

A Personal Memoir: From Terawatts to Witches My Life with Logistics at IIASA

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In 1974, when I first used logistic substitution models, a subset of Volterra-Lotka equations of competition, I certainly did not imagine my level of involvement in this stuff for the following 15 years. The first move came out of desperation. Prof. Häfele had given me the task of finding a conceptual guideline in the maze of energy markets. A model is the key word, but diagonalizing what had been done in the world in energy modeling, I snubbed the task. So much effort with zero success was practically a guarantee of failure for me. On top of that, I was then planning to stay at IIASA for only a few months.

The common feature of the models I had seen was that they were based on economic thinking. As an old-time physicist I always had the tendency to tease my economist friends for their supreme ability to construct beautifully structured models that will never be used in practice, and will never be spattered with the mud of this low world. So I kept thinking about where to look for a solution.

Before coming to IIASA I was a consultant to General Electric in New York, and systematically received their research reports. In this configuration I became a friend of J. Fisher, a very sympathetic and articulate person, then working at GE as an unlucky forecaster. So I cross diagonalized the report on "A Simple Substitution Model of Technological Change" he had written with Pry in 1970.¹ I saw it then (in 1971) basically as a tool for marketing. But I was impressed by the fact that the model was sloshing joyfully in the mud. Both Fisher and Pry were originally educated as physicists and were applying the basic rules of our trade.

So, I said, why not try that? After all, primary energies substituting each other might behave like the products (paints) or the processes (Bessemer steel) of the Fisher and Pry report. Another reason for going to this model is that it does not require prices, an inextricable bramble-bush if one goes into history and geography. A further advantage is that their transform permits the instant identification of logistics when working graphically, which I still prefer, in order to have a holistic view of the processes.

The next thing was to test the idea, and I chose American statistics because they tend to be credible and had the longest time series. I could not believe my eyes, but *it worked*. Even with the multiple competition situation Fisher and Pry had shunned in their

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¹See this Journal, vol. 3 (1971-72), pp. 75-88.

papers. True, the transition from winner to loser was not logistic, but I instantly found a strings and wax solution, in the best spirit of experimental physics, that nicely solved the situation (and still does). I felt elated because I knew from experience that such a quality of match between model and facts has no chance to happen if the model is not *the real one*.

I made a few other experiments to be prepared for the obvious questions and went triumphantly to Häfele to show my results. He got the idea at once—he is the fourth physicist in the story—and looked at me with very suspicious admiration. The solution seemed at hand, but IIASA's director, then Prof. Raiffa, was an economist. Very intelligent, open, cultivated, human, but still an economist. So Wolf had to make the appropriate political moves to let me work in peace.

At first the work was done in the folds of the then abundant budget and never surfaced in the IIASA programs. Second, he gave me an assistant, Nebojša Nakićenović, a clever young man and an *economist*, who could cover the operation with a veil of respectability (and prevent me from going wild). Third, he got a contract from the Volkswagen Foundation, a frill in times of fat cows, as a cover for a carpet bombing in the area of energy systems without directly involving the respectability of IIASA. As double insurance, the contract covered three different researches, with Nebojša and I getting the smallest slice of the cake.

Who went wild, in fact, was Nebojša, working like mad for more than one year for that contract, bagging almost 300 cases of energy substitutions by looking at countries and customers. I have seen him tired since, but that was the unshakable building block of our survival. The efficiency of the model was astonishing. It appeared as a *total quality* machine that always works well and never breaks down. It must be clear that survival does not mean legitimacy. On the other side, it was an immense consolation to observe that penetration of margarine in the United States, as Fisher and Pry did show, took about 40 years, just as the penetration of the general theory of relativity in physicists' heads.

As Nebojša, young and strong, was pulling the cart of stones, I indulged in my *Seitensprünge* and philosophical meditations. Prof. Häfele also has a philosophical bent, tainted of theology with a voluntaristic twist. Mine, on the contrary, operates from the bottom up, where chaos is the *causa incausata, motor immobilis*, and Darwin is the prophet. Discussions were learned, passionate, and inconclusive. It was obvious that the analysis with logistic substitution reveal: *ominance of the mechanisms over the actors*, and Wolf could never digest the idea of him not being the decisional branch of God and the actuator of their own providence.

The problem is serious, and I have the suspicion that this type of analysis, which popped up at various times during the last 100 years and led to particularly penetrating observations on the working of social systems around 50 years ago, never did grow roots because of a subliminal perception that it would be blasphemous to current ideologies. I say "current" because the polemics about the dominance of the script over the actors has gone on for at least 2,000 years, with dominance switching erratically to one side or the other like the earth's magnetic field. (We are now in the plus state for actors.) The situation in a historical perspective is so muddled that the Catholic Church, in spite of the obvious importance of the problem, in its infinite wisdom never took a clear position about it. Nor did the Protestants by the way.

My *Seitensprünge* activity kept hammering the nail deeper and deeper, and I started hearing the consoling whispers that it is now so deep that it can only have been there forever, like Merlin's Excalibur locked deep into its stone. The first jump into abstraction was the analysis of the evolution of the efficiency of processes where energy is transformed. Here the biological metaphor is very stimulating because we have a roof, a niche, the second law for maximum efficiency, and a sequence of configurations, e.g.,

the steam engines, which try to climb the ladder to the roof. Taking actual efficiency as the measure of progress is very logical in physical terms, but it may miss the sociological side of the process. As the experiments were cheap, I tried. *It works!* The historical evolution of the efficiency of the "most efficient machine on the market" is logistic.

The logistics of Fisher and Pry could be interpreted as the result of a mechanism of *epidemic diffusion of cultural-action tabloids through interactive clans à la Hägerstrand*. But here there is nothing that seems to diffuse. As a result of the extraordinary long time constant of the process for steam engines, about 300 years, diffusion of knowledge about current engines should be seen as instantaneous. I did muse at the time that this is the result of a stochastic search with filters, which sounds good but explains nothing and makes me feel like an economist. Actually, the stochasticity should give a certain chance to highly efficient designs to pop up since the beginning, which is not the case.

Saying it is a learning process does not help much either. It is true that learning a language, where an "external" structure diffuses into a brain, precisely follows a logistic. But here the structures are constructed from the inside. I did not yet find a satisfactory interpretation for the form of the progress, but if I had to reduce it to a diffusion process, I would look at the *number of people diffusing in and out of R&D* in the area. The rate of research may hold the key. Analyzing in fact the number of papers published in a certain area defined by a set of key words, I found that systematically they cumulate to a logistic.

Coming back to efficiency, the same results are obtained when other processes are analyzed or when we analyze the deployment of a technology in terms of the aggregate machinery in operation, although here we have to be careful about the influence of Kondratiev cycles.

In 1979 I was invited to produce a paper for a conference on innovation. It was the keynote and had to be innovative. So I worked hard and produced my "Learning Society,"² which I consider a seminal turning point for increasing confusion. Here basic inventions and innovations, as selected and grouped in waves by Mensch, were organized by logistics. In other words, the cumulative number of inventions or innovations in a wave was plotted by fitting it with a logistic. *It works*. Not only that, but the analysis reveals subtle regularities in the structure of the waves in the sequence, which permits calculating (forecasting!) the next one or, worse still, the next ones.

The dilemma emerged instantly. Innovations appeared to behave like cars where you have a maker and a consumer. But each innovation is a different object, and there is no explicit market for them as a bunch. As I said in my paper, I did suppose heuristically they were products like cars but filling a more abstract market. This is obviously verbal manicuring. Still worse, they are objects emerging from parallel processes of R&D, and the shortening of the time constants from wave to wave can be seen only as a focusing of these processes into narrower time windows. Where the coordinating feedbacks come from is certainly a mystery to me. The bottom of the barrel is reached with the inventions, which appear not only coordinated into logistic bunches, but the bunches are precisely spaced in time. The holy cow of creativity, absolutely free, if with a touch of stochasticity, was exhaling its very soul.

The physical intuition of Wolf was delighted, his theological intuition in dismay, his political intuition in red alarm. He was assembling at that time his magnum opus, *De energia mundi*, and had to protect the good name of the project. The work on energy modeling, the one that does not work, was strongly intensified. I suppose to generate a smoke curtain, and I had to withdraw deeper into the folds of the system. Unfortunately,

²See this Journal, vol. 18 (1980), p. 267.

just at that time I got an honorary degree in science from Glasgow's Technical University and for weeks brooded over the opportunity to tell the story. A low profile was vital. About the opus, the crisp results of Nebojša had to be put in—with a compromise. For what concerns the past, they could be presented just as curve fitting—a chart like any other, only with different ordinates. The superb quality of the fitting and the implicit consequences on the dominance of the script were never mentioned. The smoke curtain models were used to construct the futures—a few of them to be precise, the fashionable scenarios. Ten years later, time washed away the fashionable frills, and Nebojša's cart of stones seems to be the only thing left, if castrated of its forecasts.

Wolf has a knack for protecting his men and keeping them well provided. In spite of the philosophical skirmish and occasional bruises, my work was free and the atmosphere stimulating. When he left I had some problems, as no project leader wanted me to inturbidate his waters. So I wandered here and there working on the local problems until my results generated centrifugal forces and I had to hop away. During that period I worked on the diffusion of an innovation after it has been planted as a single point in the innovation wave curve.

Cars were the first victims, as the association of car manufacturers provides splendid historical statistics of production and running stocks. The analysis did show a curious convergence of saturation dates for the most different markets, an observation that was linked to Kondratiev cycles. The center points of innovation waves had already shown a spacing of about 55 years. Stewart of Nutevco had also produced a very interesting chart showing that the deviations from the secular growth curves of energy and electricity consumption of the United States could be reasonably fitted with a sinusoid having a period of 55 years.

Previous data series, showing a certain reluctance to logistic fitting, fall perfectly into place when we cut the time series around the end of Kondratiev cycles. Typical is the case of the growth of cars in the United States. Not knowing the trick, logistic plotters in the past were led to loss of confidence in the descriptive power of the model. Another feature that often comes toward the saturation of a logistic in a niche is the appearance of strong noise with the saturation level actually looking as a mean and the actual data switching around it.

My study on cars had some interesting spinoffs. As I was a consultant to Fiat, I showed it to them. At that time (1981) they were lulling themselves in the hope that the car boom up to 1970 would revive after the oil shock. The saturation idea was making the prospect dim. I suggested they fire 100,000 people to bring the system back to proportions. I was fired first. As a revenge I did analyze Fiat itself, fitting annual car productions with logistics. *It did work*, and this opened another area of research, where organizations in general and companies in particular are analyzed (and forecast) in their growth and decay process.

However I *do not* have the slightest idea why it should be so. The only paradigm that comes from biology is that of an organism (e.g., a sunflower plant) that has a final height written into its genetic program and grows according to a regulatory mechanism where the rate is proportional to actual size (reasonable hypothesis) by the difference to the final size (unproven hypothesis). It should also be explained how it happens that organizations have imprinted a final size since their beginning or thereabout. I have the feeling that diffusion processes cannot explain it. And the fitting works very well, from Teutonic organizations like Mercedes to gaseous structures like the Red Brigades, monitored through their yearly level of killing. Apart from the interpretations, this type of analysis opens up a golden opportunity for a quantitative taxonomy of the economic, political, and social system. We have looked into a hundred cases up to now.

Having lost the self-restraint that comes from an acceptable theory, like the diffusion

theory, in a sense delimiting the field of applicability of the model, I picked up the habit of looking with greed at any time series that comes under my eyes. So when I asked for some material from Lotka, to see what he had done apart from attaching his name to the famous equations, I got a book with his publications list at the end. So I asked myself if perhaps Lotka's equations would fit Lotka's work. *They did*. It is not clear what diffuses into what, but now I have a collection of about 200 artists, scientists, economists, and writers whose lifetime production is crisply fitted. Again a boom for taxonomists and a punch in the eye to the idea of unlimited freedom of the human spirit.

This taxonomy has been very useful in a study I did on Nobel prizes, at the personal, collective, and national (Europe vs. United States) levels, showing again very precise patterns behind an apparently stochastic sequence of events. Incidentally, looking at my collection of cases, I discovered that usually these people die when their work totals about 95% of the saturation point, the built-in life budget of creativity. It is true that I have a couple of exceptions in my list, but for a living artist or scientists a robust forecast on forthcoming publications and death is possible. Prying into others' lives may not be very ethical, but I am doing it for scientific purposes and I must say it works.

Because I have some friends in the police system, I was asked to help to solve a case and, thinking criminals are different but not really, I applied the same concept to them. *It works*. This has dire consequences on the philosophy of the judicial system, because the analysis shows that if a criminal is put in jail, it does not change his "program." Once out, he will intensify his activity to catch up for the time "lost." This means that the beautiful judicial construction operating at great expense to society does not seem to reduce the number of crimes and inflicts punishment on people who apparently cannot avoid doing what they are doing. The subject being of universal character, IASA's interest might seem natural. However, influential people in the judicial system, when presented with my results, jumped as though they were sitting on a basket of rattlesnakes. Perhaps in the spirit of the free market, we should find support from criminal organizations. The purpose of the research would certainly be a humanitarian one.

The car case was an obvious stimulus to look into transportation and the internal dynamics of machines and infrastructures. Logistic analysis reveals an intricate clockwork operating as usual with strong homeostatics, which permits, as usual, robust forecasting. I think we were the first to show why engineers, industrialists, and operators in the air transport business behave as they do and to reduce the necessary ingredients for success to simple formulas. Incidentally, not only fleets and passenger kilometers grow logistically, but also engine power and productivity of the airplanes. Infrastructures also grow logistically, just like the famous sunflower, without any evident relation to diffusion (but perhaps to the buildup of organizations). Grübler wrote his doctoral thesis on the subject, and incidentally did show with numerous examples the basic formal identity (with different parameters) in the behavior of capitalistic and centrally planned economies. The *homo economicus* seems to have a universal connotation. A hint in that direction had already come in a paper by Pry in 1973, where penetration of BOF steel making had been analyzed for the Soviet Union.

A contract from the Italian CNR on the Messina Bridge and its potential impact on transportation led me to look deeper into the micro mechanisms of traffic generation, in particular the effects of geographical barriers and their removal. The use of logistics applied to the time dynamics of case histories again revealed the fine clockwork inside the large clockwork, providing *for the first time* a solid empirical basis for planning. If I say for the first time, it is because during this study I scanned a huge pile of literature in which it was evident that people tried to masquerade their opinions and good sense

under economic theories on traffic and made unrealistic models out of that. As a counter proof, the success or failure of bridges and tunnels seem to be usually disconnected from the rationale of their construction. Because transport economists are always involved, the minimum one can deduce is that their tools are inadequate.

In 1988, I went into neat sociology by studying the case of the interaction between society, innovation, legislation, and the press. That was demanded in a contract with the European Commission in Brussels. I tried to solve the tangle with my subjacent idea that people behave according to cultural tabloids, which become implanted through epidemiological diffusion. The situation looks almost obvious if we talk of straw hats. But legislation on ecological matters is almost perfectly logistic from 1940 to date, for each of the community nations, the Commission itself, and international treaties. The center point of the wave is for all in the mid-1980s, and if legislation is a good indicator of the moods of the system, the Greens will soon feel the pinch. Incidentally, the cumulative number of papers on climatic effects on CO₂ shows the same date for the center point. Perhaps the sense of expansion on the subject comes from the press, whose impulse follows the scientific one.

Also, television and press interest on a certain subject (here nuclear plants) follows a logistic long-term (10 to 20 years time constant) development measuring *cumulative* numbers of TV stories or articles or space in the papers. Interest in the various channels of information—TV, dailies, and periodical literature, including specialized literature—is remarkably synchronous, indicating perhaps they respond to a logistic flow and ebb of public interest of which, by internal feedback, they represent a measure. If an outstanding fact appears, like Three Mile Island or Chernobyl, a short-term spike (three to four weeks time constant) is inserted without any change of the underlying secular trend. It is treated as a different kind of object. The good results are not due to aggregation. A single journal like *Der Spiegel* can be treated exactly the same way, as can the letters written by "Captain Swing," which were synchronous with the destruction of farm machinery, basically threshers, at the beginning of last century in England.

The wave leading to start the construction of reactors, or their linking to the grid, is logistic. What is extraordinary, however, is that the cumulative number of important nuclear accidents in the United States (AECL list!) is also logistic. This would seem to rot the line or misfortune of their free will! The problem becomes philosophically less acute if we observe that the public attention logistic measured through the media runs parallel to the accidents logistic, preceding it by three years. Perhaps the *breath* of public attention *on the neck* of reactor operators made them nervous and accident prone.

All explorations into social processes did show the same result with astonishing quality of the fitting. It could be the wave of construction of Gothic cathedrals or the adoption of postage stamps by different states. Taking the stimulus from an exposition on the history of witchcraft here in Austria, I also analyzed the time series of their persecution. *It works*. It works at any level of abstraction. Under our analytical knife, the "System" appears to have a *fractal structure*. As civilizations tend to interpret the external world by projecting into it internal images, this conception had been around forever. As Hermes Trismegistos—condensing the wisdom of Egyptian alchemy—says in *Tabula Smaragdina: Et quod est superius est sicut id quod est inferius ad penetranda miracula rei unius*. The only thing we really seem to need is a good theory—more general than what the diffusion theory can provide.