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THE KEY TO SUCCESS IN INNOVATION* PART I: THE ART OF INTERESSEMENT

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We all know of innovations which either made their creators a fortune or which led to their downfall. It is easy to retrospectively explain success as a stroke of genius or failure as a blatant mistake. Easy in retrospect…but what about innovation in the making? How does the innovator navigate the pitfalls which threaten him?

Keywords: Innovation; actor-network theory; socio-technical analysis.

Introduction

The nuts and bolts of the plot are well known. On the one hand is invention i.e. ideas, projects, plans, and yet also prototypes and pilot factories: in a word, all

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that occurs prior to the first uncertain meeting with the user and the judgement which he will pass. On the other hand is innovation in the strict sense of the word i.e. the first successful commercial transaction or more generally, the first positive sanction of the user. Between the two extremes is a fate played out in accordance with a mysterious script. Firms which are either going downhill or thriving, nations which are in decline or becoming hegemonic. A project deemed to be promising by all of the experts which suddenly flops, while another in which everybody lost faith suddenly transforms itself into a commercial success. And always the same questions: how can these unforeseen successes and failures be explained? How to account for these unexpected turnarounds, these resistances which turn into support or these enthusiasms which change into scepticism and then into rejection?

We all recall the brilliant answer given by J. Schumpeter sixty years ago (Schumpeter, 1934; 1939), which adopts the character of the entrepreneur and the passion which drives him to surprise his competitors, to imagine new productive combinations which make those extraordinary profits soon to be whittled away by all sorts of imitators. The entrepreneur is this exceptional being who, in hedging his bets on invention and market, knows how to bring an intuition, a discovery, a project, to the commercial stage. He is the mediator, the sheer translator, who brings together two universes with distinct logics and horizons, two separate worlds, each of which would not know how to survive without the other. If the flow of invention is interrupted, the economy is quickly taken by languor; if the engine of demand is choked, then the inspiration which fuels new projects dries up.

In the Schumpeterian model, the entrepreneur's mission is vital and his task overwhelming. He is the one doing the inspecting, the screening, the selecting, the adapting, the coupling. He is vigilance incarnate in the one and the same person. He gives the economy its dynamism and technology its commercial outlets. The Schumpeterian entrepreneur existed — historians saw him flourish at the beginning of the 20th century, both in Germany and in the U.S.A. — and he still exists — public power has placed him on a drip in technopoles or other science parks. Throughout time and space, it is such men and women who, starting from an idea of their own or that of another, come to reconstruct entire industrial sectors through persistence, ruses, cunning and the ability to anticipate. However, an economy would not be entirely dependent upon the inspiration of a handful of providential men and women. As one of the greatest creations of the beginning of the century, the Schumpeterian entrepreneur was progressively replaced by a mass of varied interventions (Schumpeter, 1943). The short-circuit, which he alone realised, turned into a long interactive chain stretching from the university lab to the marketing departments of companies, via production units, industrial research centres, technical laboratories, planning departments, even public administrations. The bringing together of market and technology, through which both inventions *and* the outlets which transform them into innovations are patiently constructed, is more and more a result of a collective activity and no longer the monopoly of an inspired and dedicated individual. The individual qualities of insight, intuition, sense of anticipation, quick reactions, skilfulness, must all be reinvented and reformulated in the language of the organisation. They are no longer the property of an individual, but become collective virtues, during the emergence of which the art of governing and managing play a key role.

How can the inherent limitations of a single individual's activities be circumvented while retaining the qualities which assured his success? How can he be replaced by a more effective multitude? In other words, how can the work be divided while simultaneously multiplying the capacity for vigilance? The answers to this question, which has been at the heart of numerous works by management experts, can be easily summarised. To be innovative an organisation or a cluster of organisations must favour interaction, permanent comings and goings, all types of negotiation which allow for rapid adaptation (Burns & Stalker, 1961; Peters & Austin, 1985). As illustrated by the emblematic figure of the Schumpeterian entrepreneur whose role it is to conjure up unexpected associations, innovation looks nothing like a linear process consisting of a series of compulsory stages moving, for example, from basic research to development. Taking up the cheerful expression of C. Freeman, who has made himself the faithful spokesperson for all economists of innovation on this point, innovation resembles a coupling process but it is of a particular nature since the two elements brought together — the market and technology — evolve in an unpredictable way (Freeman, 1974). In order to have a reasonably accurate idea of the complexity of the innovation process, imagine a rocket, pointed towards a planet whose long-term trajectory is unknown, taking off from a moving platform whose co-ordinates are only crudely calculated; additionally, imagine a division of tasks whereby some specialise in observing the planet, some in calculating the location of the platform, and others in defining the power of the engines; finally, imagine decision-makers who at all times need to consider the occasionally incompatible information produced by all of the specialists. Under such conditions, one can understand why the key words are "interaction", "de-compartmentalisation", "circulation of information", "cooperation", "adaptation" and "flexibility". This collective actor must be able to react to all fluctuations, it must be in a position to seize all opportunities. Rigid and mechanical models, overly precise task and role definitions, constraining programmes, must all be avoided in order to innovate.

These ordering words — "de-compartmentalisation", "creation of *ad hoc* structures", "adaptation" — which resonate like church anthems, are undoubtedly useful. However, what remains is the thousand ways to interact and to choose whom to interact with. The organic model (Burns & Stalker, 1961), inspired by biological metaphors, is insufficient to guarantee success. It describes an organisational climate, without which the evolutions necessary for the development of new projects become difficult, but it says nothing about the innovation process itself. And yet to progress in the art of managing innovations, we need a better understanding of the mechanisms through which they succeed or fail in order to elaborate some principles which will serve as a guide for action.

To arrive at this perceptive understanding of the mechanisms of success or failure, which is key to surmounting the gap between the participant in the innovation process and those who try hard to understand the process, we must not believe for a moment those edifying stories which retrospectively invoke the absence of demand, technical difficulties or inhibitory costs. These questions are controversial when innovation is in the making. If the electric vehicle is henceforth considered as a project which will be unable to realistically emerge before the end of the twentieth century, it is because one has learnt through many trials and tribulations that the functionality and profitability of the fuel cells depends on catalysts not yet ready to see the light of day, that the thermal automobile could be improved beyond what one initially hoped for and that the environmental protection groups were a flame without a tomorrow. All the elements that made the electric vehicle possible at the beginning of the 70s appear today as explanations for the vehicle's failure! What purpose is there in explaining this resounding fiasco by invoking technical difficulties, market evolution or the project's dubious profitability? All of these are true, banally so, but they are of a truth blindly created by the story. Doctus post factum. Once these rather provisional certainties are painfully obtained, the lesson is learned and the file closed. It is the moment that those who like to give advice choose to descend upon the floundering innovators. Minerva's owl takes off at nightfall: when we become wise, it is already too late. And yet, in midstream, who would have dared to pass final judgement? How can one forget the state of commotion and terror into which a company like Renault had been plunged by the oil crisis, and the future of fuel cells as promised by all reduced to silence over three years? Ten years later, who remembered this indecision, the uncertainties of this cacophony (Callon, 1986)? Certain protagonists, so marked by failure and so divested in the face of the learned discourse of those who come to explain to them why they were mistaken, are now ready to acknowledge the errs of their ways and their responsibility. Worse than the Stalinist trials! Their voice now trembles, whereas fifteen years ago they firmly believed in what they proposed. They have been beaten; moreover, they must now make amends. Such is the dreadful efficiency of these explanations which do not emerge from the discourse of accusation:

make those who dared to carry the blame, make those who have allowed these self-righteous judges to become scholars to retract!

This plea — to restore innovation in the making without intervening in the explanation of those elements which are unknown until the end of the process — leads to challenging every story, every interpretation which censures, evaluates, or even worse, ridicules the stands taken or arguments developed at the moment when decisions are taken. The rule is to reconstruct the perspectives and projects of one and all without taking sides, to avoid using nothing more than a bit of common sense in letting oneself believe that a given protagonist, who makes a mistake "because he is blinded by his interests or that he is ill-advised", would have been able to make a rational decision and identify the right path by himself. In other words, show sufficient tolerance and agnosticism so that the meanings of decisions, taken seriously even by their adversaries at the time they were made, are not described many years later as careless or rash. Or inversely, that a minority opinion fought by the majority is not shown afterwards to have been premonitory.

In opening the way to a theory of innovation which is closer to the actors and their experiences, this methodological demand considerably reduces the volume of useful data and information. While the management of innovation literature fills entire libraries, the case studies which avoid the trap of retrospective explanation still remain scant, even if they are beginning to grow in number. All told, we shall use some remarkable pieces of work by American historians, a limited series of journalist or engineer accounts and the all too rare sociological analyses undertaken on the spot. It is little, but enough to extract some initial lessons. These two articles are dedicated to presenting these lessons with the aim of rendering the mechanisms of failure and success intelligible, and ultimately, more manageable.

A Mish-Mash of all Sorts of Decisions Which Cannot Wait

An innovation in the making reveals a multiplicity of heterogeneous and often confused decisions made by a large number of different and often conflicting groups, decisions which one is unable to decide a priori as to whether they will be crucial or not.

One of the best accounts of the variety and complexity of the decisions which shape the fabric of an innovation is provided by Tracy Kidder in his book *The Soul of a New Machine*, which rapidly became a bestseller in the U.S.A (Kidder, 1982). In our country (France), one could scarcely imagine a journalist choosing to follow the design of a computer, day after day, for almost two years. Yet this is precisely what Kidder attempted to do. He shared the work, the doubts and enthusiasms of a small group of engineers set up in the basements of one of those numerous firms proliferating along Highway 128 which engage in fierce competition. The literary result is remarkable. This book is to high-tech industries what "Au Bonheur des Dames" was to department stores or "Germinal" to the development of the mining industry. Depicting the creation of a new technical object simply and with convincing realism, it constitutes a genuine essay on the management of innovation, illustrating the decisions constantly taken by the engineers participating in the project and the great uncertainties which surround them. Here is a story as tangled up, as illogical and apparently as irrational as any fictional adventure and yet it speaks of a technical object which is apparently the most logical and the most relentless foreseeable.

It all begins with an obscure story of relocation. In order to set up internal competition between two concurrent projects, the management of Data General took the decision to move the research teams to North Carolina (where fiscal law is favourable to enterprises). The first project, which has official support from the managers, is ambitious: a flow of money allows the handpicked engineers installed in the new company premises to work on a new generation of microcomputer. At the same time, a similar but more modest project takes shape under the leadership of West, an entrepreneurial engineer who refused the exile in North Carolina and who managed to convince his hierarchical superior almost by surprise. And, as in fairy tales, it is the team led by West which carries the day. While the official project sinks into the perfectionism and fiscal paradise of North Carolina, the little commando advances in leaps and bounds in the quasi-clandestineness, rapidly making decisions, resurrecting prototypes several times over and two years later a commercialised product appears which sells like hotcakes. One hardly dares to call the management's creating internal competition a "decision", when it would never have existed without the relocation to North Carolina and the subsequent obstinacy of an engineer who snatched the idea of continuing work at Westborough out of the hands of his superiors.

Once the train is placed on the tracks, everything else remains to be done. The decisions grow in number. Shall we maintain compatibility with the range of previous microcomputers? Do we opt for a simple 32-bit or for a mode bit which allows two computers to be combined into one where the first is "a 16-bit nothing-out-of-the-ordinary" and the second, by simply pushing a button, a "32-bit stylish and speedy computer"? Should we put our faith in a new and particularly efficient chip, PAL, whose producer recently announced its promising features and declared — but how can we be so sure that its commercialisation should coincide with the micro's launch on the market? And then we need to quickly recruit engineers — carefully screen the candidates since the project's success or failure rests with each and every one of them, define their degree of autonomy, gauge how much initiative they have to innovate without them flying off in all directions. That is not all. Once the project is launched, technical decisions become more and more pressing: for example, when testing the computer, would it be better to design complex programmes to simulate the project's computer on existing computers, rather than make do with the usual prototypes?

> '"I want to build a simulator Tom"…West said "Go ahead. But I betchya it'll be all over by the time you get it done"' (Kidder, 1982, 146).

This decision, wrung out of an experienced engineer who doubts everything, in contrast to a youth who doubts nothing, will prove to be absolutely decisive, but only in retrospect. The simulator, completed within six weeks against all expectations, will allow precious time to be gained. This time is so capital, since the innovation is a course which, from decision to decision, will lead you to the right market with the right product at the right time. Without this constant pressure which can transform a good decision into the contrary at any time, an innovation becomes an easy journey which risks ending in drama. As in a game of chess where one stops the clock to suddenly interrupt, without warning, those players who become progressively accustomed to taking all of *their* time. The Carolina project hurries along slowly, full of intentions and putting all opportunities to one side, but the time it takes is neither that of its customers, nor of that conceded to it by its competitors and the team managed by West. It lets events pass it by, occupies positions which no longer control anything and ends up leaving the game, disqualified. In order to understand the innovation process, not only must the diversity of decisions to be made and their complexity be reconstructed, but also the time these decisions create and into which they insert themselves, the irreversibility which they create day to day which turns caution into pusillanimity, deep thought into shameful procrastination.

Amongst all of these decisions, those which appear secondary at the moment they are made may later transpire to be as crucial as those thought to be strategic. It is difficult to prioritise them, to ponder over their relative importance, except in retrospect. Even the decision taken very early on to adapt the dimensions of the Eagle (the name given to the project throughout its design) to elevators in the Far East is not insignificant since it contributes to opening up a "size" market! In an innovation project, as more generally in all research activity, these are the details which often end up counting and which cumulatively make the difference between a failure and a success.

The actors which intercede to make decisions are so numerous and so entangled with each other that at the end of the process, nobody no longer knows to whom the paternity of the results should be attributed. The state of despondency which follows the innovation, analogous to the depression which takes over after childbirth, is partly due to this bizarre feeling, to this taste of ash left on the lips by each project which partially escapes its inventors. Did we really want this? Who really wanted it? The engineers themselves are completely surprised by the result. Some of them would like to present it as a coherent result, a logical plan, a chain of rational decisions!

> '"The company didn't ask for this machine", cried Guyer. "We *gave* it to them. We created that design"… Quietly, Rasala said, "West created that design"…There was a whiff of heresy in the air. "What did you say that West created?"' (Kidder, 1982, 238).

Some months later, agreement on the responsibilities will probably be secured and the paternity of the research will have come to a successful conclusion. But in the specific instance when the machine is presented at exhibitions, the engineers find themselves utterly disconcerted in front of it, not knowing how it came to be there. All will soon return to order and will construct, through successive negotiations, official stories such as the one told afterwards to explain the victory of the African Scipio over Hannibal. In the heat of action, there is no architect but several, no decision-maker but a multitude, no single plan but ten or twenty which confront one another. The microcomputer is nothing other than this turbulent story, full of noise and rage, which leaves its own actors thrown into confusion.

We do not need to imagine that this muddle of hastily made decisions, in total ignorance of reason and without really knowing which will end up counting, are the prerogative of state-of-the-art technologies where everything shifts unpredictably. The situation so well described by Kidder can be generalised. In all of the innovations studied by the CSI, whether a coal-dust burner, a fluidised bed or a new process for milk filtration, the decisions — urgent or not, explicit or implicit — follow one another in their diversity and heterogeneity, implicating a multitude of actors with dissimilar competences and projects, and each of them, as insignificant as they may seem at the time, may turn out to be absolutely crucial at the end of the line.

Difficult Decisions to Make

It is one thing to recognise that an innovation progresses by means of decisions, some of which are occasionally implicit; it is another to maintain, as we have started to do, that these decisions are made in the middle of uncertainties amongst which it is practically impossible for a sure case to be guaranteed. Such is the paradox which should never be forgotten. It is precisely when it is a question of science and technique, still considered as paragons of logic, order and rationality, that rational decisions are the most difficult to imagine! Innovation by definition is created by instability, by unpredictability which no method, however refined, will manage to master entirely.

Evanescent costs

Let us take a simple criteria, that of cost or more generally, profitability. However they may follow innovations in the making, all of the observers recognise that the evaluation of costs is often nothing more than an argument advanced by some to impose their own choices. In any case, cost is not enough to explain the progress of a project. Why does the continuous flow method for steel finish by imposing itself to the detriment of traditional production methods of plates and rolling? The answer seems all the more obvious since it is a textbook case: the process innovation leaves the properties of the final product relatively untouched. If the new technology eliminates the previous one, not this because its efficiency is better, because it reduces energy consumption and labour? Yet it is not so simple. As Bela Gold showed in the study he devoted to the diffusion of this major innovation in the U.S.A., the profitability of the continuous flow was only acquired fifteen years after its introduction into the industry (Gold *et al*., 1981)! Contrary to initial assertions of the American engineers who tried hard to promote it, if we use the calculation grids that they themselves proposed, its installation resulted in a continuous increase in costs, not in their reduction. The expected economies from the fixed capital investment were of the order of 25–40%. But such an evaluation assumed the construction of new production capacities away from existing sites. Thus during the entire period of the continuous flow's diffusion, the steel industry is in overproduction and the new technology can only be installed as a complement to existing processes which must be written off at all costs. Maintaining the "old" technology is all the more inevitable in the event of operational incidents, where one cannot afford to leave the molten steel untreated: the option of moving over to the traditional production line is necessary. The new technology, rather than substituting the old one, comes to feed off it. At the same time the economies of space, one of the main advantages of the continuous flow method realised in principle, is relative since it rests on the potential to physically integrate the new technology with the old, that it is a case of organising the movement of plant and materials or redefining the operational stages.

As this example demonstrates, any innovation presupposes an environment which is favourable towards it. If it does not exist, there is not point in talking about attractive costs: productivity and profitability are the results of a persistent action which aims to create a situation in which the new technology or product will be able to create value out of their presumed qualities. On paper, the continuous flow method appears to be more advantageous; in practice, all of the attempted experiments have shown the opposite. Where is the truth? In this favourable future as asserted by a certain few? Or in this present which contradicts all of the predictions? Everyone believes they hold the correct answers to these questions. Paradoxically, in this specific case, the continuous flow method ends up being adopted more and more, despite the long-lasting increase in costs which it entails.

Behold a significant innovation whose principle quality appeared to be the visible reduction of cost in sizeable proportions. On the contrary, closer inspection reveals that all of the decisions taken to promote it had to be taken in spite of the durable increase in costs! The cost advantage can only be, at best, the expensively obtained result of a series of decisions imposed with difficulty and not the immediate cause of these decisions.

The lessons of this empirical study are confirmed by a recent analysis of the automation process in a large French company (Molet *et al.*, 1985). Different country, same habits! Amongst other advantages, should the introduction of a robot not bring about savings in manpower, rationalise tasks and improve productivity? This is the conviction driving the engineers of the methods department when they propose a robot to a production workshop for specially treated steel plates, a robot which is "simply" responsible for transferring the plates from one furnace to another. On paper, the gains to be realised from such a "modernisation" appear to be indisputable: in two years, the cost of the robot will be recovered due to the elimination of two operator positions responsible for transferring the plates. Alas, the actual story is less rosy than predicted. It is the same disastrous scenario repeating itself. All sorts of difficulties appear during the robot's installation: separators which do not want to hold fast, conveyor belts which move too quickly, trucks whose design is ill-adapted, suction pads which do not stick. Right down to the concrete floor which needs to be remade in order to minimise the vibrations, caused by the robot's movement, which damage the plates! And to top it all off, it soon becomes clear that an operator needs to be retained in order to check for defects in plates coming out of the reheating oven. Over the days, it is the design of the workshop in its entirety which has to be reconsidered if they want to provide the robot with a favourable environment. The reduction in manpower hoped for is not realised: not only is one of the two previous posts retained, but the other operator, by virtue of collective labour conventions, is redeployed to another area of the workshop where he finds himself surplus to requirements. It is thus that unforeseen investments increase in order to adapt the workshop to the robot. However, in spite of the cost increase which it causes, the decision to continue the trial is upheld. Finally, only several years after the introduction of the robot can it be considered as indispensable and that the reintroduction of labour would prove to be costly. But throughout the long transition which eventually leads to an automated factory, the decisions will have to be upheld, despite their observable economic irrationality. The homo economicus is at worst a beautiful fable, at best a patiently constructed result. It is the codename given to a successful operation.

A Fluctuating Demand

Fair enough, you may say, admitting that cost evaluation is not so simple, even in the highly favourable case where an innovation comes to bear on the production process without affecting the end product. To show open-mindedness, you may add that no one believes in homo economicus any more. There's no need to complicate matters: if an innovation succeeds, it is because it satisfies a demand, whether of a factory manager, a supermarket customer or an aeroplane manufacturer. The price matters little: follow the market, follow the users and you will win. As we will see, such a suggestion is true, banally so, but of little use. Easier said than done! How to identify the users, how to follow a market when you are setting up an innovation which runs counter to existing markets? By undertaking market research? By listening to the customer? Once again, no single technique can claim to guarantee that a decision is correct.

Market research? Let's take the case of an innovation patiently developed throughout 1960–70: the artificial leather christened "Porvair" by the company which developed it and which then decided to commercialise it. The story of this innovation is told in detail by an English economist and is enlightening (Gibbons & Littler, 1979). Let us go over the uncertainties and technical difficulties. Artificial leather is the unexpected result of wartime corporate research into replacing sequoia used as a separator in the batteries. Chloride Electrical Storage had the idea to develop micro-porous PVC by heating starch with PVC. The starch was removed by dipping the material in an acid bath which left holes in the material when lifted from the dip. In 1959, Porous Plastic was set up to develop and exploit this technology. One thing led to another, and the engineers identified the shoe market. The pessimistic outlook for the leather market created a favourable climate for projects developing artificial leather, offering the same quality of comfort (the porous polymers help the feet to breathe) and the same mechanical properties as natural leather. After some technical research difficulties, the factory and material came together on the date chosen by Porvair: the beginning of 1971.

In order to make this decision, rife with implications, the management of Porvair took every imaginable precaution. This is because it was a risky undertaking: according to all of the available studies, the profitability of artificial leather depended on the construction of powerful automated factories. Without the large demand necessary to realise economies of scale, production costs would remain too high. Natural leather had to be quickly replaced in order for Porvair to have a chance to durably establish itself. The watchword is simple: flood the market and maintain one's position. The market research shows that such an aggressive strategy is not unfeasible: consumers, particularly women who constitute the principal commercial target, are unaware of the nature of the material itself. It does not really seem to matter whether the leather is natural or not. The key variables for the consumer are shown to be price, the comfort of the material and of course, the latest fashion trends. Porvair is ready to satisfy all of these demands: the simplicity of its shaping and moulding, easier than that of natural leather, makes it adaptable to all fashions and there is nothing to worry about with regards to comfort.

Only the question of price remains to be settled. The strategy fixed upon by marketing is simple and convincing: seize the moment when the price of natural leather peaks in order to vigorously attack it and flood the market. Once in place, and thanks to the economies of scale achieved through automation and mass production, Porvair will be unmoveable. The marketing people get down to work. They recite the lessons they learned in business school: the innovation mustn't come too early or too late but at the right time. It is a question of Kairos, as the ancient Greeks who knew all about the management of time said. The economists look into the leather market and discover interesting regularities. Leather is nothing more than a by-product of meat production: it is cheap when large numbers of cattle are slaughtered. And yet the cycle of these slaughters is regular: it is a six-year period. This means that every six years, the volume of hide launched onto the market reaches a maximum while the price of leather reaches a minimum. But that's not all. The demand for leather is itself cyclical, since the actual purchases of shoe manufacturers fluctuate in a regular manner, reaching a maximum every four and a half years. The conclusion speaks for itself. Porvair must be launched at the moment where the price of natural leather reaches its minimum and its demand reaches a maximum. It is at this exact instant where prices peak that the adversary is most vulnerable. This conjunction, as fortunate as the total eclipse which saves Tintin in the Temple of Sun, produces itself at regular intervals. All of the forecasts come together: the great offensive must be launched in 1972, the blitzkrieg which will complete the defeat of natural leather.

The battle plan is followed to the letter and the predictions hold true: in the space of a year the price of leather doubles as predicted, providing Porvair with a meteoric breakthrough. However, the trend very quickly turns around as an unfortunate coincidence occurs in 1974; the price of petrol dramatically increases. An implacable determinism is set in motion: the hike in the price of petrol leads, via the chemical industry, to an increase in the price of livestock feed, which in turn provokes a mass slaughter of cattle. Suddenly and to general surprise, leather moves from being expensive to being cheap. Despite all of the efforts of Porvair's marketing department, the shoe manufacturers who had to be supported in their difficult technical conversion reverted to the material of old: the graft did not have time to take hold. And as misfortunes do not come in ones, it is the exact moment when the fashion industry decided to cut away at the shoe, reducing the amount of foot enclosed in it, thus allowing the foot to breathe easily, irrespective of the quality of material used! By the same token, the advantage of artificial leather over the low quality and cheap nonporous polymers disappeared. Despite these reversals in trend, the company continued to scrutinise movement in the market and invest for at least a further four to five years in the hope of another chance. Four years later, the factory which cost millions to build shut its doors. Despite the market research and the predictions achieved with an unusual luxury of detail and precaution, the company finally fails to impose its product. It is outflanked by two adversaries as powerful as they are unforeseen: fashion and the petrol market.

What do consumers actually want? How do they choose their shoes? As we can see from this example, the answer to these questions is incredibly complex. It depends on the strategy and habits of the shoe manufacturers, on the policy of OPEC, on the decisions made by South American breeders, on the fluctuations of undulating fashion, on the cost of nonporous polymers…How can all of these elements be simultaneously held together in order to ensure customer cooperation, that is, to make their behaviour predictable? All of the market research in the world is powerless in untangling such an imbroglio. In order to provide plausible predictions, it must be confronted with trends which are so incontestable that in reality, not a single genuine innovation is possible.

Therein lies the paradox. To innovate is to change the consumer. But once the rules of the game are overturned, the cards redistributed, nothing is really capable of predicting the evolution: the change may suddenly bifurcate and benefit the competitor which one believed to hold in one's hand. And such reversals can even be seen in the simple case of a substituting innovation where all precautions had been taken!

Customers of a variable geometry

Fair enough, you may say, in principle this is true, but indecision in practice is rarely so grand. While you know your customers well and that they are of a limited number, one way to secure the innovation is to have a good relationship with them in order to discuss the problems which they encounter, their projects and their expectations. Who would dare to deny the wisdom of such precepts? In reality it is difficult to follow them, as the case of the company studied by the CSI which sought to develop a new type of coal-dust burner proves. After numerous hesitations, a manufacturing licence was granted to an SME which seemed to catch the interest of the market. Once the prototype was perfected, this SME took responsibility for its production, installation and follow-up. Difficulties rapidly appeared: the users whined about the poor performance of the burners, breakdowns which occurred unexpectedly. As for the installer, he took care not to cast doubt on the burner, preferring to blame the coal, the user and the coal grinder. The engineers who developed the burner are only half-convinced: should they believe the licensee who, for financial reasons, may well be trying to be taken over by the group which made the burner? If this information is true, isn't the licensee keen to exonerate the burner designers in order to pass the blame onto the users themselves for what already appears to be a failure? Who is to be believed? Who is telling the truth? The intermediary, like market research, has no reason to be trustworthy. Innovation more often resembles a liar's game rather than a game of truth.

The customer is obviously a key protagonist, but a "direct" contact is not enough to settle all of the problems. Who is the best representative: the maintenance department who expresses reservations when faced with a new material which will upset its way of doing things? The finance department which holds the purse strings? The production engineers who hesitate rushing into an upheaval of production techniques? The buyers who are not prepared to limit themselves to one particular type of coal and become completely dependent upon certain suppliers? The customer? When we appeal to him, we believe we have a hold on a concrete entity whereas it is really a case of the strongest abstraction there is! He is multiple, evanescent. He has many points of view and lets go of you at the very moment you thought you had a hold on him. In the place of a single representative or a single spokesperson, you are confronted by numerous mediators who pretend to tell you what it is the customers want. If the customer were clearly identifiable, predictable, loyal and if he always knew what it was he really wanted, then innovation would be great fun. For its own development, innovation needs this space of uncertainty, these unexpected movements which make markets that once seemed durable fade away and which trigger beneficial reorganisations. The customer is king, but of an empire whose boundaries are poorly defined and whose laws are vague. It is an enigmatic entity. This is why market research or contact with users occasionally resembles a necessary but desperate hunt. The double agents are everywhere and difficult to unmask. Innovation resembles John le Carre novels more than those of Agatha Christie's!

Technological controversies

What holds true for the market equally holds true for technology. At the start of the 1970s, how do we know that the electric vehicle, a major innovation if ever there was one, is technologically viable? In retrospect it is relatively easy to answer this question and to assert that the electrochemical generators were far from attaining the required level of performance. But to answer the question when the electric vehicle is in the making is a different ball game altogether (Callon, 1986)! Several large industrial groups and a plethora of renowned scientists fought with each other tooth and nail to impose their own points of view. The commercial future of the project depends not only on the consumers' attitude but equally and above all on the possibility of realising cheap but high-performing generators. If the question is simple — do cheap catalysts for fuel batteries exist — the answer is less so. The experts, each as accredited as the next, are irremediably divided. Some consider the perfection of the new catalysts is close at hand; the others conversely believe that a lengthy detour via solid physics is unavoidable and that no end-result is guaranteed. Once again, the question is the same, nagging away at us: whom to believe in? This renowned faculty professor? Or this still inexperienced researcher whom everyone predicts to have a brilliant future? It is necessary to make a decision without being sure of whether the right choice has been made. The meetings and colloquiums grow in number and the accounts given reveal an atmosphere which resembles more a political meeting than that of the reasonable discussion which scientists like to believe in! Like the customers, but even noisier, the experts are divided and the innovator has to cut to the quick. He finds himself plunged into an infernal cacophony, full of shouts and litigants coming from all sides: he is saturated with contradictory information, assailed by the most extreme projects and predictions. It is in the middle of this turmoil, shaken about, intoxicated with all sorts of advice, that he must make his way.

Put back into its environment, analysed in the making, innovation leaves to be exposed all of the uncertainties which surround it and above all, the impossibility of relying on indisputable criteria or procedures to make the innumerable decisions which further it. For all that, must we conclude that the nature of these decisions is completely unpredictable and arbitrary? In other words, must we abandon explaining why certain decisions move innovation closer to success rather than failure?

The Art of Interessement

Faced with an innovation like the continuous flow method, the "classical" analyst proceeds directly to the inventory of its advantages and disadvantages: raw materials spent, increase in productivity and improving product quality. These are its intrinsic qualities which then serve to explain the more or less top speed of the innovation's diffusion. Like an infectious phenomenon, this persuades more and more users. Hence those well-known logistical curves which illustrate the propagation of innovations (Mansfield, 1961).

Despite their popularity, such models only have a distant link with reality. The adoption of an innovation, whether that of Porvair, the continuous flow method or the installation of a robot, goes through a series of decisions which depend on the particular context within which the innovation is to be inserted. The evaluation of the disadvantages and advantages of an innovation is entirely in the hands of the users: it depends on their expectations, their interests, on the problems which they raise.

Let us take the case of photovoltaic kits, developed by French industrialists for the developing world market, whose development and first installations were followed by one of us (Akrich, 1992). Their starting hypothesis is simple and convincing: in the bush — more specifically, they are targeting Africa — the need for individual household lighting seems to be rampant. In the evening, children can be seen learning their lessons at the feet of all-too-rare streetlamps and families gathering around a television set at dusk, not to watch the programmes but to take advantage of the light emitted by it. The testimonies supporting this are numerous. Once this fundamental need is identified, only the most appropriate technical solution remains to be chosen. The decentralised photovoltaic lighting seems to be one of the best solutions for the future: low installation cost compared to that of traditional electrification, renewable energy, robustness and portability. The industrialists, faced with the demand of a French administration financing a pre-diffusion project, do not hesitate for long. In their laboratories in mainland France, they concoct a simple and reliable usage mechanism. They then expedite the prototypes to the test sites retained by the project's promoters. In reality, the trial procedure aims to assess the "technical" feasibility of the kits rather than to verify whether they are well adapted to the supposed needs of the users. The industrialists are not ready to question the design of the kit: if it is proved to work in its current format, then the user can take it or leave it. The engineers do nothing more than apply the beautiful but misleading fifty-year old maxim from the 1933 Universal Exhibition held in Chicago: "Science discovers, industry applies and man follows". The problem is that, whether he is in the Zambezi or France, man may not necessarily follow! The installation sites for the first kits were chosen in light of local political pressures. Some of the kits, sent to various medical clinics, end up in a private house; others are installed in an infirmary, others yet in schools. Their landing points are unpredictable. At the end of some complicated negotiations, one of them is installed in a mosque. It is difficult to deny that this strange device arouses interests and covetousness. They fight over it, they kidnap it, they divert it but in order to make it into something other than what was intended. The strange fate of technical objects makes constant reinterpretations, such as those of holy texts which, exegesis after exegesis, end up completely changing meaning. But whatever the intended uses, the trial turns to disaster everywhere. These are not so much technical breakdowns as the progressive disinterest of the users who obstruct the kits.

Faced with these unforeseen difficulties, the French engineers became embroiled in trials of accusation. The kit possesses some unquestionable technical properties. If the users do not want them, that is their fault: they do not have any infrastructure at their disposal, they lack the necessary skills, they reject new technologies as a matter of principle. The engineers have the impression of having covered almost all of the ground by themselves: they chose Africa, with its abundant and cheap sun; they refused the installation of expensive networks; they supplied a compact device, ready for use. Despite all of this and the short-lived phase of initial infatuation, the kits are not taken up by anybody. They rust under the attentive gaze of the engineers especially sent out, month after month, to check the technical performance of the photovoltaic panels.

These engineers, like numerous innovation analysts, have adopted what we call the model of diffusion. By virtue of its own qualities the product, launched on the market or more generally offered to users, ends up spreading throughout society via its demonstration. Either resistances concede or else the innovation is before its time and the users, accused of being mixed up in their prejudices, cost the innovator dearly! Failure, like success, rests on the mutual adaptation of a well defined product and a clearly identified public. Symmetry in the model of diffusion is incomplete. It is unable to challenge technology and the choices which it gives rise to. As for the adapting of users and intermediaries, it is either through force or for the sake of peace and quiet.

Such a conceptualisation, commonplace among engineers, is of little use when they must make decisions to give a blocked innovation another chance or to define the properties of an innovation to come. To understand success or failure, i.e., diffusion and its adventures, the idea that an object is only taken up if it manages to interest more and more actors must be accepted. To consider that the socio-economic context was known once and for all, as if it were possible to define the product outside of all interaction with it, is contrary to all that we know about innovation. Innovation is perpetually in search of allies. It must integrate itself into a network of actors who take it up, support it, diffuse it. And this depends very much on the technical choices made. Let us return to the photovoltaic kit and submit it to what we will call the *socio-technical analysis*. The kit's characteristics are thus transformed into as many properties as necessary to allow it to attach itself to, or conversely detach itself from, a whole series of social groups which will decide on its future.

A quick examination reveals that there is no kit but in name. Everything is rigidly fixed, nothing can be tampered with. First element of the kit: photoelectric cells. They primarily interest the specialist institutes who will follow the kit's performance on site and familiarise themselves with the photovoltaic technology. A significant ally, since it is often linked to the local public administration whose weight is important in the initial decisions about diffusion, it is this very photovoltaic panel which will ensure financial support from a large French governmental agency whose mission is to promote the renewable energies industry. On the other hand, the users and African industrialists are only partially concerned by this choice. Other elements in the kit: the battery-regulator and the wire which links it to the solar panel. The choices made by the French designers lead everything to scatter strategic allies. The length of the wire is fixed and so the users are unable to adapt the kits to their own particular conditions for use: on several occasions the wire will prove to be too short for the panel to be installed on the roof and in every case, it seems out of the question to build an enclosure to protect the photovoltaic cells from free-roaming livestock. Additionally, any makeshift repairs or alterations are impossible since the various connections are not standard. The battery-regulator forms a hermetically sealed protection from external intervention: if a breakdown unexpectedly occurs, the only solution is to send the kit back to the manufacturer who is thousands of kilometres away. Let us continue our socio-technical radiography: the battery produces a continuous current which fuels a 13 watt fluorescent tube. This series of choices once again cuts off the object from potential allies i.e. the local electricians specialised in alternating current as well as the retailers who have never distributed such types of fluorescent tube. How can the kits diffuse themselves? Nobody is prepared to adapt them. They prematurely discourage those weighty allies who would have been able to snatch them up.

In this example we see the solidarity established between the technical choices which give shape to the device and its socio-technical destiny. The kits undoubtedly interest the French industrialists, a handful of African researchers and a government agency; as friends sharing the same cause, they alienate themselves from all of those on site who should have supported the kit (users, artisans, distributors). Conversely, the latter distrust it. The kit presents itself to them as a war machine explicitly launched against them: its designers are obsessed with avoiding at all costs the possibility of the user tinkering with the kit or that a repairman should intervene, since they have so little faith in either that only a catastrophe is imaginable.

If we have chosen to present this case, it is because it is particularly simple. But all of the technologies which we at the CSI have studied can be analysed in the same way. Their characteristics correspond to technical decisions which contribute to defining the social groups concerned, setting some up as allies, others as adversaries or sceptics. A technical device distributes the forces which will support or resist it. It is in this sense that it can be analysed as an interessement device. The model of diffusion supposes an irremediable separation between an innovation and its socio-economic environment. On the other hand, the model of interessement emphasises the existence of a bundle of links which unite the object to all of those which handle it. The model of diffusion moves the technical object to the interior of a society which constitutes a more or less receptive environment. The model of interessement sets out all of the actors who seize the object or turn away from it and it highlights the points of articulation between the object and the more or less organised interests which it gives rise to. The result of such a description is a socio-technical diagram which combines two categories which we are prone to separating: the technological analysis which limits itself to a description of the object *per se* and its intrinsic properties; the sociological analysis of the object i.e. the environments within which it spreads and effects. If we want to distinguish between these two lines of analysis, we refrain from understanding the reasons behind the failure or success of an innovation.

As for the socio-technical analysis, it positions itself at the exact place where innovation is situated, in this hard-to-grasp middle-ground where technology and the social environment which adopts it simultaneously shape each other.

Since the outcome of a project depends on the alliances which it allows for and the interests which it mobilises, no criteria, no algorithm, can ensure success a priori. Rather than speak of the rationality of decisions, we need to speak of the aggregation of interests which decisions are capable or incapable of producing. Innovation is the art of interesting an increasing number of allies who will make you stronger and stronger.

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