Mathematics a Vital Tool for Government Agencies

By Joseph Pousada

Mathematics is used in one form or another for various reasons by government agencies to help decision makers make the needed decisions that affects the lives of every member in a society. Virtually all governmental agencies use various analytical and quantitative experts to help them in carrying out their stated mission and to help them make every day decisions that are most effective to the society they serve. Here we will look at various government agencies such as The National Oceanic and Atmospheric Administration (NOAA) and The Federal Emergency Management Agency (FEMA) and how they utilize various people with various quantitative backgrounds to help them make day to day decisions. We will look at how models and assumptions must be reviewed to meet the demands of an ever changing landscape and we will also look at what research methods are employed to get needed data from the public in order to make sound policy decisions.

The National Oceanic and Atmospheric Administration (NOAA) uses weather forecasting models and various technologies to provide weather forecasting data. This data will be used by other private organizations, as well as other branches of government in order to make decisions. Such models will include "stochastic numerical models" (Ewald, Penland & Temam) and various models which use Linear Algebra. One such governmental agency that makes use of various weather modeling from NOAA would be the Federal Emergency Management Agency (FEMA) who uses the data to anticipate needed response. Various defense agencies will use their own weather forecasting technologies as well. Those defense programs are considered as part of their intelligence services, providing vital information for strategic planning and for day to day decisions.

The uses for linear algebra are so widespread that in one way or another it impacts all branches of government and businesses/industry even if the person who is benefiting from it is completely unaware. One such example where the person benefiting is often unaware, is the usage of linear algebra in programing. Linear algebra is even used in the popular search engine Google. Stochastic models are used in non linear phenomenon where there is randomness and takes into account the probability of certain outcomes. Its applications are wide reaching from government and military to business and finance.

Government agencies also use mathematics in decisions that affect our every day lives and safety. One area that affects our daily lives is transportation. Tabra and Eng (2008) put together an extensive report on "Electric Low Speed Vehicles" (LSV) which was done in Ontario. The study compared standards and data in Canada, the United States, and in the European Union for various types of LSVs (manufacture specifications, speed capabilities etc...). The comparison researched various safety issues in the design, human response factors (other drivers in standard vehicles/cars and pedestrians) as well as the transportation infrastructure (i.e. creating designated lanes, changing speed limits etc...) the related costs and made recommendations to the Ontario government on various aspects including design safety standards and policy.

A more comprehensive study would need to be done to develop safety standards for transportation when the next revolution in transportation takes place. There are various designs already for the flying car. What design modifications to these prototypes would need to be made to allow for consumer production? What kind of fuel sources would be employed? What is the environmental impact of those fuel sources? Can the fuel impact be offset with new technologies? Would there be a need for a national transportation information network that would provide the flight logistics and traffic control to avoid accidents? What would be the cost involved? What if the network was for all of North America and the cost was shared with our neighbors? What kind of encryption technologies would be employed to ensure that terrorists did not cause disasters by hacking into the navigation systems of flying cars? All these questions require mathematicians, engineers, statisticians, biologists and physicists with various expertise to solve.

Mathematics is used in various forms in monetary policy by the Federal Reserve bank of the United States. The agency has many mandates, but two of the major mandates are to monitor inflation as well as the health of the economy. They utilize various quantitative tools including, statistics, statistical mechanics, econometric models and stochastic models to model real world scenarios and use this to implement policy decisions. The former Chairman Alan Greenspan was a Statistician. The Federal Reserve has many monetary tools in its arsenal. When the Federal Reserve Bank announces it's decision on the "Fed Fund Rate" (which is the rate they will charge banks to borrow) it gains a lot of media attention. This information has been popular because it is an indication of their policy decisions, not because it is their most powerful tool. The Fed has other powers at their disposal, including the ability to intervene in markets to buy and sell and to change reserve rates that banks must follow. They can sell securities to withdraw monetary supply from the market and buy to increase monetary supply. A policy decision to increase reserve levels would decrease the amount financial institutions can lend since they must have larger reserves and a decrease in reserve requirements would encourage lending institutions to lend.

When the recent financial crisis unfolded, government agencies charged with regulation of the financial system took a close look at their models, assumptions built into the models, information from financial institutions that failed, with various other indicators (i.e. rates banks charged each other to borrow) to make decisions on taking immediate action to contain the crisis and to make decisions on enhancing policy (the Federal Reserve works closely with the US Treasury) to regain the credibility of our financial system and to make for a more stable economic environment. Without extensive quantitative tools at their disposal to model which fires posed the most risk and to model various outcomes based on various responses they would not have been any where near as effective as they were in containing the crisis.

Many other agencies use statistical and mathematical modeling techniques in times of crisis to help them make decisions. FEMA will use various modeling techniques to determine potential exposure levels of toxic substances in food and water and make the needed decisions on whether it can be consumed by those in need in an emergency and which subgroups in the population would or would not be able to consume the food and water (i.e. those who are expecting or children under a certain age.) Their current strategic plan even includes improving analysis throughout the organization.

All governments look at disease control for the safety of their society. Strong usage of mathematical and statistical modeling are used to make the most effective policy for the society as possible. This is used for both defensive policies and offensive policies. In "Quantitative Evaluation of HIV Prevention", by Kaplan and Brookmeyer, various programs used by various governments are evaluated in various variables including their effectiveness & cost effectiveness. In addition, various population segments are analyzed for their exposure to the disease as may benefit from different preventive programs. (i.e. The population segment which uses intravenous substances may benefit from free clean needles compared to a segment which does not use needles at all.) It is important to note that the job of the statistician / mathematician is never to use segmentation to pass value judgments but to use the data to help maximize effective measures, and in this case to save the most lives. Knowing which segments of the population have the most exposure to a specific disease and gathering data on which programs are most effective in preventing the spread of the disease in those population segments can help maximize the effectiveness.

Various methods to gather the statistical data are used (i.e. random sampling) and they have different benefits to them. In addition to the methodologies of gathering data, the is constant quality improvements made to include data in the surveys that will enhance the modeling and forecasting. In the case of HIV prevention, better knowledge on whom the IV drug user shares their needles with and how many is vital to enhancing the forecasting models. Just as with language, human behavior is fluid and these studies need to be done periodically to modify the models and ensure currently policy is optimally effective in the appropriation of funds to the various preventive programs.

Data can be obtained by various methods for different scenarios. The issue that comes up many times is that one does not have the ability to gather data from the entire population. So, what is used quite often is random sampling. In random sampling, a small segment of the population is sampled randomly so it accurately reflects the overall population. The benefit of randomly sampling the population is that it reduces human biases. Other methods such as observation, can cause biases in the observed population. In a study done in San Francisco “An Evaluation of the Effectiveness of San Francisco's Community Safety Cameras”, by King, Mulligan and Steven, it was determined that the cameras resulted in a significant drop in property crimes. Interestingly, the cameras had no effect on the number of violent crimes.

Statistical modeling is also used in modeling other policies as well. Kaplan and Brookmeyer discuss other policies involving HIV transmission including the blood ban on donors of Ethiopian decent in Israel and rates of viral transmission to infants of mothers who breast feed vs. those who do not breastfeed. This information and modeling is not only useful for policy based on the information provided but, if there are medical breakthroughs that allow for example cost efficient way of detecting the HIV virus in donated blood then how can the models be modified to incorporate this if the policy was amended? What are the risk levels? What other benefits will society have for assuming even the smallest amount of risk? (i.e. increased blood supply vs. current blood supply and no. of patience who die annually due to the deficiency in blood supply (assuming there is one.))

Various modeling techniques are used to address modeling disease transmission in various scenarios. In “Understanding Complex Systems: Population Interactions Resulting in Disease Transmission” by Del Valle and Smith, they use various techniques to in modeling including “Iterative Proportional Fitting” (a technique that allows them to create an artificial population with characteristics that match that of a real life population they have in mind) and “Gravity” (which is not the gravity of physics but an algorithm that models the probability that a given individual will be at a certain location. (i.e. a college student would have a high probability of being on the college campus)). By modeling disease transmission, government agencies can quickly model a specific scenario and ensure medical supplies can be directed to the places that they predict will need them most at the start of an outbreak to have the most effective impact in curtailing the spread and loss of life.

Statistical and Mathematical modeling techniques are used extensively to anticipate environmental effects and the effectiveness of various techniques for treatment of waste water to minimize the impact to the environment and ground drinking water. Government agencies also use other data such as new building projects and rates of population increase/decrease to project the impact and to make the needed changes to the water treatment requirements to ensure safety for everyone.

Mathematical tools that support modeling and predicting are at the heart of the decision making process for governments as well as most fields that support the infrastructure of our modern society (engineering, biology etc...) As shown with agencies such as NOAA and FEMA these models are key tools in the day to day decision making and planning process. As shown with the

Federal Reserve Bank and FEMA these models are modified and improved to reflect an ever changing world and to deal with crisis. The techniques that are used to gather data from our environment (both physical and social) are used by various government agencies for decisions regarding disease prevention, disease transmission, the environmental safety of our water supply and is constantly changing as improved accuracy will enhance the accuracy of the models used. Advancement in the predictability of models as well as modeling of the underlying processes and their interdependence will enhance our decision making process in government and business as well as allow for innovations in the various other fields.

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