

Implementation of Statistics in Business and Industry

Implementación de la estadística en los negocios y la industria

BOVAS ABRAHAM^{1,a}

¹DEPARTMENT OF STATISTICS AND ACT. SCI., UNIVERSITY OF WATERLOO, ONTARIO, CANADA

Abstract

Statisticians have devised many tools for application and these are available to be utilized for general business improvement and industrial problem solving. However, there is a wide gap between the available tools and what are practiced in business and industrial organizations. Thus it is important for statisticians to direct serious attention to bridging this gap if statistics is to be relevant in business and industry and to the society at large. In this paper we look at some ideas for implementation of statistical methods in business and industry.

Key words: Statistics in Business, Industrial Statistics, Statistical Methods.

Resumen

Los estadísticos han desarrollado muchas herramientas para su aplicación en problemas prácticos. Estas herramientas están disponibles para ser utilizadas en el mejoramiento de los negocios en general y para solucionar problemas industriales. Sin embargo, existe una brecha entre las herramientas disponibles y las que utilizan las organizaciones industriales y de negocios. Por tanto, es importante que los estadísticos dirijan su atención a disminuir esta brecha si se quiere que la estadística sea relevante en los negocios, la industria y en general en la sociedad. En este artículo se presentan algunas ideas para la aplicación apropiada de métodos estadísticos en los negocios y la industria.

Palabras clave: estadística en negocios, estadística industrial, métodos estadísticos.

^aProfessor. E-mail: babraham@uwaterloo.ca

1. Introduction

Implementation means different things in different contexts and to different people. What do we mean by implementation? H.G. Wells once said ‘Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write’. Recently Harry & Schroeder (2000) remarked ‘We believe that statistical knowledge is to the information and technical age what fossil fuel was to the industrial age. In fact, the future of industry depends on an understanding of Statistics’.

These statements imply that Statistical Thinking and Methods should become part of the knowledge base of an organization and part of doing business. This is the kind of implementation we are discussing. In other words a business or industrial organization institutes Statistical Thinking in all its functions and the use of statistical tools and data based decisions becomes a part of the every day business.

In this context we are not thinking just about a statistician consulting with a scientist or an engineer for a project. Although such activities are very important, our goal is much broader. Our vision is that statistical thinking and tools should be entrenched in the organization so that they play a prominent role in it’s daily activities. In such organizations the roles of statisticians are quite different from the traditional one of helping a client with some data analysis.

2. Statistics in Business and Industry

In general a typical organization has three levels: Strategic, Managerial and Operational. This classification is somewhat general and arbitrary. However, this can help identify and emphasize different tools to be directed at the different levels. We envision Statistics to play important roles at all these levels.

2.1. Strategic Level (Top of an Organization)

At the strategic level the most emphasis should be on Statistical Thinking which has the following components:

- i) Notion of a Process,
- ii) Notion of measurement and data based decisions,
- iii) Understanding and dealing with variation,
- iv) Statistical tools, and
- v) Systematic approach.

The notion of process thinking is fundamental to any organizational change. Every action has some inputs and outputs which need to be identified in every

context. Decisions at the strategic level should be based on facts supported by appropriate data and this requires an understanding of variation (Deming 1986). Business and Industry have seen the arrival and demise of many programs such as Total Quality Management. Embracing any program that comes along without firm commitment and understanding is doomed to failure.

2.2. Managerial Level (Middle Level)

This is the level at which systems are devised for implementation of the directions taken by upper management. In particular, systems for robust product and process design, process control and improvement, and training are the responsibility of middle management. Understanding of some statistical tools and statistical thinking are prerequisites for those who are designing these systems.

2.3. Operational Level

At this level the methods are implemented through the system built at the managerial level. Understanding of statistical tools such as control charting, capability analysis, design of experiments, measurement system analysis, regression analysis etc are essential. Appropriate statistical tools need to be used by operational people as part of their daily work. People in some areas need to know the details only of certain statistical tools. For instance, an operator responsible for maintaining stability of a process by charting should know the workings of a control chart but need not know a lot about design of experiments. On the other hand an engineer responsible for process improvement should be knowledgeable in several aspects of statistical process control and design of experiments.

3. Implementation: General Issues

3.1. Commitment of Top Management

For the success of any program that affects an organization as a whole, full and highly visible commitment of senior management is essential. Thus the vision and values of the top level management is highly important. Employees must perceive active leadership and involvement of senior people in implementation. Top management has to assess the situation early and to decide to allocate the needed resources. They have to decide in advance what role they can and will play. For example the success of the Six Sigma program at General Electric and Motorola is due to the commitment of its senior management.

Recognition of the potential benefits of implementation in the beginning can help focus on what is needed. Top management must recognize that, in addition to help solving problems and improving processes, statistical tools can help increase customer satisfaction and help measure the performance of the organization. Implementation of statistical tools is an ongoing process and it helps the organization

to be a learning organization and a knowledge based enterprise. Knowledge based organizations will be the successful ones in the long run.

3.2. Role of Statisticians

The traditional role of a statistician in business or industry has been to act as a consultant to projects, or to train some workers in certain tools such as statistical process control and design of experiments. This role has to be broadened. Statisticians need to teach at all levels of an organization (senior managers, scientists and engineers, middle managers and operational people). Statisticians have to be leaders, facilitators, aide to management etc. They have to identify the role of statistics in various business functions and also have to interact with the outside world. These require broadening statistician's skills set. Statisticians need to acquire communication skills and have to be good communicators. We have to keep the statistical tools appropriate and simple. We also need to make sure that the implementation adds value to the organization.

3.3. Systems Thinking

As in any other implementation, there are several components involved and these need to be considered as part of a system for successful implementation. Some of these components include people, technology, organizational structure and culture, methodology, etc. and these components have to work jointly. There will be interaction between these components. Systems need to be built such that the interaction effects are positive so that the total effect from the components is more than the sum of the individual effects. For instance if there are two components A and B then $Effect(A + B) = Effect(A) + Effect(B) + Effect(AB)$ where $Effect(AB)$ is the 'interaction' between the components A and B . Statistical tools should be implemented such that $Effect(AB)$ is positive so that $Effect(A + B)$ is more than $Effect(A) + Effect(B)$. A negative 'interaction' can not only lower the total effect but also can cause long term problems. Some guiding principles such as Deming's 14 points for management can help in this regard. Such principles help to foster positive interaction between components such as people and technology. Some training programs use sophisticated software to train employees without considering the background of the trainees.

3.4. Planning for Implementation

Before embarking on the implementation of statistical methods one has to have a plan with answers to the following questions. How does it start? Who are responsible for the tasks? When do the activities take place? What is the scope of the system? Is there a calendar of activities? Is there a measurement system to track progress of activities?. What are the review points, and the associated expected results? Are resources assigned for the planned activities?

There are many project implementation systems cited in the literature. Deming's PDSA circle (Shewhart's wheel)-Plan, Do, Study, Act (Deming 1986) is a well known example. Six sigma is another system which uses DMAIC -Define, Measure, Analyze, Improve, Control. There are many others. The important fact is that it is essential to have a systematic and disciplined approach to implementation. Implementation of statistical tools needs to be interfaced with these systems. Most of these systems are very similar and it does not matter which one is used. It is better to go with what is already available in the organization rather than looking for something new. It is important to be consistent and stable with it. It is not a good idea to change to some other system in the middle. It is also possible to interface with quality systems such as ISO.

4. Implementation via Training and/or Consulting

All organizations have a certain set of existing knowledge base and acquiring new knowledge may require changes in thinking and culture. An assessment of the existing knowledge and the skills are necessary before embarking on training to introduce new skills and knowledge into any organization. Also any plans for training should reflect an understanding of the existing knowledge.

Training needs for different levels of an organization can be very diverse. The distinctive needs should be recognized and the training programs should be designed in such a way to suit each of the Strategic, Managerial, and Operational levels.

Trainers should have good statistical knowledge and good business and/or industrial experience. They should be aware of the structure and culture of the organization, the background of the trainees and the training context. It is important to make sure that the training material is relevant, appropriate, of good quality and at the correct level. Schedule and duration of each module is also important. In addition, presentation of the material in an understandable and enjoyable way requires careful planning. The use of appropriate technology is also important. For a certain level one technology may be relevant while another level requires the use of a modified technology. Communication between the trainer and the trainee and that between software and participants should be smooth. The interaction between people and technology should be positive.

Statistical training can be interfaced with other training in the organization such as ISO-9000, Six Sigma. In this context sequencing need to be carefully planned.

5. Implementation via Education

Today's students are tomorrow's employees and employers. Graduates with technical and non-technical skills are needed in business and industrial organizations. These students have to get their education from the universities. Hence it is important for universities to give more attention to the preparation of undergraduate

and graduate students for business and industry. Students need technical and non-technical skills to be successful in the workplace and it is difficult for universities to provide all the skills to function in the workplace. Universities are providing some of these already. However, university statistics curriculum can be improved so that potential employees have enough statistics and communication skills. Many authors have discussed ideas for enhancing statistical education (for example see ASA Committee (1980), Garfield (1995), Hoerl et al. (1993), Hogg & Hogg (1995), Snee (1993), Vere-Jones (1995) and Wild (1995)).

5.1. Undergraduate Program

It is important to design programs in such a way that a student has some minimum statistical and non-statistical background before he/she enters the work place. For instance students need to understand the Scientific Method (see Box (1976)), Problem Solving Systems, Measurement System Analysis, Sampling, Experimental Design, Regression, some Mathematical statistics, Process Control, and Computing and Mathematics (see ASA Committee (1980)). In addition the students should get experience in solving industrial or business problems and communicating the results to people in other areas. There are different ways of achieving this goal. One method adopted at the University of Waterloo is to enroll the students in a co-operative program. In this system the students cycle between university and business or industry after each term during their undergraduate program (Abraham 1999). This will be discussed further later. Another possibility is to have joint programs such as Engineering and Statistics, Business and Statistics, some branch of Science and Statistics, etc. Such programs help students appreciate the role of statistics in other areas.

5.2. Graduate Education

In the graduate program also there is to be a recognition of the need for non statistical training. In addition to the typical graduate courses in Statistics (Mathematical Statistics, Linear Models or Regression, Forecasting, Sampling, Design, Generalized Linear Models, Multivariate Analysis, Statistical Computing, etc.) a student needs to have some training in communication or interpersonal relationships.

One useful model to consider is to have a graduate statistics program after an undergraduate degree in another area like Engineering. Or another idea is to have a joint graduate program in Statistics and Business or Engineering. These require co-operation between departments which is not that easy. It is also good to have internships in business or industry during a graduate program. This can enhance familiarity with working environments, hands-on-experience and communication skills. Joint projects such as joint seminars between academia and business or industry will also be very helpful. In such cases business leaders should be invited to give talks in these seminar series.

6. University - Business - Industry Collaboration

Universities seek academic excellence and business and industrial enterprises require their employees to work on issues relevant to their organizations. These two goals need not be on a collision course. With proper insight universities can provide academic excellence with relevance. Typically a university provides education to students. It can also provide training in the workplace through its faculty. It is difficult for a university, by itself, to provide the well rounded education required for students to function well in the workplace. Business and industry can help by providing contexts for relevance. They can also provide input to the universities. Collaboration between university and business or industry is essential to produce graduates for the future who can handle the challenges associated with the new workplace (Brajac & MacKay (1994), Hoadley & Kettenring (1990), Snee (1990)). Such collaboration requires carefully designed systems for implementation.

The needs of the university, and business or industry must be clearly defined in a university -business-industry partnership. The roles of the partners should be clearly understood. The system need to be flexible so that the students and faculty can spend time in business or industry to enhance non-technical skills and to gain some hands-on-experience. University courses can be modified to include project oriented teaching. Business and/or industry should provide opportunities to gain experience in problem formulation, planning of approach and data collection and problem solving. Different models can be used for undergraduate and graduate students. The systems of collaboration must make sure that the transition between university and business or industry is smooth for students as well as faculty. Also should accommodate the interests of students and faculty. We note that long term commitments are required of the partners to make this partnership successful.

7. University of Waterloo and Business and Industry

University of Waterloo is involved with business and industry in several areas and at several levels. Here we focus on the involvement related to Statistical Methods.

7.1. Co-operative Programs

The University of Waterloo, Canada has a large (probably the largest in the world) co-operative program involving about 11000 undergraduate students annually. In this program a student goes to a business or industry for a four month "work term" after every four month school term. In this program the students have to compete to get jobs in each work term. They prepare their resumes, and go through interviews, before they get the job. This is all managed by a large department dedicated for this. Each student in the program has to write a report after the co-op term regarding the work done during the work term and this report has to be evaluated by the supervisor at work as well as by faculty in the

university. A student has to complete four to six successful work terms (depending on the program) during his/her undergraduate program. Thus the undergraduate program takes almost five years to complete. It is a very popular program and the students coming through this program are highly in demand.

At the University of Waterloo, the engineering program is available only as a co-op program while co-op is an option in other programs such as Statistics. Each faculty (college or school) has its own special requirements. However, all co-op placements in business and industry are administered through the Department of Co-Operative Education, a large administrative group on campus. In general placements in Engineering and Mathematics are well over 90%. During some difficult years placements of first year students had some challenges, prompting some adjustments to the timing of work terms and academic terms. The whole Co-Op set up is a huge undertaking by the university which recognized the need for collaboration by the University and Business or Industry.

There is a Waterloo Advisory Council consisting of people from Business or Industry and the University. This council meets couple of times a year to discuss various issues facing the implementation of the system. This is an opportunity for the University to get input from Business and Industry regarding curriculum changes, new courses and program.

7.2. Business and Industrial Statistics Research Group (BISRG)

University of Waterloo has many centers and institutes working with business and industry. The university recognized the importance of Statistical Methods in Quality Improvement activities and established the "Institute for Improvement in Quality and Productivity in 1985 as a liaison between the University and Business and/or Industry to implement statistics in business and industry". The goals and objectives of this group:

- To provide a focus for multidisciplinary consulting and research in technical and managerial methods for improving quality.
- To develop a centre offering courses and seminars for business and industry.
- To aid in developing undergraduate and graduate programs in technical and managerial methods for quality improvement.
- To facilitate exchange programs between university faculty and business or industry personnel
- To stimulate development of innovative training methods in quality for the workplace.

Recently the name of this group has been changed to BISRG and now the focus is more on research. BISRG has a program of in-company and public courses spanning topics in variation reduction, design of experiments, process control, etc.

Third year or fourth year undergraduate, Masters, and Ph. D. students have the opportunity of getting involved in the projects associated with the courses. They can also serve as teaching assistants for these short courses.

By promoting closer contact between faculty members and business or industry BISRГ encourages increased applied research on topics of great interest to business and industry. It publishes a research report series containing the results of current research done in this group. Graduate students have greatly benefited from the research problems generated from the collaboration with industry and business.

7.3. Campus Curriculum Changes

Faculty members involved in the group have gained valuable experience and ideas in working with business and industry. These have helped to implement substantial changes to the contents of Statistics courses at the University of Waterloo. The first course (second year undergraduate) taught to some departments in engineering now centers around continuous and process improvement. These students are exposed to experimental design, statistical process control etc and some of them have conducted experiments at industrial partner facilities during their work terms which have resulted in substantial savings. Significant changes have been made to some other courses in the Faculty of Mathematics. In some of these courses students conduct experiments in a laboratory in groups, deal with measurement system issues and write laboratory reports as a team. Changes have been made to a course in experimental design to reflect the applications in industrial partner facilities.

A variety of examples including casting, injection molding, painting, etc have been collected from partner facilities and these appear as examples in lectures and assignments. Students appreciate the fact that these examples are real and often involve thousands of dollars in savings.

Thus collaboration with business and industry provided many tangible and intangible benefits:

- Enhancements in content and delivery of courses.
- Graduate and undergraduate student involvement in real projects.
- Enhancement of applied research of faculty and graduate students.
- Professional development of the faculty members.
- Enhancement of Statistical Thinking at some partner facilities and modest cultural changes.
- Application of newly developed methods in partner facilities.
- Savings in real dollars for business or industrial partners.

8. Concluding Remarks

Statistical Thinking and Methods need to become part of the knowledge base of an organization. We outlined several issues related to the implementation of statistical methods in business and industry. Well planned systems and training are necessary for implementation. Enhancement of university education is also necessary. We also discussed the need for University -Business- Industry collaboration. Such collaboration will provide better opportunities for students. Some may argue that universities should be places for education and should not be in the business of training. It is important to keep the balance, and all such endeavors need to be motivated by “academic excellence with relevance”.

It is important that the professional statistician is equipped with good technical and non-technical skills. This is a challenge universities have to face and one model for successes is to form partnership with business and industry as we have suggested. There is no need to compromise on academic excellence, however building in ‘relevance’ to the program enhances its value.

Recibido: diciembre de 2006

Aceptado: febrero de 2007

References

- Abraham, B. (1999), Implementation of Statistical Methods in Industry, Technical Report RR-99-04, Inst. for Improvement in Quality and Productivity, University of Waterloo, Ontario, Canada N2L 3G1.
- ASA Committee (1980), ‘Preparing Statisticians for Careers in industry: Report of the ASA Section on Statistical Education Committee on Training of Statisticians for Industry’, *The American Statistician* **34**, 65–80.
- Box, G. (1976), ‘Science and Statistics’, *Journal of the American Statistical Association* **71**, 791–799.
- Brajac, M. & MacKay, R. J. (1994), Industry-University Co-Operation: A Case Study, Technical Report RR-94-02, University of Waterloo, Ontario, Canada N2L 3G1.
- Deming, W. E. (1986), *Out of the Crisis*, M.I.T., Cambridge, Massachusetts.
- Garfield, J. (1995), ‘How Students Learn Statistics’, *International Statistical Review* **63**, 25–34.
- Harry, M. & Schroeder, R. (2000), *Six Sigma, the Breakthrough Management Strategy Revolutionizing the World’s Top Corporations*, Doubleday, New York.
- Hoadley, A. B. & Kettenring (1990), ‘Communications between Statisticians and Engineers/Physical Scientists’, *Technometrics* **32**, 243–274.

- Hoerl, R., Hooper, J., Jacobs, P. & Lucas, J. (1993), 'Skills for Industrial Statisticians to Survive and Prosper in the Emerging Quality Environment', *American Statistician* **47**, 280–292.
- Hogg, R. V. & Hogg, M. C. (1995), 'Continuous Quality Improvement in Higher Education', *International Statistical Review* **63**, 35–48.
- Snee, R. D. (1990), 'A Partnership is Needed', *Technometrics* **32**, 267–269.
- Snee, R. D. (1993), 'What is Missing in Statistical Education', *The American Statistician* **47**, 194–204.
- Vere-Jones, D. (1995), 'The Coming of Age of Statistical Education', *International Statistical Review* **63**, 3–23.
- Wild, C. J. (1995), 'Continuous Improvement of Teaching: A Case Study in a Large Statistics Course', *International Statistical Review* **63**, 49–68.