# TREND IMPACT ANALYSIS

By

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## ACKNOWLEDGMENTS

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## I HISTORY OF THE METHOD

Trend Impact Analysis (TIA) was developed in the late 1970s to answer a particularly difficult and important question in futures research. Quantitative methods based on historical data are used to produce forecasts by extrapolating such data into the future, but such methods ignore the effects of unprecedented future events.

This criticism is appropriate of essentially all quantitative methods that are built solely on historical data—from time-series techniques to econometrics. Quantitative methods assume that forces at work in the past will continue to work in the future and future events that can change past relationships or deflect the trends will not occur or have no appreciable effect. Methods that ignore future possibilities result in surprise-free projections and, therefore, are unlikely in most cases.

As explained in this paper, TIA is a simple approach to forecasting in which a time series is modified to take into account perceptions about how future events may change extrapolations that would otherwise be surprise-free. In generating a TIA, the set of future events that could cause surprise-free trends to change in the future must be specified. When TIA is used, a data base is created of key potential events, their probabilities, and their impacts.

The TIA method is used frequently. At least one commercial information service, Health Care Futures, produces forecasts of pharmaceutical markets using this method. In addition, TIA forecasts were used by the Federal Aviation Administration, Federal Bureau of Investigation, Joint Chiefs of Staff, National Science Foundation, Department of Energy, Department of Transportation, the State of California, and other U.S. agencies.

## II DESCRIPTION OF THE METHOD

TIA is a forecasting method that permits extrapolations of historical trends to be modified in view of expectations about future events. This method permits an analyst, interested in tracking a particular trend, to include and systematically examine the effects of possible future events that are believed important. The events can span widely to include technological, political, social, economic, and value-oriented changes. Consider, for example, a manager interested in tracking the price of raw material delivered from an overseas source. An extrapolation of available historical data could certainly be used for a forecast, but the manager might feel that too many contingencies make an extrapolation of past trends unrealistic. TIA is a method analyzing the consequences of future developments on this future trend.

## III HOW TO DO IT

Two principal steps are necessary:

(1) A curve is fitted to historical data to calculate the future trend, given no unprecedented future events; and

(2) Expert judgments are used to identify a set of future events that, if they were to occur, could cause deviations from the extrapolation of historical data. For each such event, experts judge the probability of occurrence as a function of time and its expected impact, should the event occur, on the future trend. An event with high impact is expected to swing the trend relatively far, in a positive or negative direction, from its un-impacted course.

These concepts are illustrated in Figure 1.

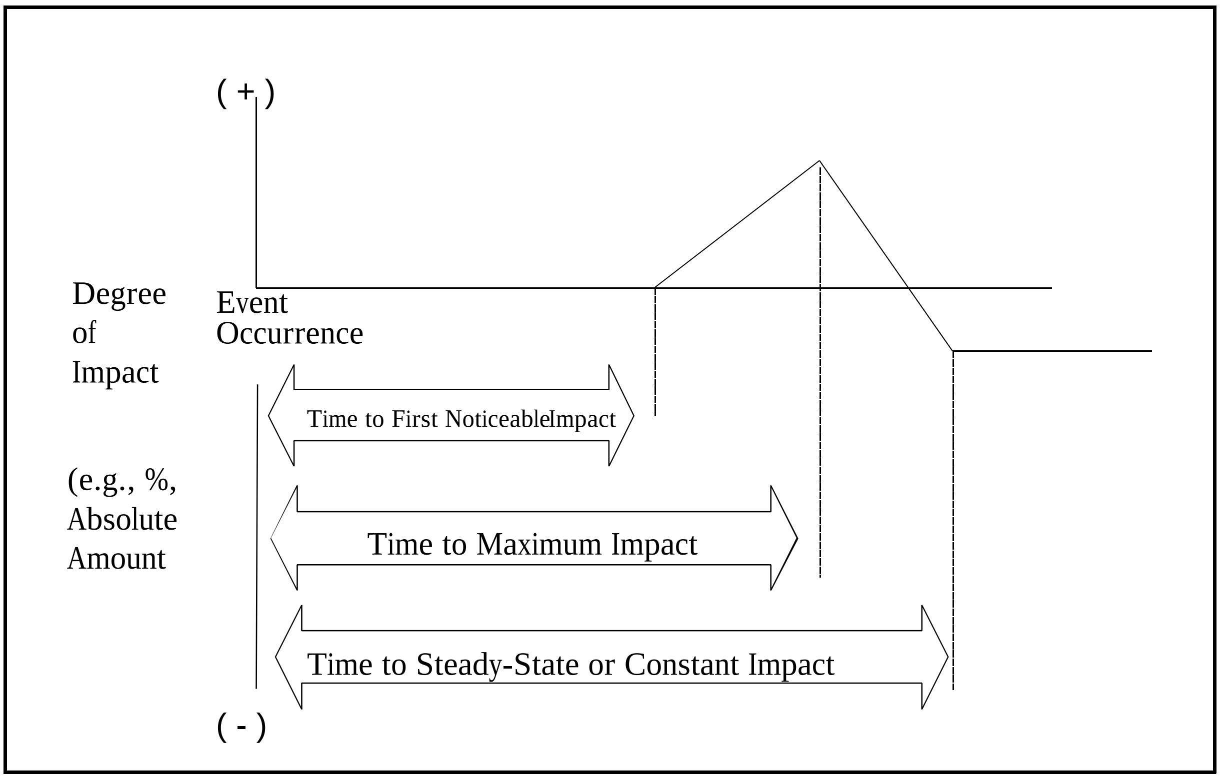



***Figure 1. Typical Event Impact Parameters***

TIA provides a systematic means for combining surprise-free extrapolations with judgments about the probabilities and impacts of selected future events. As an example, Figure 2 shows annual historical data for chlorine demand in the United States and a surprise-free extrapolation of the historical curve. Important, but unprecedented, future events could affect this trend. One such event might be the enactment of federal legislation limiting the use of all fluorocarbons. Such a change might be expected to swing the curve downward. In this case, a surprise-free extrapolation would overestimate future sales, and an impacted curve would be a better forecast.

Surprise-free extrapolation is the first step. Most curve-fitting routines first specify the general shape of a curve to fit a set of historical data; next, a curve-fitting algorithm is used to select a specific curve that falls as closely as possible to the given data. The algorithm then extrapolates the curve to generate the surprise-free forecast. Selection of the proper general curve shape can be difficult. Two different curve shapes, for example, can each fit the historical data well and yet produce markedly different extrapolations. In effect, selecting the curve shape predetermines the surprise-free forecast. In practice, a number of different types of curves are used to fit historical data, ranging from straight lines, to complex s-shaped curves.

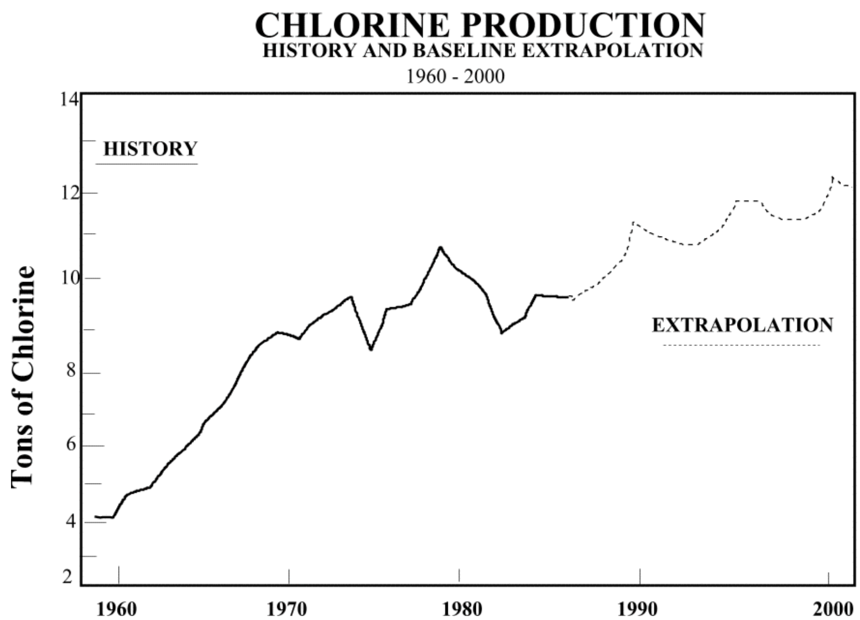



Fig. 2 Chlorine Production

Judgment and imagination are crucial to the second step of TIA. At this point, the program modifies the surprise-free extrapolation to take into account important unprecedented future events. First, a list of such potential events is prepared. These events should be plausible, potentially powerful in impact, and verifiable in retrospect. The source of this list of events typically might be a literature search, a Delphi study, or an informal consensus among consultants. The events selected comprise an inventory of potential forces that could lead to a departure from a surprise-free future.

Several judgments are made about each selected event. First, estimates are made of the probability of occurrence of each event as a function of time. Second, the impact of each event on the trend under study is estimated. Impacts can be specified in several ways; one procedure involves specification of (see Figure 1) time from occurrence of the impacting event until:

1. the trend begins to be affected;
2. the impact on the trend is largest; or
3. the impact reaches a final or steady-state level.

Or, the magnitude of:

1. the largest impact; or
2. the steady-state impact.

Each of the three specified times and the two magnitudes of impact associated with them are taken as completely independent. For example, the maximum impact might be positive and the steady-state impact negative, or the steady-state impact might be zero and the impact only temporary. Finally, the maximum impact might be the same as the steady-state impact. Of course, the impact shape could be stated in other terms, but the five used here have proven applicable to most situations.

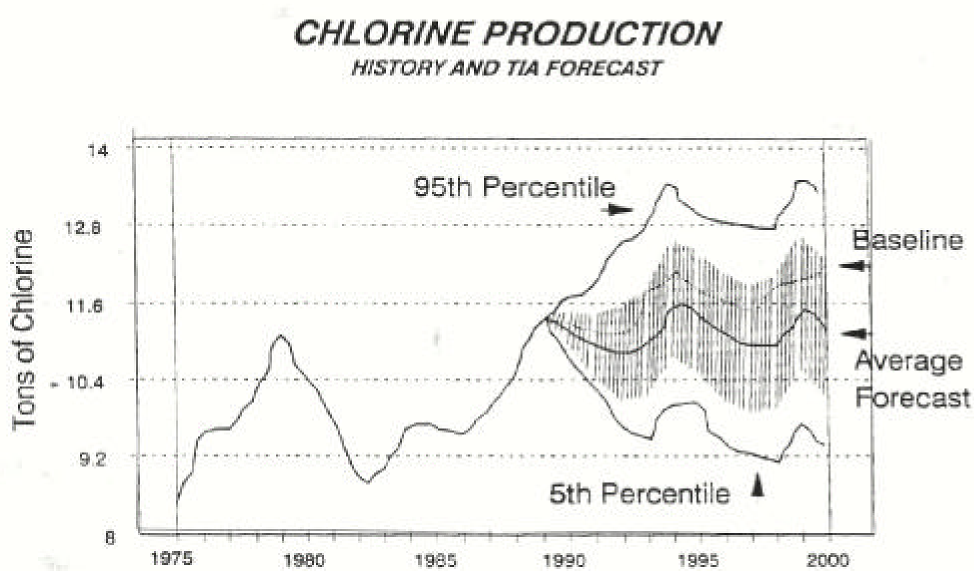
The TIA computer program combines the impact and event-probability judgments with results of the surprise-free extrapolation to produce an adjusted extrapolation. This analysis typically includes estimates of upper and lower quartile limits or limits at some other probability levels. The expected value of the combined impacts is computed by summing the products of the probabilities of impacting events for each year in which they were possible with the magnitude of their expected impacts, taking into account the specified impact lags. The simplest approach treats the events as though they were independent of one another. When the events are coupled—that is, if the occurrence of one were likely to influence the probability of another—cross-impact approaches become part of the solution.

The variance of the impact-adjusted forecast is taken to be the sum of the variance of the trend extrapolation (as measured by the square of the standard error of estimate) and the variances of the impacts of the associated events (calculated from the probabilities of the events).

Two procedures can be used to estimate the upper and lower quartiles of the adjusted time-series forecast. In an early approach, the first four moments of the expected impact distribution were calculated, and the Pearson function was found whose moments most closely approximated the moments obtained. The quartiles were then calculated from tabulated values of the selected Pearson function. In a more advanced mode, the quartiles are estimated from the mean positive deviation from the expected value and the mean negative deviation, each computed separately.

An illustration of a TIA analysis is shown in Figure 3. The projection of U.S. chlorine demand in Figure 2 has been modified by the set of events listed in Figure 4. Shown in Figure 4 are the values of the probabilities and the expected maximum impact of each event. The choice of events and their probabilities are based on judgments. Where possible, the impacts may be derived analytically; however, in most cases, they will be based on judgment, as is true of those shown in Figure 4. Comparison of the baseline to the average or most likely TIA outcome shows how the events have combined to decrease the future demand for chlorine.

Figure 3. Chlorine Production




TIA is well suited for policy evaluation. Imagine, for example, that a manager wishes to modify the course of a specific time-series indicator. S/he can test his contemplated approach by changing the probabilities and impacts that it would affect. By accomplishing two runs, one with the policy and one without, the effect of the policy on the indicator can be clearly demonstrated.

Analysts can also use TIA to rank-order which events will have the greatest impact on future sales. Since the impacts are expressed in the form of a time series, rank order is more complex than simply finding the product of probabilities and impacts; sometimes results are surprising. By knowing which events are most important, managers can focus on tracking a select few important events in the most efficient manner.

One of the most powerful uses of TIA enables managers to calculate the probability that current strategic targets will be met over the coming years. If the probability is low, new strategic plans can be formulated to overcome shortfalls.

TIA is a forecasting tool of considerable power, yet relatively simple and easy to use. This method enhances the usefulness and accuracy of approaches to trend extrapolation.

| Event No. | Event Description | Probab by 1990 | Probab by 1995 | Probab by 2000 | Years to First Impact | Years to Maximum Impact | Maxim Impact % |
|---|---|---|---|---|---|---|---|
| 1 | Pulp and paper industry turns away from chlorine bleaching | 10% | 30% | 70% | 1 | 3 | -10% |
| 2 | Cutback in the use of chlorofluorocarbons (CFCs) | 90% | 95% | 99% | 2 | 5 | -5% |
| 3 | Health concerns lead to limited use of chlorosolvents | 15% | 30% | 70% | 0 | 1 | -10% |
| 4 | Construction market for PVC expands rapidly | 20% | 40% | 40% | 1 | 2 | 15% |
| 5 | Superconductor development allows small membrane plants at point of use | 1% | 10% | 60% | 3 | 7 | -10% |

***Figure 4: Events Used in TIA Analysis.***

## IV STRENGTHS AND WEAKNESSES OF THE METHOD

One of the most important strengths of the TIA method is gained from requiring the analyst to specify what events will make a difference in the future. Instead of merely saying, "Here's where I think the variable will go in the future," when using TIA, the analyst can add, "and these are the events I've taken into account." At this point, critics of the analyst's forecast can argue about the events included and their impacts. In other words, the discussion has moved to a more detailed level, focused on the factors important to the course of the variable.

In a way, the events and judgments about them constitute a scenario. In fact, TIA is used to add quantification to a scenario. When TIA is used in a scenario, the method helps ensure internal consistency. For example, assume that several TIA forecasts are made within one scenario. If a particular event effects more than one time series, it always appears with the same probability. When several scenarios are involved, the probability associated with an event can be scenario dependent.

When a series of TIAs are accomplished as part of a forecasting study, those events that "swing" important variables are possible, to identify through sensitivity analysis. Based on this knowledge, a scanning system can be established to search for developments that presage changes in the probabilities or impacts of critical events.

Finally, since TIA provides a range rather than a single-point forecast, uncertainty can be considered explicitly in decision analysis. Thus, TIA matches risk-analysis techniques well.

The method has received several criticisms. First, the list of events is almost certainly incomplete. Second, even if the list of events were complete, what about the accuracy of the probabilities and impact judgments? Such lists of events are simply expectations about the future that may or may not be correct. At the very least, they express assumptions about the future that are otherwise unstated.

## V FRONTIERS OF THE METHOD

The TIA method is designed to modify simple extrapolation. An extrapolation, as considered here, is based on a best fit to one of several linear equations. One can imagine extending the number of curves used in making the fit or the nature of the fit algorithm itself.

The general concept of including perceptions about the future in otherwise deterministic forecasting methods has great potential. Researchers have used the concept, for example, in conjunction with systems dynamics to produce a "probabilistic systems dynamics" method (see

Stover, 1975) in which external events that "occur" during a Monte Carlo[1] run can affect:

- probabilities of other events (cross impact);
- the structure system; or
- table functions that express the magnitude of feedback within the system.

In addition, the concept might be used in other simulations and gaming techniques.

## VI SAMPLES OF APPLICATIONS

The example presented here is from a study performed by The Futures Group for the State of California. The forecast deals with transportation in the state; the variable under study was petroleum consumption in transportation (in trillions of BTUs). The object of forecasting this particular variable was to assess the outlook for petroleum consumption and the likely effectiveness of several policies under study.

## APPENDIX

Amara, Roy, "Views on Futures Research Methodology," *Futures,* Institute for the Future, Menlo Park, CA, July/Aug. 1991. Describes the evolution from techniques that promise to describe the future to less precise and rigid techniques.

Coates, Joseph and Jarratt, Jennifer, "The Future: Trends into the Twenty First Century," *The Annals of the American Academy of Political and Social Sciences,* July 1992. This issue contains not only substantive articles about future developments, but a chapter on methods: Gordon, Theodore, J.,

6 "Monte Carlo" is the name of a technique that includes random chance in the forecast by including random sampling. It is often used in operations research in the analysis of problems that cannot be modeled in closed form. In a Monte Carlo simulation, the values of independent variables are selected randomly and the equations in which these variables appear are run to achieve a single result. The process is repeated many times, perhaps thousands with the aid of a computer, each time with a new random selection of the values of the independent variables. This process produces a range of results of the dependent variables.

"The Methods of Futures Research," including Delphi, time series analysis, probabilistic techniques, and notably, Trend Impact Analysis.

Godet, Michel, "Future Studies: A Tool-Box for Problem Solving," Paris, UNESCO, Bureau of Studies and Programming, 1991. Godet describes key futures forecasting methods, including scenarios, scanning, morphological analysis, cross impact, Delphi, relevance trees, etc.

Porter, Alan L., Thomas Roper, Thomas Mason, Frederick Rossini, and Jerry Banks, *Forecasting and Management of Technology*, Wiley, 1991. Book includes a description of technological forecasting methods, such as monitoring, scanning, trend extrapolation, S-shaped curves, Delphi, cross impact, systems dynamics, scenarios, etc. Extensive bibliography and a TOOLKIT floppy disc.

Stover, John, "The Use of Probabilistic System Dynamics an Analysis of National Development Policies: A Study of the Economic Growth and Income Distribution in Uruguay," *Proceedings of the 1975 Summer Computer Conference*, San Francisco, CA, 1975.

*The Caribbean Basin to the Year 2000: Demographic, Economic and Resource Use Trends*, The Futures Group, Westview Press, 1984