Epilogue

What I almost forgot to tell you!

I almost forgot to tell you about the numerous questions I have had been asked over the years by practicing engineers and managers about my methods and techniques during seminars and live workshops that I conducted over the last few years on Rapid Innovation.

It was natural of them to have asked these questions. There were of course many reasons. For most, it was plain and simple curiosity. To some, questions arose because they were simply not able to connect my concepts and principles to existing frameworks of concepts, methods and techniques that they either knew of or used (a natural tendency for people trying to relate something new to something that exists). Others looked for 'chinks in the armour' in my reasoning and arguments. Whatever it might be, the answers to these questions prove useful since they bring home some of the underlying concepts of Rapid Innovation with more clarity and depth. .

Though it would not be possible to list down all the questions that I have had faced from different quarters it would be fair enough to list down at least six questions, which I think are important in the sense that the answers to these carry the main tenor of my argument for an alternative path to improvement in reliability, availability and performance of manufacturing systems, which in essence translates to survival, growth and sustainability of a company.

Question 1:

What would be the 'step by step' process to be followed in Rapid Innovation?

Answer 1:

Rapid Innovation carefully avoids the idea of following any fixed line of thinking or having a very structured process in place or breaking up the concept and principles into a series of prescriptive 'to do' steps though it gives an overall approach with clear guidelines.

The reason is simple. The other existing improvement processes were based on the edifice of 'command, control and predict' philosophy of life. With this philosophy we were naturally forced to create well structured 'step by step' prescriptive processes, which employees were supposed to blindly follow. I have purposefully avoided this perspective for the simple reason that most often machines and processes stubbornly refuse to yield to the 'command, control and predict' mindset.

Hence the alternative approach is to understand the inherent behaviour of any system and respond to specific nonlinear (that gives rise to random failures and chaos) traits of the system in an appropriate manner. Naturally, the responses would differ from system to system. Therefore, I have avoided the path of designing a well defined 'step by step' process.

The idea that systems would listen to us and work as we want them to work, provided we have a structured plan in place, took deeper roots with the advent of Henry Ford's unique assembly line concept that started in Detroit. The assembly line gave us the feeling that everything can be controlled by us to clockwork precision and the behavior of our designed systems may be predicted accurately in the long term. The machines and processes would blindly obey what we wanted them to do. After all, we designed the system so why won't they listen to us?

Simply told we were trying quite hard to manipulate and control the machines and processes in our manufacturing environment. How did we go about doing this? We went about the task by designing a series of well structured routine activities that employees were supposed to strictly follow. The belief was that if we could only do things in a particular manner, with nearly 100% conformity, our systems would obey us and produce consistent quality without variation. And we would then be able to achieve our business objectives of productivity, quality, delivery and costs with unerring precision.

The mantra during this period of intense industrial development was to 'eliminate variation' in the processes. But this did not simply happen even in the best manufacturing set up in the world. Reports, which are confidential in nature, indicate that even the best car model that we now produce could have around 600 varieties of defects arising out of variations that came up during the manufacturing and design processes. All along, our design and planning processes to bring machines and quality under our control faced quite a bit of difficulty and seem to run into rough weather now and then. We were never sure as to what might happen next. Rather it seemed that the machines and the processes had a mind of their own and they behaved just as they wished to, exactly as nature behaved. But we decided to stick to our original position of having inflexible and static plans in place to be executed without much deviation. But this did not fulfill our requirement of high reliability, availability and performance that we demanded from our systems.

Obviously, one of the sensible things to do is to identify parts of the system that behave nonlinearly and find out as to why they do so and then apply small design innovations to convert the nonlinear behaviour to that of a linear behaviour. In this manner the system would become more stable, reliable and more predictable; almost free of failures and nonperformance.

Why is it so? This is because nonlinear behaviour is actually responsible for producing the multiple failures that we experience with systems. Linear systems hardly produce random failures and their failures are quite predictable in the long term. Also note that we need not focus our attention on all parts of the system with equal intensity. We need only to focus intensely for some time at least on the nonlinear parts of the system that create nagging random problems for us.

In this manner we may then not only ensure stable and consistent behaviour of the system but also extract the desired output and performance from any system. This is the objective of Rapid Innovation. As you can appreciate that to achieve this end a structured 'what to do' and 'when to do' approach might not work at all. Therefore, well meaning structured routine activities need to be replaced by something more valuable. Those valuable things that we need to achieve our business objectives would be knowledge, spontaneity and creativity of the people involved. That is why Rapid Innovation places, so to say, a premium on the development of people.

The important objective is to empower people to think freely in an unbiased manner about what should be the right way to go forward without binding them to rigid rules, regulations, strict to-do steps, and unscrutinized beliefs. People should be able to question everything openly and honestly and base their reasoned and/or creative responses on their direct observations and insights gleaned from such observations. And they should be able to do exactly what is necessary; nothing more nothing less.

To sum up, we may say that all improvements are based on the current reality of the organization, the present dynamics of the systems and the present level of development and realization of the people. We might then obviously conclude that the improvement approaches to be taken at two different manufacturing facilities would not be the same. Being different only increases the chance of success.

Therefore, I would just like to pull myself back from the temptation of associating the term ‘process’ to the concept of Rapid Innovation. The application of Rapid Innovation should always yield a new custom built responsive process for each different application keeping the basic flow (the Observe- Respond- Do cycle) in mind. Thus the acronym ‘Rapid Innovation’ is best left as a stand alone term without the qualification of a structured process.

Question 2:

What are the different ‘levels of realization’ of the people that you talk about?

Answer 2:

I feel width and depth of ‘realization’ or ‘awareness’ evolve in stages against time. I suspect that these would appear in the following sequence for most people:

a) Stage 1(The Fundamental Awareness Level) –

   At this stage the person realizes three things.

   First, one understands that all elements within a system are interdependent on each other for the proper functioning of the system. So, none of the elements can be individually responsible for a failure or ‘nonperformance’ event.

   Second, one gets the idea that though space (system space) and time co-exist they are not related to each other. Time works on the space to transform the interdependence of elements within a space to give birth to variations and ‘random’ multiple events that constantly arise within a system.

   Third, one realizes that seemingly multiple events can be handled or managed from a level that is at least one level higher than the event level; the level that actually causes failure events to take place.

This would help a person in three ways.

First, it helps one to perceive reality from various perspectives to form a holistic picture of the system behaviour rather than understanding system behaviour from the point of view of 'events' and be worried about it. Making sense of a system in this manner also enables a person to discover patterns behind events. One understands that while the events are not very important by themselves; except for the fact that they definitely do help in predicting the future states of the system in the short term; the patterns are of extreme importance in determining the overall behaviour of the system.

Second, it helps the person to initiate the right responses to deal with the system and the events. These responses, which are vital for the correction of the system, automatically flow from the deeper knowledge gained from understanding patterns.

Third, it helps a person to go about his/her job or work in a relaxed and creative state of mind as opposed to tackling an issue with a tense and worried mind. This springs from the fundamental realization that one can't be held solely responsible for any event. This would generate the primordial quality of spontaneity and fun in one's daily work, which I think is acceptable and attractive to all but most are presently deprived of it in their daily work, where work and spontaneous creativity are highly compartmentalized concepts.

b) Stage 2 (Higher Awareness Level) --

The next stage of realization would come from the understanding of chaos and the factors that cause the ever changing patterns to evolve.

The realization is that chaos is not erratic or random as it seems to be but is governed by a set of deterministic laws or principles. At this stage of realization one starts recognizing the laws and the principles behind the patterns. This I call as the 'factor level'.

We now have three levels to work on.

The 'event level' is the most basic level. At this level we would able to predict in the short term the next possible event that might take place. For example, if I know that there is 'misalignment' (event) in the system I may then predict with a great amount of certainty that this would affect the outer race of the bearings on which the shaft is rotating. But I would not be able to tell as to why the misalignment happened though it was perfectly aligned before the machine was switched on.

The next higher level is the 'pattern level'. At this level we can understand that the multiple events that take place are connected by some specific pattern(s) in the system.

Then we have the ‘factor level’ which is one level higher than the ‘pattern level’. Once we reach the ‘factor level’ we immediately identify the principles and laws at work that cause multiple events. For instance, we can identify whether the system is showing ‘extreme sensitivity to the changes happening in the initial inputs’ or there is a presence of some ‘strange attractor’ in the system. With some effort we may then identify the specific factors (like friction, material composition, flow) that are responsible for the events. Hence the next task would be to eliminate the presence of such factors or ‘imperfections’ to put an end to the occurrences of multiple events.

At this stage the focus now shifts from identifying patterns to seeing both the patterns and the factors at the same time not only their interconnectedness but also to find the fundamental imperfections at work that create events. Accordingly, the quality of responses to eliminate the ‘imperfections’ improve.

c) Stage 3 (Highest Awareness Level) --

The third stage of realization would spring from the deeper understanding of how small imperfections in the system design are responsible for all that manifest at the physical level as ‘events’ going through the factor level and the pattern level. Hence I tend to call this level of awareness as ‘system design level awareness’, which is one level higher than the ‘factor level’ of awareness and therefore is at the highest level from the event level. From this level one has the widest and the deepest perspective of the multitude of events happening in a system and also affecting other systems.

This is the highest stage of awareness where a clear understanding of the design of the system is needed to understand parts of the design that produce the factors at work and the various patterns before precipitating them into the physical plane of our existence as ‘events’. These are the ‘design imperfections’ that I talk about.

At this stage of realization creating the necessary solutions is the easiest. All that one needs to do is to find the parts of the entire design that create non-linearity in the system and then find ways and means to correct them. The advantage is that by doing so multiple problems or events and even other interdependent systems would be corrected in one go rather than trying to tackle different factors and patterns individually.

At this stage one is expected to think freely and deeply in a spontaneous and creative manner about all the issues or events that might be tackled in one shot.

Needless to say that such wide and deep ‘awareness’ would only come to self motivated people who don’t shy away from continuous practice of ORD cycle with a ‘ non-judgmental’ attitude. The other advantage of practicing this cycle is that it may be applied with ease to all issues and events that bother a human being. For example, it can not only be applied to engineering systems but also to service and design departments, and to business and social environments with equal ease and fluency. It works almost everywhere since we are always surrounded by systems and part on one or the other interdependent system.

Though anyone can become quite adept in this it would do well for a practitioner to remember that one must not get addicted to any concept, method or technique but to be consciously open to all ideas, concepts, methods and techniques and critically examine these before rejecting or accepting any. Only then the skill would develop easily. This skill enables a person to take a balanced view of things, design stability into a system and maintain the desired flow of the system.

Here I would like to define the term skill as defined by Patanjali, the great Indian sage who wrote the definitive treatise on yoga. I find this definition most appropriate in this context. He defines ‘skill’ as something that can be done with effortless ease. The highest skill is achieved when a person can observe a system and respond effortlessly to improve the system with the idea to improve the lives of people.

But I must admit that is by no means an easy task. It would only come to those who have a lot of patience and practice the ORD cycle regularly in the right direction for a considerable length of time. However, it would be fair to say that some exceptional people go through these stages of ‘awareness’ with effortless ease. But I think that we would find only a handful of such persons.

Question 3:

Can you give a comparative assessment between the existing line of thinking and Rapid Innovation?

Answer 3:

Though I feel that a comparative assessment is neither desirable nor needed I would like to differentiate the salient features by means of the following table.

#	Existing Improvement Processes	Rapid Innovation
1	Eliminate variations, randomness and risks through process standardization and standardization of human behaviour	Eliminate system imperfections. Rapid Innovation does not place too much reliance of standardized human behaviour since human behaviour of all things, is most unreliable and unpredictable (highly nonlinear).
2	Institutionalize changes through rules, regulations, definitions, SOP, benchmarks. Success is measured by measurement of short term financial objectives	Changes are only brought about through social realizations Success is measured by development of human capability.
3	Arrangement focused activity based view with structured approaches that encompasses all components and elements	Human centred view based on reasoned thinking, spontaneous creativity and the focused will of the management and the people.

	of the system: as a standardized response to all machines, processes and systems without taking into considerations the dynamics of the system.	Focusing on the dynamic behaviour of critical systems under consideration and responding accordingly rather than undertaking a series of routine activities, which are often mundane.
4	Changes are triggered by ‘best practices’ and ‘benchmarks’ – more of competitive practices rather than internal evolution	Changes are triggered by issues of long term sustainability of the business where development of human talent is the basic strategy.
5	Focus on turnover, speed of operation, random cost reduction measures across the board and manpower reduction.	Focus on achieving balance, stability and flow of a system and doing just what is necessary for a given situation. Business results would automatically follow.
6	Success is achieved through registering odd or problematic events and finding the Root Causes of such events: usually trying to fix the responsibility on inconsistent or irrational human behaviour.	Success is achieved by focusing on patterns, factors and system imperfections rather than focusing on events and trying to find direct root causes (barring a few odd ones) for each event. Attention is aimed at correcting principles that cause most of the events to place.

Question 4:

Why do you not stress too much on Root Cause Analysis of ‘events’ and stress on ‘design imperfection’ instead?

Answer 4:

The concept of finding a root cause for an undesirable event is very appealing indeed and seductive to say the least. Finding a cause (or causes) is indeed useful and necessary for improvements to take place. I am not averse to the idea at all and I am all for it. All I say is that the concept should be handled with great care and discretion. In a moment we would see why it is so.

The existing methods and techniques have been constructed on the foundation of ‘linear logic’. That is every undesirable event must have a cause that can be directly related to the event and with some effort the root cause should be immediately identifiable.

This is very much possible only when the events and the causes are directly related and are very close to each other. Suppose we operate a machine in such a way that it results into an immediate failure we simply know the cause: wrong operation. For example, when caught in traffic jam, if we suddenly decide to accelerate or reverse the car instead of standing still, the car it is bound to hit another car and cause an accident. We can directly relate the cause and the ensuing event. We can easily find the root cause because the cause and the event were not much separated by time and space.

But for most problems it is not simple as that. Most cases turn out to be complex. By complex I mean that the cause(s) and the event(s) are separated by time and space. In such complex problems several factors interact in relative manner acting over a considerable period of time to produce underlying patterns that manifest into undesirable events. In such cases finding a direct root cause might prove extremely difficult, if not impossible.

Hence, there is a need for an alternative path such as shown by Rapid Innovation. In Rapid Innovation we basically have many methods to arrive at system imperfections or causes and design new systems. Therefore, most of the methods are actually tools for thinking, designing and implementing action plans. And such tools have been generated from the basic principles and concepts that I have used to develop Rapid Innovation.

Here I would like to briefly illustrate the use of three such tools. The first tool, know as PLS3D (Point, Line, Surface and 3 Dimensional) tool, is a thinking tool that works at the 'pattern level'. The second tool, known as IAR (Initiator, Accelerator and Retarder) tool, is also a thinking tool that works on the 'factor level'. And the third tool, known as the 'System Design Imperfection tool' is both a thinking and design tool that works at the 'system design level'.

The first and relatively easier method relies on not focusing too closely on an event but start by knitting together a pattern by observing all events that have either taken place or taking place within the system and then try relate them in a coherent manner to construct the underlying pattern, which is nothing but a number of interacting 'imperfections' that cause an event or failure to happen over time. This I term as the 'PLS3D Tool'.

To illustrate the use of this tool let us take a case of frequent failure of gear coupling. Imagine a head pulley drive of a belt conveyor mounted at the top of a structure (around 15 metres off the ground). A gear coupling couples the motor to the gear box. Let us also assume for a moment that everything is perfectly aligned and all seems fine when nothing is moving.

But as soon as the belt conveyor starts moving the pattern of the dynamics change. The relatively tall structure deflects and upsets the perfectly aligned system. This creates a lot of stress on the gear coupling as gear couplings are not meant to take in a lot of misalignment. So, over time, the teeth of one half of the gear coupling fail and the coupling fails to transmit the torque. Had we only concentrated on the failed coupling (the event) it would have been very difficult to come up with the root cause. We would have come up with the reason that 'fatigue' was the cause of the failure. But it would then be very difficult to account for the fact that only one half of the coupling (towards the pulley side) was failing (wear out and breakage of teeth). So when we move our observation from the event and try to see a pattern it immediately brings into focus the causes or system imperfections that induce a failure event.

The second method, which is slightly more difficult than the first is based on the governing concepts of 'Unity in Opposites' and 'Dissipative Structures'. Let us first explain the concept of 'Unity in Opposites' in brief. We know that for any motion to happen there must be at least two forces that oppose each other. For example, if we walk, the force that we apply to move forward is immediately opposed by frictional force. If any one of the two forces were absent or when one force is much greater than the other then motion would stop (a failure event). So for a failure to take place there must be at least one factor that initiates a failure that would change the characteristics of the forces being applied onto an object. And there must be at least one factor (called a 'retarder') within the system that would like to resist this change. Now if the 'initiator(s)' proves much too strong for the retarder(s) or the retarder(s) become much too weak with respect to the 'initiator' for any particular reason then a failure must happen.

Closely coupled to this concept is the concept of the 'Dissipative Structure' of dynamic systems that I would like to explain in brief. All dynamic systems are dissipative in nature. That is to say that they lose energy through vibration, heat, wear etc. So when the rate of any of these factors increases it accelerates a potential failure to physically manifest as a failure. Hence we term this factor as an 'accelerator'. We now have three important factors or properties of a system that cause failure events; these are: the 'initiator', 'accelerator' and the 'retarder'. Therefore, when we study the interactions taking place between these factors or system properties we may quickly pin down the underlying system imperfections that cause one or several failure events to take place within a system. The responses we have in hand are a) eliminate or weaken the initiator b) strengthen the retarder c) eliminate or weaken the effect of the accelerator. I term this thinking tool, which might be used at the factor level, as the IAR (Initiator, Accelerator, Retarder) Tool to find imperfections.

To illustrate the use of this IAR Tool let us take an example. The lip guard portion of a certain type of cooler plate handling hot amorphous and brittle material was wearing out very fast. In a year's operation of around 330 days these plates were replaced 26 times. These cooler plates were being cooled by normal air at ambient temperature blowing past the plates. However, the air also carried along with it grains of solid abrasive particles, which glided past the lip guards.

In this case we can identify the 'initiator' as erosion (actually the velocity of the particle laden air going past the plate); the 'accelerator' as heat in the system and the 'retarder' as the material property that would resist the hot erosion phenomenon. Hence the effect of the initiator was minimized by reducing the air velocity. And the effect of the accelerator was minimized by adding more cooling fans and increasing the draft for smoother flow to take place. And the retarder was strengthened by changing the composition of the material by lowering the sulphur and phosphorous content of the alloy steel. The life of the plates dramatically increased after I, A and R factors were successfully tackled. Now the plates were changed once in two years only; i.e. the life increased by a factor of about 50 times thereby achieving the much needed balance, stability and flow of the system.

Alternatively, our third tool, 'System Design Imperfection Tool' though relatively difficult than the other two, focuses our observation directly on the system as a whole to study the interactions of the different components or elements within and outside the system that affect it. Insights are then gained about the underlying design imperfections of the system and they also give instant clues about elimination of such imperfections to stabilize a system. Therefore this tool is both 'thinking' and a 'design' tool. This method is better than the previous two because of its inherent potential to simultaneously eliminate multiple problems or undesirable events of the specific system and other related systems with a single or a few solutions. With the previous methods we were restricted to find solutions to a few particular patterns that were causing a few particular events (failure modes) to happen within a specified system. This tool is holistic for two reasons. Firstly, this tool can be applied to various environments like System Design, Maintenance, Quality, Safety, and Product Design. Secondly, by application of this method, problems of productivity, quality, maintenance and safety could be tackled simultaneously in the shortest possible time. It might not be necessary to look and deal with each event, pattern, factor or system separately.

This method has been applied on a variety of practical applications with a lot of success. So, let me illustrate the use of this thinking and design tool through a very interesting case. The machine system that we were examining became a critical element in the business system since enhanced performance of the system would help in sustaining the business in the face of rapidly changing consumer preferences. But the company had many problems to deal with, which were the following:

a) They would have to increase the productivity of the system by over 30% of the present rate of production for each of their systems if they want to reach the desired business target. This they thought can be easily done by increasing the speed of a system to produce the desired number of products. But as soon as they increased the speed of the system by a slender margin of only 8% the system could not be operated. This was because the product quality became poorer and the frequency of machine breakdowns increased to such an extent that maintenance time was greater than the productive time. However, hard they tried this was always the case.
b) Normally the vibration of the system was normally within 65 microns but as soon as they wanted to increase the speed of system the vibrations shot up to 120 microns which made operation difficult.
c) In the present system there was always a product variation of +/- 25%. This was unacceptable to both the customer and the manufacturer. Either the consumer or the manufacturer lost money.
d) Since the final product was in a liquid form it had to be sealed in small plastic like packets and in 25% of the cases the sealing wasn't good enough. The seals leaked. Again both the manufacturer and the consumer not only lost money but also caused of a lot of inconvenience.
e) Then during the process, around 10% of the product leaked out of the system
f) The failure rate of the machine was high and the associated maintenance cost was also high. The MTBF (The Mean Time between Failures) of the system was only 4 days.

So, now we have a situation where all types of problems co-exist: productivity, quality and maintenance. The traditional way would have been to look at and optimize each issue separately.

However, when you apply the ‘System Design Imperfection Tool’ the approach becomes entirely different. Here we try to identify the design imperfections within the system.

To cut a long story short, we then came up with a few solutions to eliminate the existing system design imperfections some of which were the following:

a) Change the proportion of the machine system to bring the centre of mass and the centre of stiffness of the machine close by so as to increase the stability of the entire system.
b) Change the proportion of the product dispensing unit so that stick slip phenomenon could be eliminated to reduce product variation.
c) The force transmission path was made shorter and direct to eliminate ‘tolerance build up’ in the system along with better heat distribution in the sealing area to improve accuracy of sealing.
d) Small changes in material composition were made to prolong the life of some of the vital components in the system.
e) Space was created for better ‘heat dissipation’ to eliminate the problem of heat build up within the system.
f) Layout of the product pipelines was changed and the shape of the product hopper was also changed along with pipeline fittings to eliminate air entrapment into the system and minimize vibration of the pipelines. This was done to eliminate product wastage during processing.

Notice that we did not attack any problem directly the way we do it with our existing methods of Root cause analysis. We just went about correcting the system design imperfections. So, what were the results?

After the changes were incorporated to build a new system the following improvements were observed:

a) The productivity of the system increased to the desired level by 30%
b) The normal vibration level of the system reduced from 65 microns to 3 microns
c) Product variation was reduced from +/- 25% to +/- 1%
d) Sealing defects were reduced from 25% to less than 1%
e) Product leakage during the process reduced from 25% to 0%
f) MTBF of the system increased from 4 days to 90 days

The good thing was that these improvements could be implemented in less than 60 days by the people who were involved in the improvement process. Also notice that small design changes cured all the different types of problems in one go. We were not much bothered about classifying the type of problem or about the complexity of individual problems or tackling them one by one. We addressed all the issues together by addressing design shortcomings or ‘imperfections’. It was something like solving multiple parameter simultaneous equations. The interesting thing is if done right, it is always a one time effort as opposed to continuous or continual efforts, which gives a company ongoing benefits for years to come.

What is also interesting with all these methods is that the outcome is really not dependent on past experiences. Generating solutions is not based on 'reproductive thinking' (i.e. solve problems based on what you already know) rather the approach leans heavily on the quality of productive thinking, which is thinking, solving problems and doing things in new ways. We are naturally pushed into thinking in fresh ways and from different perspectives, understanding interdependence, combining opposites and relating different things into one meaningful whole to bring about the desired effects and make the lives of people more comfortable. However the foundation of the process lies in incisive observations, direct understanding and creating new interactions.

However, the most important question that arises in my mind is 'why for so long we kept inventing a rather long list of methods and techniques to find root causes directly and tackled problems individually and kept focusing on events rather than on patterns, factors and system imperfections that cause all events to happen in the first place?'

The answer is a bit technical and involved but I would try to keep it as simple as possible for readers to get the essence of the reasoned thinking behind my disagreement with the prevailing methods of Root Cause Analysis. However, I would take an intentional detour to bring home the point.

I think that deeper understanding of this misdirected human effort must start by having a basic idea about the methods and work of mathematicians and philosophers that have shaped our present day thinking and approaches towards solving problems which we now term as scientific and logic thinking. It was not very unusual for mathematicians to lay great stress on classifying problems into different types. Once segregated, they applied their precision of logic to solve them one at a time.

Since the time of Archimedes, Pythagoras, Aristotle and Plato, logic was considered to be the most important capability of the human brain, overriding other important human capabilities like creativity. The idea that some knotty problems were not amiable to mathematical logic was abhorrent to them. But somehow, over centuries, we slowly got ourselves imprisoned by concepts of the world as seen through the eyes of mathematicians. We now call that traditional approach as 'scientific' and 'mathematical logic' that examine problems individually and in isolation; more precisely known as the 'reductionist approach'. However, I don't suggest in the least, that mathematical concepts are not useful in understanding our worldly events and nature. In fact they prove quite useful so long as we appreciate the limitations of their application and approaches.

For instance, by the end of the 19th century and during the 20th century mathematicians and scientists became aware of the fact that real life dynamic systems can prove to be too complex to handle because of non-linearity issues. And they found it impossible to solve such cases through existing mathematical reasoning and linear logic. For example, Henri Poincare's three body problem is not a very nice problem to apply the immaculate and precise laws of mathematical logic and Newton's laws to find a solution. We know this. And we also understood that clearly there was a need for a different type of approach to the whole problem. Maybe we might have to abandon the 'reductionist approach' for something else. But how did the mathematicians grapple with such problems?

Their approach was indeed novel. They came up with an elegant way to locally transform a non-linear system to that of a linear one. For example, they used tools like Jacobian matrix, Eigen vectors and Eigen values to locally 'linearize' a non-linear behaviour. Note that they did not try to see nonlinearity as it is; they simply applied their rules of linear behaviour to nonlinear systems in extremely clever ways.

This mathematical trick to convert a difficult real life problem that defies logic to a problem that is amiable to logic proved quite useful. All we have to do then is to pretend that the transformed function, which is now appears to be linear, truly represents the original non-linear system at every point in the state space.

This simple pretension, which I think is a gross approximation, enabled us to predict the behaviour of the transformed linear system within the given state space with great ease like any other linear problem. We could then predict every point in the state space with high degree of accuracy and ease and find whether the function is converging or diverging. We could easily draw graphs or orbits to depict the system's behaviour of convergence and/or divergence.

Everyone liked it since it made our job easier. The scientists liked it and so did the engineers. Well, they assumed that this is how the system in spite of its non-linearity is more or less expected to behave; a good enough approximation, they thought. It was definitely an elegant way to have a feel of non-linear dynamic systems though it did not provide the true understanding. No doubt about that. It was, therefore, a gross error that we chose to ignore for so long and did not realize the mistake till very recently (1970 - 2000) starting with the paper by Edward Lorenz on Chaos as applied to weather prediction systems.

The other line of thinking that held its sway over the minds and the scientific spirit of people was Newtonian mechanics. The concepts were powerful and useful. For the first time in our history we thought that we may not only understand nature more fully but also control and exploit it too. And we did it wonderfully well for the benefit of mankind. It unleashed a scientific temper and enthusiasm to an unprecedented level that was never witnessed before. Science suddenly became accessible to the common man. And it enhanced our understanding of nature greatly and we were held in awe by the beauty, elegance and power of Newtonian concepts followed by Maxwell's famous equations. Even today, engineers can't do without these. Till this day our engineering design calculations begin by the application of Newtonian laws or Maxwell's equations. These were and would continue to be extremely useful tools for us. For the first time, the common man could get a feel of what was going around him and explain the hitherto 'strange phenomena' with exceptional clarity and ease. However, there were some tiny but very significant flaws in our scientific understanding as seen through the lens of Newtonian mechanics. But these were left undiscovered for a pretty long time since Newtonian concepts remained unchallenged till the early part of the 20th century.

And the first of a few scientists and mathematicians who challenged Newtonian concepts was Boltzmann. He came along and boldly forwarded the concept of Entropy and the

Arrow of Time; the natural disorder of dissipative systems behaving non-linearly. But none bothered to listen to him and he found it extremely hard to make others accept his idea. So much so was the social and political disdain for anything so weird that the University of Vienna, a great centre of learning in Europe, ignored to put up a bust of Boltzmann adorning the main entrance of the university though they honored all other great thinkers of the university by putting up their marble busts at the entrance of the university building.

Boltzmann was so depressed that he took his life by hanging himself as if he wanted the Arrow of Time to at least stop for him. It is said that had Boltzmann left for England and cared to live for another five years or so the story could have been quite different as he would have had the opportunity of being honoured in his lifetime as other great scientists of his age. Without doubt, he was the first to challenge the time honoured Newtonian concept of 'time irreversibility'.

But there were others too who looked hard at the 'linearity' issue with a great degree of doubt and rightfully so. They were George Cantor (famous for Cantor Sets and 'Continuum Theory'), Kurt Gödel (who carried forward the work of Cantor and with whom Einstein is said to have enjoyed walking back home every day from Princeton University) and Alan Turing (famous Englishman known for breaking the difficult communication codes of the Germans during the Second World War) who espoused the concept of 'limits to logic' through experiments done on computers. Of course we were so preoccupied and enamored by the concepts of linearity, time irreversibility and the mathematical elegance of 'local linearization' and the beauty and precision of mathematical logic that we turned a deaf ear to people like Cantor, Gödel, Boltzmann and Turing.

As a result Cantor turned insane and died a pauper in a mental asylum, Turing and Boltzmann committed suicide and Gödel starved himself to death. Society refused to believe in Non-linearity and the Arrow of time and the associated unpredictability concepts. Believing in such revolutionary concepts was almost an act of heresy at that point of human history from the political, social, and religious standpoints. Everyone wanted order and stability and expected that good times would roll on. Kingdoms and dynasties were there to stay forever. The rich would remain rich and the poor would be turned away from the gates of their castles. The ideas and concepts also went against the prevailing human concept of God (perhaps not the right concept). Even the great Einstein once remarked that 'God does not play dice'. Societies thought that they could keep acting the way they please without ever bothering about the consequences of their actions (the present environmental degradation is a case in point). And industries thought that their business would just be as predictable as ever and money would keep flowing into their coffers and grow beyond limits.

We were convinced to the bone about linearity. Or rather we deluded ourselves in believing it. After all, it made life simple, orderly and predictable. It was such a comforting thought that we wanted to cling onto it. We all wished that things would remain so. This was indeed a great mistake for which we are now suffering. Things were crying for change. But we did not care to think otherwise. Since our minds believed that all cases of nonlinearity can be reduced to that of a linear system then finding direct root causes for any deviation or undesirable event would appear absolutely logical indeed. The logic would appear something like this: since we know how the system would behave at any point of time (for any linear system) there is no reason as to why we can't find the cause of an erratic behaviour of the system in case a deviation occurred or find out as to why it deviated from its predicted or pre-determined path. To find out the cause we simply have to go back in time to identify the cause by understanding the events that went before the final failure event happened.

This appears logical. But unfortunately this is not possible for three fundamental reasons. The first reason is that The Arrow of Time erases the evidences of the previous events (since irreversible transformations take place) and hence the 'event memory' of the system is completely wiped out. So, we can't find the evidences of the past events by going backwards in time.

The second reason is that for nonlinear systems we simply can't go forward and backward in time as we please. This is because we would not know what would be the behaviour of the system in the future. Nor can we say very precisely about the previous state of the system from which the present state evolved.

The third important reason is that logic has its own limits as proved by Turing. While attempting to go back in time to find root causes, logic is soon overtaken by imagination, fanciful thinking and crude form of reasoning as soon as logic (linear thinking) struggles to establish itself without solid evidences. I have seen this inevitable breakdown of linear logic in innumerable cases where people were trying to establish the root causes for 'events'.

This argument probably clearly brings out the need to start the search for causes at least at a level higher than the 'event level' that primarily caused the event to happen. It means that the minimum level we must start our search for the reasons of nonlinearity and failures should be at least at the 'pattern level'. Higher we go up (factor level and system level) better would be our chances to establish the real reasons for undesirable events taking place in the system.

Hence most of our efforts in establishing direct Root causes of events and developing the skills of linear Root cause analysis are wasted since it can only be applied to a limited number of cases which when considered against the backdrop of the total number of cases we face in our daily life and work turns out to be really insignificant to bring about improvements in system behaviour.

However, it is must be said that there would be some tricky problems or events which might elude a solution by any technique. In such cases, the only alternative that comes to my mind is to redesign the entire system ground up. I find no other way at this moment of time.

Question 5:

What are the limitations, constraints and drawbacks in applying Rapid Innovation?

Answer 5:

The only serious limitation I would say is the knowledge and capability of the people involved in the improvement process. If knowledge and capabilities of the people are poor the chances of success in improving the situation is equally poor. Likewise, if the knowledge and capabilities of the people involved are of a high order then the chances of success are extremely high (the probability would be around 1). So there exists a high degree of correlation between success of the company's growth and the knowledge and capabilities that exist within an organization.

Similarly, the only important constraint in applying Rapid Innovation is management's unwillingness to invest time, energy and resources in developing people. If the management turns a blind eye towards the human development process then applying the concepts and principles of Rapid Innovation would prove disastrous. To me, this appears to be the only constraint.

As of now, I don't see any drawback of applying Rapid Innovation expect for the fact that people at the workplace would be free from the shackles of professional boredom of running routine activities. This is because their one time effort towards improvement (if done right) would give the company on-going benefit. It means that machines and processes would run smoothly without too much human interference. It follows that people would be able to free up their time they were otherwise spending in their daily firefighting rituals and routine tasks in the hope of minimizing risks. They may then use this 'free time' for further self-development to ensure the growth and sustainability of their company.

However, I call this a drawback because I have come across many managers who simply and firmly believe that people should be busy (moving their hands and legs) or at least pretend to be busy and should never waste their time studying and thinking during work hours. To please the bosses people actually invent work which in most cases is utterly unnecessary. In fact, I personally had to face this humiliation not once but thrice in my professional career where I was firmly chided by my 'linear' and 'time invariant' bosses, if I may say so, to keep off from idling not withstanding the fact that my work was going on more smoothly and more productively than ever before after I have instituted the necessary changes.

Such ongoing benefits can only come to enlightened management if the management is whole heartedly willing to create the environment that would truly nurture spontaneity, creativity and deep respect for human knowledge and capability.

I feel that time is not far when this would happen and would become the order of the day for survival, growth and sustainability.

Question 6:

How is the basic concept of reliability applicable to such diverse fields like quality, safety, maintenance, design and even to service offerings? Isn't it a tall order?

Answer 6:

In the most general sense, reliability means 'freedom from failures'. Therefore, the concepts in Rapid Innovation are aimed at obtaining the desired freedom from failures.

But before I get to that point I need to explain the concept of reliability a little more. We design material objects (system) for our well being and we operate and maintain them so that they serve the intended function. But then nature takes over and either forces the system to behave differently than what we intended doing or breaks the system down. Then we again rebuild the system, probably better than what we did earlier and maintain it again so that the system behaves as per the original intent.

So there are three stages: a) Design, b) Operate and maintain and c) Redesign, Operate and Maintain. Reliability is the basic theme that pervades all the three stages of our engagement with systems. How is that? We need to design systems reliably so that the original intent of the design is preserved for a long time and the system does not fail too early or intermittently to disrupt our operations. We need to operate the system reliably so that productivity, quality and safety are ensured. And with our deeper understanding of operating the system for some time we need to redesign parts of the system so that failures can be kept at bay, maintenance of the system becomes easier and less costly and we can get the desired availability and performance from the system as intended. If business objectives demands we may then with this available knowledge completely redesign new systems that are more sustainable, environmentally friendly and inherently safer.

So as you see the concept of reliability is intertwined into every aspect of our material world and its success. And as you might have guessed reliability as a subject encompasses all fields of engineering science and manufacturing management.

But if you look at it from the broadest perspective isn't all that we do as human beings aimed at providing this promised freedom from failures? We buy a product and we don't want it to fail or underperform. We construct roads and we don't want the roads to develop potholes and crumble. We build houses and don't want them to tumble down. We design townships and cities and we want them to be as safe, as habitable and as efficient as possible. We use an internet connection and we want uninterrupted service. And nobody wants to die during their productive years. As human societies we want justice to be delivered efficiently and accurately as possible. These are all different faces of reliability.

So, whether we offer a product or a service it is a 'promise' that we don't want to break. All man made systems are designed to a) protect us from nature b) exploit nature and c) improve our standard of living. And we do this with the basic premise that these would inherently serve the original intent or purpose. That is the 'promise' in everything. Only our designs change according to situations and prevailing needs. But the concept of ‘promise’, i.e. ‘reliability’ continues to remain the central building block of all our honest investments in terms of efforts, time and money. I would say that the concept of reliability stands for delivering social justice as a policy. This is the greatest promise the subject of reliability can offer and deliver.

Therefore, it is not strange to find that the concept of reliability is applicable to seemingly diverse fields like quality, safety, maintenance, design, products, networks and many more. Our fragile human societies are held together by nothing more than the slender threads of ‘promise’ and ‘mutual trust’ or simply by ‘reliability’.

So, we would do ourselves a world of good by keeping these slender threads of reliability from ‘snapping’.

I hope you enjoyed reading about the things that I almost forgot to tell you in the previous chapters.

With this we come to the end of the book for now.

In my next book I hope to write about the application of Rapid Innovation on other systems like organizational systems or social systems. I haven’t quite made up my mind on this. So, the next book has to wait for some time.