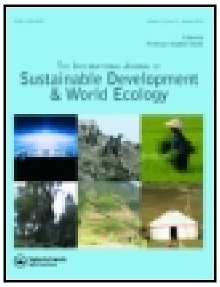

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Chaos and complexity in development

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Key words: Chaos theory, self-organising behaviour, environment, development, India

SUMMARY

The paper outlines some main features of chaos theory. Examples of chaotic systems in society and the environment are given. Spontaneous interaction of components, without being planned or directed, is known as 'self-organising behaviour'. Chaos is an essential aspect of this self organisation, occurring in many forms. A chaotic system is defined as one that shows sensitivity to initial conditions. If the errors relative to the initial conditions become too great, the system will eventually collapse. Development projects are sensitive to such initial conditions. In particular, two examples in development are outlined in some detail and commented upon. One is the occurrence of a project promoting self-organising systems among the poorest of the poor. The other outlines how rehabilitation after resettlement in a power project has transgressed the 'edge of chaos' socio-emotionally, in spite of the socio-economic development being good.

INTRODUCTION AND PROBLEM

Development projects often fail or turn out the wrong way, more so in developing than in developed countries. In order to understand why, one has to consider that they are typically conceived as the result of linear thinking. This thinking has been imposed as a rigid grid on dynamic phenomena or non-linear processes. The same observation is also true of other systems in society. The instability in, for instance, large-scale complex power and irrigation systems becomes evident when applying the thinking of non-linear dynamics and chaos theory.

Chaos theory is the mathematical treatment of non-linear dynamics, and provides a framework for understanding irregular or erratic findings in nature. Chaotic systems are found in the dynamics of human and animal populations, in biological and biophysical systems such as forests and rivers, and in many areas in science and engineering. A chaotic system is defined as one that shows sensitivity to initial conditions. Any uncertainty in the initial state of a given system, no matter how small, will lead to rapidly growing errors in any effort to predict the future behaviour of the system (Gollub and Solomon, 1989).

So far, no applications of chaos theory seem to have been attempted in development work, at least in resettlement and rehabilitation. The present paper is proposed as a venture into the area. It is written primarily in the form of an introduction to chaos theory along with examples and some suggestions, rather than as a formal chaos theoretic treatment of any development phenomenon.

THE EMERGENCE OF CHAOS THEORY AND SOME EXAMPLES OF CHAOTIC SYSTEMS IN SOCIETY AND THE ENVIRONMENT

Although chaos theory was conceived at the end of the nineteenth century, it was not until the

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1960s, with the advent of high-capacity computers that it gained momentum. Initially, the American meteorologist Edward Lorenz, studying weather, found that a simple deterministic model of thermal convection in the atmosphere in fact showed sensitivity to initial conditions. In terms of the new theory, it was a chaotic system. After that, many researchers started to study the progression from order to chaos in various systems. Applications are now found in physics and many other disciplines of science. It has also been found increasingly valid in the neurosciences, in ecology, in economies, and in the social sciences, for instance psychology, crisis theory and management, and so forth. Applications have also become a growing business, in the form of consultancies, services, literature, etc.

However, the term 'chaos' is actually a misnomer. Consider a ball bouncing on an oscillating plate. The bounces look irregular and unpredictable, yet the behaviour is not random in the way that raindrops strike a small area of surface at irregular intervals. The arrival of a raindrop does not allow one to make any prediction of when the next will arrive. By contrast, the bouncing ball can be described by a rather simple set of differential equations that can be solved to predict precisely when the next bounce will occur and how fast the ball will be moving on impact, given the time of the last bounce and the speed of that impact. In other words, the system is precisely determinate, yet to the casual observer it is devoid of regularity. There is a coexistence of irregularity with strict determinism. Systems that are determinate but irregular in this sense are called chaotic. However, this is a technical expression that bears no necessary relation to the word's common usage. Hence, many prefer the expression 'complexity theory' to chaos theory. We will use 'chaos' interchangeably in its conventional as well as in its technical sense, as defined by the context.

The weather is an excellent example of chaotic systems and the difficulties in making accurate predictions. For instance, a depression over the sea may or may not develop into a cyclone. Neither the severity nor the direction can be safely predicted. The October 1999 supercyclone over the east coast of the State of Orissa in eastern India surprised the meteorologists with its unpredicted severity. It was further predicted to hit the northeastern coastline of Orissa, but engineers in the rocket launching base in northeastern Orissa who followed the cyclone saw how it suddenly deviated 3–4° just before landfall, and the coastline was hit much further southwards.

Before outlining some further characteristics of chaotic systems, a few more practical examples may be helpful to the reader. In fact, in a developing country such as India, chaos is experienced in many aspects of everyday life, without people paying enough attention to them. They may complain but do not do anything about it, just as with the weather.

A serious example is deforestation and its widespread negative consequences in many respects: soil destruction, which helps the erosion of rock formations, decreased soil moisture, lowered watertable, drought, increased temperature, absence of wildlife, and ultimately desertification. The unhampered, and in many respects unplanned, growth of cities in the developing world is yet another example. The city administrations are poor, there are land and building mafias everywhere, there is a severe housing shortage, a third of the urban populations lives in slums, half the urban population is without sanitation, 80% of the city hospital patients suffer from air- and waterborne diseases generated by waste, the waste disposal is inadequate or missing, the pollution is high, there is a water scarcity, the crime rate is high, and so on (*Times of India*, Jan. 20, 2000: 11). These are self-organising systems that have transgressed the edge of chaos.

The worst chaos scenario, of course, is the uninhibited and uncontrolled population growth. What caused families in western countries, such as Sweden, to stop having an excessive number of children is well known: improved general education, improved socio-economic conditions, and indefatigable information efforts by dedicated individuals and organisations. To achieve this in India where the agrarian joint family is the motor in population growth will take a long time indeed. Family planning measures have by-and-large failed.

In all these examples, the current outcomes are much more serious than people have assumed, and they are getting worse. In all these cases, small initial errors are multiplied. As very little is being done at an early stage to rectify the problems, they steadily and exponentially grow worse. The outcomes are impossible to predict in detail, although the large-scale picture of consequences is easy to conceive. This is typically the case with some rudimentary efforts of control. The outcomes of these efforts often take a very different course from those intended.

Obviously, none of all these examples are examples of deterministic chaos. It may be allowed to introduce the term 'indeterministic chaos' for systems that will not organise themselves into anything that can be described even as a non-linear system. Let us apply some chaos theoretical principles to an indeterministic chaos system.

In India, traffic is a good example. It is virtually unregulated and the legal enforcement of traffic violations is close to non-existent. Traffic patterns border on anarchy, and cannot be predicted with any degree of certainty. At certain times of the day, the congestion amounts to virtual standstill for long periods of time. Some may say that Indian traffic resembles some kind of disorganised order, and thus has not transgressed the edge of chaos. However, the immense number of accidents, and the number of injured and killed in the traffic tell a different story. Indian traffic has indeed passed over into chaos.

The organised traffic in developed countries follows linear solutions. A well-defined set of rules, road signs and other paraphenalia, as well as a working law-enforcement system create the order. Thus, there is no route to chaos there. Could there be a self-organising traffic system with a specified route to chaos? Well, there was an embryo in India up to the mid-1990s. The overriding unwritten rule, which even the courts followed, was 'big goes first, big pays'. Any big vehicle had the right of way, no matter whether it came from right or left, or from small road to big road, etc. But if anything happened, the owner of the bigger vehicle would have to pay. This worked very well, but after the mid-1990s, the virtually exploding number of new drivers do not know even this simple rule. This rule seems to be part of a route to chaos. Four to five simple rules like that might actually work as a route to chaos and create a selforganising traffic system.

CHARACTERISTICS OF COMPLEX SYSTEMS

It has been observed that complex systems show certain common behaviours. For instance, at the critical point when an ordered system begins to break down into chaos, a consistent sequence of so-called period-doubling transitions would be observed. An example of period doubling follows (Kumar, 1996). Consider a leaking tap, dripping monotonously drip-drip-drip, like a water clock. If the flow rate (the control parameter) is increased beyond a certain threshold, the pattern changes to drip-drip drip-drip drip-drip, with a very short interval between drip and drip, and a slightly longer between drip-drip and drip-drip. The period has doubled. If the control parameter passes another, higher threshold, the period again will double, and so forth. Finally, the dripping pattern becomes aperiodic and infinite, so that an uneven stream runs out of the tap. This is chaos.

Many parameters influence the pattern: the viscosity and density of the liquid, its surface tension, the diameter of the tap, etc., but the period doubling is robust and universal, i.e. valid for all fluids (Kumar, *ibid.*). This was the first route to chaos that was observed and subsequently verified by many investigators. Later, many more routes have been discovered. In fact, an infinite number of routes to chaos can be described. Several of them are 'universal', or broadly applicable. That is, they obey proportionality laws that do not depend on the details of the given system.

The repetitions when the periods are doubled are called iterations. They cannot be expressed in a simple formula, i.e. the information cannot be compressed. In any given situation, the entire course of iterations has to be run through in full. This kind of computation complexity is called algorithmic complexity, and characterises chaos. In the final analysis, the simple can be equated with the periodic, and the complex with the aperiodic.

Chaotic dynamics initially referred to the evolution of a system over time. Chaotic systems also often display a spatial disorder, as in complicated fluid flows, such as whirls. Present-day research is incorporating both spatial and temporal patterns into theories of chaotic dynamics.

One type of mathematics in chaos theory is the use of fractals. When a physical body is symmetric, it can be exactly described with Euclidean geometry. We live in a three-dimensional space which can be expressed in three Cartesian coordinates, say x, y and z. A plane surface is two-dimensional. The line is one-dimensional. Dimensionality can also be used for measuring the contents or capacity of a geometrical object: the cube has a volume, the square has an area, and the line has a length. This is called the metric or capacity dimension. However, frequently there are unconventional geometric objects which are irregular in all length scales and dimensions. Their capacity dimension may be a fraction.

Such an amorphous geometrical object is called a fractal. When the IBM mathematician B. B. Mandelbrot studied complex geometric structures of irregular shapes such as coastlines, the lightning's zigzag paths, clouds, etc., he realised they could be expressed in fractions. He developed the mathematical theory for this, and the term fractal is now used to refer to the theory as much as to the objects. Fractals belong to a class of complex geometric shapes that commonly exhibit the property of self-similarity, the discovery of which led, in turn, to remarkable developments in computer graphics.

Although not all fractals are self-similar, or at least not exactly so, most evince this property. A self-similar object is one whose component parts resemble the whole. This reiteration of irregular details or patterns occurs at progressively smaller scales and can, in the case of purely abstract entities, continue indefinitely, so that each part of each part, when magnified, will look basically like the object as a whole. In effect, a self-similar object remains invariant under changes of scale i.e., it has scaling symmetry. This fractal phenomenon can be readily seen in such objects as snowflakes and tree barks. All natural fractals of this kind, as well as some mathematical self-similar ones, are stochastic, i.e. random: they thus scale in a statistical sense.

Another central concept is that of attractors. In classical mechanics, the behaviour of a dynamic system can be described geometrically as motion on an 'attractor'. The mathematics of classical mechanics effectively recognised three types of attractor: single points (characterising steady states), closed loops (periodic cycles), and tori (combinations of several cycles). In the 1960s, a new class of 'strange attractors' was discovered by the American mathematician, Stephen Smale. On strange attractors, the dynamics is chaotic. Later it was recognised that strange attractors have a detailed structure on all scales of magnification; a direct result of this recognition was the development of the concept of the fractal.

The edge of chaos is jargon, rather than a scientific concept (see below), but it expressively indicates the stage just before a system turns chaotic, and is in fact a useful parable.

TYPES OF SELF-ORGANISING BEHAVIOUR

Researchers have realised that the behaviour of complex systems cannot be explained by analysing the separate components of a given system. Rather, the behaviour seems to arise from the spontaneous interaction of the components, without being planned or directed. Such behaviour is called 'self-organising'. It has now become clear that systems maintained far from equilibrium organise themselves in space and time. Chaos is an essential aspect of this self-organisation beyond certain thresholds.

There are many types of self-organising behaviour. One is adaptation. This is seen everywhere. Corporations adapt to the marketplace, brain cells adapt to external and internal signals, the immune system adapts to infection, and people adapt to changing circumstances. Another type is the way complex systems seem to strike a balance between the need for order and the imperative to change. Complex systems tend to place themselves near the chaotic edge, at a place where there is enough innovation to keep a living system vibrant, and enough stability to keep it from collapsing into anarchy. This is a zone of conflict between the old and the new. If a living system comes too close to the edge, it will pass over into incoherence and dissolution. If the system moves too far from the edge, it becomes rigid and fossilised. Both conditions ultimately lead to extinction.

If the errors relative to the initial conditions become too great, the system will eventually collapse. This collapse may be more or less sudden. It may be slow and take the course of eventual decay, but it will be there. In large systems, there are too many parameters to control. Many development projects are sensitive to initial conditions. Small mistakes in the planning of a project will multiply and become major in the end. For instance, in the case of dams, cost overruns from 500% to 1000% are a rule and make one wonder what other miscalculations are being made by engineers who make that kind of mistake in computation (Paranjpye, 1988, 1990; Singh, 1990).

When an area is submerged, for instance, human social life and culture, forest, agricultural land, wildlife habitats, and innumerable plants and animals of many varieties are deliberately destroyed, as well as the river itself with its biodiversity. The developer then has to try to recreate these things in another area, so-called rehabilitation.

CHAOS IN DEVELOPMENT

'Rehabilitation' is used as a political mantra by people who often do not understand what they are talking about. For instance, the Union Minister for water resources, Mr. C. P. Thakur, addressing a news conference in Delhi in December 1999 (*Times of India*, Dec. 24, 1999: 13) made a strong case for big dams, contrary to trends in the rest of the world where big dams are no longer endorsed (McCully, 1998). Smaller dams, Mr. Thakur said, can only be supplementary in nature. He dismissed as 'misinformation' the well-established risks for salinity, waterlogging, displacement and poor rehabilitation. He also disregarded the fact that the State of Madhya Pradesh wants the Sardar Sarovar dam height reduced, arguing that it does not have the land to rehabilitate everyone to be displaced. He ended his speech by saying, 'we are changing our minds about rehabilitation; we must rehabilitate first'. He did not go into the mystery of how submerged nature can be rehabilitated before the submersion has taken place, or the scarcity of land for environmental rehabilitation and for resettlement. Nor did he present any arguments against the above-mentioned risks or the frequently poor or indefinitely postponed rehabilitation. Truly, with ministers like him, a country does not need any other enemies.

Rehabilitation has not yet met with much success, and the mantra is thus an empty shell, used to relax people's apprehensions. The paramount failure of the rehabilitation of dislocated populations and submerged or clear-felled areas has been discussed in detail elsewhere (Ekstrand and Ray, in progress). Common sense tells us that this must be a well-nigh impossible task. There are too many variables that are difficult or impossible to predict and control. The basic problem is that a watershed is a system of non-linear dynamics, but it is treated by planners and engineers as a linear system. Unfortunately, these planners and engineers cannot do anything else. They are trained to work with linear systems, and are mostly ignorant about dynamic systems. Insofar as they know anything about non-linear dynamics, they certainly do not apply their knowledge. If engineers and planners could be trained in biology and the mathematics of non-linear dynamics up to an advanced level, they might begin to understand what dynamics mean, understand the difficulties of controlling and monitoring a complex system, and come up with different solutions.

Development work is abundant with chaotic collapses; sometimes crises would be a more appropriate word. As mentioned, they do not necessarily occur with a drastic suddenness. The green revolution in India is one example, where many events have combined to make the present situation precarious over the past several decades. Soils are now losing much of their fertility because of salt accumulation as a result of waterlogging, due to over-watering. The food production in India is now at a 20-year low, reports *BBC World* on October 12, 1999. The WorldWatch Institute cautions that India may soon face a food crisis (*Times of India*, Jan. 13, 2000). Chemical fertilisers kill many necessary microbes in the soil. The heavy use of pesticides and herbicides, especially notorious substances such as DDT and numerous other organochlorines, has contributed. Statistics are frightening, but a more telling example follows. In the early 1990s, some organisation in Maharastra became known for selling so-called smokeless chulhas, i.e. stoves. They came in different sizes. They were not really smokeless, but at variance with the traditional Indian chulha which lets out the smoke inside the kitchen, these chulhas were provided with a steel tube that could be led out through the wall or the roof to let out the smoke. These became very popular. They were made from empty DDT containers. Imagine the amount of DDT that had been spread from these containers, which were so many that serial manufacturing could be based on them.

Applying chaos theory to resettlement and rehabilitation, it is clear that resettlement as well as rehabilitation are usually systems of (indeterministic) chaos. Dislocation is a major upheaval of the community. When a community has been uprooted from the traditional habitat and 'resettled' in some other area, the social fabric, much of the culture, habits and traditions, as well as property such as land and housing are all changed. Planners and engineers do not fully understand or empathise with the social implications of disrupting a natural system or a community, but they certainly pay lip service to the need for rehabilitation. In social assessment studies, the initial harmony or happiness of a village community is never assessed, only socio-economic parameters. There is no telling what course the development in the new community will take. Follow-up studies some time after relocation, including some kind of assessment of community harmony, are rarely made, at least by the planners. This is assuming that there is a new community. Land is a scarce commodity everywhere, especially in India. Rather often replacement land cannot be found, for instance in the Narmada development. Sometimes the people from one community are resettled in different areas, i. e. the community is split up. Sometimes they are shuffled in among previous residents. Further, it is not even necessary to physically relocate people for drastic changes, both for better and for worse, to take place. It may be enough that a development project such as a thermal power plant suddenly comes up in an area to change the community profoundly.

'Talcher revisited' (Ray, 1998) is a description of changes following a development project. The changes in the Talcher case are socio-economically apparently positive, but socially highly disruptive. Ever since the 'Evaluation of the Rehabilitation and Resettlement of Talcher STPP' was conducted (Ray, 1992), there has been a continuous and finally total transformation of the entire locality. The Talcher project is short for the Talcher Super Thermal Power Project, Phases I and II. This coal-powered power station is situated on the edge of the widespread Talcher coal fields in the middle of the State of Orissa in eastern India. In 1997, a limited 7-year follow-up study of the 1990–1992 evaluation was done. The Talcher STPP Phase I has now been completed. The Talcher STPP Phase II has been projected and land acquisition has started. This is the story of how the farmers in Kaniha were affected by the project's Phase I.

The findings of the 1992 evaluation showed that a volatile situation had been created, mainly because of a communication gap between the people and the project. The assurances given by the political leaders during the 1990 general election added fuel to the fire. Because of the rehabilitation policy, there occurred a break in the emotional outlook in the family, the household, and the community at large. Already at the outset, the rehabilitation programme was doomed: there were too many managers and a lack of a clear policy. The major cost for rehabilitation was to be borne by the NTPC. The State Government was supposed to implement, organise, and monitor the process. However, the Government had not formulated a clear rehabilitation policy. As Ray (1992) states, p. 108: 'The State Government has always worked out *ad-hoc* programmes depending on the nature of the problems that have cropped up in different projects.' In early 1988, the NTPC had formulated a policy which envisaged rehabilitation by land for land, but it was poorly acted upon. Cash compensation, which is disastrous to the small-scale farmers, was mostly given.

Looking at the changes 7 years later, in the 1998 study, Ray writes (p.15):

> 'Infrastructural facilities in the Talcher project area have been expanded enormously. The roads have been widened and made into all-weather motorways. The infrastructure looks impressive, as well as elegant. There were some apprehensions during the planning of the comprehensive road network that this would make the place look ugly. This is not the case. All villages are easily accessible through standard cars. This was not possible during the period when the pre-project study was carried out. However, in spite of living close to a power station, most people still have no electricity. Some street lighting has come up, but that is all. This is a source of constant irritation among the people.'

Not that lack of electricity among neighbours to a power station is unique for developing countries. The Lapps having their summer camps close to the Ritsem, one of the biggest hydro power stations in Sweden, also lacked electricity as recently as the end of the 1980s, and possibly still do. To continue with the changes in Talcher, Ray (1998) observes that not only roads, but housing, schools, and medical facilities have all improved enormously. The area even looks greener than before. However, regarding the social situation, prospects are not as bright. Ray (*ibid*) writes:

> 'Men, women and children, unfortunately seem to have been thoroughly misguided, mostly because of the mishandling of the rehabilitation work at the initial stage of its implementation. Therefore it is obvious that the communication between the NTPC and the people has collapsed. The Project Management also admits to this. Self-styled leaders are instead utilising the people to attain their personal goals.
>
> This has also alienated the older generation from coming to the forefront of the discussion of the concerns of the people. The older generation has been made invisible and marginalised. It was this group who tried to see positive changes of the Thermal Project, and were talking sensibly about resettlement requirements during our previous study. This generation should now be the spokespeople for the community. Instead, the younger, largely misguided and confused, generation is spearheading the discussion in an unfortunate way.
>
> It is, furthermore, depressing to see that the PAPs in general have become much more dependent on the project authority than before. This is detrimental to their adaptive processes. Self-sustainable methods of survival are gradually disappearing from among the youth which needs close and systematic monitoring before it is too late.'

From the description of the Talcher case, it may be fair to conclude that chaos is a diversified phenomenon which may reflect various aspects of a system. Chaos in communities may be present in some areas of everyday life, but not in others, and the severity may be more or less pronounced. This is certainly also true of other biological systems.

CAN TRANSGRESSING THE EDGE OF CHAOS IN DEVELOPMENT BE AVOIDED?

There seem, in fact, to be several ways of coming to terms with the chaos in development, especially in resettlement and rehabilitation (R&R) which is one primary focus of interest in the work by the present authors. There are some relatively straightforward linear solutions, and there are certain applications of chaos theory.

Given that R&R does not seem to work, in spite of much research and many efforts by governments and donor agencies, we propose that the most important among the linear or conventional solutions is to drastically reduce R&R. This can, in principle, be done in the following manner. The old-fashioned, polluting coal-powered power plants and the obsolete, unsafe nuclear power plants in India and elsewhere, as well as the megalomaniac huge dams, may be replaced with new sources of energy that are coming up. Especially interesting is the particle accelerator-driven nuclear transmutation energy, which not only hardly yields any nuclear waste, but can feed on nuclear weapons material as well as old nuclear waste, solving the major waste-disposal problem in the process. Substituting these for other installations would vastly reduce the need for resettlement and create a much more ecological environment. Developing countries would do well to send their technical scholars for learning to the many research centres for this new energy.

The megadams and huge irrigation canal systems should and could be replaced with various water-harvesting installations, especially rainwater harvesting structures, on a small to medium size scale. Many new, simple technologies have been developed, and these types of water harvesting are gaining popularity all over the world, including developed countries. This would be immensely more cost-effective and ecological than the mega-scale projects. Such solutions are not attractive, however, to politicians because they cannot stand as monuments to a government or a minister, and they will not provide the same opportunities for bribe giving or bribe taking.

The overriding objective for any water development scheme, and any development scheme whatsoever for that matter, must be to prevent and sustain the system from coming too close to the chaotic edge, but at the same time not staying too far from it. In other words, stability combined with an optimal degree of development must be maintained. Most certainly, no system or project can be allowed to transgress the chaotic edge and collapse into chaos, as resettlement and rehabilitation, forest management, the green revolution, and many other schemes have already done. Sometimes the reason for the collapse is the rigidity present especially in government undertakings, keeping the development project too far from the chaotic edge. Avoiding the Scylla of transgressing the chaotic edge and the Charybdis of staying too far from it takes careful planning with new thinking, with the full involvement of the people.

To analyse an example: S. R. Singh (in Swain and Das, 1999), discussing the 'conjunctive use' in planning and management of canal commands, states (p.221): 'It employs the groundwater simulation and mathematical programming techniques for optimal allocation of water resources'. Given the scarcity and overuse of groundwater, and the risks of depletion, instead of groundwater simulation, the simulation of locally suitable rainwater harvesting techniques ought to be employed, and the mathematical programming techniques would have to take the dynamics of the watershed and the community into consideration. The results would then have to be transformed and imparted to the people in digestible form, for them to discuss and decide. Above all, planners and engineers will have to take seriously the dangers and disadvantages which they now play down or pretend not to see. First and foremost, in dynamic contexts, such as development projects, non-linear, dynamic thinking will have to replace conventional linear thinking. This presupposes a new kind of training of engineers with contents focussed on environmental, social and chaos theoretical issues.

In order to avoid the social and psychological discord that often follows materialistic and socio-economic progress, like in the Talcher case, some applications of an upcoming branch of chaos theory might eventually be applied, viz. the theory of emergence. This has recently attracted interest from many scholars in diverse fields. Emergent phenomena are constituted by and generated from underlying phenomena, and at the same time they are autonomous from those underlying phenomena. 'Emergent phenomena are ubiquitous in the systems studied in psychology and in the life sciences, and the language of emergence is commonly used to refer to the behaviour of many recent models in these sciences, especially those models in the so-called sciences of complexity' (Bedau, 1999).

Bird (1999) addressed the same issue. He stated a fundamental question in emergence: how can a new property appear from a combination of elements, none of which in itself has that property? The theory of emergence is still embryonic in spite of the recent interest from scholars. Many key challenges must be addressed before the robust, multiple-levelled, supply adapting, emergent behaviour that is characteristic of living and intelligent systems can be modelled.

It appears to be possible to apply the principles of self-organising processes to the complexity and dynamics of the human system and development processes. It might be possible to regard, for instance, rehabilitation as a complex adaptive system, and let the people themselves take more responsibility for their own development. As is sometimes stated in similar contexts, 'to gain control, you have to lose control'. That is, to attain successful, i.e. controlled rehabilitation, it should be less controlled. Rehabilitation is now predominantly being done as a 'top-down' model, and it may be time to switch to a 'bottom-up' model, as is being done in organisational theory and applications. The notion of control – so predominant in a hierarchical society as India – seems to ignore the counter-productive nature of control. Often the controllee tends to become the controller of the controller and the game of control ensues, as to some extent occurred in the Talcher example. Instead of pursuing such a self-defeating game of control with 'intelligent' controllees, there could be a possible alternative such as 'let it be'.

Interestingly, this has been done before in India, for instance in the principles of Gandhi. It has more recently been done in certain development projects in Orissa and West Bengal, long before the application of chaos theory in life sciences and notions such as self-organisation in social sciences had become commonplace. The Lutheran World Service (LWS, India) had taken up the WHAT projects – the Water-Health-Agriculture Trident in Mayhurbanj in northern Orissa and the Burdwan area in West Bengal, as well as two slum areas in Calcutta (Ekstrand, 1989). These were projects for the 'poorest of the poor'. Apart from improving the people's standard of living, among the goals were cooperation and self-reliance. The LWS staff would only suggest developments, any decision had to be taken by the Village Council or, in Calcutta, the Colony Council. If there was no functioning council, the first thing was to establish or re-establish one.

Any suggestion had to be given time for the villagers to discuss among themselves until they were ready to make a decision. Before LWS could take up any idea, all possibilities must have been tried, and failed (*ibid*, p.59). Only then could LWS go in to provide materials or pay the villagers for their labour, or guarantee bank loans that the villagers would need to take. The poverty spiral poor monsoon – poor harvest – moneylender – debt trap was met via grain banks and savings. Out of 60 kg of rice harvested, 15 kg would stay in the grain bank. The LWS staff provided moral support and was a final resort that gave a feeling of security to the people.

Eventually, when the poor and harassed people felt that they could attain some progress through their own efforts, their confidence would grow and they would come forward to suggest their own schemes, such as a new village road or whatever. They set up non-formal education centres, and it could happen that the women came forward to demand one for women only. In short, the LWS worked as catalysts and advisers. All work was carried out by the villagers themselves. Because of that, the villagers were able to maintain the various installations, such as tube wells, water-harvesting structures, roads, tanks and so on. Maintenance of common property is an old Indian tradition, but it has often collapsed under the stress of poverty. The people were, of course, helped by skilled advisers, such as water experts for the watershed management, and medical staff in the health centres.

Now, this is very similar to a well-run rehabilitation project – if one existed. By letting go of the authoritarian direct top-down control, the system became self-organising. What in most rehabilitation projects become one type of chaos or the other, now developed into stable and sustainable systems. The LWS projects ultimately contained much more than water, health and agriculture. The villagers developed pisciculture, horticulture, kitchen gardening, silviculture, and many other things. Savings in banks and grain banks secured an uncertain future. NFE centres and vocational training centres were set up. In fact, the projects developed into integrated rural development projects, but without the usual flaws in such projects. This means that two similar localities could develop in very different directions. By letting go of control, the LWS projects developed into self-organising systems which were vibrant and flexible, with a minimum of rigidity and friction. Present-day R&R plans are admirable: they take care of every detail. Nevertheless, the diversity in self-organising systems will be more than in any R&R plan, however well-conceived. Certainly this constitutes appearance of new properties from a combination of elements, none of which in itself has that property.

There are certainly other attempts in the same direction, such as the so-called self-help groups (SHG) for small and medium-scale farmers and farm women in India, or participatory rural appraisal (PRA), but neither is very successful so far.

Eventually, much research will have to be done in development in general and resettlement and rehabilitation in particular in order to find suitable non-linear solutions. Finding the parameters of deterministic chaos in projects such as the LWS projects would help in other and larger projects, although in the particular case of LWS it would be an academic exercise only.

Some pertinent research questions which sooner or later will have to be addressed in such research are: what are the chaotic and non-chaotic attractors pivotal to self-organisation in development? How can autonomy and adaptive behaviours be elicited and stimulated in a rehabilitation scenario? How can emergence theory be developed and applied in development situations? How can good attractors be promoted, e. g. co-operative behaviour, and bad attractors be avoided or suppressed, such as mutual exploitation? How can self-organised group formation be studied and promoted? How can errors and mistakes in the initial stages of any system be avoided or minimised so as to prevent the continued development to transgress the edge of chaos? How can routes to chaos in highly complex and dynamic systems of development be identified? Is it possible to develop fractals that can describe such systems? What would be the meaning of iterations in development and how would they be identified and defined?

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