Figure 11.1. INDUSTRIAL PROBLEM SOLVING: An Introduction

In Part 11 of these Course Materials, we discuss statistical issues relevant to cost-effective manufacture of goods and delivery of services of high quality; the motivation for these activities is success in the marketplace. Ideally, three conditions need to be met to achieve commercial success (locally or globally):

- a product (goods or a service) that fills a real or perceived need;
- high (or highest) quality – of design,
  of implementation: *manufacturing* and *assembling* goods,
  delivering a service;
- low (or lowest) cost.

These basic matters are introduced in the following six points; more details are given in later Figures of Part 11.

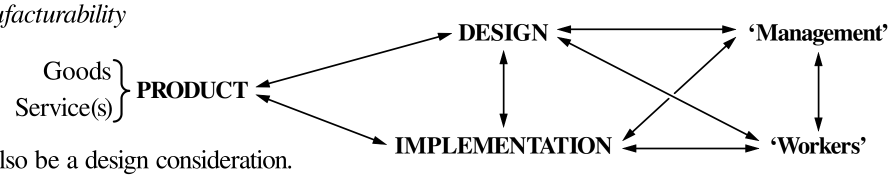
1. Every activity, every task, can be thought of as a *process*; a flow diagram of any process will divide the work into *stages* – the stages taken together form the process:

   Stage 1 ⟶ **Stage 2** ⟶ **Stage 3** ⟶ **Stage 4** ⟶ **.......**

   Work comes into any stage, changes state, and moves on to the next stage. Each stage has a *customer*, the *next* stage; the *final* stage will send the product to the ultimate customer, the person who buys the product. *Any* process, whether in the manufacturing or the service sector, needs to be concerned with the *quality* of its product.
   - It is generally agreed that, for a process (or company) to remain profitable, there must be *continuous improvement* of its product(s), including continuous improvement of quality.
     - Successful companies have often integrated the means for achieving continuous improvement into the basic structure of *all* aspects of their operations [product(s), service(s), internal administrative functions, etc.].
     - Some people think product quality and product cost are *directly* related, but there is increasing recognition that higher quality can result in *lower* overall costs.

   When a process is working properly (*e.g.*, low maintenance, local optimization), each stage cooperates with the other stages towards optimum accommodation that will result in a level of product quality the ultimate customer can boast about.

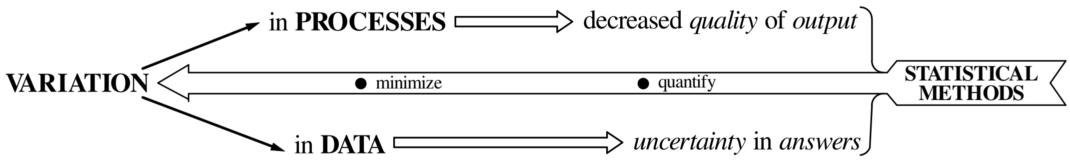
2. As summarized in the flow chart at the right below:
   - the *first* requirement for a quality product is a good *design*;
     - The processes of developing and of implementing a good design themselves require proper design.
   - the second requirement for a quality product is proper *implementation* [*i.e.*, proper *manufacture* and *assembly* of goods, proper *delivery* of a service].
     - One feature of a good design is that it minimizes, as far as practicable, the difficulty of *implementation*; *i.e.*, a good design is concerned with *manufacturability* and *assemblability* (of goods) and *deliverability* (of services) *as well as* with end use.
     - *Servicability* of goods should also be a design consideration.



3. Company operations involve both 'management' and 'workers'; each group must adequately discharge its responsibilities with respect to design and implementation if a quality product is to be delivered to 'customers'.
   - It is the responsibility of management to set up a 'system' in which conscientious workers *can* perform in a manner that results in a quality product.
   - Management does not always appreciate its responsibility for the 'system' and its defects; rather, management is apt to see careless workers as the main impediment to quality – *e.g.*, poor quality output from an assembly line.
     - There is growing recognition of the *90/10* (or *95/5*) *rule*: at least 90% (or 95%) of quality problems are a result of improper management (*i.e.*, they are 'system' problems over which workers, however conscientious, have little or no control) whereas fewer than 10% (or 5%) of such problems typically are 'caused' by careless workers.
       - A consequence of this 'rule' is that industrial problem solving usually needs to focus on *process improvement* rather than on people.
   - It is also management's responsibility to ensure that workers are properly *trained*, by an appropriate combination of hirng qualified personnel and providing on-the-job training.

4. Quality is an elusive concept to define; however, *lack* of quality (either real or perceived) is usually associated with one or more manifestations of *increased variation.*
   - This facet of product quality has a *data* analogue: data variation (when coupled with incompleteness) is a source of *uncertainty* in *answers*, as reflected in *limitations* imposed by (our six cetegories of) error.
   - A central concern of statistical methods, whether of data generation and analysis or of industrial problem solving, is to *minimize* and to *quantify* variation – see the schema overleaf; minimizing variation usually entails identifying its *source(s).*

(*continued overleaf*)



5. Difficulties in timely delivery of competitively-priced goods and services of high quality may involve *all* the areas of design, implementation, management and workers; as a consequence, a wide variety of problem-solving methods is often needed to overcome the difficulties.
   ∗ Statistical methods provide *one* important approach to overcoming many (but *not* all) such difficulties.
     ○ A vital contribution of statistics to this area is the idea that a *planned* approach to problem solving is both *possible* and *effective*.
       – One reason for the success of Japanese manufacturing activity (*e.g.*, starting in the 1970s for consumer goods, including automobiles) is their use of statistical methods to achieve variation reduction.
     ○ Contrary to common perception, *simple* statistical methods will allow most companies to make major gains in quality.
       – Also contrary to common perception, the simplicity of the statistical methods is *not* matched by the simplicity of ensuring their adoption in an effective manner; rather, this is a *difficult* process that requiring much dedication.
   ∗ Other subject areas relevant to the development of successful businesses are:
     ○ organizational behaviour; ○ human behaviour; ○ accounting; ○ finance; ○ labour relations.

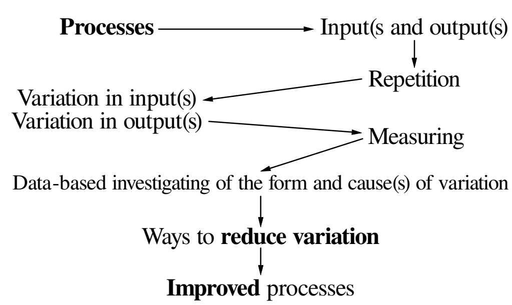
     Thus, there is an opportunity to complement the study of statistical methods in STAT 221 with suitable courses from areas like Management Sciences, Psychology, Accounting and Economics.

6. An extension of the matters in the foregoing points 4 and 5 involves the distinction between *strategy* – the *broad* perspective – and *tactics* – the *narrower* focus; both can conveniently be thought of as a set of components. One version of names for components is shown at the right; this schema also includes, with*in* tactics, the data analytic techniques known as Ishikawa's *Seven Tools*.

Strategy	**Tactics**	**Tools**
Project	Formulation	Check sheets
Measuring	Design	Pareto diagrams
Statistical thinking	Execution	Cause-and-effect diagrams
Improving	Analysis	Histograms
Implementing	Conclusion	Stratification charts
		Scatter diagrams
		Control charts

   Noteworthy points about the schema are:
   ∗ We distinguish a **project**, which is *broad* and involves *many* questions, from an **investigation**, which is *narrower* and involves *one* (*or a few*) *questions* – see also the Appendix starting at the bottom of page 11.5.
   ∗ In all projects and in most instances of data-based investigsting (using, for instance, the FDEAC cycle), it is necessary to investigate the measuring process(es) to check that their inaccuracy and imprecision are appropriate in the question context.
   ∗ *Statistical thinking* is concerned with *process improvement* by means of *variation reduction*; it can be summarized as in the schema at the right, where the arrows are to be read as *bring(s) in the idea of*.
     ○ The importance of variation *reduction* in industrial processes is to be contrasted with *maintaining* variation in populations in nature, to provide a base from which natural selection can operate.

Statistical Thinking



   ∗ An illustration of strategy is the *Six Sigma* system, developed by Motorola and Asea Brown Boveri and adopted by companies like General Electric and Bombardier. The names *this* system uses for the components are:
     ○ Define; ○ Measure; ○ Analyze; ○ Improve; ○ Control.

     Analyze refers to improving existing processes on the basis of identifying causes of variation in process output;

     Control means making the improved process the *normal* (or default) way of operating – this is also described as *taking irreversible corrective action.*
   ∗ Ishikawa's seven tools are described starting in Figure 11.18; these tools are valuable but less formal methods of data *analysis* – they thus belong in the Analysis stage of the FDEAC cycle.

   The structured process of the FDEAC cycle (described in Statistical Highlights #88 and #89 and summarized here on pages 11.5 and 11.6), illustrates statistical thinking applied more broadly to describe the statistical (as opposed to the scientific) method.

In summary, a quality product requires a good design;
careful control of variation in making and assembling components;
in delivering a service.

Given a good design, lack of quality arises because things go wrong in manufaturing and assembling components,
in delivering a service;

(*continued*)

Figure 11.1. INDUSTRIAL PROBLEM SOLVING: An Introduction (continued 1)

things go wrong because of 'problems';
thus, statistical and other problem-solving skills are needed to attain and continuously improve quality.

In the last few decades (*i.e.*, in the later middle decades of the twentieth century), these ideas have been implemented with the most conspicuous success in manufacturing industries in Japan – for example, in the automotive industry.

REFERENCE: One book which deals with these and related matters in detail is Deming, W. E.: *Out of the Crisis.* Massachusetts Institute of Technology Center for Advanced Engineering Study, Cambridge, Mass., 1986.

1 With reference to Point 1 on the first side (page 11.3) of this Figure 11.1, identify the main product(s and/or service(s) associated with each of the enterprizes listed below; in each case, indicate your *expectation* of quality and the extent to which it is *achieved* in your experience:
- an automobile manufacturer (identify the make of vehicle you have in mind);
- a building contractor (specify the building you refer to);
- Canada Post (identify the category of mail you discuss);
- the University of Waterloo (deal with a specific aspect of the University);
- a hospital (indicate the hospital and the nature of the service you are considering);
- a Government department which deals with the public (*e.g.*, Employment Canada, Canada Revenue Agency).

2 With reference to Point 1 on the first side (page 11.3) of this Figure 11.1, name some of the *internal administrative functions* of a company that need to be concerned with continuous improvement.
- Briefly describe possible 'quality' problems, *how* improvements might be made, and *why* the improvements you indicate would be beneficial.

3 With reference to Point 1 on the first side (page 11.3) of this Figure 11.1 and using a specific context (*e.g.*, an automobile manufacturer):
- explain briefly why costs might go *up* with improved quality;
- explain briefly why costs might go *down* with improved quality.

Indicate which of the two outcomes is likely to be the dominant one in practice.

4 With reference to Point 2 on the first side (page 11.3) of this Figure 11.1 and using a specific context of your choice, discuss briefly the *impediments* to good product *design*.

5 With reference to Point 3 on the first side (page 11.3) of this Figure 11.1, list possible *causes* of poor quality output from a production line assembling an item from components; to make your discussion specific, deal with the manufacture of an item of consumer goods (a car, a household appliance, etc.
- Arrange the causes you describe in what you consider most likely to be the order of *de*creasing importance in the case of the type of item you have chosen.
  - Which of the causes are 'management' problems and which are 'worker' problems?

6 With reference to Point 4 which starts near the bottom of the first side (page 11.3) of this Figure 11.1, describe situations you have encountered (involving manufactured items *or* services) where decreased quality is due to increased variation.
- For each situation, suggest how the variation might be *de*creased; indicate the 'cost' of each method you suggest for achieving decreased variation.

7 Suppose that the internals of an automobile transmission consist of seven sub-assemblies (each containing an appreciable number of parts); these sub-assemblies must be put together end-to-end (with appropriate interlocking connections) to form the complete 'works' of the transmission, and the whole must then be fitted inside a casing. Indicate briefly what difficulties you would anticipate in the production of complete transmissions from the sub-assemblies and casings, on an assembly line with an output of 1,000 transmissions per 8-hour shift. [Assume that acceptable tolerances are very *small* for an item as complex as a transmission, which may contain of the order of 1,500 individual parts.]

8 With respect to Point 5 on the second side (page 11.4) of this Figure 11.1, suggest reasons why *simple* statistical methods are most effective for dealing with the majority of industrial problems.
- Suggest plausible reasons why it is often so *difficult* to ensure that even simple statistical methods are applied effectively (and on a *continuing* basis) in industry?
- What are the likely advantage(s) and disadvantage(s) of using more *complex* statistical methods for industrial problem solving?

1. Appendix: The FDEAC cycle – Projects, Investigations and Problems

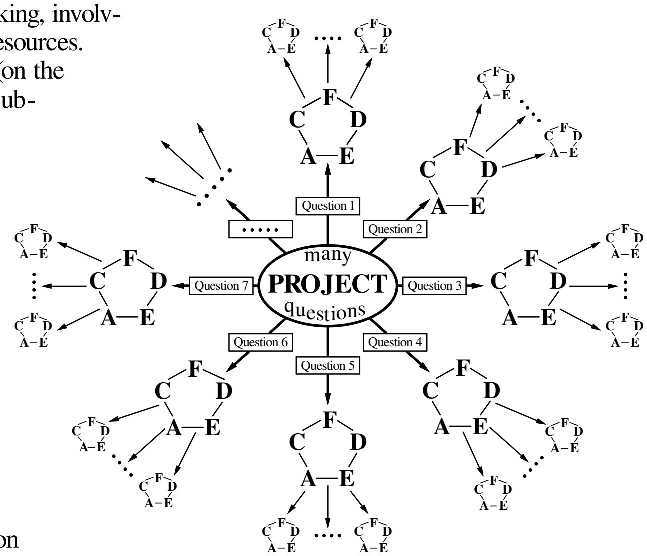
As introduced in point 6 on page 11.4 (and to develop the ideas encompassed by the FDEAC cycle), we distinguish:

(*continued overleaf*)

* a **project**, which is *broad* and involves *many* questions [one goal of project *formulation* is to *prioritize* these many questions];
* an **investigation**, which is *narrower* and involves *one* (*or a few*) question(s) – this question(s) may arise from a project or it may be of interest in its (or their) own right.
  – The question(s) to be answered are the *input* to the Formulation stage of the FDEAC cycle.
  – With*in* the FDEAC cycle, the *output* of each stage is the *input* to the next stage, except that the *knowledge* output from the Conclusion stage *answers* the input *question(s)* to the Formulation stage.
  Further discussion of dependencies between stages of the FDEAC cycle, and between four of the stages and the model (whch is needed as a basis for *formal* methods of data analysis) is given in Appendix 2 on page 2.18 in Figure 2.1 of the STAT 220 Course Materials, and likewise in Statistical Highlight #88 on page HL88.16.

In both projects and investigations, there will inevitably be matters of formulation that require subject-matter expertize – that is, *extra*-statistical knowledge. Examples of projects (phrased as ***How can*** .... questions) are:
○ How can the amount of scrap produced by a manufacturing process be reduced?
○ How can the quality of drinking water in a province be improved?
○ How can the performance on standardized tests of students in a province be improved?
○ How can transparent decision-making processes in a large organization be achieved?
○ How can a large software system be made less prone to failure or easier to maintain?
○ How can satisfaction for the customers of a company providing goods or services be increased?

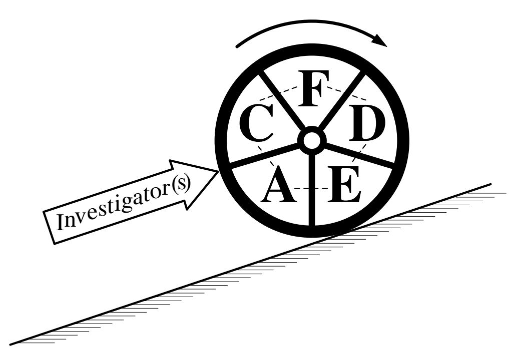
As indicated in these examples, a project is a *broad* undertaking, involving answers to *many* questions and substantial commitment of resources. The tasks of *formulating* a project and *prioritizing* its questions (on the basis of factors like importance, cost, logical necessity) require subject-matter expertize. The display at the right shows the prioritized questions from a project as inputs to a sequence of FDEAC cycles; each ‘main’ FDEAC cycle (shown larger) may involve one or more (smaller) sub-cycles to answer questions that arise in answering each ‘main’ question.



As with answering a statistical question using the FDEAC cycle, a question requiring *extra*-statisatical knowledge is usually also best answered using a *structured process* – for example, the five-stage DefineMeasureAnalyzeImproveControl of Six Sigma. *Statistical* questions arise most obviously in the I stage of DMAIC, but the FDEAC cycle is also relevant to the tasks of project description and question prioritizing in the D stage; statistical considerations of measuring processes, introduced in Section 9 on page HL88.14 in Statistical Highlight #88 and pursued in Statistica Highlight #38, are relevant in the M stage.

● To help distinguish contexts which require *distinct* structured processes like the FDEAC cycle and DMAIC, we can say:
  – the FDEAC cycle deals with *answering (statistical) Questions*, – DMAIC deals with *(extra-statistical) problem solving* [although, in a context like that of Highlight #90, *we* might prefer: DMAIC deals with answering *(extra-statistical) Questions.*]
  We *avoid* equivocal phrases like *a task to be done* or *a conclusion to be drawn*.
  Also, these Course Materials use the more evocative *data-based investigating* in preference to *empirical problem solving.*

To emphasize the *onerous* nature of data-based investigating, the diagram at the right conveys three images relevant to using the FDEAC cycle to obtain Answer(s), with acceptable limitation in the investigation context, to substantive (statistical) Question(s):
○ the *effort* of pushing a (heavy) object *up*hill;
○ potential *waste* of resources by *premature* cessation of effort;
○ the *circular* object is a reminder of the FDEAC *cycle.*



Despite the ‘obviousness’ of matters like formulating *clear* Question(s) and using measuring processes of acceptable inaccuracy and imprecision in the investigation context, often-poor implementation of these and other components of the FDEAC cycle (*un*necessarily) yields ‘wrong’ Answer(s).
Experienced investigators realize that *one* misstep in data-based investigating can negate doing correctly *all the other* components of the investigation; an example is malfunction in a measuring process that results in loss of some or all data or yields inaccuracy and/or imprecision that impose unacceptable limitation on Answar(s).