The Newtonian Paradigm

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May 2001

Abstract

This article sets the scene for a study of complex systems. It seeks to explain the paradigm that has dominated Western thinking and scientific method since the eighteenth century, namely the Newtonian Paradigm.

The focus in this article is to explore how a theory of physics came to be adopted as a philosophical underpinning to traditional management processes and explain what how it influences what we view as 'scientific' and 'professional'.

Introduction

Most managers would accept the premise that to change something you have to, at minimum, have a goal, a plan, undertake some activity, review progress and measure outcomes. Indeed much management training is aimed at helping people follow this process in a more systematic manner. Improved information technology allows more sophisticated planning, better management information, more streamlined analytical processes and better data, so we are even more inclined to follow the plan-do-review route which underpins, amongst other things, strategic planning, change management, project management, performance management and business process re-engineering. The not-unreasonable premise is that, if you are clear about what you are trying to do, communicate effectively, organise well and track progress, then you will get where you want to go. Emphasis is often on breaking problems or projects or processes or organisational structures into smaller parts and handling them separately, the assumption, again perfectly reasonable, being that you cannot think about or manage things if they are too big and complex.

This approach clearly seems very 'scientific.' The same approach underpins economics and indeed most scientific method. So, for example, experimental science tends to try and isolate certain variables and examine the relationship between them whilst excluding other possible variations. Generally it is not regarded as either desirable or possible to look at the object of interest as a whole.

What is not always recognised is that the belief that this plan-do-review approach will work is a **paradigm** - that is, a set of self-consistent axioms or premisses that are taken to be self- evidently true. For it to be true, we would have to assume that organisations, market places and economic systems behave like machines and are entirely predictable in their behaviour – and this is not true!

In this article we will explore this mechanical or Newtonian paradigm and investigate why we hold it to be a good approximation to reality.

The premise of scientific management

We base our approach to strategy and management on the following precepts: -

- there is a set of data which is relevant to the issue and, generally, we can identify what this is and measure it

- we can develop techniques to analyse the data and plan a way forward

- the past is causally related to the present and the future so we can develop strategies based on past experience and on an analysis of the market place and we can base plans for changing organisations on an understanding of where we are and where we want to be

- we can divide problems and processes into largely independent parts and handle them separately

In essence, we treat organisations or market places as if they were machines. Providing we understand how the parts inter-relate, we believe we can predict how the machine will work in the future. Any failures in our predictions are put down to insufficient or inaccurate data or to wrong choices of analytical tools or to the cussedness of the people involved who do not always seem to behave like cogs in a wheel. We tend not to consider that the whole basis of our approach is flawed.

This mechanical paradigm owes its birth to Isaac Newton and his laws of motion, developed in the seventeenth century and it is important for us to understand why specific 'laws' of physics, applicable to certain problems of interacting bodies, came to be adopted as ***the*** scientific theory, a theory that still pervades much of scientific method to this day.

Let us explore how Newton's physics came to be developed.

Isaac Newton and his antecedents

The Father of scientific method is usually taken to be Aristotle (384 – 322 BC). He believed that theories must be deduced from analysing relevant data taken from observations and this method was propounded by Newton. The method can be summarised as follows: -

make observation (1)	➔	analyse observations and induce principles which explain the observations (2)	➔	deduce a theory from the principles (3)	➔	check against further observations (4)

He also believed, as did Newton, that there are certain axioms that are indisputable and cannot be proven. For example, the statement that there is no such thing as a vacuum is such an axiom. It is likely to be true but cannot really be established through experiment as it would be impossible to know whether you measurement of zero was a limitation of the measurement system or whether it really existed.

This bottom-up approach to developing theories outlined by the diagram above is to be contrasted with the top-down approach attributable to Plato (428 – 348 BC) and developed, amongst others, by Archimedes (287 – 212 BC) and Descartes (1596 – 1650). Their focus was on developing theories via mathematical principles or thought experiments and, whilst they believed these should accord with reality, they focused on ideal conditions rather than actual ones. For example, they considered what would happen to a weightless, unbending body not acted on by other forces; these things do not occur in the real world but are merely idealisations. Plato and Descartes and Archimedes were not interested in practical experimentation.

The development of Newton's theories combined both a bottom-up and a top-down approach. He developed his laws of motion partly through experimentation and partly through 'thought experiments'. He also based his science on certain axioms. For example, he believed in the concept of absolute time and space. These are not measurable qualities and their existence has to be assumed. Specifically, he believed that God created the universe with the planets in specific places at a point in time and thus time and space could, in principle, be related to this starting point. So, although Newton seems ultra-rational and his theory does indeed relate to observations in certain circumstances, his theory of motion is nevertheless based in part on premises that cannot be proven, specifically the notion of a starting point in time and space. This brings into question its place as a law of universal applicability.

Interestingly, Descartes' philosophy also rested on the existence of God. He believed that, as God created us, we can trust our view of what is clear and evident because God would not let us believe it if it were not true.

The Newtonian Paradigm

Despite some rather questionable axioms, which brings into question there often-assumed universal relevance, Newton's theories of motion were an enormous step forward for physics. They have allowed us to design and build complex mechanical structures, such as bridges. And, within limits, they give correct descriptions of the interaction of mechanical bodies under certain conditions. These conditions are that: -

- the system is closed (i.e., it does not interact with the outside world)
- the forces are linear (i.e., an increase in the size of an input gives a proportional increase in the size of output)
- the system is unchanging

Newton's mechanical systems are entirely deterministic (i.e., a future state can be precisely predicted from a previous state) and it is this determinism that is the most beguiling element of his work and why it caused such an impact on scientific thinking. It suggested that the world is essentially predictable and controllable.

What in some ways is quite amazing is that the scientific method and premises developed by Newton to look at mechanical systems were adopted as a general approach that can be applied to other problems. Newton's approach, for the majority of people even to this day, is what science ***is***.

What seems to have happened in the eighteenth century (the Age of Reason) is that Newton's laws of physics became a paradigm (that is, a self-consistent set of assumptions which form a perspective within which the world is viewed).

We came to believe: -

- that all systems can be treated like independent mechanical systems
- that the future can be predicted accurately from analysing the past
- that relevant data both exists and can be measured and analysed
- that problems can be reduced to largely independent parts (a consequence of assuming linear (proportional) interactions)
- that the constituent parts of a system can be idealised and parts within one class can be regarded as identical (i.e., assume all people in a class will react in the same way to the same stimuli)
- that those qualities of the constituent parts that are more subjective and less tangible can be discounted
- that theories can either be built up from analysing observations or, if developed top down, can be tested against observations. Any such models or theories, once shown to fit, will continue to fit

This, then, is the Newtonian paradigm. It incorporated the best of the preceding philosophy of Aristotle, Plato etc. It revolutionised physics and our sense of our ability to control nature. As a philosophical underpinning it placed reason on the throne and assured us that, if we work hard enough, we will be able to treat organisations and economic systems as machines, develop strategies that work, achieve our plans and, generally, be in control.

So, you may say, what is wrong with that? Of course we would try and analyse data and build plans, models and strategies. Of course we would focus on what is tangible and rational. Of course we would believe that the future can be predicted from the past. What else would we do? Otherwise, you might argue, we would have no control and no predictability and sink into chaos, inefficiency and anarchy.

Our work on complex systems will explain why the Newtonian view is a misleading way of thinking about the complex world we live in, other than for the case of mechanical systems for which it was designed, and will present alternative perspectives which are more applicable. It is important to emphasis that, by giving up on the certainty of the mechanical perspective, we are not suggesting that the only alternative is chaos. Although in real life we have less control, information and certainty than we might like to think, that does not mean that we are relegated to the opposite extreme of no control, no information and complete uncertainty. A more realistic set of assumptions on which to base our decisions is likely, in fact, to lead to better management processes, a more accurate understanding of what is happening and hence better outcomes.

However, it is indisputable that Newton's notion of mechanical systems not only does not apply to most organisational, economic and environmental systems, but it also does not apply to most physical systems either.

First, however, we will try and understand why it was that Newton's physics was so eagerly adopted as a theory of everything in the eighteenth century.

The Age of Reason

It is important to recognise the grip held by the Christian church, at and before the time of Newton, on what was deemed acceptable in philosophical and scientific thought. It was regarded as blasphemy for example that Galileo thought the earth rotated around the sun and not visa versa, as this contradicted the Bible. He was forced to retract his view to the Inquisition and was then kept on house arrest for the remaining few years of his life. Equally, Descartes' works were put on the banned list of the Catholic Church [1, p 14] in 1663, seemingly because, despite giving God the role as the guarantor of truth, he had not treated the Church in the same way!

Newton's theories, leading to the notion of a clockwork universe, allowed God to be separated from the so-called rational laws of physics. We no longer needed God to do other than to set off the universe at time zero; thereafter it functioned (according to Newton) in a rational way. And this notion of the separation of God from day-to-day reality came to be known as Deism. It took away, for example, the option for God to undertake miracles or intervene in any way that contravened the rational laws of nature. The science of Galileo and Newton and the value placed by Descartes on man's (albeit God-given) ability to reason was also an escape from the tyranny of the Church, both Catholic and Protestant, and the fear of the accusation of heresy.

So, the Enlightenment in part allowed the separation of reason from the judgement of the church; it also differentiated reason from emotion. The philosophers of the Age of Reason believed, in contradistinction to animals, that Man has a rational will, which makes it possible to make and carry out plans. Animals, they declared, are slaves of their emotions. When an animal is afraid, it tries to escape; when it is angry, it fights. Man, however, can develop a number of alternative strategies and select the most appropriate; he can also make moral and ethical decisions. In that way, the Age of Reason placed Man in a dominant position above animals (and by inference, all nature) and placed the outputs of rational mind above those of the intuitive mind or the instincts. This notion of a hierarchy of mind above emotions (and also emotions above the body) is first attributed to Aristotle, underpins Judaeo-Christian thought and was presumably influential to Maslow in developing his notion of the hierarchy of needs (ref?). Incidentally, it also is consistent with a patriarchal vision. Woman was regarded as closer to nature than Man and more prone to be driven by the emotions (the word hysteria, for example, is derived from the Greek hyster, the womb). Thus, this precedence of reason over instinct legitimised Man's superior position over Woman and over nature. He was the caretaker, benefactor and patriarch, but also had the right to control, decide what was best and, indeed, exploit.

The results of Newton's theories, more widely applied, thus had enormous social and political consequences:-

- they reduced the power of the Church to decide what was right

- they empowered the Common Man, who can now be valued, not for his status or connection with the Church, but for his intellect.

- they created the sense that the world operated rationally and could be controlled.

- they asserted the dominance of Man over nature and His right to control it.

It is not surprising, then, that the shift from physics to philosophy was so easily made. This is a very important point, one made very eloquently by Chris Clarke in his book, 'Reality Through the Looking Glass'.[3] We like to think that in some sense science is absolute - at least that the concept of an absolute science, which were we to know it, would explain everything, exists. However, what is deemed to be self-evidently true is very much culturally determined. It seems to be the case that all science, like philosophy, must rest on axioms - self-evident truths (such as the notion of a time zero when God created the universe) that cannot be proven or disproved. That these truths are felt to be self-evident is culturally determined.

The implications of the clockwise universe

So, by the time we reach the end of the eighteenth century, we are quite clear that we can approach all problems in a rational way and that most problems we approach have a unique solution and are hence solvable.

These ideas were incredibly empowering. They led to the Agricultural and Industrial Revolutions. The ability to build machines, trains, bridges, to analyse problems in a systematic way, to organise factories, crop rotation and, indeed, military campaigns created enormous steps forward for the Western world and allowed an increasing control over nature (in farming and in mining) and over our fellow Man.

The Newtonian Paradigm underpins Taylor's[4] (1856-1915) system of scientific management. His approach was to decompose tasks on, say, an assembly line, into their constituent parts and then streamline the actions in order to reduce the time and effort needed to undertake them. By so doing he believed that the workers could become more efficient cogs in a more efficient machine.

The machine model underpins economics. It underpins traditional strategic planning, business process reengineering and the thinking behind many change programmes. It justifies our obsession with measurement, facilitated by the explosion in information technology. It justified the 'new' approach, in the UK, to managing the education sector, in 'measuring' the quality of schools, children and teachers. It still largely underpins most scientific method in most sciences and is still widely regarded as self-evidently the 'scientific' and most professional way to tackle most management issues.

Irreversibility and entropy; a different perspective

The Newtonian machine, in the absence of friction or noise, will keep going forever. Laplace generalised this perspective and called it scientific determinism. This states that, through mathematics, it is possible to predict everything that will happen by just knowing the existing conditions at an earlier point in time and projecting those into the future[5]. Not only will the machines keep going forever, but the motion is reversible, ie it is impossible to tell, if you see a film of the system, whether it is going backwards or forwards.

One of the problems with the machine model is that life in all its facets is not reversible. If you put two different gases in a jar, they will mix together; they will not un-mix (although nothing in Newton's laws suggest they would not un-mix); houses fall down, they do not rebuild, we age, we do not get younger!

This irreversible move towards a lower energy state, to decreasing order, is true of all closed systems (ie a system not interacting with the environment). They move towards equilibrium (eg totally mixed gases or totally fallen down houses) and when they reach equilibrium they stay there (which is why the end state is called equilibrium as it is stable).

Sadi Carnot[2] (1796-1832) is attributed with first formulating this 'law' (later developed by Ludwig Boltzmann[6]); the term 'entropy' (which is said to increase as the disorder of the closed system increases) was coined by Clausius in 1865. In essence, as Silver summarises [2,p224]: -

- isolated systems spontaneously move towards more probable states (ie those with higher entropy) and stop changing when they reach an equilibrium state (which is characterised by maximum entropy)
- this spontaneous process, for isolated systems, is irreversible

We thus have the seemingly contradictory paradigms coming from physics; one suggests a deterministic, reversible, smooth running machine which goes on forever; the other suggests an irreversible, but predictable degradation into an equilibrium state. As Peter Allen so eloquently puts it – 'we either have no change (if you apply Newtonian thinking) or death (if you apply the ideas of equilibrium thermodynamics dynamics).

Interestingly, whilst the idea of entropy is in common usage and people intuitively know that time is irreversible, the laws of thermodynamics have not influenced organisational and management theory or scientific method in the same way as the Newtonian paradigm (perhaps because they offer a more pessimistic perspective).

In practice, life is even more complicated than either of these two illuminations on nature. Take evolution. Animals and plants seem to evolve into more and more complex and sophisticated species – they do not sink back into a homogeneous soup). Does this contradict the second law of thermodynamics? Take the life of one organism. To quote Silver[2] , 'living organisms are islands that swallow matter and energy from their surroundings and use them to keep themselves in a state of ordered dynamic equilibrium, a state that collapses and becomes disordered when they die.'

They do this by interacting with their environment. In other words they are not closed but open systems. Ilya Prigogine [6, 7] was largely responsible for initiating the study of such open, dissipative (so called) structures and Peter Allen worked closely with him for several years. It is out of this work that the study of complex systems[7] and their implications has evolved.

Conclusion

We have set out to describe the two most salient concepts of classical physics – the perpetual, predictable machine (the Newtonian paradigm) and the irreversible thermodynamic system, slipping incontrovertibly into stable 'death.' Neither, in fact, is a good metaphor or model for human or economic systems. However, as we have sought to demonstrate, for various historical, philosophical, religious and sociological reasons, the machine model gripped the eighteenth century psyche as a good description of reality and, despite it being challenged in its validity by modern physics (in the form of relativity, quantum physics and non-equilibrium thermodynamics, the work initiated by Prigogine) and by bitter experience (in the failure to predict the future of economic theories, business strategies and plans for organisation change), we still, by and large, stubbornly refuse to give up on it as **the** way to tackle management (and science) in a 'professional' manner.

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