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In this month's issue:

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Case Studies In TRIZ: Trouble On The Buses

The following case study originates from a real problem described in the Russell Ackoff book ‘Idealized Design’ (Reference 1). The case as it was presented in the book reads as another of those classic ‘great solution, but how did they get to it from the problem they started with?’ situations. Consistent with almost every one of these other cases, Ackoff’s book never provides any kind of description of a method that could be reproduced by others. The aim of this article, then, is to present someone else’s nice case study but in the context of how a systematic innovation technique bridges this gap between problem and solution. Inevitably, therefore, the article is describing a case study that fundamentally didn’t use a systematic method. It is our hope that the learning points that emerge when we run someone else’s solution through our process justifies this action on our part.

Trouble On The Buses

Our problem centres around a UK public transport company and the incentive schemes they had put in place to ‘motivate’ the drivers that drive the buses, and the conductors that take fares from passengers. As illustrated in Figure 1, the driver and conductor are physically separated from one another, the driver being placed in a cab at the front of the vehicle, and the conductor being in the passenger areas, nominally standing at the rear where the passengers enter and exit the bus.

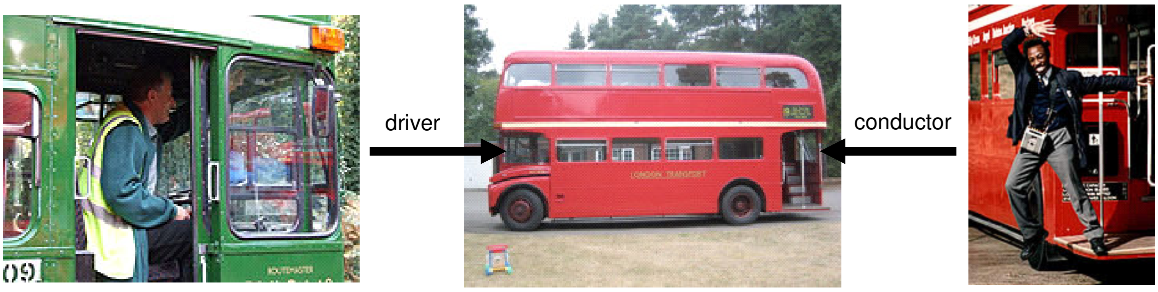


Figure 1: Drivers And Conductors

In an attempt to increase productivity, management have introduced pay-based incentives to the drivers and conductors. The incentive scheme for drivers is relatively simple; their bonus pay being based on how well they meet the printed schedule. When the scheme was introduced, it was immediately popular with the drivers as they were taking home more money each week than on the previous fixed-salary system.

The incentive scheme set up for the conductors was likewise popular since they too ended up with more money than on the previous fixed salary scheme. The incentive scheme for the conductors was nevertheless more complex than the scheme for the drivers. The conductors collected variable fares from customers according to how many zones each individual passenger was planning to travel. Conductors were supposed to collect fares from passengers as they entered the bus, and then check tickets as people left the bus in order to establish that the correct fare had been paid. Conductors had the responsibility to instruct the driver – via a button signal – when to stop or start the bus. Unless the conductors signalled the driver not to stop at the next stop, for example, the drivers were expected to stop. The conductors were also supposed to signal to the driver when it was safe to move on after a stop. Passengers who wanted to get off the bus at the next stop signalled directly to the driver by pressing an easily accessible button. Undercover inspectors rode the buses several times during a shift to determine whether conductors collected all the fares and checked all tickets. Incentive payments to conductors were then reduced depending on how many times they were observed by the inspectors to have either failed to collect fares or check receipts, the former being a more critical error. So, the conductors started with a high pay incentive, which then reduced according to mistakes made.

To avoid delays during the busy traffic periods, conductors developed a habit of letting passengers board the bus without collecting their fares, the idea being that the conductor would walk around the bus collecting fares between stops. Because of the crowded conditions on the buses during these busy periods, conductors could not always return to their station at the rear of the bus in time to signal the driver when it was safe to move on after a stop. This inevitably caused delays that were costly to the driver. The delays, however, had no negative impact on the conductors. Indeed, their incentive scheme made it likely that the conductors would delay the bus in order that they could be diligent in collecting and checking fares and tickets.

What we have here is a classic case of two perfectly logical sounding incentive schemes that end up being incompatible with one another; the more one group of people earned, the less the other group earned. The incompatibility in this case lead to considerable hostility between the drivers and the conductors, in some cases to the point of violence. The situation wasn't helped by the fact that the drivers worked through a different trade-union to the conductors. Things reached a head when one of the trade unions threatened strike action unless the party they represented was paid the full potential of their particular incentive scheme.

Finding Contradictions

Incompatible incentive schemes represent a common and clear contradiction. According to TRIZ and Systematic Innovation, someone somewhere will have already been solving such contradictions. This particular problem is very clearly a 'people and process' type story and as such is most likely to be helped by using the business version of the Contradiction Matrix. We can plot the story in terms of both conflicts and contradictions by using the schema first shown in the business version of the Hands-On Systematic Innovation book (Reference 2). The picture for the bus problem is shown in Figure 2:

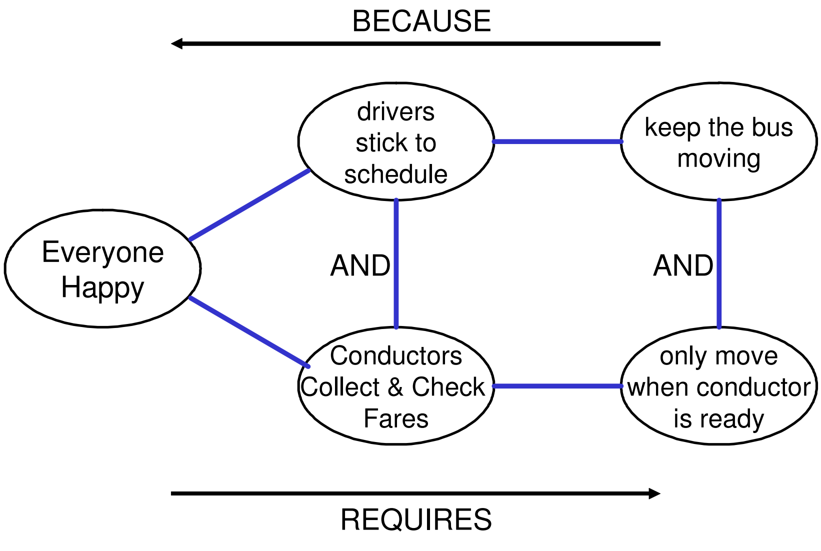


Figure 2: Defining The Incentive Scheme Mismatch Contradictions

In order to resolve the contradictions present in this kind of system, the job essentially involves challenging at least one of the blue links joining each pair of conflicting statements. Our preference is usually to look at the central vertical link in the model since this is the conflict most closely attached to the use of the Matrix. (The vertical link on the right hand side of the picture, alternatively, is often preferred by those with a natural inclination to define and solve 'physical contradictions'.)

Our conflict pair describes parallel desires for the driver to stick to schedules and for conductors to do their checking job. If we can genuinely 'solve' the contradiction, both the drivers and the conductors will end up being happy. Contrast this with the usual ways of trying to solve this kind of problem. The first solution proposed by the management in fact was classic trade-off and compromise – get the driver and conductor to pool their incentive payments and share them equally at the end of each week. The net result of this attempt was that both parties were compromised and therefore neither party was happy. Conflicts continued to simmer.

In order to see how others have successfully achieved no-compromise solutions to similar problems, the next thing we need to do is interpret the words we have used to describe the problem to the words that make up the menu of possible options in the Contradiction Matrix. Figure 3 illustrates how we have achieved this using the Matrix+ version of the business tool.

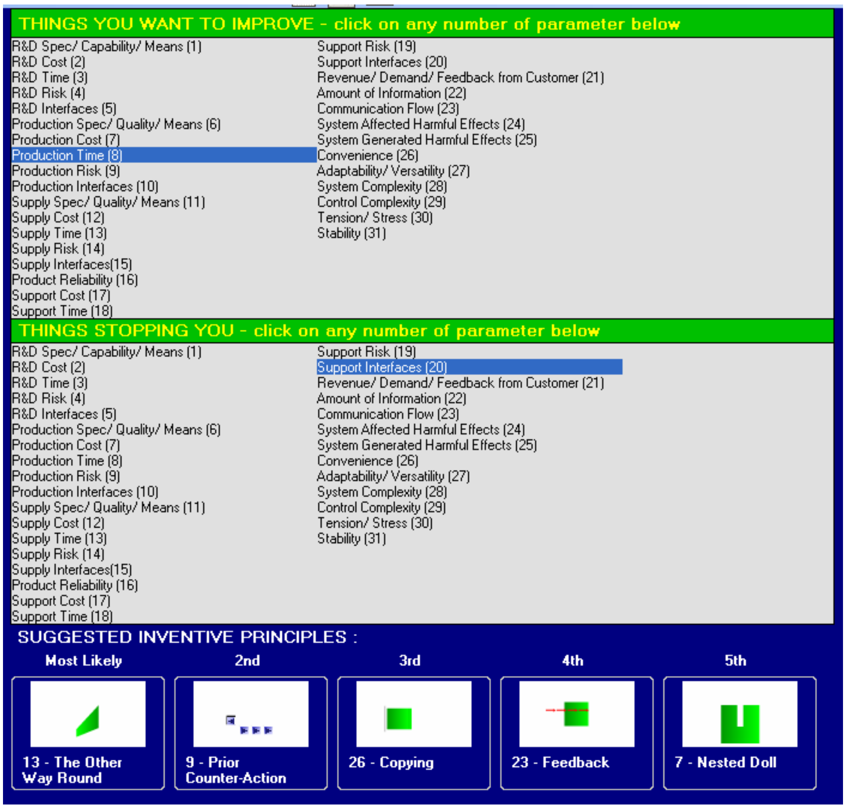


Figure 3: Mapping The Problem Onto The Business Contradiction Matrix

In the figure you can see how we have mapped the 'driver sticks to schedule' desire onto the 'Production Time' parameter. Then we have mapped 'conductors collect and check fares' as 'Support Interface'. The key to making these kinds of connections is not to over-analyse the details of the problem, but rather to make the simplest most direct connection possible to the available menu of options. In this way, 'sticking to schedule' is very much about an aspect of 'time'. All we have to do next is work out which of R&D, production, supply or support best match what the drivers are there to do. The same connection-making strategy then applies to the conductor side of the problem; how best to map 'collect and check fares'. Here we decided that this is best represented as an 'interface' issue (interfaces being defined as the links between any thing and any other). Having made this connection, we are only left with a decision to think about where the interface is occurring – R&D, production, supply or support.

Having then defined our conflict pair in terms recognized by the Matrix, we are given a number of Inventive Principle suggestions. These represent the generic strategies used by others to solve similar issues.

We will examine only the first suggestion on the list here as a way of demonstrating how we might make the transition from 'generic' to 'specific' solutions. Of course, if we were really working to solve this problem, we would continue examining each of the other suggested Inventive Principles in a similar manner.

As discussed in an earlier e-zine article (Reference 3), the Inventive Principles essentially work in two parts; firstly making a connection with something in our system, and then moving in a certain described direction.

Principle 13, The Other Way Around has three basic connection:direction instructions – invert an action; make movable parts fixed and fixed parts movable; and turn the object, process or system upside-down. Figure 4 shows the basic essential elements that comprise the current system. If we are to use any of the Inventive Principles successfully we will need to make connections between one or more of these elements and the Principle instruction.

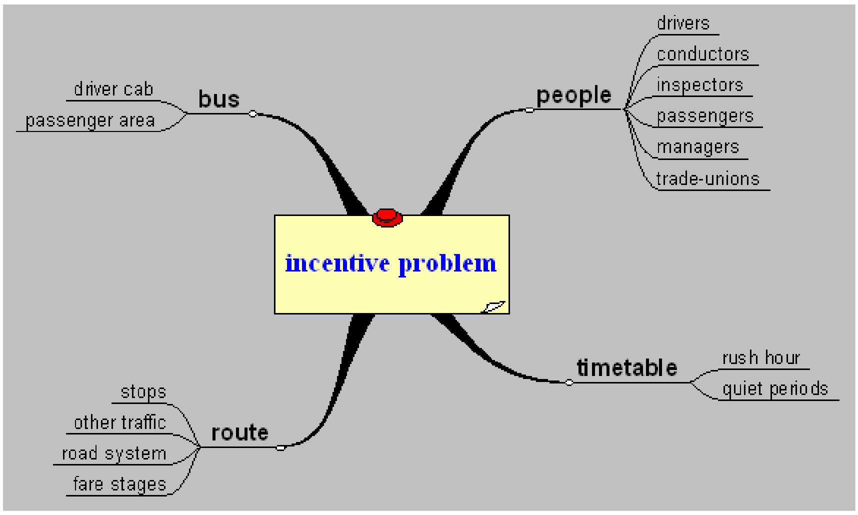


Figure 4: Possible Connections Between Driver/Conductor System And Principle 13

The simplest way to do this job involves trying each possible connection in turn and then applying the direction suggested by the Principle. Something like:

Invert the timetable
Invert the stops
Invert the other traffic
Invert road system
:
Make the bus fixed (instead of moving)
Make the driver fixed (instead of moving)
Make the conductor fixed (instead of moving)

Make the timetable variable (instead of fixed)
:
Turn the fare stage upside down
Turn the bus upside down
Turn the timetable upside down
:
Etc

In none of these cases does the Inventive Principle know anything about the specifics of this particular conflict situation, and so it is up to us to make sense of the connections. Things like turning the bus upside down, don't sound so promising, while others – like making the timetable variable – sound like they have some potential.

(Intermission: If you want to try and create your own specific solutions, now is the time to try it. The next paragraph contains the Inventive Principle 13 connected solution actually used by the management involved in this problem).

As is often the case, some of the apparently least obvious solutions turn out to be ones that deliver the biggest benefit. A very good solution to the problem – the one adopted by the bus company in this case in fact – turns out to be one about making the conductor fixed. How to turn a moving conductor into a fixed one? Basically take him off the bus and position him at the fare stage bus stops during busy periods. In this way, he is able to collect the fares of passengers as they wait for the bus, get people on and off the bus quickly when the bus arrives, and then check the tickets of the passengers after they have got off the bus.

The story makes a nice exercise to try in workshops. Whenever we've tried it in fact, people never get to the actually adopted solution using their normal brainstorming strategies. But as soon as they are given Inventive Principle 13, nine times of ten precisely this actual solution has emerged. Not only that, but looking at the other Inventive Principle suggestions, many other complementary solutions have also been generated.

Here then is the main point of using systematic processes; it is about allowing yourself to be guided towards the good solutions of others, the persistence to make as many connections as possible, and the ability to not reject non-obvious solutions too soon.

References

1) Ackoff, R.L., Magidson, J., Addison, H.J., 'Idealized Design: Creating An Organization's Future', Wharton School Publishing, 2006.
2) Mann, D.L., 'Hands-On Systematic Innovation For Business & Management', Chapter 12, pp287-301, IFR Press, 2004.
3) Systematic Innovation e-zine, 'Connections & Directions Towards The More Ideal System', Issue 33, December 2004.

Causal Chains And The Sixth Why

More Problems With Root Cause Analysis

For want of a nail, the shoe was lost;
For want of the shoe, the horse was lost;
For want of the horse, the rider was lost;
For want of the rider, the battle was lost;
For want of the battle, the kingdom was lost;
And all for the want of a horseshoe nail

The beginning of Ben Franklin's cautionary tale of missing horseshoe nails is one of those stories we never forget. It is beautifully emotive and makes the important point that a seemingly minor event can lead to significant consequences. And that the devil is truly in the detail.

An enormous problem with images like the one in Franklin's tale is that it drives an enormous amount of psychological inertia. Specifically in this case it leads many of us to the belief that by tracing back a series of causal links we can find 'the' root cause of a manifest problem like losing the kingdom.

From the tale comes the 'ask why five times' aphorism. Actually, although it rarely gets linked to this aspect of root cause analysis these days, it nevertheless fits very nicely:

The Kingdom was lost
WHY?
The battle was lost
WHY?
The rider was lost
WHY?
The horse was lost
WHY?
The shoe was lost
WHY?
The nail was lost

It is crucial to remember, however, these chains of causality, elegant as they might appear, are only ever seen in hindsight. Nobody ever lamented, upon seeing the unshod horse, that the kingdom would eventually fall because of it. Equally important, yet also tending to be overlooked, is that, when we trace these events backward, starting from the fall of Rome and finally ascribing it to a blacksmith oversleeping one morning we are following branches of a tree structure, and we don't notice that at any point, we could have chosen a different path and ended up at a totally different conclusion. Here is a classic example of a 'root cause' – the lost nail – that a) is untraceable a priori, and b) there is nothing we can sensibly do anything about in the future to avoid a recurrence

It is also an illustration of one of the key underpinning ideas of chaos theory, known as sensitive dependence on initial conditions. The initial condition in this case being the presence or absence of the horseshoe nail. We actually see the ramifications of small changes every day. For example, we're driving along, and the car in the next lane is five feet ahead of us. Because of that, it is just able to get through a green light, while you, just behind, are forced to stop for the red. The small difference between your being one foot behind or five, can then translate into his lead opening up to a mile. It is sometimes assumed that the effects of the initial change will be magnified as time goes on; this is the basis of several science fiction stories that place a time traveller far in the past performing some utterly innocuous action, then returning to his starting time to find the universe totally unrecognizable.

A very nice recent example is the film Paycheck, based, as is often the case in Hollywood these days, on a Philip Dick short story.

The basis of the story, as told by Dick is '"How much is a key to a bus locker worth? One day it's worth 25 cents, the next day thousands of dollars. In this story, I got to thinking that there are times in our lives when having a dime to make a phone call spells the difference between life and death. Keys, small change, maybe a theatre ticket; how about a parking receipt for a Jaguar? All I had to do was link this idea up with time travel to see how the small and useless, under the wise eyes of a time traveller, might signify a great deal more. He would know when that dime might save your life. And, back in the past again, he might prefer that dime to any amount of money, no matter how large."

Again we experience the problem here of a highly compelling story – one that we are highly likely to remember – that in the cold light of day sends us in completely the wrong direction when it comes to offering meaningful insight into how to tackle the problems we might be expected to work on.

What the psychological inertia effect tends to make us forget is that it is equally likely that the effects of the two different initial conditions soon merge, and it turns out to be inconsequential which one actually obtained. For example, the car with the initial five foot lead may continually pull farther and farther ahead with each controlled junction along your path, or it may be that you'll catch up to it again at the very next light. Just as it is likely that the rider bearing the vital news could just have picked a different horse bearing a full complement of shoes.

The fact that a small change in the initial conditions may actually *not* cause a significant difference down the road then leads to the idea from dynamic systems of a strange attractor, which is a complex behavior that a system may exhibit, and to which it will tend to return even if the initial condition is changed slightly. (A sufficiently large change, of course, will lead to different behavior, but often to *another* strange attractor with its own range of initial conditions.)

For want of a nail, the shoe was lost;
..is just if not more likely to be insignificant because, whilst one nail was missing, this was not a problem since there were four others holding the shoe on.
For want of the shoe, the horse was lost;
..likewise, lacking horseshoes, the rider decided to ride on the grass beside the road, not on the road. Consequently, he avoided the hail of arrows launched at that section of the road by the enemy.

And so on. Or how about a different story looking at the problem from a different perspective: In a war, a cook takes special care of his knives, making sure he has one set (blue handles) for cutting uncooked meat and another set (red handles) for cutting cooked meat. This prevents bacteria transferring from uncooked to cooked eats and hence prevents potentially infecting soldiers. This keeps them healthy and alert, and able to partake in the 'big push' that wins the war, instead of sitting around being sick and getting killed. Sure, the cook may well be helping to win the war by keeping his knives clean, but other things more directly lead to victory, i.e. having good tactics, competent generals, not stubbornly sending wave after wave of soldiers to get mowed down by enemy machine guns, etc. If the 'big push' fails, it is much more likely to be the fault of generals than cooks.

Anyway, here's the first point: If a plan fails on a single point, it is as much the fault of the person who made up the plan as it is the person who failed. As long as people do their jobs properly, they cannot be blamed for 'unforeseeable results'.

The second point brings us back to finding root causes through the ‘ask why five times’ strategy. Here’s an example from the recent Lexington air disaster:

The passengers were killed
WHY?
The plane crashed
WHY?
The runway was too short
WHY?
The pilot was on the wrong runway
WHY?
The system didn’t tell the pilot
WHY?
The system assumed the pilot could not make such a mistake

A highly likely consequence of this kind of analysis is that in the future, the FAA and other aviation regulation creators will insist that all aircraft systems must feature automatic detection and warning systems. As a consequence we will make prevent this particular (special cause) failure from occurring again, albeit at the expense of making every aircraft heavier, more complex (and therefore prone to new modes of failure that weren’t there before) and more expensive.

The point here is not so much that fitting automatic ‘right-runway’ detection systems on aircraft is necessarily a bad thing – the political consequences of not doing all we can to protect the lives of passengers alone effectively remove any kind of debate – but that the assumption that five why’s was the right number to get to the root cause.

Here’s what happens when we dig deeper into the problem and add a sixth and seventh why:

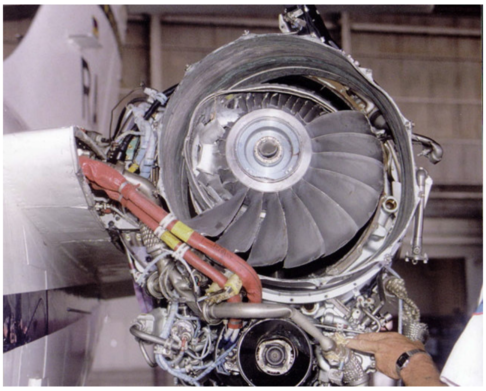
The passengers were killed
WHY?
The plane crashed
WHY?
The runway was too short
WHY?
The pilot was on the wrong runway
WHY?

The system didn't tell the pilot
WHY?
The system assumed the pilot could not make the mistake
WHY?
An intelligent person could not make such a mistake
WHY did they?

And now here's the same idea applied to the earlier nail problem:

The Kingdom was lost
WHY?
The battle was lost
WHY?
The rider was lost
WHY?
The horse was lost
WHY?
The shoe was lost
WHY?
The nail was lost
WHY?
An intelligent blacksmith would not insert the nail incorrectly
WHY did they?

Or how about a new problem:



The engine was destroyed
WHY?
The fan-blade came off
WHY?
The blade was damaged
WHY?
It was struck by a foreign object
WHY?
Small objects were left on the floor
WHY?
Nobody picked them up
WHY?
An intelligent person could not make such a mistake
WHY did they?

Spot anything common to these different causal chains? The answer, I think, is that by the time we get to the sixth or seventh ‘why’ the problem starts to focus very clearly on human psychology and the way the mind works. The airline industry and every air force in the world spends enormous amounts of time and money educating personnel about the importance of not leaving foreign objects lying around – Figure 1 – and yet, somehow, despite all that (or perhaps because of it!) millions of dollars of unnecessary damage are caused every single year. The fifth ‘why’ here is not a genuine root cause at all. Merely one that is easy to act upon.

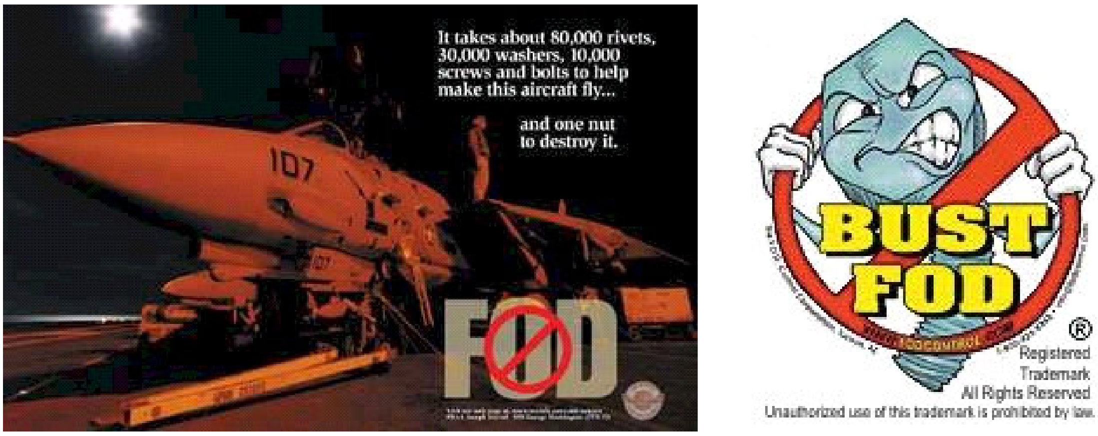


Figure 1: The Obligatory FOD Poster Campaign

The sixth (and sometimes seventh) why somehow tends to bring every problem full circle to a common ‘root cause’; human beings are not infallible. We are not ‘six sigma’ (3.4 defects per million opportunities) creatures.

For some reason – whether it is the psychological inertia of an expression dedicated to digging down five levels into a problem or something else – we rarely seek to tackle *this* psychology centred root cause. Perhaps that is because it is far easier to get a bunch of posters printed up. Or to remind people of Ben Franklin’s poem and hope that will do the trick. Either way, whenever we ‘solve’ a problem by finding that fifth ‘why’ root cause, we have almost invariably not found an actual root cause.

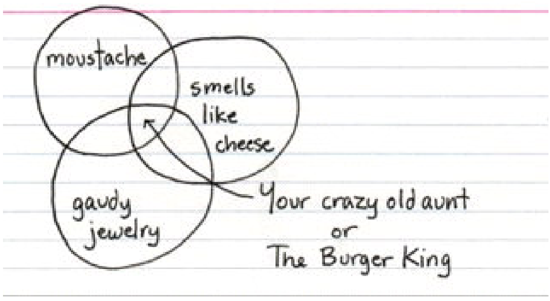
This is so either because there are deeper underlying root causes, and/or, as demonstrated in the horseshoe nail problem, we can’t possibly know beforehand whether something will turn out to be significant or not.

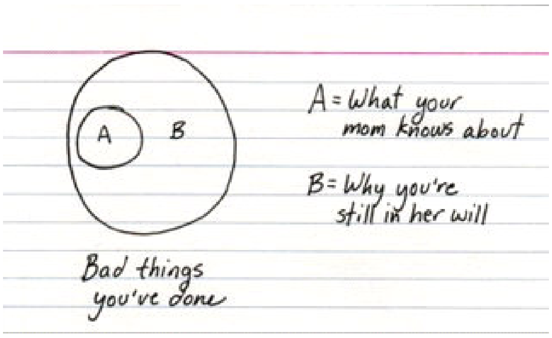
So what can we do about it? Well, the main aim of this article has been to try and describe the problem in the hope that awareness might go some way to solving the issue. It is also a reminder that tools like Perception Mapping are built on a foundations that subtly avoid the main psychological inertia problems caused by Ben Franklin and all those other compelling, yet alas mis-directing root-cause stories. Perception Mapping attempts to solve the ‘root cause’ conundrum by turning the whole problem story around the other way. Asking the ‘what does this lead to’ question is a vital contributor to the issue of gaining genuine insights into any problem. Building a perception map on the ‘Intelligent people do dumb things because…’ question is a great way to start getting some breakthrough solutions because it recognizes that in almost every problem, many causes are connected to many others, and the more of those links we can map, the more likely it is that we will generate effective and robust solutions. More on that subject in future articles.

Humour – Prove It

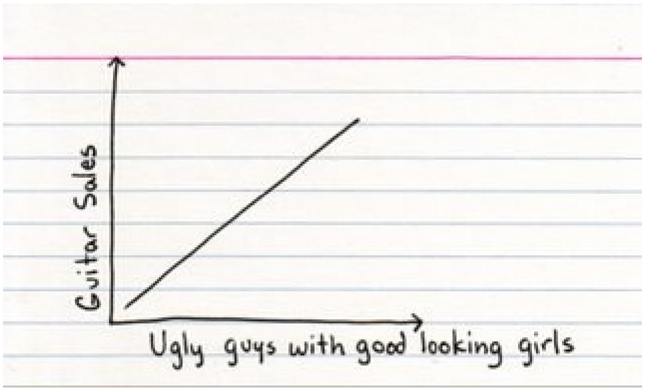
We frequently find ourselves in discussions starting with the question 'show me the data to prove….'

Some things don't require data; you just know they're true. Take the following pair of examples, both taken from indexed.blogspot.com:





Or our current personal favourite (we definitely know this one is true!):



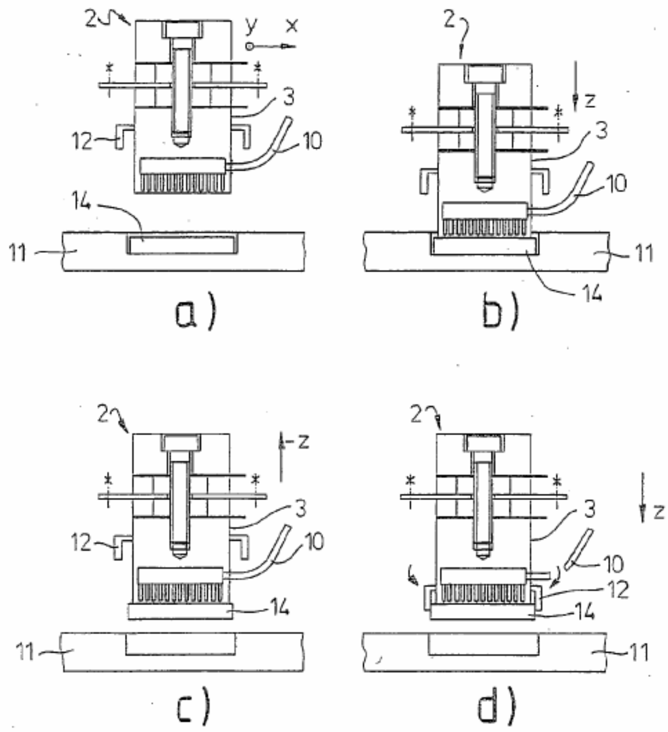
Find hundreds more equally thought provoking examples on the website. More examples being added every month, so well worth book-marking for those idle moments.

Patent of the Month - Contact-Less Gripper

If this patent didn't have the name 'Bosch' in the Assignee box, we might well have placed this invention into the crank-inventor reject pile. US7,168,747, however was granted to inventors at Bosch's Stuttgart division on 30 January. The invention describes a 'device for gripping and holding an object in a contact-less manner'.

The focus of the patent appears to be on the manufacturing of micro-systems in general and semiconductors in particular. The small size, high dimensional accuracy requirement and sensitivity to contamination potential, means that these components are sensitive to handling problems. Such problems can be made to effectively disappear if the components can be moved without physically touching them. Several prior art inventions have achieved such a capability, albeit with a number of adverse side effects, most usually that the object to be held and moved has to be 'gripped' from below. In the case of certain applications, however, the component may only be grasped and held from above, i.e. the direction aligned *with* the direction of the force of gravity. This occurs, for example, when grasping a component that was laid down on a storage area or a transportation device, or when mounting or assembling the component on a specified object or storing it. Such cases of application exist, for example, in the bonding of semiconductor disks, or during so-called wafer bonding, in which case the corresponding component is to be applied accurately and with a defined contact pressure to a structural element without damaging corresponding structures or surfaces. In the case of these applications, no grasping or holding devices may be used which hold or grip the component from two opposite sides.

Here, then, is the basis for the Bosch invention; a need to be able to pick objects up, against the action of gravity, without touching them.



This from the invention disclosure:

…In this regard, the device according to the present invention has the distinction that the holding element is designed as a vibrating holding element for generating levitation waves.

…At this time, devices are already known which are able to hold and transport objects with the aid of the physical principle of so-called near field levitation (cf, for example, U.S. Pat. No. 5,810,155 or German Published Patent Application No. 199 16 922). However, it is common to these and comparable devices that the object to be held or transported is positioned above the vibrating holding element, i.e. that the vibrating holding element is situated below the object in the direction of gravity.

The technical world assumed up to now, among other things, that the object may only be pressed away from the vibrating supporting element because of the sound pressure of the levitation waves. In regard to this, known devices using the principle of acoustical near field levitation have been provided exclusively for applications in which extending below the object is implementable.

The possibility of extending below the object to be grasped and held is not necessary when using a device according to the present invention. As a consequence, according to the present invention it is possible to grasp and lift up an object, in a contact-less manner, at a pick-up location exclusively from one side or rather from above, possibly to transport it over a certain distance and subsequently to position it at a deposit location designed in any desired manner.

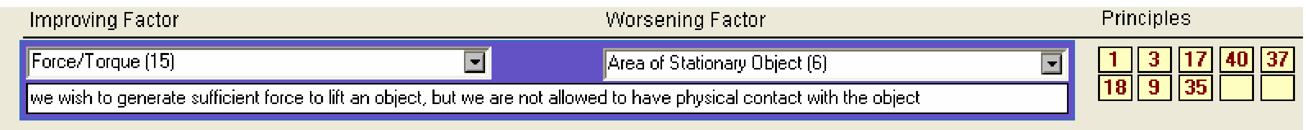
…The vibrating holding element is advantageously designed for decoupling ultrasound waves having frequencies between 16 kHz and 1 GHz., especially between 20 kHz and 40 kHz. With the aid of this measure, advantageous holding performances or rather holding forces may be implemented for grasping and holding the object. In an advantageous manner, adaptation of the frequencies is provided in dependence upon the object to be grasped and held. With this concept in mind, above all, an advantageous adaptation to the required procedural dynamics of each respective application case, such as the so-called "pick and place" task, may be implemented.

Surprisingly, in practice it turns out that just one holding element positioned counter to the direction of gravity above the object, i.e. counter to the direction of sound propagation, which, in particular, generates acoustical levitation waves, is able to grasp and hold an object at an advantageous distance apart. In this instance, no second holding element has to be positioned on the side of the object lying opposite the vibrating holding element, such as, for example, a reflector or a second vibrating holding element for generating standing waves between the two holding elements.

Beyond that, it also turned out that the object to be held and grasped may have any desired, particularly three-dimensional form or geometry. Furthermore, using a device according to the present invention, floppy parts such as foils, diaphragms, papers, textiles or the like, fragile components such as glass elements, comparably thin semiconductor components or similar items, as well as surface-coated objects or components, having structures sensitive to the touch, may be grasped, held and positioned at their surface.

Beyond this description, disappointingly and surprisingly, the examiner appears to let the Bosch engineers get away without fully revealing how the system works. There is no way that a 'skilled artisan' could reproduce what has been achieved here based on what has been disclosed. This makes the patent difficult to analyse and fully reverse engineer.

That being said, something we found quite surprising (in an encouraging way) is that when we look up the basic conflict solved by the invention – we want to generate sufficient force to lift an object, but we can't touch it - in the Contradiction Matrix, we get the following:



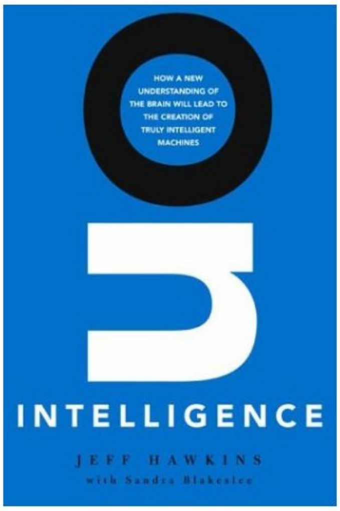
What most surprised us about this result is the presence of Principle 18, Vibration as a recommendation. Lifting something up using ultrasonic levitation waves sounds pretty non-obvious to us, and yet the Matrix gives us very close to that very suggestion. This fact should serve, if nothing else, to remind us that even though something might sound very non-obvious like this, that shouldn't cause us to assume it is irrelevant.

Less surprising in the analysis, then, is the presence of Principle 1, Segmentation. It isn't totally clear how precisely the inventors have segmented the input, but it is clear in the statement 'vibrating holding element is advantageously designed for decoupling ultrasound waves' that this is a key element of why the system works.

This failure to disclose full and frank details of the invention and what this segmentation looks like shouldn't ultimately allow us to detract from the potential importance of the invention. An oft repeated quotation from science fiction author Arthur C Clarke; 'any sufficiently advanced technology is indistinguishable from magic' is a pretty good definition of great inventions in general and this Bosch invention in particular. Pick things up without touching them? Really? Apparently so.

Best of the Month – On Intelligence

'On Intelligence' by Jeff Hawkins – the inventor of the PalmPilot – was published in 2004, so we're a little slow getting to this one. It has sat on our shelf, in fact, for over two years now. Shame on us since this is a considerable contribution to the world's understanding of how the brain works, and, perhaps more important, how we can make practical use of what we learn. Hawkins in that sense is like a growing number of entrepreneurs; spending considerable amounts of his hard-earned rewards into practical research. Less blue sky (polite phrase for 'detached'?) than university academics, but at the same time willng to make some fairly radical re-interpretations of the findings of previous researchers.



This from the prologue of the book serves as a useful insight into Hawkins world and motivation:

The question of intelligence is the last great terrestrial frontier of science. Most big scientific questions involve the very small, the very large, or events that occurred billions of years ago. But everyone has a brain. You are your brain. If you want to understand why you feel the way you do, how you perceive the world, why you make mistakes, how you are able to be creative, why music and art are inspiring, indeed what it is to be human, then you need to understand the brain. In addition, a successful theory of intelligence and brain function will have large societal benefits, and not just in helping us cure brain-related diseases. We will be able to build genuinely intelligent machines, although they won't be anything like the robots of popular fiction and computer science fantasy. Rather, intelligent machines will arise from a new set of principles about the nature of intelligence. As such, they will help us accelerate our knowledge of the world, help us explore the universe, and make the world safer. And along the way, a large industry will be created.

Fortunately, we live at a time when the problem of understanding intelligence can be solved. Our generation has access to a mountain of data about the brain, collected over hundreds of years, and the rate we are gathering more data is accelerating. The United States alone has thousands of neuroscientists. Yet we have no productive theories about what intelligence is or how the brain works as a whole. Most neurobiologists don't think much about overall theories of the brain because they're engrossed in doing experiments to collect more data about the brain's many subsystems. And although legions of computer programmers have tried to make computers intelligent, they have failed. I believe they will continue to fail as long as they keep ignoring the differences between computers and brains.

What then is intelligence such that brains have it but computers don't? Why can a six-year-old hop gracefully from rock to rock in a streambed while the most advanced robots of our time are lumbering zombies? Why are three-year-olds already well on their way to mastering language *while computers can't, despite half a century of programmers' best efforts? Why can you tell a cat from a dog in a fraction of a second while a super-computer cannot make the distinction at all? These are great mysteries waiting for an answer. We have plenty of clues; what we need now are a few critical insights.*

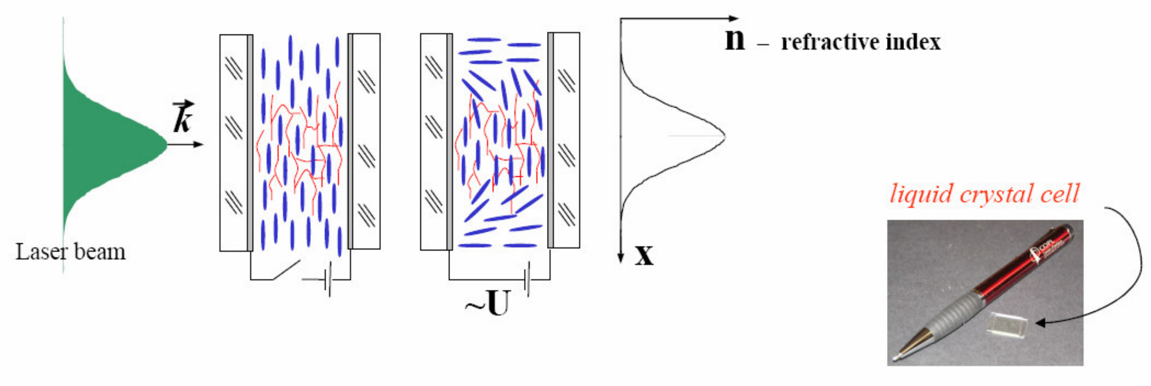
Insight is then the key thrust of the book. Key amongst Hawkins hypotheses are a number of thoughts and re-interpretations of known facts:

- the neo-cortex of the brain is formed as six stacked layers, in each layer of which is a very large number of neurons (with around 30 billion in total), each of which in turn is anatomically like every other neuron. Therefore, each neuron is capable of performing only a very small range of different tasks. Therefore again, the great complexity of the human mind – that collection of neurons effectively *is* your mind – emerges from massive reproduction of building blocks that are essentially all the same. In this way the part of the brain responsible for, say, visual processing consists of the same neurons as the part of the brain responsible for auditory processing. Or, put another way, the brain uses the same basic process to hear as to see.
- Each neuron possesses axons and dendrites which can form connections (synapses) with other neurons. The pattern of axon and dendrite connections determine the behaviour of the neurons and therefore the mind. This wiring is extremely 'plastic' – meaning that connections can be changed and re-wired according to the types of inputs being received.
- Our perceptions and knowledge about the world are built from both spatial and temporal patterns. So visual processing – which we tend to think of as spatial – also has a distinct temporal component, and auditory processing – which we tend to think of as temporal – also has a distinct spatial component.
- Neurons are slow and yet we can perform some amazingly complex tasks (like recognising whether someone is happy or sad) in fractions of a second. In half a second, any information entering your brain can only possibly traverse a chain one hundred neurons long. So although there may be much parallel calculation going on, fundamentally those complex tasks are being performed with a remarkably small number of steps. The answer to this conundrum is that the brain doesn't 'compute' the answers to problems; it retrieves the answers from memory.
- The neo-cortex works hierarchically, with relatively small sub-tasks being performed at one level; these sub-tasks then get collected into bigger mini-tasks at the next level up the hierarchy, and so on.
- There are many more connection paths sending feedback down this hierarchy than there are paths sending input information up the hierarchy. Here is a fact that has seemingly been ignored by nearly all earlier neuro-scientists. They have done this since the function of these feedback loops has not been established. But Hawkins hypothesis then goes something along the lines; nature wouldn't be so wasteful as to put in 10 times more feedback connections than input processing connections if there wasn't a useful function they had to perform. That function turns out to be making predictions. The brain is thus essentially a prediction engine – anticipating what is going to happen next and constantly then checking and updating those predictions.

Often the most profound insights come through seeing what others have seen a million times before, but realizing that there is another way to put the pieces together. This is the feat achieved by Hawkins in this remarkable book. Whether he is 'right' about everything only time will tell. What is important, though, in the short term is whether he provokes new and better ways of seeing the world. We think he has achieved this admirably and as a result, has produced some profound implications for the future of, for example, computing and the design of robust software systems. It has already, for example, had a profound impact on a project we are conducting for a client on speech recognition software. Here is a problem that is probably one of the most difficult in the world, one that is being worked on by several thousand researchers, who have made seemingly little progress in the last 40 years. According to Hawkins, this has happened because we have been suffering from a profound psychological inertia; we have ignored the obvious (10 times more feedback connections than input connections!) and because we have somehow let ourselves focus on finding the differences between things we have failed to see the similarities that may just turn out to offer the keys to the kingdom.

Investments – Opto-Electrical Lens

US patent number 6,398,981 was granted to inventors at the University of Lavala in Canada in June 2002. The fact that it only makes it to the 'investment' part of the e-zine over 4 years later should give a pretty good indication of some of the difficulties of transitioning a good idea into practical reality. Anyway, that aside, scientists from Université Laval's Faculty of Sciences and Engineering recently announced further developments of the lens system described in their patent. The lens is now five times thinner than a sheet of paper and, perhaps its biggest single innovation, is able to zoom in and out without mechanical parts. Tigran Galstian and Vladimir Presnyakov presented this amazing piece of optical instrumentation in a recent issue of the Journal of Applied Physics.



"There are several possible applications for such a lens. We believe one of its most promising developments could be in camera-embedded cell phones," says Galstian. "Our opto-electrical zoom lens would be of much higher quality than the ones that currently equip these phones."

The digital zooms now used in camera phones only enlarge part of a picture without enhancing its quality, giving sometimes disappointing results. Other than its size, the greatest advantage of the lens invented by the two Université Laval researchers is that it allows for the movement of the focal point – as with a real camera – thus increasing the clarity, detail, and overall quality of an enlarged picture.

Such a technology looks set to boost a market that seems to be losing its snap – and hence its feature in this part of the e-zine. According to a recent market study by one of the major camera makers, a significant number of camera phone owners find their devices less than satisfying, mentioning among other problems the poor picture quality.

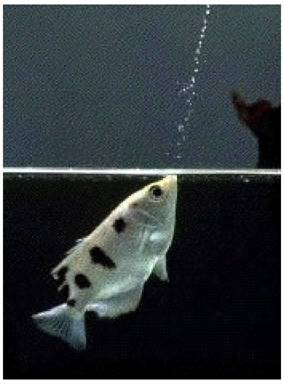
The lens is made by adding a small quantity of photosensitive material to a liquid crystal cell. When the material is exposed to laser light, it forms a network of stable polymers varying in density according to the intensity of exposure. "The network is like a spider-web, with its centre denser than its periphery," explains Galstian. "When we apply a weak electrical current to it, the crystals in the centre re-align differently from those in the periphery and thus take on the shape and behaviour of a lens."

The curve of the lens – its focal point – can be modified by changing the intensity and frequency of the electrical current. The researchers have thus been able to modify the lens' focal distance from 1.6 to 8 meters in a few milliseconds by increasing the voltage from 1.5 to 4.5 volts. "The reaction is very fast and doesn't involve any mobile parts or mechanical movements." The focal point of the lens can go from 60cm to infinity.

Biology – Archerfish (*Toxotes jaculatrix)*

Archerfish are famed for their ability to shoot down insects and small creatures resting on foliage or mangrove roots. The fish are like submarine water pistols and can spit out a strong and accurate jet of water. To get a good jet of water, the snout sticks out of the water, but the rest of the fish remains underwater. They direct the jet of water with the tip of their tongue. For accurate aim, they have large eyes located very near the mouth, which give good binocular vision.

Their eyes, however, do not automatically correct for refraction, and they have to learn how to do this. The position of least distortion is directly below the prey, and the fish soon learn that this is the best shooting spot. The fish can squirt up to 7 times in quick succession, and the jet can reach 2-3m, but they are accurate to only about 1-1.5m. Fish as small as 2-3cm long can already spit, but their jets reach only 10-20cm.



The fish has adaptations to the mouth which enable this spitting ability. The right-hand image shows the presence of a deep groove which runs along the roof of the mouth. When a Seven-spot Archerfish shoots a jet of water, it raises its tongue against the roof of the mouth so that this groove then forms a tube. The gill covers are then quickly sanpped closed which forces water along the tube. The tip of the tongue acts as a valve.

Once the jet of water knocks down the tit-bit, the fish gulps it down in its large deep upwardly directed mouth. If the blast doesn't knock down the prey, sometimes the weight of the water on the wings causes the insect to lose its grip and fall.

Scientists have recently learned that the sharp-shooting fish has developed sophisticated means of minimizing the amount of energy expended in creating its projectile jet of water. Spitting water over 2metres requires a lot of effort and so any ability to reduce the amount of energy required can be expected to result in a definite survival advantage. Using high speed cameras, researchers at Erlangen-Nürnberg University in Germany have determined that the fish adjust the amount of water projected according to the size of the prey. The key determinant seems to be how much force is required to dislodge a given prey from its perch. The researchers showed that the fish accurately adjusts the amount of water projected to deliver about 10 times that needed to overcome the adhesion capability of any given size of prey. We can map this design conflict as follows:

Improving Factor	Worsening Factor	Principles
Force/Torque (15)	Adaptability/Versatility (32)	15 17 3 19 29
the archerfish needs to generate minimum but sufficient force to dislodge prey, but some prey is bigger than others		35 4 18 24

Actually, if we plot the likely evolution of the fish's extraordinary capability, it has had to resolve a succession of conflicts and contradictions; in the first instance, for example, there was the need to solve the first problem of how to catch prey that was some distance away and out of the water. Then, once the water-jet solution had appeared, the conflict probably shifted to 'how to increase the distance that could be attained by the water jet. And then later on, and perhaps in parallel, how to minimize the amount of effort.

Specifically in this latter contradiction, we can interpret Principle 15, 'Dynamics' as the one being used by the fish today – adjusting the amount of water projected according to the prey. We can also see in this conflict similar Principle recommendations to the ones used in solving earlier problems – specifically Principle 29, 'Pneumatics & Hydraulics' in the first instance, and then Principle 3, Local Quality in the modification of the mouth parts to create a suitable nozzle through which to eject the water droplet.

Although none of the research we have found mentions it, it would also appear that the fish is making some use of Principle 19, Periodic Action in a bid to further improve the prey-dislodging efficiency – see the central picture at the top of the article.

Also worth noting, even though it is a different contradiction, is the flattened body shape of the fish. This presents a narrow profile from above, so they can sneak up on their prey. The dorsal profile of the body from the tip of the snout to the dorsal fin is almost straight. This body shape in combination with the location of the dorsal fin well back on the body, allows the fish to swim very close to the surface and look upwards without creating surface disturbance. This is an advantage when hunting insects which rest on overhead vegetation.

Despite their uncanny projectile capabilities, Archerfish, nevertheless, prefer to leap out of water to grab the prey in their jaws when it is close enough. When the leap fails, they may then resort to spitting. Archers usually swim in shooting parties. Often, several shoot at the same prey, and shoot relentlessly. When the prey finally falls, all rush to grab it. As the sharpshooter doesn't always get the prize, if the prey is within reach, the fish prefers to leap out of the water and grab it in its jaws. A prey in the mouth, apparently, is worth two spat at! They can jump up to 30cm high. But Archerfish don't just eat above-water prey. They also hunt small aquatic creatures and fishes, sometimes swimming in deeper water to catch these.

The Seven-spot Archerfish lives in freshwater and estuarine habitats throughout much of south-east Asia.

Short Thort

"The paradox is the source of the thinker's passion, and the thinker without a paradox is like a lover without feeling; a paltry mediocrity"
Søren Kierkegaard

News

TRIZ Organizer
Regular visitors to the www.systematic-innovation.com website will already have noticed that the 'TRIZ Organizer' feature is now fully up and running. The main aim of the site is to allow users to conduct a functionally oriented search of public domain literature. So far we have classified the whole of the TRIZ Journal and our own e-zine archives. In coming months we expect to add other knowledge sources to the database. The site will also feature a direct link from TRIZ Journal, starting from the February issue.

Live Systematic Innovation
The end of January saw the running of another of our public two-day 'live systematic innovation' workshops. Due to the continuing success and positive feedback received, we will be running the event again on 6 and 7 June in our Bristol office.

SABIC
Following a programme to train 50 of its senior management and technical staff towards the end of 2006, we are happy to announce that SABIC – one of Saudi Arabia's biggest companies – have asked us to conduct a full certification programme. The workshops and projects will be commenced during February, with certification expected to take place by the middle of April.

Matrix 2003 – German Edition
We are pleased to announce that the German language edition of Matrix 2003 will be published at the beginning of March. Contact the translation team at Kassell University for more details. Or check out the link on the Products page of our website.

Innovation BootCamp
The Asian version of this 4 day boot-camp will be held in Kuala Lumpur from the 5th to 8th of March. We are very happy to be working and co-presenting with Sandy Ping from the US. Sandy is ex Procter & Gamble and a person with an extraordinary record of transitioning good ideas into practical reality. Check out the website or TRIZ Journal for more details.