

ahead, prediction times on that order could reduce discretionary costs, including secondary impacts on transportation, by tens of percent. A week's prediction could provide similar cost reductions for local restaurants and entertainment. Summing these effects, the total impact could be on the order of the 14% shown. (The slight reduction from the benefit from aviation is intended to indicate that the reductions are less likely to dominate this sector, not to imply 10% precision in the estimates.)

Natural Disasters cost about \$120 B in 1998 and averaged about half that over the past decade. Much of this damage and loss of life could have been avoided, had accurate predictions of the extent of winter storms, the landing points of hurricanes, and the boundary conditions for fires been available. While some loss is unavoidable, the availability of enough time for preparation or evacuation could have avoided much of the loss of property and most of the loss of life. The 13% shown is a conservative figure based on the limited data due to the generally inadequate warning-time available through the present.

Construction is a major sector of the economy. While some components such as office or industrial construction is largely insensitive to weather, other parts such as residential and commercial construction is carried out primarily in good weather. The impact of unforeseen adverse weather on them is three-fold: the direct financial cost to the builder due to the delays, the lost wages to the workers, and the delay of occupancy by the buyer. Each is significant. For example, if a three month project was interrupted for two weeks by unforeseen adverse weather, the builder's construction cost would increase $\sim 2/12$ weeks $\sim 17\%$; the workers would lose $\sim 20\%$ of their wages, and the buyer would have to pay a similar amount for interim facilities. Thus, the total cost of the project would increase $\sim 20\%$. Since major storm fronts take on the order of a week to pass, and do so on the order of each month during the building season, the 12% estimate shown is probably conservative.

Agriculture. Fertilizer, irrigation, harvesting equipment, transportation, and storage are major costs of the food produced, and timing is the essence of getting it to market in a timely and economical way. Improved forecasts could improve each. With longer range forecasts, it would be possible to fertilize where needed and irrigate only when needed. That would minimize the equipment, transportation, and storage needed for interim and final disposal. Two- to four-week predictions of weather and particularly precipitation should make it possible to optimize the combination of input factors and harvest time to maximize production and profits. As the harvest interval at any given latitude is on the order of a few weeks, and adverse weather during harvest can be catastrophic, the potential savings are tens of percent. However, the times that detailed forecasts are needed are a fraction of that total, so the overall benefit is reduced to the $\sim 10\%$ shown, which is in accord with independent estimates.

Apparel purchases are extremely weather-elastic, as indicated by the racks of winter clothing and ski parkas currently marked down 50% or more. While avoiding all of these commercial losses would require 2–3 month predictions, 2–4 week predictions could at least minimize the costs of overproduction, transportation, and advertising. Such predictions would both reduce the producer's cost through more timely purchasing and advertising and the consumer's cost through better informed preparation for the next season or year through sale-shopping. While the benefits in the components above are extremely large, the overall impact is reduced to the 10% shown.

Entertainment and Recreation are, like hotel-usage and vacations, largely discretionary activities, which can be delayed or cancelled due to adverse weather. Thus, improved predictions should make possible improved planning of activities and support, with an indirect impact on transportation and energy requirements. Improved forecasts would improve the consumer's ability to plan outings and the retailer's ability to provide supplies. As entertainment is generally planned a few days to a week in advance, prediction times on that order could reduce costs by tens of percent. The total impact could be on the order of 6–10%.