OF ALL TRAINS DERAILMENT RISK FACTORS

Introduction: This is the second of four papers on Accident Risk Management System focusing on aspects of DERAILMENT ACCIDENTS, and explains in detail, identification of derailment risk arising. The objective of the first paper, was to describe the phenomenon of derailment seen in a new approach concept, and highlight the philosophy of accident risk management. While in the current (old) method, one always examined and worked to find ways and means to improve reliability of the many failing components that were incriminated as responsible for the precipitation of derailment, *the new philosophy on the other hand directs all thinking into PREVENTION OF ALL RISK ARISING in the first instance.* Based on the methods of risk abatement discussed in this paper, the third paper will describe generally the equipment design and performance specifications. It leaves the actual device designs to specialist railway equipment manufacturers to offer a cogent ARMS, that will not only deal with derailment but also other types of train accidents. ***ARMS concept is a total trains accident protection and prevention system and takes care of both imminent hazard and immanent risk arising or development!*** The fourth paper will concentrate on aspects of data management to help trouble shoot device design, material science, manufacturing process and other relevant aspects that go to achieve a self stabilized or automatic regulating mechanism to maintain optimum reliability and economy of ARMS itself. Thus, ARMS as an acronym also stands for Automatic Reliability Maintenance System!

DERAILMENT RISK FACTORS:

It has been mentioned while concluding the first paper, that **"No protection is possible against DERAILMENT! It has ONLY TO BE PREVENTED"! The author would hasten to add that protection would be needed for imminent consequential risk of infringement to adjacent track and trains collision in the event of a derailment including that caused by saboteurs too! This is sum and substance of the ARMS philosophy of *self protection* mentioned later.** It calls for Identification of all derailment risk factors. This is more or less the epitome of the description of derailment as a phenomenon dealt with in the first paper. The risks may be itemized as under:

1. Track defects including all component failures
2. Infrastructure ground train engine and trailing vehicles
3. Rolling stock including train engine and trailing vehicles
4. Obstruction on the track
5. Operating errors due to human or device failures
6. Sabotage/Vandalism etc. *(There are not considered as accidents being wanton human interference as has been mentioned also in the first paper)*

It will be noted from the above that there are only FIVE SOURCES of risk as against the conventional methodology, where there are practically as many risk causes as there are cases of derailment. Railway, classification and grouping of all investigation reports is mentioned in the first paper, "Phenomenon of Derailment".

TRACK DEFECTS: The track defects are limited to working safety standards for new and used conditions. Still derailments take place. The case study on the influence of short wheel-base bogies given in the first paper revels the track defect arising from a combination of two non-matching features of track and bogie. There are many more such disharmony that one can identify. Thus, track can not be incriminated as the sole contributor to risk arising. So, all the various types of defects mentioned in various investigation reports, are only consequences of a design mismatch. ARMS solutions call for the following remedies:

1. ***Track structure*** is a FLOATING SUPPORT for train running. This is the basic shortcoming in the design concept, that needs progressive modernization with new design concepts. ARMS has foreseen a ballast-less track that is rigid and will not be disturbed in the normal train operation services. This is a separate paper

being in the nature of a new technical development. While, the new system, - (through a proven technology in other applications being still a concept for use in track design), will naturally take time to establish its acceptability, reliability, economy, and project planning for regular planned implementation. Accident Prevention can not wait indefinitely. Hence, ARMS has other ready practical remedies to abate risk to allow existing tracks to be used safely! It can always be **updated** progressively, anywhere, anytime and in anyway with no demands for contiguous sections's.

A. Important Sources of track defects are: Flange forces, these arise from:
   1. Track defects like, unevenness, rail kinks, or buckling
   2. Unidirectional traffic combined with wide thermal excursions
   3. Over-speed on turn-outs and short curves without transition
   4. Poor vehicle and bogie design affecting track stability
   5. Excessive amplitudes of lateral sway and rolling of vehicle body
   6. High center of gravity of vehicle with large side-bearer gaps

While the above may appear disparate effects or causes, in fact they are all inter related phenomena. They are the result of supply of fault energy from the train engine (or stored gravity potential energy), on long falling gradients. They, thus contribute for increased virtual train resistance, that can not be directly measured, and does not find place in the specific track-vehicle running resistance formulae! Railway engineers are aware of the above mentioned defects, and largely put in more maintenance to restore safety standards. But, in the absence of any solution to remove the core cause, tracks deteriorate generally linearly with traffic (freight) measured in terms of gross ton kilometers moved per unit time, say, per day, in any section under study. We shall examine the function for each of the above under ARMS principles and determine the solutions for each.

2. ***Track unevenness***, rail kinks, buckling, and other defects are consequences of train operation. One can reasonably assume that tracks when new or after overhaul conforms to all prescribed track safety norms. HOWEVER, the fact that track is floating on an artificial infrastructure foundation means that the support is not free from ground disturbances like subsoil dynamics that is unpredictable the effect of rolling stock design, locomotive characteristics, and influence of weather changes as affecting track stability for smooth train running. Track is not anchored to terra firma and is free to drift and it does require slewing back to restore safety. **The focus is on the track that is controllable. This being a major project by itself is dealt with in a separate paper, outside the ARMS scheme, though the idea itself is a consequence of ARMS principles.**

   ARMS solution for all types of track defects, has already been mentioned as consisting of two stages. The first is to abate the influence of rolling stock inflicted tract defects that is of immediate concern. Technical specifications and operating needs are detailed in the third paper. The second solution is basically a new type of design, but is capable of progressive implementation for upgrading existing tracks and adopting for future standards after due process of acceptance protocols. ARMS provides not only total protection, prevention of derailment but also management of reliability assurance!

3. ***Traffic pattern*** can not be changed suddenly for a novel solution to reduce track defects, say, to operated a double line section as TWO SINGLE LINES, which will give a good balance on tangent level tracks and greatly reduce track defects like kinks and rail creep. Curves will be doubly stressed, while gradient sections will have no practical benefit, as the effect of gradient pull on the track due to train is always the same (sown hill), whether it is accelerating or decelerating! The problem is concentrated in the valley for undulating terrain (junction of vertical curves). However, problem of kinks and buckling can be serious for long welded panels of used, and hence heavy periodic anchors are used at close intervals to prevent accumulation of rail

creep stressing at rail junctions.

The ARMS inherently aims to reduce the intensity of track drag due to traction and braking as much as possible. The relief is not insignificant, as the author found in actual long term demonstration experiments. There is both technical and traffic gain! Driver does normal driving! The details are as follow:

1. For maximum traffic (through-put) every train must run at the designed maximum speed for the track. The concept of running very long trains at lower speeds is theoretically counter productive in practice. High tracive efforts at higher train resistance tends to slew the track to flatten the curve and is helped by large temperature falls. This is a slow change and not easily perceptible.
2. The interval between trains by way of time and space, should be optimized to minimum, to achieve maximum section capacity. Modern traffic control system calls for it too. ARMS foresees trains following operation as a necessary economic solution and it has minimum separation protection against collision risk. This is discussed in the third paper dealing with accidents other than derailment.
3. If very long trains have to be run for a special reason, additional engines should be distributed along the train to give a multiple train operation instead of putting multiple locomotives at the head of the train.
4. ARMS equipment helps to avoid total train brake application by regulating train speed suitably with dynamic braking, thus eliminating track drag. This is possible also with distributed locomotives and greatly helps to prevent derailment risks inherent to working very long and heavy trains.

4. ***Over speeding*** on turnouts and short curves, is either due to failure of brake effectiveness, - (generally termed as brake fading), or driver error. Derailment can occur even for a new tire profile! The author found from his experience, that the problem is more in the nature of inadequate assistance to driver through lack of route data and inadequate cab instrumentation for driver guidance. It is always a source of anxiety for driving in darkness, and entails considerable difficulty or inconvenience in timely recognition of proper bench marks for driving decisions. At high speeds the handicap is augmented seriously. Invariable cautious driving is at the cost of punctuality and traffic capacity! ARMS solution is, use of appropriate cab console instrumentation and track embedded bench marks, similar to basilles, but of a special, simple, passive device, dealt with in the third paper of the ARMS series.

5. ***Poor vehicle and bogie designs*** has major influence on generating derailment risks as has been discussed in detail in the first paper, for a case study. Therefore, it will suffice to indicate the ARMS solution. ARMS recognizes that it is not desirable or practical to alter track standards. It is essential to ensure that any bogie design should be capable to inherently help smooth rolling of wheels over rail head without undue lateral flange pressure and contact length. Double cone wheel trend and rail tilts should be adequate to provide necessary linear guiding automatically automobile designs use, what is termed as Caster + Camber, as it has to run with at least two degrees of freedom, while rail guided vehicle has only one degree of freedom, restrained by rail gauge and flanged wheels. The details of bogie performance on tracks is discussed further, as vehicle design and performance.

The most important of all defects inflicted by rolling stock is disturbance to cross levels by frequent and alternating wheel weight transfer from side to side of axles, due to the rolling motion of the vehicle body. This also causes binding or locking the bogie in a skew position, as the body rests on one side or other on side bearers. This results in the continued hard bearing of the flange on rail head for a long duration, causing rapid diagonal wheel flange wear, and equally also damaging the rail gauge by corresponding excess wear. This gives rise to cyclic rail wear pattern. When the running speed matches with nosing frequency of the bogie, serve resonant lateral oscillations are set up. With a high center of gravity, the momentum of the rolling mass becomes to dangerous to topple the vehicle and derail. With a badly worn flange and reduced *flange angle, and high skew angle of bogie, reversal of the oscillation from one side to another produces a very high force couple and heavy flange force to when this happens at a switch point, the tongue rail can gape open for the rear bogie wheel to take to two roads. Running skew with thin flange and tread wear of wheel set to 1/40 or less a vehicle negotiating a crossing, can derail by flange riding the nose point. This is the reason for observing many instances of nose point damage at frog of crossings. Component damage and failure for items like suspension links, bogie spring breaking, hot roller axle bearings, abnormal wear of vehicle couplers etc. are consequences of severe lateral oscillations and reversal of momentums of vehicles. In a derailment case these are by no means small contributory causes, as has been considered so long but really main ones!*

6. ***Track infrastructure*** defects arise due to lateral oscillations and creep damages, not only from badly designed or damaged skew bogies of rolling stock, but also due to scouring of track foundation to cause more deflection under wheel loads. This can happen due to poor track drainage, subsoil subsidence in the underground mines in the proximity of the tracks. Because of these defects there needs to be rectification of the danger zones before it is too late. Thus ARMS is predictive by sensing developing risks in their nascent state and helps the track and rolling stock engineers for timely action for not only correcting the anomaly but also guide in finding the solution to eliminate the cause for the risk factor itself to arise in the first instance if possible. Such data management guides future more reliable designs

NOTE: A wide range of problems generating a high level of maintenance is largely a case of mismatching (square) short wheel base bogies with old Indian railway track standards. New track design concept is described in a separate paper which practically eliminates derailment for track causes irrespective of source disturbances.

1. Good performance of track, rolling stock, locomotives, signal track interlocks have a synergistic need for economy and safety.
2. Lack of harmony in the system entity leads to varied problems
3. Technical problem syndrome has to be studied liked in pathology!
4. Apparent component failure can not be incriminated as primary source of problem, as it is only like headache or spasm that are like warning symptoms of some serious malice that is mostly occult
5. It can not be said that square bogie concept is wrong, but bogie design did not match track standards *only some corrective action is required for linear guidance*
6. A single axle is a bogie of zero rigid wheel base

7. ***Track obstructions*** such as at a grade crossing by road traffic or fallen goods from a train earlier in the adjacent running track can cause a derailment. The method of detection and protection elsewhere on running lines is similar to ARMS scheme for grade crossings, and is reserved for the third paper. It must however be said, that such hazards are of uncertain success, if it happens in other than station and grade crossing zones and is influenced by available time interval for protecting or averting derailment hazard.

A. Rough shunting of vehicles in yards results in bogie frame distortion and skew running
B. Slide collision of trans at turnouts, due to inadequate or inappropriate warning devices for the guidance of guard of driver

These are in fact track obstructions or infringements, but arise from human error. ARMS gives total protection as well as prevention of future risk arising for such hazards. Details are reserved for paper three that covers technical performance specification for ARMS needs any where on the railway network, not necessarily on traffic running lines.

CONCLUSION:

We know how computer and bio viruses spread infection. Now we know railway problems likewise spread accident virus risk factors by conduction and induction.

It is clear that most of the defects and damages exhibited as failures and poor life of many components are only apparent syndromes and behind these clues lies the seat of the disease. Merely treating these many symptom failures is only anodyne help that leaves the original disease unresolved. In the next paper, the tools required to get access to the true disease is explained.

RECOMMENDATIONS:

From the information contained in the first two papers, it will be possible to identify the path for the flow of fault energy and trace back to the prior stages and get a good appreciation of the derailment phenomenon. The practical method of instrumentation and pin pointing the source defect and the succeeding nodal points will follow next.

TRAINS ACCIDENT RISK MANAGEMENT SYSTEM AND PERFORMANCE SPECIFICATION FOR ACCIDENT PREVENTION DEVICE FUNCTION MODULES

INTRODUCTION: Earlier two papers were titled, "Phenomenon of Train Derailment" and "Accident Risk Management for Identification of All Trains Derailment Risk Factors" In this third paper, a brief description is given of the method of working of ARMS in general to cover all types of trains accidents, but give more information focusing on Devices that provide Functions for Identifying, Detecting, and outputting various types of signals for achieving the Goal of Totally Averting or Preventing Derailment Risk arising anywhere and at any Time in any type of Train movement or handling on the entire Network. *There is **NO Protection** at all against wanton Human Interference or omission/neglect of Legitimate Obligatory Maintenance and Repairs in Time in the pre-notified schedules of Routine or Special works recommended in ARMS!*

TRAINS ACCIDENT RISK MANAGEMENT SYSTEM (ARMS)

The following are the salient features of working of Accident Risk Management System:

1. It is a Self Protection System applicable to all zones in the entire railway network and includes, station section, traffic yards, assisted sidings, block sections with all the road-rail level crossings, irrespective of number of tracks and trains that are equipped. suitably. Electric traction power supply installations can be added too.
2. The system is based on radio communication platform using neither cables or wires.
3. This safety system is a support to railway operation and does not substitute Humans.
4. ARMS is dedicated to detect hazard risks and protect or prevent all accidents.
5. Humans will continue to have the same extant responsibility for vigilance in operation. However, *ARMS takes over in any event of Human Vigilance Failure!!*
6. Introduction of ARMS does not in any way influence current railway operating rules and practices and neither calls for introduction of new fundamental rules.
7. ARMS has no connection with any kind of traffic control systems, though it is normal that all train control operations have to be intrinsically safe and reliable.
8. ARMS equipment on board locomotives, station or yard master control, does not control normal operations, BUT can activate any EMERGENCY DEVICE as may be so desired by railways for each specific requirement, such as applying emergency braking of a train, stopping all train movement in station zone or yard, etc. as an overall security and protection function. Normally this requirement is met by local security system and traffic control and train control systems. ARMS is not planned to include this function, but its technical versatility can be availed!!! This means that ARMS will function only within its defined ambient by stopping all train movements through ARMS devices installed at stations, yards and trains within 5Km radius from the reference location Km of the station ARMS.
9. ARMS is based on Accident Risk Identification, Detection, and averting an IMMINENT hazard or preventing IMMANENT future risk arising for all types of accidents like, trains collision (head-on or rear-end), grade crossing crashes with road vehicles, derailments and though with uncertain success few chance cases of sabotage and terrorism.

ARMS WORKING METHOD

The working method of the ARMS may be briefly stated as under for all accident types.

TRAINS COLLISION:
Trains Collision Accidents may involve one or two trains that may be End-On or Head-On. It also includes side collisions that may occur at turn-outs and crossings of tracks at fouling mark locations that are zones of infringement to moving dimensions. It takes into consideration all cases where collision is consequential to derailment or derailment consequential to side collision. This is important in discussing derailments.

GRADE CROSSING CRASHES:
It is invariably the train that hits the road vehicle and not the other way round, principally because the road vehicle was already on the track as an obstruction to free train passage. The new ARMS ensures that the train driver and road vehicle driver are adequately pre-warned equally on the status of the crossing as well as the proximity of the train in terms of the time interval for the arrival of the train at the location Km defined at the center of the crossing because such a measure is independent of train speed and assures safety and a time margin to avert an accident!. Though railway has the Right of Way, *it is essential to prevent a crash as a means of Self Protection of the train from derailment accident – a legitimate responsibility of the carrier under railway Act.*

DERAILMENT:
ARMS treats all derailment cases the same way, as one can not determine if one type or place for a derailment is worse than the other. Collision of trains is always a possibility in yard line, station tracks and mainlines. Hence, the train has to self protect against derailment, as well as against a later potential collision. Further discussion will examine the performance specifications for preventing derailment risk arising.

There are various possible locations of trains at the time of derailment, such as mid-section, station section, assisted siding or a yard. Train locations are alternatives, and not necessarily all at once. Risk conditions are taken as under, to cover all cases as experienced over several decades. This helps to appreciate the significance for the ARMS device specifications for performance needs for averting or preventing a derailment accident, that are based on the phenomenon of derailment dealt in the earlier two papers.

A. **Mid-Section Derailment:**
In this case, the train is between stations anywhere. The derailment is assumed to be due to a bad track and/or bad vehicle, to cause unstable dynamic conditions, principally due to short wheel base or distorted bogies, that give rise to the characteristic cyclic wear of rails described in the first paper, "Phenomenon of Train Derailments". The performance of the track and the train is difficult to comprehend by the track engineers, either by traveling on the engine, or observing the passing train and track at the same time, as there is a phase lag between the lateral rolling oscillation of the wagon and the amplitude of vertical deflection of the rail at a few sleepers. Our focus is on detecting the abnormalities that are risk factors that will cause derailment.

RISK FACTORS CONSIDERED FOR TOTAL PROTECTION FUNCTION:

TYPE OF RISK FACTOR DETECTION PARAMETER & DEVICE amplitude of lateral deflections and frequency of lateral oscillates influence dynamic wheel loading speed and rolling frequency are related for resonant oscillations. Loss of brake pipe air/vacuum accelerometer trivector type & distance measurement frequency measure air flow & pressure

A. Vertical Deflection
B. Lateral Rail-Flange Gap
C. Lateral Body Deflection
D. Frequency of Lateral Oscillations
E. Ratio Bogie & Axle Centers
F. Train Parting

NOTE: There are two other types of Risk for derailment, viz.:

1. Rail crack or even rail fracture as a natural risk arising but not sabotage. Rail flaw or crack detector is foreseen as a special device, that will continuously monitor each side rail on the run. The mere presence of rail crack does not immediately cause derailment, but if neglected, can cause accident with badly damaged rail.
2. There can be an obstruction on thè track, say, a parcel had fallen from a wagon of the same train or from another train earlier. ARMS can detect any obstruction of a minimum dimensions. The driver has to drive cautiously like approaching a level crossing. The size of the obstruction does not indicate the magnitude of hazard, as it may just be an empty container or a hay bundle, but protection has been assured.

The instrumentation pertaining to ARMS functions mentioned above relate to sensing all abnormalities relating to track~vehicle interactions. For the case of mid-section train derailment, it has been mentioned earlier that track is primarily damaged by only the rolling stock and the influence of thermal stresses and rail creep in usage. Hence, all relevant abnormalities of track can be checked from the locomotive at the head of a train. The basic parameters are deviations from design limits of safety in operation. While the lateral accelerations give the degree of flange ~ rail forces, that is limited to about 40% of designed stationary axle load, oscillations check the dynamic wheel weight transfer, that should not fall below, say, 40%. Excess over these limits will promote derailment. **The sensing devices give the necessary measurement signals, based on which ARMS evaluates the approaching unsafe conditions as a pre-warning annunciation to driver for reporting.**

ARMS provides data for down loading at the locomotive trip inspection depots. At the same time, ARMS also transmits UNUSUAL OCCURRENCE DATA over the radio on run for the ARMS at the nearest station ahead or rear to take action as per station rules. Technical details of the processing method is out side the scope of this paper. ARMS has a number of common devices that are required for all types of accidents. These are mentioned at the end.

Irrespective of the reason for the derailment, the infringement of derailed wagons or coaches, poses a potential risk of a consequential collision. The second down train T_d is automatically alerted by SOS Beacon from the up train T_u. ARMS on the second train assures the slowing down and stopping well in advance, due to the instrumentation that precisely determines the location and distance between trains at every instant. **Thus consequential collision is averted, provided there is adequate distance for the train to stop with emergency braking. Some times, derailment may happen during a train crossing, - though very rare. Obviously there is no scope for any protection at all. However, since ARMS works predictive to eliminate all vulnerable risk locations the probability of derailment is very low. These conditions also apply to risk of derailment due to sudden obstructions, as may arise due to Farm Tractor Crossing across <u>unregistered and unauthorized crossings called cattle crossings.</u> This is discussed in more detail under Grade Crossing Protection.**

B. Derailment in Station Zone: The station zone extends between the outer most signal locations on either side of the station. For the purpose of Derailment Risk Detection, ARMS has defined some sub-zones for risk detection management. These are;

1. **SWITCH OR TURNOUT AND TRACK CROSSINGS:** In these locations, the tracks are damaged only by excess speed and skew bogies. These are dealt by automatic speed checks as may be stipulated for each type of switch and for each location. Being flat curves bogie design for negotiating switch tongue rail imposes heavy lateral thrusts, and particularly Co-Co Three axle types. The design contrivance of reducing axle spacing leads to skew running of leading axle pairs, and further, use of very thin flanges tends the flange to hit the nose point at the crossing. ARMS remedy for this point is discussed under rolling stock. However, speed check in advance of such locations is done by ARMS, as explained under common devices.
2. **FOULING MARK LOCATION:** Since there are many tracks and interconnections in station area, due to loops, sidings, and yards, the incidence of side collision due to infringement at Fouling Mark locations has a high probability. Presently it involves total Human <u>vigilance, with *no technical assistance what so*</u>

ever. Berthing track circuits did not help, as often the LV last vehicle indicators are missing for shunting trains, and no facility either to detect or indicate side-collision risk situation, leading principally to derailment as a consequence. ARMS has foreseen automatic detecting and elimination of such risks. This device is described under common facility for many applications.

3. **SEVERE SHUNTING AND BUMPING IN YARDS AND BUFFER SIDINGS:** Apart from very poor track conditions in yards, total absence of technical aids to perform safe shunting has contributed to high probability of derailment risks. ARMS uses the same common device facilities to prevent yard derailments.

Human errors and Signal-Track interlock failures would normally cause un-intended switching of train to another track, that generally leads to collision Head-On or Rear-End. If a train is already stabled in a loop line at the station or in the yard lines locations also represent side collision risks and consequent derailment. Hence, the ARMS has common modules to deal with risk of collision when functioning for prevention of derailment. Driver gets cab indication of the route set for train reception, and also the exact location with negotiating speed of the particular location.

Traveling on the engine one can feel the lateral shocks and oscillations, but can not judge the condition of tracks. Thus, it goes un-noticed due to more sophisticated vehicle and bogie designs using springs and hydraulic dampers. The unfortunate influence of the middle axle of Co-Co bogie, with special thin flange standards, also vitiates subjective assessment. The author had traveled on BOBS and BOXN wagons for experiencing the lateral oscillations during investigations, apart from observing the track deflections at locations where the rail head wear is maximum in the cyclic wear zones.

The other considerations in a mid section are, the rarer incidence of track creep, track buckling, and rail crack. Identification of these locations call for simple instrumentation such as the following, but far less complicated than the designs for track recording cars. These may be listed as under.

LIST OF COMMON ARMS FUNCTION MODULES:

1. Basille device on the track for track to engine route DATA transfer, such as ;
   a. Determine precise train speed on the track
   b. Indicate exact location track Km corresponding to track index bench marks
   c. Maximum permissible speed for the track and permanent speed restrictions
   d. Important permanent traffic operating data as per working time table
   e. Track identification and direction of running
   f. Names of station in rear and ahead and location Km.
   g. Track profile 500 m ahead, such as + gradient, curve, bridge, tunnel etc.
   h. Alert 2 Km ahead for sighting of first stop signal
   i. Alert temporary caution orders and reason there for, - repair or construction work
   j. Alert for location of all electric traction operation, - neutral section 500m ahead, lower/raise pantograph end of neutral section etc.

NOTE: *Any number of such basilles can be installed and carry any information of a temporary or permanent category and will be indicated to the driver on ARMS monitor. Failure to acknowledge will be treated as lack of vigilance of driver. After a special vigilance warning, if driver does not respond, penalty emergency brake will be applied, and the guard will be summoned to the engine.* ***ARMS unit on the engine will automatically transmit an SOS message that will be received by all stations and trains within 5 Km radius of the disabled train, following the general rules for protection of tracks in front, rear and adjacent tracks. This does not substitute other extant rules for train protection! ARMS has special design for day & night hand signal, inspection, tools and light for train crew and guard, that conform fully to all the rules and performance stipulations for various situations, which present equipment in use do not cater for. Technical details do not fall in the purview of the subject here.***

Listed below are the general schematic of the configuration of the ARMS set up. The complete operating system consists of;

NOMENCLATURE OF MODULE UNIT	APPLICATION LOCATION
A. Radio Transceiver Communicator,	Engine driving cab, station master, special track inspection. Vehicles etc.
B. ARMS Processor & Monitor,	Same location as above
C. Input Transducers & Sensors	These are peripheral equipment distributed in various locations in the proximity to main CPU, such as, speed sensors, Basille code readers, trivector accelerometers, shock sensors, track obstruction detectors, rail flaw detectors, rail~flange clearance measurement, rolling motion frequency counter, bumping shock recorder, ECC TV for train track monitoring, brake system air flow for air/vacuum systems, Breathalyzer, authorized operator identity verification, duty and event log recorder, crew/operator vigilance monitor, recording operator log-in and log-off messages, and many other data as may be needed for operating safety, such as, important abstract of relevant safety rules, guide for action to be taken in emergencies etc.
D. Portable ARMS Cellular type phones,	The main ARMS CPU functions as the base station, and is effective for a radius of Km reach. This will be necessary for assistant driver, guard, signal inspector etc. for emergency working, as well as for normal inspection or maintenance, say like inspecting a train, shunting in yards, or non-interlocked working at stations.
E. ARMS for Level Crossings.	Scanner for crossing, with special processor for evaluating the nature and risk content of any obstruction over crossing, and send out SOS signal to approaching train, transmit warning signals to gate indicators like RED/YELLOW Flasher signals both at the gate as well as a road signal 500m away from the gate. ARMS unit on the train engine also transmits approach warning to the crossing indicating the interval of time in seconds to arrive at the center of the crossing. These radio beams can be picked up by special pager type units that road user can procure. They will not work on the public cellular services. It can be used by any person, road vehicles, tractor trolley etc. not only for regular crossing but also for cattle crossings. It will indicate particulars of the train, location and speed of running.

NOTE:
A. is any ARMS Unit at Station, Engine etc.
B. are Sub-systems of ARMS installed at any location as Base Unit.
C. *is any other ARMS Unit at another location like Engine, station etc.*

PREVENTION OF COLLISION ACCIDENT: Unlike the conventional approach to treat every case of collision different from any other based on the circumstances leading to the accident, and introducing new rules for operation or adding to vigilance measures assuming Human error as the prime cause, ARMS treats the train, station etc. equipped with ARMS equipment as animated objects of these zones and apply the principles of SELF PROTECTION by the train or station themselves. It may involve the driver or the station master to carry out some operations and confirm action taken. Thus ARMS focuses on averting or preventing a collision or other types of accident taking care of human failure also! The various circumstances for a collision to occur may be listed as under, but it is immaterial what the circumstances are to ARMS to achieve reliable safety as objective.

1. SPAD or Signal Passed at Danger has the highest potential for both derailment and collision accidents. When nothing unusual happens, the incidence is suppressed. ARMS handling of the same situation is as under. However, the incidence is high!

   Now, the ARMS units concerned are engine and station, as well as other engines in the vicinity of less than 5 Km radius. Any train approaching a station establishes contact and transceiving all data for the reception of the train, indicating all signal aspects, and routing with details of track section number, switch number etc., (as on the mimic board in station master's room), as may be set by the station master control. Thus if the signal concerned is ON, and access is denied, ARMS will not allow the train to pass the signal location, as its location is part of the transmission by station ARMS. The Basille for the signal that is placed before the signal will alert the driver and if the driver does not acknowledge, it will result in a penalty emergency brake stop. Hence, SPAD is fully averted, also preventing any type of consequential derailment or collision accident.

2. Human Error in electrical connections after maintenance work by signal & track staff, whereby contradictory movements can become a hazard to admit a train on the track with a train already positioned. Station master fails to observe the abnormality, in spite of no lack of vigilance on his part.

   All the ARMS when active, (even on a stabled engine without load), continuously beam radio identity, giving relevant details including its location, say, track or loop number, name of train.. These data are automatically available to the ARMS at the station, directly from the train when it arrived earlier, and the track/loop is memorized as occupied. This is a direct transfer of data from the Engine to the ARMS at station. This also confirms the action of station master while setting for receiving the earlier train on loop. ARMS merely records all settings of station movement control panel. Station master is not called upon to operate the ARMS unit unless warning alert is activated. Thus, when another train is permitted to enter with wrong data, ARMS at the station will alert station master with details. On the incoming train engine, ARMS will automatically stop the train at the signal, as it receives directly the location of a train in its path. These data are independently obtained by trains on line, and is the actual field position information, and not derived from station or traffic control, which may not be able to detect or suspect an electrical wrong connection by field staff. In principle ARMS will not allow two trains on the same track path with less than a 2 Km separation distance in normal operation. With a special protocol facility, ARMS allows another train to get closer for an emergency, like a shunting operation, say, to assist or push a disabled train ahead near a station to clear the section.

3. Infringement of a fouling mark at a station loop, not detected by station berthing circuits, posing a hazard of side collision.

   Complete reception of a train is confirmed only when the guard communicates the clear signal over his portable cell phone type ARMS unit. This is done by merely pressing a button, that provides alright code to train ARMS and the station master in turn by the engine ARMS automatically with no driver intervention. Driver will draw ahead if the rear FM is not cleared. ARMS at station will not allow any operation if FM is not cleared. Normally train engine should stop at the STOP fouling mark near starter signal. But is not obligated under the station working rules. However, ARMS software foresees automatic comparison of Berthing capacity with train length, using passive bassille system.

4. Derailed Train in a mid-section infringing adjoining track, to risk collision. Whether the adjoining track is infringed or not, the derailed train will automatically broad cast the SOS for derailment, and all trains in the rear of its own track, and of the adjoining track in the same or opposite direction will be alerted automatically. Thus, the possibility of a consequential collision is eliminated.

LEVEL OR GRADE CROSSING ACCIDENTS:

1. Train admitted on to a wrong track can not happen for the same reason as that of case 2 discussed above.

   The crossing may of any type including un-official cattle and tractors crossing from one side to another side of the track in the agricultural area. Detector senses the difference between an occupied and free crossing protected zone. Train identity beacon is sensed by the detector at the crossing and regulates signal aspects according to prescribed standards for road and rail. Track basilles are placed at 5 Km for high speed trains, and at 3 Km for normal trains. Train engines are alerted of the proximity of the crossing, and automatically radio beam train identity and time interval to reach the crossing in seconds for the guidance of road traffic, that can pick up pager data for advance alert. Irrespective of individual's watch settings, pager will work like a time interval alarm clock very reliably to prevent risk of a crash. The residual count down at every instant is set by train speed and it has nothing to do with any watch time.

   If the train has stopped before reaching the X-ing, the road traffic can be allowed to resume moving, as the train can not restart unless the X-ing is clear for train. If another train in the opposite direction or another parallel track in the same direction approaches, the ARMS acts severally and independently for each train. The operation is governed only by the prescribed working rules for each X-ing.

   In the case of manned crossings, and when the freight trains do not run to any scheduled paths, and if the majority of trains do not run precisely to advertised times the gateman is unable to plan his absence from the gate for answering nature's call, or any other distraction, as risk factor for a gate accident will increase. With the help of the pager, the gate man gets his alert wherever he is, when he has to be away outside the scheduled train passing times. This will be about two to three minutes advance warning for him to get back to his post. Normally however, with automatic barriers X-ing need not be manned. The new ARMS scheme for prevention of level crossing risk development can even protect against sabotage by placing obstruction on the track. In any case, even if the detector equipment fails at the crossing, the engine driver will be alerted for cautious driving, when the engine passes over the respective basilles, and when the train arrives at the safe distance for service braking halt, the train will automatically be braked if the driver fails to control the train and stop short of the road crossing. Subsequent action depends on the field situation to carefully pass train with public co-operation.

CONCLUSIONS: It is therefore evident from the study made of the prevention and protection for Derailment and other types of train accidents, trains collision and train crashing into road obstructions represent less than 20% of the total accidents according to prevalent statistical reports. Impact of derailment accident is heavy on traffic losses!

Prevention of collision and grade crossing accidents are by far the simplest, fastest and most economical to achieve through ARMS. They do not call for any change in the method of railway operation, or involve any high investment. Prevention of derailment is dependant totally on the efforts to get ARMS detected defects and track locations rectified progressively. The rolling stock design defects and hard yard bumping should also be attended to appropriately, to practically eliminate risk factors that contribute for derailment. As long as the rolling stock are not rectified, they will continue to damage the tracks, and risk arising will call for more maintenance. In fact, a special program on a war footing for rolling stock attention can be achieved very fast in the ordinary maintenance work shops, as it will progressively reduce the maintenance work to finally eliminate extra maintenance introduced by way of intermediate overhauls, and major repairs and stop gap repair and re-use of old reconditioned worn components will be eliminated. Many material failures like hot axles with roller bearing stock, or replacement of components with poor life etc. work will reduce too.

No doubt, initially the defect reports will be very high, due to back log of known cases, but what will be more revealing is the many occult cases, because there was no way of knowing them in the absence of any concept and facilities like Accident Risk Management. High technology is used for only ARMS, but NO NEW TECHNOLOGY OR UNPROVED DEVICES ARE USED IN THE SCHEME. IT IS THE MOST ECONOMICAL WAY TO INCREASE TRAFFIC CAPACITY AND REVENUES AND THAT IS THE ONLY BUSINESS OF RAILWAYS.

ACCIDENT RISK MANAGEMENT SYSTEM
DATA LOGGING & PROCESSING

INTRODUCTION:

This is the fourth and final paper, that explains the new methodology for the processing of the voluminous data that will be supplied by the ARMS Installations, - (Accident Risk Detection Sources), at the stations, on board locomotives, grade crossings, and electric traction power and switching stations along the electrified routes, all over the vast railway net work. The design of the protocol has to be simple, and data processing at the ARMS field installations, and at the various subsequent stages of accident investigations, examination of premature material and equipment failures and damages from the point of view of design adequacy to withstand the onerous service conditions, determination of the cause for the component failure to find if the failure was due to accident or the accident was due to component failure, and what kind of remedial action should be taken for the final solution. The data have also to be processed, if the changes made earlier had given satisfactory response, and that verifiable proof of improvement can be established. It is natural, that references will be required to various field units for giving more data or provide feed back information in a systematic fashion, so that the evaluation and interpretation follow a set pattern until the final answer for prevention or protection is well established to become a standard for the field units to follow for maintenance.

All these data that would be raw or semi processed, would require to be exchanged between various administrative and field centers. Indian railways already possess a microwave network, and now further augmented through dedicated satellite links, that will facilitate convenient and very fast communication to inter connect all selected ARMS centers to the central ARMS control at any place nominated by railways. Thus this paper explains the decision making system for ARMS working, from the field level to the apex with least paper work and human control or interference, but will be illustrative only, as it is the railway board that will design the architecture. **Thus ARMS is a country-wide live Web-Net, and not merely some equipment installed here and there like old type Vigilance Devices!!**

The ARMS design concept is based on self-protection principles, and hence, even selection of risk abatement remedies are also programmed with least human involvement and limited to only choosing alternatives or providing guiding data, when further processing is hindered!

BASIC PRINCIPLES IN ARMS PROGRAMING AND MANAGEMENT:

The following Basic Principles are adopted for Programming Automatic Processing of Risk Parameters Detected by ARMS Units, as well as any such input voluntarily by human operators. These are indicated for each level of ARMS operating System.

1. **List of Field ARMS Centers and Scope of Data Collection and Processing:** *All Railway Stations including Large independent Yards:* All Risk Data either Detected or Reported over ARMS communication system will be processed locally and is fully controlled by station master for taking decisions for direct action or forwarding to the higher level for action. This will be fully and automatically guided by the data bank provided in the unit for all relevant rules like, station working rules, general rules, accident rules, etc. Normally, in most cases, the station ARMS responds directly as per the action taken, say for setting train reception or dispatch, train stopped and waiting for call on signal etc., and in cases of SOS calls, the station master will just receive messages on his ARMS, but will have no operating inputs to be entered into his ARMS unit. *However, all cases of risk situations for any IMMINENT HAZARD will be automatically and FULLY PROTECTED, because, it has a need for self-protection and needs no consulting requirement. Such ARMS commands are like human reflexes! All station units are interfaced with both traffic and traction control communication facilities.*

   All Grade Crossing ARMS units are very small with only one function to detect crossing obstructions and send out status of crossing with location details, and beam alert for locomotive ARMS units and pager data for road vehicles. It will activate other local gate warning devices.

All Electric Traction Feeding Posts and Switching Stations: These are similar to grade crossing locations, except that it provides communication of data and voice between locomotives and central traction and traffic control center concerned. These are spaced around 10 Km. Apart, and intended only for emergency needs. The ARMS unit is interfaced with traction power control communication scheme. All railway station ARMS units also are connected to this communication Omni-Bus lines.

ARMS on all Locomotives and other self Propelled Vehicles: **These are all roving ARMS units, and survey every part of track traversed for risk presence. Such monitoring is humanly not possible for both quantity of work and precision in quality of risk sensing. Risk is mostly hidden, nascent and developing. *It is this lack of data that puts the human experts in handicap and responsible for not tackling the problem of derailment for over 150 years of rail transport technology! The modern advances in electronic sensors, transducers and mobile communication technology makes ARMS principles possible and reliable for realization!!***

2. **List of Administrative Level ARMS Units for Management:** In contrast to the Field ARMS, that have only accident averting and protection function, administrative ARMS management deals with data processing and accident prevention responsibilities. Specific operating programs are predetermined, and the computer processing is made automatic to eliminate human drudgery in handling a large volume of data. It however requires intelligence inputs whenever called for and requested by ARMS for human decisions, which can not and should not be computerized. However, in course of time and experience, administration may set up standards and solutions in a directory for the ARMS to act on its own pre approved logics for decision making, avoiding repetitive decisions in cases of preferred choices for alternatives. The parameters can be defined easily. ARMS will not handle correspondence, which work belongs to office management, and not Accident Risk Data Processing!

Field Level supervision & control ARMS Centers: The following locations may be indicated, but railways have to decide the number that depends on the organization of the supervisory control zones.

Field workshops for running repairs, for wagons, coaches, engines, tracks, signal & interlocking, electric traction etc. These are generally zonal division central workshop facilities.

It is here that all statistics of material and manpower inputs are generated. Hence, ARMS unit can generate all primary data for accidents, damages, abnormal consumption of components, etc. from which standard data statements can be processed and furnished to the higher divisional level, as periodical administrative reports . Divisional headquarters process these data gain and send summary reports to zonal headquarters for further administrative scrutiny and exercising management control to assure maintenance of ARMS conformance.

ARMS at Railway Head Quarter Offices: There are many Major Zonal Railway Central Work Shops controlled directly by zonal general manager administration and departmental heads. The ARMS statistics from these workshops deal only with major overhauls and accident repairs and will submit ARMS reports to the concerned head offices, who will scrutinize divisional ARMS reports, and discuss the same with the heads of departments to assist the divisions with necessary sanctions and funds and advice for assuring safety in operation. New consolidated statistical reports will be compiled by the ARMS, for periodical submission to central design and standards office, and railway board. These can be daily unusual occurrence reports as well as 10 day reports as per extant practice.

ARMS at Railway Manufacturing Factories come directly under railway board like zonal railways. They have warranty service to do for the rolling stock or equipment supply made to railways. Hence, ARMS reports of unusual occurrences have to be sent by zonal railway workshop concerned to ARMS design center and ARMS manufacturers, (which may include even locomotives, rolling stock and any other that railway board may prescribe, purchased by out sourcing). This will eliminate inadvertent introduction of new designs that may vitiate railways' efforts to achieve ZERO accidents.

ARMS in Railway Board & Ministry of Railways: This is the Apex Body, who report to the government on safety matters in train operation, and provide all financial and administrative assistance to zonal general managers and can assure ARMS norms are maintained.

Presently, railway board get daily unusual occurrence reports from zonal railway offices, mostly over telephone followed by fax and other means. In the absence of proper and precise information, and mostly due to inability to determine the cause of the accident, statements are made impressional guess work. The recipients of such reports working on the basis of such reports often find themselves working on the wrong track or unable to work forward.

Thus ARMS reports are automatically generated according preset format, and every time a new summary report is to be made, necessary calculations and evaluations are made in accordance with built in program, requiring the operator to check and forward the same with any notes he may add.

IMMEDIATE ACCIDENT ABATEMENT WITH SOME ARMS SOLUTIONS:

Implementation of ARMS scheme or any other equivalent system, will take some time, but one would like to take immediate steps to control risk arising, though not eliminate them under full ARMS scheme. The author has studied and experimented some of the solutions during the phase of development of the concept over many years. These steps will go a long way to greatly ease the pressure on maintenance, and if implemented immediately will help to hasten the ARMS gains when installed. No major investment in equipment or special material or equipment is involved. The list given below are the result of the ARMS concept of self protection. The Pre-ARMS is a Hardware solution and can be managed with existing facilities, while Post-ARM scheme is totally software oriented and needs special facilities!!

LIST OF PRE-ARMS SOLUTIONS FOR ACCIDENT ABATEMENT:

Pre-arms solutions recommended below are not for PREVENTION OR PROTECTION as available with ARMS concept, but are only palliatives that go to ABATE or lessen the risk propensity, and helps in the smooth implementation of ARMS for TOTAL ACCIDENT RISK PREVENTION against immanent risks, and PROTECTION by AVERTING any IMMINENT risks of hazard.

Solution Defined Remarks For Track Check/Guard

Wing Rails - Reduce Slope Of Flare To 1/10
Increase Length Of Flare To 1200 mm By Fixing An Add-On Piece For Locomotives Only
Use 1/40 Wheel tread Taper Instead Of 1/20 As Existing
Use Flange Lubricators For First And Last Axles Only
Provide Suitable Large Convex Mirror For Rear View On Both Sides As Used For Big Highway Lorries
Arms Baton Signal Lamp For Driver And Guard Rolling Stock
Do No Use /40 Tread Taper For Wheels Of Wagons An coaches!!
Provide One-Use Maintenance Free Flange Lubricator For All Brake Vans
Provide Hot Axle Indicators For All Axles
Provide All Running Staff and Train Examiners With Inspection Hammer

This reduces lateral shock on wheel flanges infringing on short wheel base bogies and other bogies with damaged and distorted skew frames due to yard bumping. Saves wheel gauge widening. Axle bearing damages, & hot axles. *This will reduce the nosing frequency by 50%, and help to reduce tread wear on the short wheel base of CO-CO bogies. It is possible to use extra thick flange with gain on flange life and amplitude of lateral oscillations with wear. Use graphite bituminous or suitable polythene thick walled tube as lubricator, constantly pressing on flange. This helps to monitor train behind frequently. The mirror should be retractable and latched when not in use. These are tricolor high intensity LED lamps with flash mode with facility for standard CODED signaling facility as prescribed in general rules and operating manuals. Safety signaling demanded in GR is absent in all existing signal lamps other than the original 150 year old design! Use of 1/40 tread taper on a large scale for all wagons will generate fast wear of tires as well as rail table improving the smooth linear guidance available with 1/'20 design. 1/40 also causes risky reduction to flange angle and promotes hollow wear detrimental to points and crossings. Rail life reduces and maintenance increases. The flange and tread wear pattern promotes DERAILMENT RISK !! While the engine lubricates the wheels of its own vehicles the brake van lubricates the track for the benefit of following trains. Over passage of few trains flange and rail wear will be significantly controlled to improve tire life. Problem of cyclic rail wear and lateral oscillations will reduce and contribute to abate derailment risk development, Not Stop! This is a simple button-like component of the shape of 50 a stud type thyristor, that can be fitted to axle box cover in the factory and sealed. It is once use type. Axle box covers can be changed during overhauls, repairs and also in the yard depots. With hot axle, driver or guard and any one on the ground can notice as provided in operating manuals. It will prevent derailments and traffic hold-ups. It can be used for sounding wheels, security hooking of wagon doors, under frame Inspection in inaccessible places with safety, engine roof Inspection from ground, and also like a cricket umpires stool for resting. Very Light!*

ARMS STATISTICAL DATA REQUIREMENT & SOLUTION RESEARCH:
In the ARMS Research for Solving Accident Risk Prevention, the most important field of activity pertains to only DERAILMENT RISKS that concerns only track and rolling stock, as has been discussed in the earlier papers. Collision and grade crossing accidents have NO RELATION to track and rolling stock performance! Hence, these will not be included here. The type of statistics for these will be limited to incidence of such accidents and events of averted accidents. This is because, collision and gate crash largely concern, operation of other systems like signal-interlocking, traffic operation and human errors or Intervention including railway staff and outsiders! By the magnitude of accidents, derailment represents over 80% incidence. Thus dealing with track of over 40,000 route Km with over 15,000 route Km of high density traffic, and over 400,000 axles in circulation of all types of vehicles at any one time, the wear and tear of track and vehicles is colossal, though spread out over a large network. For any realistic statistical approach for identifying, locating, grouping comparable components to solve problems, one can not apply the simple law of averages to decide the remedial prescriptions. ARMS process of evaluation takes all these into consideration.

It may be worth repeating the finding of the author in his investigation into very high incidence of derailment and poor performance of AC electric locomotives on South Eastern Railway in 1969-1970, was ,"that, non-matching design of short wheelbase bogies introduced in bulk replacement, damaged the tracks, which in turn damaged all other types of stock running in a closed circuit in the same section, and the combination of poor rail and stock led to very high incidence of failures of many vehicle components like, axle bearings, fast flange wear, spring breaks, and very high rate of wear of even special manganese liners, suspension links, equalizing bogie frame bars, high capacity center buffer couplers, etc.!" Such phenomenon was not confined to Indian Railways alone and could be observed in other advanced countries also, even today. The derailment incidence is of such magnitude, that all the world railways have embarked on a serious search for correct solutions to abate the problem. ARMS has taken the approach of eliminating the source primordial cause for all accident types! The Co-Co design of AC electric and diesel electric locomotives may be taken as an illustrative example for relevant statistics for ARMS Data processing and research investigations.

DAMAGES REMARKS "HOT AXLE AND INNER RACE ROTATION EQUALISER CRACKS PRIMARY SPRINGS BOGIE FRAME HORNCHEEKS/GUIDES CENTER PIVOT SIDE BEARERS FRICTION SNUBBERS" **CHECK RAIL BREAK.**

Plain bearings flailed faster, and changing over to roller bearings, has reduced failures. The reason is the excessive lateral shocks due to high frequency of regular oscillations. Skew angle of leading axles with only 1702 mm spacing is practically a square on BG with 1676 mm standard gauge. Gauge face of leading wheels hit check rail end flares with a lateral acceleration of 1.6 G at the permissible speed of 10 Km/h. For an over speed of 20 Km/h, the lateral acceleration will be around 6.4 G, and sock level of , say, 32 G/sec. With such magnitudes, the axle box guides, side bearer support manganese steel floating slides, sustain friction streaks similar to rail burns observed with wheel slip. The Friction Snubbers get worn out fast and lose their damping force. The center pivot support fixing bolts and cracks on bogie frame and bolster beam are due to yard bumping, when even the CBC coupler and draft gear get damaged.

Note: The author would like to make a passing observation, that during the fifties, steam locomotives with pony trucks that had short wheel base had nosing oscillations and exhibited fast flange wear. Derailments were common. There is no doubt that three or four coupled axles, combine with with reciprocating piston thrust also contributed for the nosing sway motion, but even the 1500 volt DC (EF1 Type), freight electric locomotives on central railway, that had no reciprocating piston also exhibited nosing oscillations, with use of pony trucks of short wheel base.

Note: Schematic of possible extension of Check Rail Flare to reduce slope.

ARMS OPERATING STATISTICS AND CONTROL MANAGEMENT:

The Operating Statistics as employed now is true only for a homogenous system, like uniform plain terrain, all rolling stock of the same or similar designs, all trains are evenly spaced irrespective of traffic density, etc., where simple averages can be adopted for calculation of statistical probability of some credence! The figures like number of accidents per million passengers carried, or million train kilometers, has no significance at all for tackling the problem of accident prevention, nay, even its abatement!

ARMS allows any number of classifications that one may desire for a particular investigation, since all data as and when they arise will automatically fall into relevant groups as foreseen in the ARMS Software. While the details can not be discussed, the basic principles are described, but at the same time no new major deviations are made in the railways' methods of inventory, or record of reporting component failures, or accidents at source, like the field ARMS locations previously mentioned.

FIELD LEVEL REPORTING ARMS DATA FOR OPERATIONS:

1. Traffic Yard Master ARMS Reports such as;
   Number of Terminating Trains (Pass./ Freight) received up to mid-night. Total no. of vehicles by types
   Number and type of defects reported
   Number of Vehicles repaired, total idle hours and repair hours
   Number of New Trains formed and dispatched
   Number of Vehicles by types cleared from yard. Difference between Input and output of vehicles
   Number of stabled serviceable vehicles more than 24 hours
   Number of Condemned vehicles in holding and reasons

2. Rolling Stock TXR and Locomotives Depot EXR (Engine Examiner):
   Note: The workshop or inspection shed report is similar to yard master, except the following additional data are included in ARMS requirement. List of engine components damaged, replaced, repaired, condemned with information on premature or normal replacement. The program will automatically group them as every item has a reference stores identity, that is used for investigations in data processing by ARMS. List of failures of components for onward dispatch to designs office. This is done automatically by ARMS unit on the basis of reference directory, that may change by administrative decisions.

3. Permanent way Track Structure Data Processing:
This is also similar to rolling stock data processing, that have the permanent way inspector depots and railway's central engineering and track workshops. The field reports concern only abnormal features like excessive frequency for deep screening, heavy loss of ballast due to pumping, rail cracks, points and crossing damages etc. Since the reports are confined to zones controlled by PWIs, or even special sub-PWI zones as may be determined by administration, data so collected get automatically divided into groups of sections with similar terrains and traffic intensity, that do nor require any human interference, except at the time of designing the software, following certain norms for statistical compliance.

4. ARMS Running Data From Locomotives, and Railway Station Units:
It has been explained earlier, that the ARMS units on locomotives and stations record all relevant data for ARMS function. The following are major items of interest. Every tenth track Km location, date and time, speed, station passed. Any abnormal even pertaining to ARMS function with time and location data transmitted/received over ARMS transceiver unit. Date, time and location for any data downloaded. Data not erasable. But storage in memory is limited by design, say 16 MB, and FIFO overflow.

All the Data I/O can be down loaded for investigation and study at maintenance workshops. ARMS workshops can edit and forward and original data for reporting to zonal ARMS centers, for further administrative needs, and all technical data can be forwarded to design center by the central workshops directly. No word processing program is foreseen to handle correspondence, but every type of reporting can be done on prescribed formats, where it mostly filling the blanks as data, following the recommendations of general rules and operating and other manuals!

Since, the stores organization has already the data on stores transactions, corresponding each and every bulk material drawn by users, a very reliable statistics of usage of every component is available as, what is termed as PL (Price List) number with full specification **References to all types of materials transacted.** ARMS merely uses these data, for investigations, say, to examine excessive consumption of components in the link of fault energy paths for derailment accidents as discussed earlier. For example, leaf spring suspension link undue wear and failures, is not expected to be the result of unsuitable material as it suitability for design and acceptance specifications and inspections are not to be suspected normally and regularly. There can be some oversight in inspections, but not procurement of unapproved or non proven components. This means, after a routine material compliance for specification, statistics of all component failures in the path of energy flow for derailment is studied. The quantity of material failures are then automatically grouped for comparable sections for a correlation check. These data are in the nature of a moving statistics for fixed periods, say every ten days. The derailment causes are then classified, for deriving information on the effectiveness of solutions implemented and other questions that arise in the ARMS pursuit for accident prevention.

It may of interest to see the effect of overloading locomotives and wagons from the point of view of coupling draft gear loading in traction and buffing, on a steep gradient up or down hill run. The author has observed side buffer over riding on a 1/27 ~ 1/40 slopes on Western Ghats of central railway (India) on both tangents and curves. Center buffer couplers also exert excessive lateral forces. Climbing UP-HILL with heavy multiple locomotive banking for only one train engine at the head end, imposes not only buffing forces beyond design limits for coupler, the problems results for any excuse of a momentary wheel slip of the train engine at the head end. Similarly, while working down hill, with multiple locomotives at the head-end, creates problems working on mechanical brakes, the time of entering sharp curves. With electric braking, the problem of buffing forces is well controlled steplessly, but to achieve this safety and reliability, operation should ensure that the specification limits to traction and braking forces are not violated. ARMS unit on the locomotives are programmed to achieve this norm to prevent accident. Details of design are outside the scope of this paper, ARMS gives only the signal out-put, but locomotive control block design has to provide the interface coupling. However, it may be mentioned here, that the yard master ARMS unit always prescribes the train loads when the parameters dialog box is filled for ordering each train. For this purpose, a directory of wagon characteristics is a normal data base. In any case driver always gets the most appropriate advice to achieve the best traffic output reliably.

5. SPAD (Signal Passed At Danger) Investigations:
   Instances of signals passed at danger are quite common, but no statistics are generally available, until a collision or derailment takes places or such accidents are averted! Collision cases in automatic signal zones call for a proper solution, that ARMS provides automatically through alternative modes. In the case of sub-urban train units, the acceleration to braking distance ratio at the maximum speed can be about 2 ~ 3, or even superior for very fast services. The normal SPAD protection is by the aspect of the signal ahead obtained by ARMS on the train from the station ARMS unit. All trains continuously beam their identity, track occupation, location Km, time, and speed and direction of movement. Thus every train has automatically minimum alert indication for less than 2 Km separation. Further, if the distance reduces ARMS flashes SOS and gives signal and audio-visual warning to reduce speed, until the distance increases to over 2 Km. To negotiate passing the yellow signal, after passing a red signal earlier. The train can not pass another RED signal and will be halted on penalty Braking. Thus, almost all risk events have the primary and back up for detection and protection in special circumstances, where prevention is not in natural control, being surprise random events.

6. ARMS Statistics For Index Of Performance:
   Statistics for train running guidance: ARMS on board the locomotive gives the actual passing time at a station and scheduled arrival time at the next station. Any late running of the train is indicated and also informs the ARMS of the next station of the delay and expected arrival at the next station. In the case of non-scheduled trains running to open timings, there is no data for delays, but the total running hours and halts are recorded from start to finish of journey.

   The above are available from the joint train reports, but are essential data for train operation needed for investigations for any reason. As mentioned before, the complete journey diary or log is down loaded at engine terminal or home shed.

   ARMS caters to recording sudden traction catenary voltage, power and current up or down variations over the previous levels for successive sampling intervals of 10 seconds. This data is used in the evaluation of wheel slips, skidding, train parting, bumping, concertina coupler shocks, as well as micro investigations of the history of running for solving certain safety problems.

   Similarly, ARMS also records all abnormal events in the control and brake circuits.

   The above data are needed for accident investigations and locomotive performance trouble-shooting, in inspection sheds and in design offices. Such data are also promptly transmitted over railway railnet links, as needed. The details are outside the scope to include here.

CONCLUSIONS:

1. For any type of statistical calculations, only the normal locomotive, station and other ARMS records are used, including those data compiled as per general rules or special Instructions of statistical department, at various ARMS zones. Hence, no extraordinary requirements are placed by ARMS use.
2. Data compilation is automatic and eliminates possible human errors.
3. ARMS being totally software oriented, can be continuously improved.

Mortality In The Indigenous People Of New Zealand And Australia

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ABSTRACT

Objective: To compare the major causes of mortality between contemporary indigenous and non-indigenous people in New Zealand and Australia, and to briefly examine how contemporary health policy is addressing these problems. **Method:** Information on the mortality of indigenous people in New Zealand, Maoris, and Australia, Aboriginal and Torres Strait Islanders, and of their non-indigenous counterparts, was obtained from a literature review. **Results:** The major causes of mortality in Maori communities include cancer, circulatory and respiratory diseases, injuries, where as the major causes of mortality in Aboriginal communities include circulatory diseases, injuries, respiatory diseases, cancer and infectious and parasitic diseases. Life expectancy and infant mortality in Maori communities is better than Australian Aboriginals, but worse than non-Maori New Zealanders. **Conclusions:** Patterns of Maori and Aboriginal mortality include a range of degenerative diseases, but differ somewhat in their priority, as well as in the areas of injuries and infectious and parasitic diseases. The health of Maori people appears to be superior to that of Australian Aboriginals, but lower than that of non-Maori New Zealanders.

INTRODUCTION

There are striking similarities and differences in mortality amongst indigenous peoples in New Zealand, Maoris, and Australia, Aboriginals and Torres Strait Islanders. There is a similar pattern of high adult mortality in both the indigenous peoples of both New Zealand and Australia, however there are differences in the leading causes of death and life expectancy. Historically, the number of indigenous people declined markedly following the arrival of Europeans in Australia and New Zealand. High levels of mortality continued for some time due mainly to infectious diseases. In contemporary Maori and Aboriginal populations, the major causes of mortality have shifted towards degenerative diseases, accidents and violence.[1] Life expectancy, infant mortality, and causes of mortality between Maori and Aboriginals are compared here. A brief overview of current policies on addressing Maori mortality in New Zealand is also given.

OVERVIEW OF MORTALITY

"The overall mortality rates from all causes of Maoris in New Zealand have fallen substantially since the 1970's"[2] The same cannot be said for Australian indigenous peoples and their mortality rates are about 1.9 times the rate observed in Maoris.[2] Mortality rates appears to differ between indigenous and non-indigenous in several age groups, namely infants, middle age, and older people. Several key health issues in Maori mortality are recognised,[3] and these are compared with those of Australian Aboriginals in Table 1.[4] Steps to improve reporting of ethnicity in New Zealand mortality statistics have been recently undertaken.[5]

The major causes of mortality in New Zealand Maoris are accidents in the younger age groups and ischaemic heart disease, cancer and chronic lung disease in older age groups.[6] Age-standardised death rates are higher in Maori males compared with non-Maori males for most degenerative diseases and injuries, except for cerebrovascular disease, pneumonia and influenza (similar), large bowel cancer, and suicide.[7] Age-Standardised death rates are higher in Maori women compared with non-Maori women for most degenerative diseases and injuries, except pneumonia and influenza, large bowel cancer, breast cancer, unintentional injuries other than motor vehicle accidents (similar), and suicide.[7] The major cause of death amongst the major age groups of Maori are given in Table 2.

INFANT MORTALITY

Infant mortality, another important health indicator, has improved dramatically in the past 40 years in the indigenous communities of Australia and New Zealand and have been reduced by two-thirds or more.[8] In the 1980's, Maori and Australian Aboriginal infant mortality rates had dropped to 18 per 1000 live births and 20-34 per 1000 live births respectively.[8] Infant mortality is still higher in both groups compared to their non-indigenous counterpart.[8]

LIFE EXPECTANCY

Life expectancy of Maori people is approaching that of non-Maori New Zealanders, whereas Aboriginal life expectancy is much lower than non-Aboriginal Australians.[8] Maoris are living around 6-8 years longer than Australian Aboriginals.[1] Available statistics appear to indicate that the life expectancy of Maori men and women has improved dramatically in the last 60 years. Unfortunately, similar statistics are not available in Australia for that period, however Aboriginal life expectancy has shown no sign of dramatically improving in recent years and remains some 15 or more years behind that on non-Aboriginal Australians. In some Toores Strait Islander communities, the expected higher life expectancy of females was not observed in recent studies by Speare et al (personal communication) and in fact the reverse appeared to the case. This finding is yet to be explained.

DEGENERATIVE DISEASES

In examining some of the major disparities in causes of morbidity between Maori and non-Maori New Zealanders, death rates from diabetes, rheumatic and hypertensive heart disease of Maoris are 4 to 5 time higher than non-Maori rates.[6] Similar excesses are observed in rates of nephritis and some respiratory system diseases.[1] There is also a marked disparity in mortality from cancer of the stomach and the cervix in Maori over non-Maori.[1] Alcohol-related deaths amongst Maori males are also 2.8 times higher than non-Maori males, whereas Maori females have half the non-Maori rate for alcohol-related deaths.[6]

Many of these diseases are associated with western affluence, however other lifestyle factors are thought to be important in Maori communities, particularly nutritional imbalances, alcohol and cigarette smoking.[6] When examining mortality figures between Maori and non-Maori from 1974-1978, ethnic differences in socioeconomic status accounted for about 20% of the excess risk of death, especially amongst males.[9]

INJURIES AND VIOLENCE

It appears that Australian Aboriginals have cause-specific death rates (per 1000 per year) about 3 times that of New Zealand Maoris for injury, poisoning and violence, at 1.0 and 0.3 respectively.[1]

INFECTIOUS AND PARASITIC DISEASE

In Australian Aboriginal populations, infectious and parasitic diseases are still a prominent feature, not only of morbidity figures, but also of mortality figures, which is in sharp contrast to that of Maori people. In Australian Aboriginals, these infectious and parasitic diseases include intestinal infectious diseases, tuberculosis, and a range of other infectious and parasitic diseases, such as strongyloidiasis. These diseases used to be the one of the leading causes of mortality in Australian Aboriginals about a quarter of a century ago.[4] Maori communities continue to suffer an excess over non-Maoris of acute respiratory infections, acute rheumatic fever and associated chronic rheumatic heart disease, glue ear, and skin infections.[7] Improvement in immunisation rates and other basic public health measures have been a major factor in reducing mortality due to infectious and parasitic disease, although environmental conditions which promote infectious and parasitic diseases are often considered third world, such as poor housing, and poor nutrition.[1]

REDUCING EXCESS MAORI MORTALITY

In addressing the issues of mortality and improved public health for Maori, the former New Zealand Public Health Commission (PHC) Suggests that the Treaty of Waitangi should be the starting point.[10,11] In the PHC document He Matariki: *A Strategic Plan for Maori Public Health*, it makes clear the government responsibilities to improve Maori health status. In Australia, no such treaty exists, although recent judicial decisions have made some progress towards restoration of land rights for aboriginal people. A desire for self-determination and to manage the delivery of public health services appear to be common to the indigenous peoples of both New Zealand and Australia.

The PHC notes that several health-related areas need to be addressed to reduce Maori mortality. [10] Some of these areas include reducing:

- smoking, especially in young women
- alcohol and drug abuse, especially in your Maori men
- risk taking behaviors, especially in young Maori men and addressing MVA's
  and improving
- nutrition.[10]

Health care reform for Maori needs to be undertaken in parallel to concerted efforts in "understanding and giving impetus to its cultural, economic and social origins". [12] If a conflict of values results from health care reform, then this can be counterproductive.[12] This is not to suggest that western medicine has not had some impact on the health of Maori, but that an appropriate power alliance needs to be established between Maori and health professionals to maximize benefits to Maori. Cultural appropriateness of some health services also needs to be fostered, e.g. Maori women having access to cervical smear-takers and educators who are Maori women.[7] This is also not to oversimplify Maori tribal and power structures, which are beyond the scope of this paper, but need to be understood by various health authorities.[13] In addition to Maori, there are indigenous south Pacific islander people living in New Zealand, who must also be considered. Aboriginal health policy also needs to be considered in a similar light.

CONCLUSIONS

Patterns of Maori and Aboriginal mortality include a range of degenerative diseases, but differ somewhat in their priority, as well as in the areas of injuries and infectious and parasitic diseases, the latter being are a greater problem in Australian Aboriginal communities. The health of Maori people appears to be superior to that of Australian Aboriginals, but lower than that of non-Maori New Zealanders. Areas which need to be addressed in Maori health include reduction in substance abuse, especially cigarette and alcohol consumption, and accidents, and also improved nutrition, areas also important to improvement in Aboriginal health. It is important that reforms in health policy for Maori parallel that of an understanding of Maori culture and participation in health care, a situation not dissimilar to that of Australian Aboriginals.

REFERENCES

1. abRing IT, Firman D. Reducing indigenous mortality in Australia: lessons from other countries. *Med J Aust.* 1998; 169:528-533.
2. Hogg RS. Indigenous mortality: Placing Australian Aboriginal Mortality within a broader context. *Soc Sci Med.* 1992; 35:335-346.
3. Ministry of Health. *Policy Guidelines for Maori Health* 1996/97. Wellington, NZ: Ministry of Health, 1996.
4. Thomson NJ. Recent Trends in Aboriginal mortality. *Med J Aust.* 1991; 154:235-239.
5. Kilgour R, Keefe V. Improving Maori Health statistics (Chapter 7) in *Kia Piki Te Ora: The Collection of Maori Health Statistics.* Wellington, NZ: Department of Health, 1992: 80-93
6. Pomare EW, de Boer GM. Health Risks (Section 8) *in Hauora: Maori Standards of Health.* Wellington, NZ: Department of Health, 1988: 141-161.
7. Department of Health. 'Whaia te Ora Mo Te Iwi: Strive for the good health of the people'. *Maori Health Policy Objectives of Regional Health Authorities and the Public Health Commission.* Wellington, NZ: Department of Health, 1992: 11-18.
8. KunitzSJ. Death in the fourth world (Chapter 2) in *Disease and Social Diversity: The European Impact on the Health of Non-Europeans.* New York: Oxford University Press, 1994: 22-43.
9. Smith AH, Pearce NE. Determinants of differences in mortality between New Zealand Maoris and non-Maoris aged 15-64. *NZ Med J.* 1984; 97:101-108.
10. Public Health Commission. *He Matariki: A Strategic Plan for Maori Public Health.* Wellington, NZ: Public Health Commission, 1995.
11. Reid P. A setback for the Maori health model. *Health Reforms: A Second Opinion.* (Wellington Health action Committee), 1992 : 27.
12. Durie MH. The treaty of Waitangi and health care. *NZ Med J.* 1989; 102:283-285.
13. Durie MH. Maori, Health, and the State. Keynote Address). Proceedings of the Public Health Association of New Zealand Annual Conference, Christchurch, NZ, 1992.

Table 1: Comparison of key issues in Maori and Aboriginal mortality

Major Issues In Maori Mortality[7]	Major Issues in Aboriginal Mortality[4]
Cancer (lung, prostate, stomach, cervical, breast cancer)	Circulatory disease (heart disease) Injuries (MVA's poisonings)
Circulatory diseases (heart disease)	Respiratory diseases
Respiratory diseases (C.O.P.D., asthma)	Cancer (lung, liver, bowel, cervical)
Injuries (MVA's)	Infectious and parasitic diseases

Table 2. Major causes of mortality amongst different age categories of Maori[7]

Age Category	Major Causes of Mortality	Comparison to non-Maori death rates
Children (Aged 0-14 years)	Sudden infant death syndrome respiratory diseases injuries, especially MVA's	
Young People (aged 15-24 years)	injuries received in MVA's suicide (particularly young men) other injuries	higher for homicide and assault
Adult Women (aged 25-64 years)	diabetes lung cancer coronary heart disease CORD	6 times non-Maori rate 3 times non-Maori rate 3 times non-Maori rate 3 times non-Maori rate
Adult Men (Aged 25-64 years)	injury, especially MVA, suicide cancer (esp. lung, large bowel) ischaemic heart disease, Strokes, respiratory diseases, HIV/AIDS, diabetes	2 times non-Maori rate 1.4 times non-Maori rate (lung cancer) 7 times non-Maori rate
Older People (age over 65 years)	ischemic heart disease, cerebrovascular disease, cancer (lung, large bowel, stomach, prostate, breast CORD, pneumonia/influenza, diabetes	

MVA's = motor vehicle accidents; CORD = chronic obstructive respiratory disease

GENERAL INDUSTRY ACCIDENT PREVENTION

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reprinted form the WSO Conference Proceedings 2001

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Following an explosion in the mine eleven men died at work in an underground coal mine at Moura in Queensland, Australia, in August 1994. Hopkins (1999) states that this explosion was entirely predictable with even its time, 25 minutes to midnight being predictable. After conducting an investigation into the events of this accident and the conditions existing prior to the accident the accident inquiry panel produced a 70 page report. This report found and concluded the following as causes of this accident.

1. **Communication failure:** In the Moura Mine there was a significant concentration of methane gas. In certain circumstances coal has ability for spontaneous combustion. If coal is allowed to heat up it can reach the ignition point of methane gas and cause this gas to generate an explosion. In the weeks prior to the explosion the miners had detected a distinctive tarry smell, excessive carbon monoxide (CO) in the atmosphere and a visible heat haze at times. The work crew supervisors, in their end of shift report, documented these signs of spontaneous coal combustion. The Shift Manager had the responsibility to sign these reports, but management did not read the shift reports. There was no management response to this identified hazard by anyone who had the authority, or the inclination, to do something about it.

   Following an explosion, which had killed 12 miners in 1986 at the same mine, the inquiry report recommended that all mines install a gas monitoring system to detect carbon monoxide in the atmosphere. This monitoring system was in operation at the time of the explosion. When CO in the mine atmosphere exceeded a predetermined specified level the monitoring system produced a warning on the monitor computer screen and a siren sounded an alarm. As there was no workplace procedure for what to do if an alarm sounded in this workplace alarms were canceled by anyone who was around. There was no record kept of who had canceled the alarm or if any action was taken in response to the alarm sounding. During the days prior to the explosion CO gas alarms sounded on several occasions, but were canceled with no action being taken.

   Prior to the explosion management did suspect that spontaneous combustion of coal was occurring in the mine. They decided to seal off the area of the mine in which this was occurring. This meant that the sealed area would no longer be ventilated. When ordering this action management understood that the concentration of methane in the sealed area would rise and enter the explosive range (above 5% of the atmosphere) some time after 11:30pm. With the sealing of the area management hoped that the level of methane gas would continue to rise above the explosive range without ignition and that there would not be enough oxygen in the area to sustain a fire.

   Spontaneous combustion of the coal in the mine was an ignition source. The mine exploded at 11:35pm on the night that the area was sealed. This was 5 minutes after the methane gas was predicted to enter an explosive concentration. Despite knowing the danger of an explosion occurring management sent their workforce underground for the night shift without informing these men of the situation. The shift manager was told not to raise the issue with the miners working this shift, although management expected that the miners might know what was happening due to informal communication (the "grapevine").

2. **Poor standard of auditing:** Moura had received accreditation from Standards Australia for its Quality Management System two months before the explosion. Safety Management at the mine was included in this audit. The mine managers relied primarily on oral communication for occupational safety but none of the communication system problems came to light in the Standards Australia audit. Company Executives from the BHP Head Office had also conducted an audit of the mine in the months prior to the explosion. A senior BHP Executive had been down the mine just a few days before the explosion. None of the safety management problems that led to the explosion were identified and the employees at the BHP Head Office in Brisbane thought that the Moura Mine had a high standard of safety management.

3. **Inadequate Risk Analysis for potential catastrophic events:** In the four years preceding the explosion management had halved its loss time injury rate by concentrating on preventing high frequency/low severity accidents. Prior to the explosion, the management at the Moura Mine had a brain storming session to identify all of the hazards that could be encountered in the area that was to be mined. One of the hazards identified was the possibility of the spontaneous combustion of coal in the mine. Management judged the risk of this hazard occurring as 'unlikely' and that if spontaneous combustion did take place it would cause no harm to employees. It was scored as a low priority hazard. The possibility of it causing an explosion if methane gas was present (and there was a considerable amount of this gas in the mine atmosphere) was not considered. There were no safety management plans, or engineering strategies in place, to minimise risks for potential catastrophic events faced by employees in the underground coal mine.

4. **Under resourcing of the government safety regulatory authority:** In Queensland, due to inadequate government funding, there were insufficient safety inspectors employed to check that the State legislative requirements for occupational safety and health were met in industry. Hopkins (1999) recorded that the government was prepared to accept a certain level of work related fatalities and injuries in industry, as long as their budget targets were met.

5. **Economic pressures:** In the year of the explosion the Moura Mine had achieved the highest level ever of production of coal from the mine. Due to economic incentives to continue to achieve a high level of production the Moura Mine managers did not stop mining to deal with the problem of the spontaneous coal combustion that was occurring in the mine. To the managers, at the time, achieving production targets was more important than occupational safety. They did not consider the fact that if the mine exploded the cost would be greater than the loss of a few days coal mining.

In the year prior to the explosion BHP reported a profit of $1.28 billion (Australian). The Moura mine contributed to less than 2% of all of the coal exported from Queensland by BHP in the year prior to the explosion. The loss of this mine was of no financial consequence to the BHP shareholders, and did not have any financial impact on senior executives of the company. Even following the mine explosion there was no economic pressure on BHP to improve mine safety and neither BHP or its managers were prosecuted for what happened at Moura.

General Industry Accident Prevention Models

It can be seen from the above events that the causes of this accident were a multitude of factors. Similar situations can, in the future, be avoided by having:
effective safety auditing and follow up actions implemented to improve safety management,

- using effective hazard identification, risk assessment and risk control strategies,
- having and using clear workplace safety and health communication, and
- by using recognized accident prevention models as a basis for devising and implementing effective safety management plans.

An **accident** is an unplanned event that resulted in harm, injury, or interruption to work processes. Accidents are caused by many factors, usually an unsafe environment, work practices, equipment or products, or by the actions or omissions of people. Many Safety Practitioners have devised Models of Accident Prevention that can be used as a framework for occupational safety management. The first well publicised accident prevention model was developed by Heinrich in 1931. While Heinrich was Superintendent of the Engineering and Loss Control Division of the Travelers Insurance Company he had 43 years experience in analysing accident reports. On the basis of this experience he developed the **DOMINO THEORY** to use to identify causes of accidents and to prevent the occurrence of future accidents.

From analysing his reports Heinrich believed that the unsafe acts of people were responsible for the majority of accidents. This started the myth of the careless worker and employee responsibility for occupational accidents. The 5 factors in Heinrich's accident sequence model were:

1. Ancestry and social environment
2. Fault of the person
3. Unsafe act and / or mechanical or physical hazard
4. Accident
5. Injury (Heinrich, 1980).

Heinrich believed that these 5 factors were like dominos. The fall of the first domino (the employee's ancestry and social environment) precipitated the fall of all of the dominos unless one of the other dominos (factors), such as the unsafe act and or mechanical or physical hazard was removed, then the accident did not occur.

There were updates on Heinrich's model. Frank Bird became the Father (developer) of **LOSS CONTROL** with his model. He still used dominos, but he believed that the 5 dominos were:

1. Lack of Control by management
2. Basic causes - such as employee lack of knowledge, skill or motivation, or job factors such as inadequate work standards, products, or equipment maintenance.
3. Immediate causes, such as unsafe acts or conditions like the presence of methane gas and an ignition source in the mine.
4. Accident - contact with the hazard.
5. Injury or damage - Loss.

In Frank Bird's model Management had the responsibility for *Planning, Organising, Leading* and *Controlling*. In relation to accident prevention he believed in the planning stage Management were responsible for having a Safety Program which included job safety analysis. Workplace audits. Conducting accident investigations and implementing loss control strategies to prevent future accidents occurring due to the same, or similar causes. Having known and used safe work procedures. Having effective workplace communication. Providing employee work related education and safety training. Using design engineering to eliminate or minimise hazards. Purchasing safe products and equipment. Hiring the best person for each work position, and having managers responsible for workplace occupational safety and health plans.

In organising he believed that Management set the standards for work performance. Through their leadership and control role Management were then responsible for implementing safety standards, measuring the achievement of the standards and for correction as needed. Frank Bird introduced Management Responsibility into accident prevention. He believed that it was important to attack **Basic Causes** to prevent the occurrence of future accidents. Effective use of all of the principles of this safety management model would have prevented the Moura accident from occurring.

A model commonly used for accident investigation is the **MULTIPLE CAUSATION MODEL**, as most accidents have many causes. Investigating the Moura disaster some people would just identify the following:

- Unsafe environment as the spontaneous combustion of coal was occurring.
- Unsafe act. Management did not cease employees' work at the mine when the spontaneous combustion of coal was detected.

- Correction. Get rid of the ineffective mine managers.

Using the multiple causation accident investigation model the following questions may have been asked:

1. Why were ineffective workplace communication practices not identified during the Standards Australia Quality Assurance Accreditation Audit or the BHP safety management audit?
2. Why were there inadequate risk assessment and risk control measures for identified workplace hazards, which had the potential to cause a major workplace catastrophe?
3. Why were no government safety inspections conducted to assess this workplace and the work processes?
4. Why did the employees ignore the carbon monoxide gas detection alarm?
5. Why was there a communication failure between the miners who identified the occurrence of the spontaneous combustion of coal in the mine and the mine managers who were able to make a decision to control the risk of this identified hazard causing an explosion?
6. Why did the mine managers not realise that the spontaneous combustion of coal was an ignition source that could cause the methane gas present in the mine to ignite?
7. Why did the workplace have no safety management plans, or engineering strategies in place, to minimise the risks for potential catastrophic events faced by employees in underground coal mines after the previous explosion in this mine in which 12 miners were killed?
8. Why did the shift supervisor allow the miners to go down to work in the mine when methane gas in the sealed area of the mine would be at an explosive level?

The answer to these, and other questions, would lead to these kinds of corrections.

1. Improved auditing of the workplace quality and safety management systems.
2. Effective risk assessment and risk control strategies being implemented for identified workplace hazards.
3. Improved financing by the government of their safety regulatory authority so that an adequate number of safety inspectors could be employed to inspect workplaces throughout the State to check that appropriate recommendations for workplace safety were implemented.
4. The implementation of safe work procedures.
5. Improved employee work related education and safety training.
6. The use of workplace safety management plans.
7. The implementation of effective work related communication strategies.

In Petersen's Model motivation is an important factor in accident causation and prevention. Employees are described as being motivated by what they are rewarded for. Petersen called his model the **MOTIVATION, REWARD, SATISFACTION MODEL.**

In this model employee's work performance is motivated by the Job Climate (influenced by Top Management, employee's relationship with other managers and staff opinions), employee's own personality, employee's ability to achieve, if the work is enjoyable, if the employee can do the job, if there is responsibility and a chance for promotion, peer group norms and pressures, union norms and pressures, training in and competency to perform the work.

The outcomes of motivation are work performance, reward by the boss, peers, union, self and a sense of satisfaction. To try to motivate employees to work safely some work places reward employees for not reporting accidents. This system seems to hide many minor accidents so that major accidents and disasters are more likely to occur because needed changes were not made when hazards caused minor problems. Another difficulty with aiming to work safely through rewards is that, because humans are all individuals, they have different needs, and are not all motivated by the same job factors or rewards. Also, what motivates people may change over a period of time.

Motivation was a key factor in the accident at the Moura Mine. The workplace managers were more motivated to continue to achieve a high level of production than to have a safe workplace. The loss of the mine, and 11 miner's lives, had minimal impact on the profits of the company, so financial considerations were not an issue for improving safety at the Moura Mine. Doctor (2000) states that in the United States of America Chief Executive Officers of large corporations have been personally prosecuted for major safety management failure in their organisation. Hopkins (1999) suggests prosecution for poor safety management should also be implemented in other countries so that Chief Executive Officers would be more motivated to prevent occupational accidents occurring in their organisation.

Dr. Russell Ferrell developed a **HUMAN FACTOR ACCIDENT CAUSATION MODEL**. Behind all accidents, he believed, there was a chain of human errors. Ferrell thought that human error was caused by one of three situations.

1. *Overload.* This may be due to the task, the environment, the person's emotional state, the situation, the capacity of the person to be able to do the work or the person's motivational or arousal level.
2. *Incompatibility* between the person and the work equipment.
3. *Improper activities.* These are caused by employees not knowing what to do, or employees deliberately taking risks.

Ferrell found that employees who usually took risks did so because they perceived that there was a low probability of an accident or disaster occurring, or because they did not know that their actions would cause an accident. In the case of the Moura accident the CO gas detecting alarms were turned off and no action to prevent an accident was taken following each alarm because there was no workplace procedure to deal with the alarm that warned of a high level of CO. Using this accident sequence model it can be identified that the mine managers deliberately took a risk to continue mining when the workplace was unsafe. Due to lack of knowledge they did not consider the possibility of their actions causing an explosion.

The science of Ergonomics (Human Factors) was built around Dr Ferrell's model to identify and implement work design, equipment and workplaces to meet people's needs, and to match people's knowledge and abilities to their work requirements so that they could work safely.

Petersen adapted Ferrell's model to devise an **ACCIDENT - INCIDENT CAUSATION MODEL**. He combined his previous Motivational Model with Ferrell's Human Factor Model. This model takes into account Management's responsibility for leading, controlling and having safe systems of work in place, and employees decision making ability. Section 19 and 20 of the Western Australian Occupational Safety and Health Act 1984 makes safety the responsibility of both the Employer and the Employee, as does this accident causation model. The responsibility for the Moura accident lies with the actions of both the employer and the employees.

As well as Human Factor models there are many System Safety models. A simple **SYSTEM SAFETY MODEL** is the one developed by Bob Firenze. He looked at the relationship between employees, their machines and other tools, the work environment and safe completion of work tasks. Firenze theorised that if there was a human, equipment or environmental failure an accident could result.

In the work place Firenze believed that the following occurred to complete a work task.

1. The *employee* needs to make a work related decision and may take a risk in order to complete the task. The more information the employee has, the more calculable the risk becomes and the better the decision can become. To make a good decision the employee needs to know the requirements to successfully complete the task, and the nature of the harmful consequences of not completing the task correctly. Adequate education and job training are important to provide this information. If the employee does not have enough information, then the person may make a bad decision and take an action that results in an accident as happened at the Moura Mine.

2. *Equipment* must function correctly without failure. If equipment is poorly designed or maintained it may cause an accident.

3. A failure in the *environment*, such as glare, temperature extreme (heat or cold), poor lighting or a toxic atmosphere,

may affect the employee or equipment and set up an accident situation. In the case of the Moura Mine an unsafe environment resulted in an explosion that killed 11 miners.

4. In addition to the above psychological (eg. fatigue, anxiety, aggressiveness, pressure to complete too much work in the available time), physiological (eg. alcohol, narcotics) or physical stressors (eg. noise, poor lighting) can affect a person's *decision making processes.*

One of the most comprehensive System Safety Models is the **MANAGEMENT OVERSIGHT AND RISK TREE (MORT) ACCIDENT INVESTIGATION AND PREVENTION MODEL.** There are over 1,500 events depicted on this fault tree (USA Department of Energy, 1995). The model was designed for proactive use to ensure safe operational readiness for an organisation by including a reference to all aspects of safety for use in the design stage of an organisation to prevent accidents occurring when the organisation becomes operational. MORT was also designed for use as an audit or as an accident investigation tool.

At the top of this risk tree there are two boxes. One box has *future undesired events?* If the chart is used proactively to prevent accidents this is where the safety professional commences use of the chart. If the chart is used for an accident investigation the safety professional begins with the box *Injuries. Damage. Other costs. Performance loss. Degraded program. Public impact.* The risk tree analysis flow chart has two sides. Events documented on the left side describe the system operation factors. This side of the tree describes **what** happened, or can happen, in an accident. When investigating an accident this is the side of the fault tree used first and then the right side of the chart is used. Events documented on the right side of the fault tree identify management system control factors. This is called the **why** it happened side of the fault tree flow chart and is the side used first for proactive accident prevention. Weaknesses in the management side lead to related deficiencies on the system operational side of the chart. This left side is used secondly for proactive occupational system safety design.

The System Safety Society lists 101 system safety models in their System Safety Analysis Handbook (Cousins, 2000). Systems safety models emphasis a general system flow, information flow, analytical aspects of safety design and management and the hierarchical features of a system that need to be considered when designing accident prevention strategies for industry. They consider the safety of people's actions, equipment, materials used, work processes and the environment in the organisational concept stage, engineering and construction stage, operational stage and in the disposal phase of the organisation. System safety models bring into focus the importance of the work environment, appropriate selection and maintenance of equipment, and the importance of human knowledge and decision making ability as accident causes.

Building on the importance of human decision making Jean Surry (1974) developed a model with 3 stages and 2 cycles. Surry believed that people were affected by their knowledge of the total environment (temporal and spatial) and by the person's action, or non-action, when danger occurs.

Throughout the *Danger Build Up Cycle* a person has to make decisions about the following.
1. Is there a warning of danger build up?
2. Is the person able to perceive the warning?
3. Is the person able to recognise the warning?
4. Does the person know how to avoid the danger?
5. Does the person decide to avoid the danger?
6. Does the person have the ability to avoid the danger?

If the answer is *YES* to all questions, then the person does not become injured. In the case of the accident at the Moura Mine the answers to the above questions by the mine managers and the miners who were killed was *NO*, so an accident occurred. Answers to the first 2 questions are affected by the person's perception, to the second 3 questions by the person's cognitive processes and to the last question by the person's physiological response.

The *Danger Release Cycle* has the same 3 stages for the same 6 questions, except that the first question is now "Is there a warning of danger release?" This model makes people aware of the need to label, sign post, provide warnings for dangerous situations and to supply knowledge of hazards so that people are able to make informed decisions to avoid danger. The use of this accident sequence model for implementing accident prevention strategies would have prevented the death of the miners in the Moura disaster.

According to the Department of Minerals and Energy (2000) in 1998/99 in Western Australia in the Mining Industry there were 43,219 employees. For these employees there was one fatality in the Gold Mining Industry, one in Iron Ore Mining and one in Nickel Mining; accidents caused 9,096 workdays lost; there were 258 serious injuries and 329 minor lost time injuries. Accident prevention is both a science and an art that needs to be implemented, not only in the mining industry, but also in all industries. Accident prevention represents control of the physical workplace environment (including the equipment and products used), having safe work processes and having safe employee and employer actions. Knowledge and the use of the above accident prevention models can provide a framework for ergonomically sound work organisation and be used as accident prevention strategies to prevent the occurrence of occupational accidents for all industries.

References:

Cousins, T. (2000). So what is System Safety all about? In Barrett, T. & Cameron, D. (Eds.). *Safe Business. Good business. A practical guide to workplace safety, health and insurance in Australasia.* Perth, WA: Allen Gianatti Vineyard Publishing.

Doctor, S. (2000, June). Money & Manslaughter. *NSCA's Australian Safety.* p.4.

Hopkins, A. (1999). Repeat Disasters: The lessons of the Moura Coal Mine. In Mayhew, C. & Peterson, C. (Eds.). *Occupational Health & Safety in Australia: Industry, Public Sector and Small Businesses.* St. Leonards, NSW: Allen & Unwin.

Heinrich, H. (1980) *Industrial Accident Prevention (5th ed.).* New York: Mc Graw Hill.

Surry, J. (1974). *Industrial Accident Research.* Toronto, Ontario: Labour Safety Council.

United States of America (USA) Department of Energy. (1995). *MORT user's manual.* Idaho: Author.

Western Australian Department of Minerals & Energy. (2000, June). Western Australian Mining Industry Safety Performance 1998/1999. *Minesafe.* 11(2), 7-8.

WorkSafe Western Australia. (1996) *Occupational Safety and Health Act 1984.* Perth: Government Printer.

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Published by the: WSO World Management Center
PO Box 518, 106 W Young Suite G
Warrensburg MO 64093 U.S.A.
Tel. (660) 747-3132, Fax (660) 747-2647
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2001, U.S. $5.00