

Finding Human Performance
Patterns in Safety Data

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Introduction

Aggregate loss data from such diverse fields as on-the-job injuries, airline crashes or highway traffic deaths follow decreasing trends, showing that prevention has been improving over the long term (1). But the rate of improvement is not smooth: delay periods during which failure rates range around a relatively stable average or even rise end with spurts of improvement and a lower average. We believe that a prevention model would promote better understanding of the delays and may lead to shorter delays and faster prevention.

The Value of Models

A model is generally useful as long as it provides a frame of reference to help us interpret and measure what we observe in the real world; successful models may even allow prediction (2). Models can be of many types.

One type of model we use often is physical: crash test dummies or test planes have provided insights into safety gaps that were not otherwise apparent. Another type of model is verbal, and this conference is a good example of using verbal models to explore topics and describe results. Yet another type is mathematical. Mathematical models appear to be more complex than physical models but are in the end far simpler, as for example flight simulators versus airliners, or Computational Fluid Dynamics versus wind tunnels.

A safety failure model might reveal opportunities for prevention by assisting in the gathering of failure data and the interpretation of what we measure. At the very least, it could help align the multiple verbal models of prevention, and facilitate the adoption of successful initiatives from related groups or even different fields. Because a mathematical model remains the same regardless of language or circumstance, it would widen the range of users who can benefit from its use. A useful model would make prevention more accessible to practitioners, researchers and regulators.

this presentation introduces a "drum"
model that:

links prevention with safety performance

takes recurring injuries as revelations of
persisting deficiencies that were previously
missed or ignored

predicts that recurring injuries will recur
with statistical regularity until something
changes and they are prevented

A Prevention Model

In this paper, we propose a model that, in its simplest form, links prevention with safety performance. This model arose from our work in trying to interpret workplace safety experiences covering over 16,000 person-years in two different industrial settings separated by 10 years (3)

Basis and implications of the model

Our model interprets injuries as visible evidence of deficiencies, and injuries that recur as the visible evidence of deficiencies that persist; persistence hints at statistical regularity in the recurrence, and regularity implies predictability. That such injuries will continue to occur until they are prevented is consistent with the observation that delay periods of relative stability are followed by spurts of rapid progress to a lower average.

This suggests that the persistent deficiencies and regular failures we see today result from earlier choices of technology and management competence. Regularity and predictability tie future failure rates to current choices of technology and the going-forward competence and effectiveness of management policies, systems and practices.

The factors that connect subsequent steps of persistence and regularity connote human dimensions in the opportunities for improving prevention.

Observations:

The context of incidents contains
hints of prevention

The failures that we ignored will
recur

They will leave traces and form
patterns

Observations

Consider first that the historical record of injury investigation reports contains prevention hints.

Most injury investigation reports are likely to contain traces of the underlying deficiencies. The traces of deficiencies that persist are likely to form patterns and fall into trends that would be strong enough to attract prevention if they were recognized. Routinely searching failure reports for patterns and trends can lead to their recognition; it can also reveal ways to make future failure investigations more sensitive to trends and patterns and therefore more attuned to quicker results.

Second, recurring injuries will persist with statistical regularity until prevented.

Persistence means that injury rates do not change unless something changes. Regularity means that it may be possible to detect patterns that, if they are statistically significant, hint at the activities, groups or areas that most need attention. Detecting patterns and establishing statistical significance become more demanding as the incident frequencies drop.

Finally, the deficiencies revealed by injury will expose equipment failure, production loss and waste.

The "drum" model

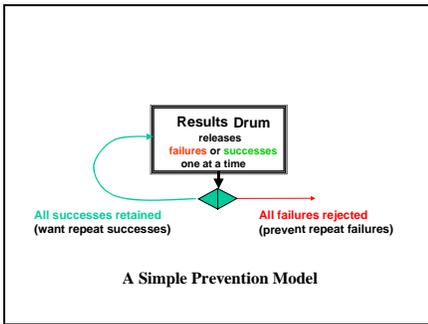
ties present and future performance to managerial:
 choices of technology
 policy decisions (prevention,
 knowledge transfer...)

suggests that prevention works on equipment failure or production waste as it works on injury and vice-versa

accepts changes in safety and efficiency as mutually reinforcing - up or down- and perhaps not separable

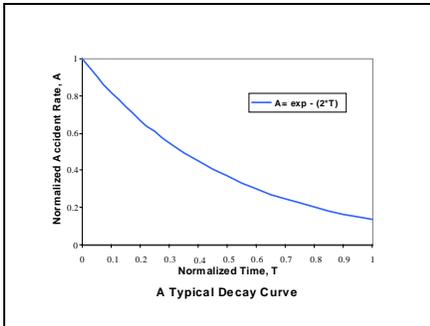
The Model Links Prevention with efficiency and time

Our model interprets all failures that recur as evidence of deficiencies that persist, and postulates that they will cease to recur when the deficiencies are neutralized or eliminated. That is, preventing injury will, in at least some cases, prevent equipment failure, production loss and waste: failure analysis and prevention will work on efficiency as they work on safety and vice-versa. The model thus suggests that safety and efficiency may be mutually reinforcing and may not be separable. The failures of the Ford Explorer/ Bridgestone tires are a good example of what I am talking about. They recurred until they became unacceptable and something changed. Consider the possibility that a deteriorating safety was the first visible evidence of disarray and efficiency loss and thus presaged Ford's recent financial problems. Persistent deficiencies and regular failures tie future injury rates to the original choices in technology and to the competence and effectiveness of management policies, systems and practices.



The Drum Model

Imagine a "drum" containing many green balls, representing good events, and a few red balls, representing failures. It is perfectly mixed and releases one ball at a time, red or green according to their respective concentration in the drum. In the simplest case, we recognize all failures and reject them, while we return all successes to the drum. The more red balls we reject, the lower their concentration in the drum: the frequency of red balls follows an exponential "decay" curve. This is a negative feedback system. It agrees with our experience: most activities are safer today than they were years ago. We live longer lives. Whether it is mining, manufacturing, health care, we have been improving. We have identified the causes of some failures and we have prevented them or, at least, we have neutralized their effects.



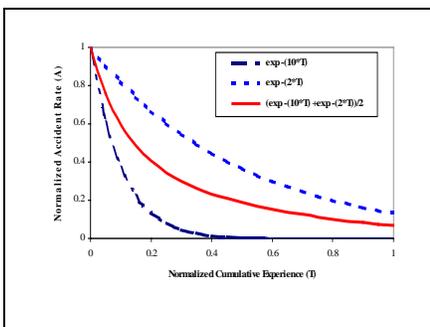
Learning from experience

This figure shows a simple decay curve, incidents versus time. At time zero, technologies and processes are not perfect, but we improve them and manage them better as time goes on and we learn from experience. We should pause to think what this means. Learning from experience basically means learning to prevent failures- or their effects- after we learn from their consequences. First we crash, then we get seat belts.

That's what we do. It implies that injury records are, by and large, lists of failures that were not prevented. There are two implications: one, that we could have improved faster, and two, we may still be able to use injury records to learn:

- about overlooked deficiencies and how to fix them,
- about making the investigations more prevention-friendly
- why some prevention hints were missed, ignored or not implemented
- which policies, processes, systems, procedures, work and which don't
- how to ensure that prevention initiatives are implemented.

These steps outline a learning-improvement cycle that would improve anticipation, detection and prevention. The faster we learn, the faster we improve. A good model for management training, too



The hidden risk of averages

The "drum" model can also help visualize what may be hidden in the aggregate failure rates of groups like managerial areas with multiple work crews, or industry sectors with multiple companies. Each sub-group operates their own mix of technologies and management skills, and each gets its own rate of failure. The example of Figure 7 shows two participants. One of them uses technology well and learns quickly from failures and progresses quickly.

The other lags in technology or management skills and progresses slowly. Over time, it would accumulate significantly more accidents and greater costs that its more prevention-oriented counterpart.

The middle line in the graph represents the sum of the two. It falls in between them, and shows that averages can mask important differences among sub-groups. One of the groups may deserve recognition while the other needs help, but the average would mask the differences.

For two companies or groups in the same activity:

the group with the better prevention will have less accidents and lower accident related costs than the other one

the differences between the groups accumulate over the life of the technology

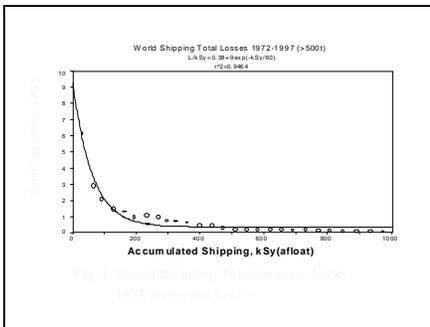
aggregate results mask any differences between the groups

improving the laggard has the greatest effect on the aggregate, now and in the future.

Focus Prevention on the Problem

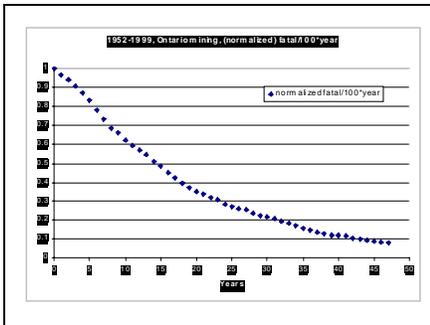
Statistically significant rate differences between sub-groups insinuate significant differences in technology, management, or both. The largest improvement in aggregate rates comes from improving prevention in the sub-groups with the most problems, or with the most serious ones. That seems obvious, but we tend to fix problems by sending everybody the same message.

How does the drum model fit reality?



The long-term track record: shipping

Duffey and Saull have analyzed incident data from various industries. Figure 9 shows their graph on world shipping; it displays total losses versus accumulated shipping tonnage as a decay curve.



More long-term records: mining

Figure 10 shows 50 years of mining fatalities in Ontario, and it, too, looks like a decay curve.

Observations from Long-term Aggregates of Failures:
 accidents decrease as experience increases: we learn from accidents, after they happen
 therefore:
 the sooner we recognize (admit?) the damages, the sooner we can learn to prevent or mitigate them, and learning can be transferred across industries, across companies, across crews....

Learning form the learning curves

Both of these graphs represented long-term data from many companies and many groups with a wide range of technologies and management skills, and both of them depict “learning” curves, despite including a variety of technologies, management systems and other factors. We can surmise from them that it may be possible to speed up prevention, and that, eventually, prevention diffuses from one industry to another.

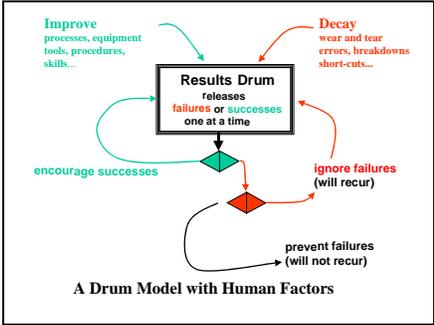
Human choices affect:
 what to prevent, what to ignore
 asset maintenance and upkeep
 choices of technology and upgrading

Human factors

In the simple version of the “drum”, we had assumed that red balls-failures- were prevented once recognized, perfect reaction. Now we are adding red balls as wear and tear and failing procedures, and removing them by way of prevention and “prediction”. “Prediction”, as in “predictive maintenance”. Imagine removing red balls that have yet to be seen but we know are there.

The mathematics of this model is difficult, but the Montecarlo simulation is relatively easy: it produces a decay curve as long as more red balls are rejected than added in.

If prevention stops, failure rates likely rise; failure rates straddling a straight signal that red-ball input equals rejection. A constant rate of failure suggests balance, but it means that some failures may be recurring with regularity and becoming “hazards of the job”.



Hazards of the job?

Voltaire, a French philosopher, warned us about this possibility 250 years ago. He said that what we call a hazard is nothing but the known effect of a cause that we ignore.

By ignoring the causes of recurring failures, we are treating them as inevitable one-of-a-kind events, and they become “invisible”. Let me explain.

Voltaire's caution

Human Factors make patterns invisible

Direct experience, hard learning

I had been the manager of a large plant in Canada, employing about 1500 people, for about 4 years. We had made great gains in costs, productivity, and safety. Compared well with the competition. Then, a visitor told me that we seemed to be risk-complacent.

We checked the injury records of all employees with at least 14 years seniority, long enough for validity. Here is what we found.

A Case History

Invisible Patterns

Risks did not spread evenly

55% of the workers injury free; 4%, mostly mechanics and electricians, with 5 injuries each, 10 times the plant average. Mechanics injured more often than operators, electricians more than mechanics. Clearly, the "normal hazards of our business" were not "evenly distributed".

We had been looking at injuries as one-of-a-kind events, evidently a misleading model. WCB costs were lost in corporate overhead.

As Voltaire might have said: when recurrent injuries become "hazards of the job", they become acceptable.

Our visitor had a point: perhaps we were complacent.

Injuries/worker over 14 years	Injuries in 14 years	Workers in sub-group	Predicted if equal chance
6	6	1	0
5	60	12	1
4	68	17	6
3	129	43	32
2	188	94	118
1	205	205	291
0	0	436	359
Per worker	Injuries	Workers	
0.8	656	808	

Table 1: Fourteen Year History of 808 workers

The reaction? Pick on the 30 workers with 5 injuries each; we thought they were "accident-prone", putting themselves at risk. We were wrong again.

A Case History (continued)

Manager's Intent

Persuading the Actors

Quine⁷ and Borges⁸ on Shared Understanding

Risk factors were not what we first thought

A closer review of the records revealed a tangle of inadequate tools, irrelevant procedures, delayed repairs, and a work order system that favoured equipment over people.

I tried to improve prevention by talking to workers and supervisors. But as Borges, an Argentine poet and essayist had pointed out:

Las palabras son simbolos que postulan una memoria compartida. Words are symbols that presuppose a shared experience.

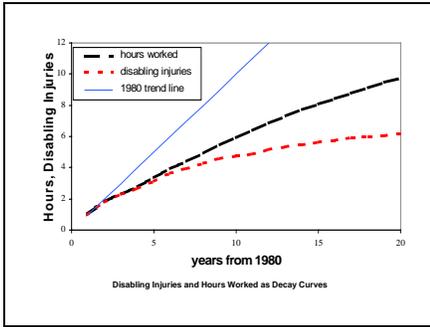
Our shared experience seemed to be production first and a tolerance for injuries and inefficiency. Turning that around was a challenge.

And Quine, an American philosopher, had pointed out the need to get confirmation of any presumed shared understanding. Consent would not be enough.

So we tried dialogue-using examples from the workplace, first to explain what we meant, then to promote the activities that we favoured. The safety and maintenance systems had to be seen working to be credible. Safety First had to be practiced, not advertised. And dialogue meant that the workers had to be willing to participate.

I'll talk briefly about three examples of recurring injuries: back injuries to Electricians and Heavy Duty Mechanics, and winter slips and falls to Roaster Operators.

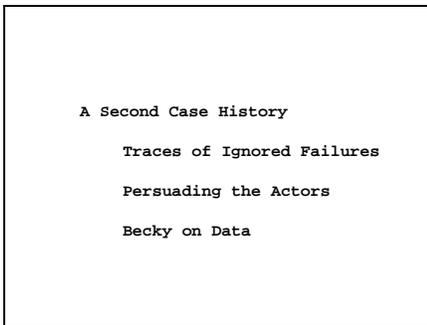
The workers had to be persuaded that we were looking for solutions, not culprits, before they agreed to look in depth at the injury history within their groups. They could not see any patterns at first, but through repeated discussions led by their supervisors, they started to find common factors in the context of their injuries. Electricians pushing heavy wire drums over irregular floors; mechanics heaving a six-foot steel wrench in close quarters; operators getting in or out of the building in freezing weather. The crews that identified the problems invented the solutions: 4-wheeled cable carriers, an electric torque-wrench, and a steady supply of sand and shovel at the required doors; the operators modified their schedules to do the sanding. All practical and inexpensive solutions.



Getting help from poets and philosophers

We learned that the people at risk of injury had to understand the dangers and be involved in their control. Management had to ensure follow-up and prevention work.

The improvements were remarkable. For example, back injury recovery dropped from 400 days per 100 employee-year to less than 100, and ice slips at exits dropped equally dramatically.



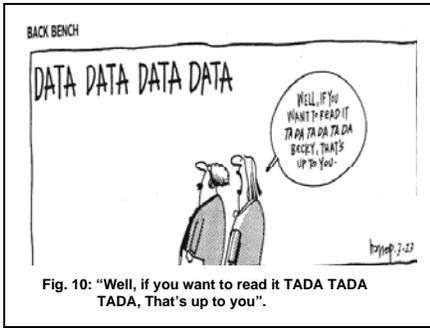
Another case study: different place, different time

I have another example, 15 years later. 54 months of recorded safety data in a mine with about 1000 employees, also in Canada. Good outfit, leading safety performance. We made time charts, bar charts, mind maps, Pareto charts, looking for patterns. The rate of incidents had improved since the mid-eighties, but the record still contained patterns of recurring injury.

They too thought of normal “hazards of the job” and viewed each injury as an independent event. Some injuries were regarded as “rare” even though they occurred repeatedly. Recurring falls, back injuries, slips, fires.

Since then, they have improved their report tracking system and made it accessible at the various sites; they are improving the database so they can search for workplace examples to use in the regular supervisor safety meetings. They see these meetings as an effective channel to dialogue with the workers about increasing awareness and preventing injuries. There is good reason to feel optimistic.

Voltaire was talking about a human characteristic, so we should not be surprised that multiple murders could become invisible in Vancouver-for a while. These are parallax problems, matters of perspective, and so, to some extent, matters of choice. But it was not obvious to me 20 years ago, and it may not be obvious to you now.



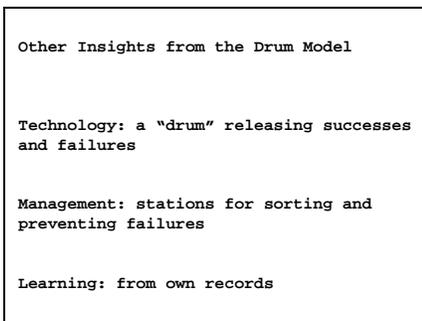
Patterns and Choice

This is a cartoon about choices about data. What we see in the record depends on what is in it, what we look for, and how well we look for it; all three depend on what model we assume. We think that the drum model provides a solid prevention perspective based on patterns.

Patterns from recurring incidents are getting increasing attention. You may have read about Rossmo using geographic crime patterns to pinpoint the block where the criminal resided. Or Jack Maple using crime pattern analysis to reduce crime in N.Y. and New Orleans. Or John Snow using plots to pinpoint the source of cholera during an epidemic in London. Or Ignaz Semmelweiss preventing post-natal death in Vienna and Edinburgh. Or, more recently, Paul Ewald writing on models, patterns and illness prevention.

And now, in Canada, renewed interest in tracking medication errors, the most common kind of the medical mishaps that cause patient damage or death.

And as in the two cases discussed earlier, the process involves encouraging doctors and health workers to report mistakes without fear of retribution, tracking and milking the reports for prevention hints, and discussing the findings with drug companies, doctors and other health workers to find ways to prevent the mishaps.



More Insights from the Drum Model

The drum model can help prevention in other ways. It explains that prevention differences between groups reflect differences in technology and management. Upgrading management systems to improve prevention is faster and cheaper than changing technology, which ultimately require management change. In extreme cases, incompetent technologies can't be salvaged by competent management, and vice-versa.

In cases where injuries are very infrequent, companies need to look for failure precursors and incidents beyond their historical record into the records of other groups or other industries. The safest companies tend to be the most intensive and thus would incur the highest costs in case of failure. The Swissair case may be a good example.

At the risk of repeating myself, I would like to review some of the issues once again.

The Drum-Model's Tripod

Voltaire: ignored failures will seem random and recur

Quine: assent does not mean understanding

Borges: understanding requires shared experiences

those who have to change what they do to prevent failures are the ones who must grasp why and how

The Tripod

The drum tells us that failures that we accept will happen again, and again, and again. Predictably, but with results that we can not predict.

Voltaire warns that the preventable failures that we accept will become invisible.

Borges says that we have to develop a shared understanding of what can and should be prevented.

Quine tells us to make sure that if we say safety first we confirm that is what people hear and think. He even suggests that we confirm that safety first is what we mean when we say safety first. And I showed you that safety records covering 16,000 person-years in different settings in different companies and in different times revealed the patterns of recurring failures that could have been prevented but weren't.

And so, I can recommend to you that you assure yourself about your group's records by checking. Voltaire, Borges and Quine gave us that advice.

JanusSM



Roman god of gates and doors, beginnings and endings, is represented with a double-faced head, each looking in opposite directions.

Safety and efficiency, constantly watching in each direction to reduce preventable failures

Safety and Efficiency: two Views, one Prevention

SOME READING MATERIAL

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