CONCEPTUALIZATION OF QUALITY OF INFORMATION IN THE EDP-ORIENTED LITERATURE

S.C. Blumenthal (1969)

IN THE CONTEXT OF PRESENTING A FRAMEWORK FOR PLANNING AND DEVELOPMENT OF MANAGEMENT INFORMATION SYSTEMS

> FUNCTIONAL REQUIREMENTS. Such documents and its amendments should always reflect the current statement of WHAT is to be done by the system.
>
> The functional requirements define the constraints placed on the system by its users. The DATA REQUIREMENTS, the DATA VOLUMES, and the RATE OF PROCESSING are constraints imposed by the immediate users. The constraints of more remote users are imposed through the specification of INTERFACES with related systems.

For better understanding of the concept of functional specifications, compare it with the author's concept of NON-FUNCTIONAL specification: it reflects the hardware and software characteristics of the method of system implementation. The author develops a system definition based on a "black box"concept of a system. The definition of system then consists among other things of defining the INPUT DATA.

> INPUT DATA DEFINITION includes specifying:
> - Where they come from
> - What FORM they are in, and
> - Who is responsible for their PRODUCTION
> - Furthermore the definition may include the clerical procedure for transcription of a document into machine readable input at its place of origin, the method of transferring data between locations, and the clerical procedure for producing subsidiary source documents if for example data are gathered from a number of source documents.

In discussing the data base as one of the technological elements of a management information system, the author considers the issue of the "cost-value relationship".

> The COST-VALUE RELATIONSHIP must be applied by the user to his analysis of requirements concerning
> - The DEGREE OF DETAIL
> - The AGE OF DATA
> - The ease of retrieval, and
> - The variety in formats maintained by his system.

As a methodological background to his concept of system, the author undertakes a synthesis of Jay Forrester's concepts of information-decision-action, Herbert Simon's programmed-non-programmed decisions, and Robert Anthony's hierarchy of planning and control. This results in the following definitions:

- A DATUM is an uninterpreted raw statement of fact.

- INFORMATION is DATA recorded, classified, organized, related or interpreted within context to convey meaning.

F.J. Carr (1970)

IN THE CONTEXT OF URBAN STATISTICS AND THEIR TREATMENT AND USE FOR DECISION MAKERS

Urban statistics includes all observations made by the public, semipublic and private organizations. The reasons for collecting the data are because of legal requirements, administrative needs or to facilitate decision-making. It appears that very little of the data recorded is, in fact, collected for decision-making purposes. This is an important fact.

The characteristics of the data systems suggest that most DATA ERRORS occur at the time the observation is made and that there is no significant ACCURACY DETERIORATION after recording. The RELIABILITY of data, however, is good - i.e. most data tends to be CONSISTENT from one reporting period to the next.

(Casual) Document (1964)

IN THE CONTEXT OF A STUDY ON THE COST AND VALUE OF INFORMATION

VALUE of information is most certainly tied to those familiar standards of ACCURACY and TIMELINESS. While well-known as clichés, they are, nevertheless also difficult to formulate.

ACCURACY, for example, may be merely spurious, tied to some degree of precision more apparent than real. There are cases where penny bookkeeping can give way to dollar amounts and truncated figures, probably with little loss in the essential MEANING and ACCURACY. Conversely, there are numerical methods which give entirely meaningless results because all PRECISION has vanished at the level of single length floating point computation. Approximate answers serve satisfactorily for many problems, while being inefficient for others. Building a system to obtain more accuracy may encounter additional costs with questionable improvements in value.

TIMELINESS of information is a complex function of the time period for which the information is gathered (interval) and the waiting time until it becomes available (delay).

DEPENDABILITY of information is an element of the value of the information and contains the statistical concept of STANDARD DEVIATION. More than PRECISION or AMOUNT OF DETAIL involved, dependability implies a system of BUILT-IN CHECKS from data - gathering, through data-processing (via validity and parity hardware), to data-recording, along with sound sampling techniques to insure that information is ultimately portrayed for conclusions with a high DEGREE OF CONFIDENCE.

(Casual) Document (1966)

IN THE CONTEXT OF A STUDY FOR THE DEVELOPMENT OF A CORPORATE PRODUCT INFORMATION SYSTEM

The Product Information System processes the information that is required to develop, market, build, schedule and maintain the company's product line.

The fundamental objective of any product information system is to provide to the operating functions of the business ACCURATE AND TIMELY information required to perform their tasks at a minimum cost.

System performance should be monitored against objectives and an evaluation should be done of the financial returns.

The performance of an information system is measured in terms of thruput capacity, TIMELINESS, CYCLE TIME, ACCURACY, cost per unit of information, ease of use, etc. Further, each of these factors interacts with the others, e.g. ACCURACY of information is directly related to its TIMELINESS. Fragmentation of the information system into subsystems contained within organizational divisions makes correlation of these factors difficult and financial understanding of the operation of the system almost impossible.

(Casual) Document (1970)

IN THE CONTEXT OF FOLLOWING UP THE DEVELOPMENT AND PREPARING FOR THE INSTALLATION OF A CORPORATE INFORMATION SYSTEM

The progress of the project of designing the corporate information system showed that the data bank has come to be recognized as being one of the most important parts of the system.

In parallel with this recognition it has become abundantly clear that the INTEGRITY OF THE DATA in the data bank, and the operational problems associated with the MAINTENANCE OF THIS INTEGRITY are going to be of major importance to the success of the overall system. The result of these insights is the evolution of the concept of DATA MANAGEMENT.

DATA MANAGEMENT is now a concept associated with the following activities which will ensure the continuing ACCURACY and INTEGRITY of the data bank:

1. DATA SPECIFICATION, for the documentation and control of all data codes, data elements, records, files, transactions, messages, and reports.
2. GENERALIZED INFORMATION RETRIEVAL, raising the problem of data security.
3. DATA SECURITY, requiring safety-dumps procedures and policy for protection of vital records.
4. FILE CLEAN-UP based on VALIDITY CHECKING of the data. Continuing DATA-BANK INTEGRITY, after initial clean-up will be based on CRITERIA FOR THE ACCEPTANCE OF DATA as well as on SAMPLING PROCEDURES, by which Data Management will be able to accept or reject the addition of a new system or of a system-extension in an on-line environment.

The paper goes on listing other activities of minor importance for our issue, such as: data bank layout and creation, file reorganization, and forecasting/allocation of storage space. The paper later states that the Data Management activities will be allocated among:

- LOGICAL Data Management, controlling e.g. the INTEGRITY of the data bank against data-specifications.
- ADMINISTRATION of Data Management, administering SECURITY procedures, documenting security violations and DATA ERRORS, and gathering data-bank statistics.
- TECHNICAL Data Management, controlling FILE CLEAN-UP and back-up procedures.

In a discussion of future organization and staffing of Data Management, the paper suggests a split of its responsibilities, allocating a part of them to the the company functions going under the names of:Technical Support (to Data Processing), Data Processing, Applications Development, and the "USERS".

Eventually the paper states that other concepts exist in close association with Data Management,(on which we have concentrated up to now) :

SYSTEM INTEGRITY - Analyzes e.g. the data-flow within a divisional location, considers environmental constraints, develops and issues philosophies for the design of information systems, and controls the INTEGRITY of the information system and of the data bank.

PLANNING AND CONTROL - Analyzes e.g. already installed local systems for compatibility,etc., develops installation plan for hardware, software and applications, and controls system costs and SYSTEM PERFORMANCE.

G.B. Davis (ed.) (1968)

IN THE CONTEXT OF AUDITING EDP SYSTEMS

In addition to evaluating the internal control of an EDP system, the auditor must evaluate the REASONABLENESS of those records produced by the system, which relate to the EXISTENCE and proper VALUATION of assets, liabilities, equities, and transactions.

Computer audit programs can assist in the performance of auditing procedures such as:

- Selection of EXCEPTIONAL transactions and accounts for examination.

- COMPARISON of data for CORRECTNESS AND CONSISTENCY.

- CHECKING of information obtained directly by the auditor, with company records.

- Performance of arithmetic and clerical functions.

- Preparation of confirmations.

EDP Analyzer (February 1968)

IN THE CONTEXT OF USE OF DATA MANAGEMENT SYSTEMS

> Unstructured reporting systems used for management control will be at the mercy of the QUALITY of the data stored in the data files. In structured data systems, experience from use has led to the establishment of the necessary data quality controls. Data of secondary interest, that does not appear in the structured reports, generally is not controlled - and therefore might have a high ERROR CONTENT. Such data could affect the unstructured system.

The following are given as some of the major causes of POOR DATA:

> ERRONEOUS DATA, including INCORRECT CODING of classification fields and WRONG INPUT of quantity fields.
>
> MISSING DATA - transactions not entered
>
> EVENTS THAT DO NOT CONFORM TO POLICY, but recording of these events is forced to fit existing data recording structures.
>
> Important fields normally NOT RECORDED FORMALLY; hard to control their quality when input to system.
>
> The TIME an event occurs may differ from its planned time of occurrence; it may be either early or late; may result in an apparent deviation from the plan that really has little meaning.
>
> Different organizational units may have different INTERPRETATIONS of the TIMING of an event; one "date of transaction" may not satisfy all users.

An example of the fourth cause above may be taken from a department store stock control where dollar inventory records are normally kept by class of merchandise. While it might be desirable to have actual stock inventory records by units of merchandise, it usually hasn't been economical to do so. Whatever the sales clerk records about the class of merchandise sold is used for updating of inventory records with no way to insure good accuracy of the class number.

Unfortunately, no examples are given of the very interesting case of events that do not conform to policy, being forced to fit existing data recording structures.

N.P. Edwards (1964)

IN THE CONTEXT OF EVALUATING THE COST-EFFECTIVENESS OF MILITARY COMMAND AND CONTROL SYSTEMS

A military command and control system may be seen as composed by subsystems for data-gathering or reporting, analysis, and transmission or promulgation of orders.

The relation of the first and of the third of the above subsystems to the issue of quality of information will be reviewed below. Prior to this, the author states that the ACCURACY of a cost estimate for a new control system depends upon:

1. The value of performance
2. The ACCURACY of the system, i.e. how well the function to be performed has been defined
3. The performance level desired.

In the context of the DATA GATHERING OR REPORTING SUBSYSTEM, the author argues that its major performance factors are timeliness, accuracy and reliability.

TIMELINESS. How much is it worth to have the data a day, hour, five minutes or sooner ? Given a specific data requirement, it is probably possible for an experienced military commander to put an arbitrary (approximate) value on the timeliness of the data.

ACCURACY. How much is accuracy worth in a data - collection system ? This again is dependent upon the nature of the system, of the situation and of the data, but also on the ACCURACY OF THE RAW DATA and the quantity of the data. Given a specific requirement for the data, arbitrary and approximate values can be assigned by the commander. It is not possible to do this in the abstract. (The ACCURACY OF THE SYSTEM could be defined as the percentage of the data entered into the system which arrives UNCHANGED at the output of the data-collection system).

RELIABILITY could be defined as the percentage of the time that the system is performing in its normal manner.

Certain types of command situations permit a relatively ACCURATE and profitable assessment of the value of timeliness, accuracy and reliability. Consider the case of a moving target with a known top speed. Knowledge of the EXACT PRESENT LOCATION is limited by the speed, accuracy and reliability of the reporting subsystem. If we don't know of any restraints on its direction of travel, we must assume the target has a certain probability of being within a circle whose radius is determined by its speed and the AGE AND QUALITY of our knowledge of its last position.

> If we assume for simplicity that we have an ACCURATE, reliable delivery system and a certain radius of kill, we can calculate the number of weapons which must be applied to the target area to give a desired probability of destroying the target.
>
> According to a model, the number of weapons goes up as a function greater than, but asymptotic to, the square of the LINEAR UNCERTAINTY as to the location of the target. This uncertainty includes, when you are estimating the number of weapons to stock:
>
> 1. The reporting ACCURACY
> 2. (Speed of the target) x (Probable reporting time loss)
> 3. A safety factor for the fact that the information you have may be older than you think (reliability of the reporting subsystem).

In the context of the ORDER TRANSMISSION SUBSYSTEM, the author states that

> ACCURACY is extremely important for the improved performance of each subsystem. RELIABILITY, i.e. the probability that the command will be delivered, is also of great value. The value of speed may be dependent in part upon the response time of the force commanded. Values can also be assigned to degrees of reliability and accuracy.

W. Edwards et al. (1968)

IN THE CONTEXT OF PROBABILISTIC INFORMATION PROCESSING SYSTEMS

Probabilistic information processing systems embody ideas which are relevant to any setting in which formal diagnosis is important, including governmental and business settings. In all such settings the decision-maker must face uncertainty and he typically feels that he has too little information. Much of the effort was aimed at dealing with uncertainty by providing decision-makers with more and more information. Unfortunately, more information is not the complete answer. Some way of providing better information would be ideal - a military commander would be delighted to know his opponent's battle plans.

But BETTER INFORMATION is often not available. ABUNDANT and often ACCURATE information about questions only peripherically related to what the decision-maker really wants to know must somehow substitute. THE PROBLEM OF DIAGNOSIS IS IN LARGE PART THAT OF MAKING QUANTITY OF INFORMATION SUBSTITUTE FOR QUALITY.

If people estimate likelihood ratios for each datum and each pair of hypotheses under consideration or a sufficient subset of these pairs, a computer can subsequently aggregate these estimates, by means of Bayes' theorem of probability theory, into a posterior distribution that reflects the impact of all available data on all hypotheses being considered. This circumvents human conservatism in information processing, that is, human inability to aggregate information in such a way as to modify own opinions as much as the available data justify.

J.C. Emery (1969)

IN THE CONTEXT OF THE ECONOMICS OF INFORMATION IN ORGANIZATIONAL PLANNING AND CONTROL SYSTEMS

In a formal model, one can through a process of selectively varying INPUT DATA over the estimated range of possible values, identify those variables that are critical in determining pay-off. Effort can then be spent on refining the estimates of the variable: but if the costs of such REFINEMENT or the INHERENT STATISTICAL VARIABILITY in a process preclude narrowing the range of the estimate to within the region of relative insensitivity for the variable in question, one might better try to make structural changes in the physical process (e.g. production process) being modeled, rather than try to improve FORECAST ACCURACY.

In the absence of quantitative estimates of INFORMATION VALUE, design decisions in developing organizational information systems must be guided by QUALITATIVE CHARACTERISTICS OF INFORMATION that govern both its value and its cost. We speak then of approaches that require a lower degree of formalization.

ACCURACY and RESPONSE TIME may be seen as two of the quality characteristics that determine the VALUE and the COST of information.

QUALITY CHARACTERISTICS WHICH DETERMINE THE VALUE OF INFORMATION :

RESPONSE TIME can be defined as the time interval required to perform an information processing operation: updating of a record or the retrieval of the data. Reducing the time interval to update a record means that the data base provides a more CURRENT VIEW of nature: if the planning horizon extends only a short time into the future and if nature is quite uncertain so that any prediction about the future is subject to rapid decay, the reduced updating time (or more generally a reduced processing time lag) means a significantly shorter prediction span and increases the ACCURACY in estimating (predicting) the future state of planning variables over the planning horizon.

ACCURACY. In the case of decision processes that deal with unaggregated data, the VALUE of information may be highly sensitive to ERRORS, (e.g. an error in a bank account balance may be very expensive). When data are aggregated for high-level decisions (such as an analysis of bank deposits by districts) the VALUE OF GREAT ACCURACY drops off sharply.

Accuracy refers not only to the DEGREE TO WHICH SENSED INFORMATION CORRESPONDS TO THE ENTITY IT PURPORTS TO MEASURE; it also applies to the DEGREE TO WHICH A PREDICTED VALUE (such as sales forecast) CORRESPONDS TO THE EVENTUAL ACTUAL VALUE.

If the values over time of a given variable exhibit some stability (e.g. if the current rate of sales is related to previous rates), RANDOM ERRORS in sensing or prediction can be reduced by "smoothing" the data through an averaging process. Increasing the time span over which data are averaged reduces the random component of the resulting average at the expense of reducing its RECENCY (dealying its availability). Thus a trade-off often exists between ACCURACY AND RECENCY.

QUALITY CHARACTERISTICS AS THEY AFFECT THE COST OF INFORMATION

RESPONSE TIME costs are related to computation costs (batched or random processing of transactions) and to data transmission costs.

ACCURACY. Almost any degree of PERFECTION can be achieved, but costs tend to rise very steeply as perfection is approached. Accuracy is achieved primarily through REDUNDANCY,DUPLICATION, CHECK DIGITS, REASONABLENESS CHECKS, VALIDITY CHECKS; all these ERROR-CONTROL TECHNIQUES rely ultimately on some form of redundancy, and all cost money in the form of extra data-collection, transmission, storage or processing.

QUALITY AS DISCUSSED IN THE CONTEXT OF DATA-MANAGEMENT

In order to keep the data base a faithful image of reality, the data-management function must maintain the VALIDITY of the data entering the system.

Typically, the data base already contains considerable prior information about input data: their format, allowed character mode (e.g. alphabetic or numeric), and the set or range of permitted values. The input data are thus partially redundant. THIS PROVIDES A MEANS TO TEST FOR VALIDITY. If the input data meets all checks as to FORMAT, RANGE, and so forth, they are assumed to be valid. Validity checks can then screen out many common errors and can usually call into question a "large" error. A "small" error is much more difficult to identify, but failure to detect it often results in relatively minor consequences.

IBM (Form F20-0006)

IN THE CONTEXT OF AUDITING AND OF MANAGEMENT CONTROL OF ELECTRONIC DATA PROCESSING

In considering the entire business organization, the controls which management uses to accomplish its objectives may be described as
"the plan of organization and all of the coordinate methods and measures adopted within a business to safeguard its assets, check the ACCURACY and RELIABILITY of its data, promote operational efficiency, and encourage adherence to prescribed managerial policies."

This broad concept of control applies to any function in an organization, including an EDP system. In terms of the EDP system itself, however, controls may be described as
"a plan to ensure that only VALID data is accepted and processed, COMPLETELY and ACCURATELY, and that necessary information and records are provided".

The auhtors go on developing the meaning of several of the terms used in the statements above.

VALID means CORRECT and AUTHORIZED

COMPLETELY means "remaining intact throughout processing, and being fully processed through all appropriate computer operations".

ACCURATELY means "without undetected ERRORS". It means further, that processing FULLY ACCOMPLISHES ITS PURPOSE and is in accordance with management's policies and instructions.

NECESSARY INFORMATION means "data reported by the EDP system both for operating purposes and for comparison with related data available from within the EDP system or external to it for the purpose of proving the COMPLETENESS and ACCURACY of the processing and identifying exceptions thereto".

RECORDS means "an information trail and retrievable data storage adequate for the reconstruction (if necessary) of current records either for future processing or to meet the information requirements of management, customers, auditors, Internal Revenue Service, and other outside agencies".

By incorporating control-providing procedures in an EDP system, not only will the system possess a high degree of RELIABILITY, but also the ACCURACY and ORDERLINESS which result will lead to greater processing EFFICIENCY by reducing the number of ERRORS that require manual intervention and reprocessing. Another advantage to be derived from accomplishing the control objectives concerns the risk of loss through INTERNAL FRAUD.

IBM (Form SC20-8096)

IN THE CONTEXT OF AN INTRODUCTION TO "DATA MANAGEMENT"

> DATA MANAGEMENT is the control, retrieval, and storage of information to be processed by a computer. Each of these three areas of data management is an essential function of any information system.

The paper goes on defining and discussing each of the three concepts above. We shall concentrate our attention on "control" since it most closely affects the aspects of information-quality.

> CONTROL is the authorization and supervision of the data management process. AUTHORIZATION IS THE VALIDATION of a user's right to access or modify the information in the system. SUPERVISION includes monitoring the location of information, insuring against data loss (DATA INTEGRITY) and insuring that the information in the system is CURRENT.
>
> In the above context, INFORMATION is defined as ideas and FACTS about ENTITIES such as people, places, machines, etc. Information about entities is composed of:
>
> 1. CONTEXT defined by the characteristics of an entity, also called information ATTRIBUTES. For people they are e.g. Name, Address, Social Security Number etc.
> 2. DATA, which is represented by DATA VALUES, e.g."John Smith"for the attribute "Name"
> 3. DATA REPRESENTATION, which is represented by DATA ATTRIBUTES (e.g. "20 Alpha Characters")
>
> It is the function of Data Management to build MEANINGFUL INFORMATION by bringing together the PROPER context, data, and data representation.
>
> An Information System is a system that controls, maintains and provides concurrent access to a pool of information for AN IDENTIFIABLE SET OF USERS. One of the advantages of an information system is that it makes possible DATA CONSISTENCY: access to data can be limited to those users capable of using it correctly. Because the system processes each field it can also check to see IF THE VALUE OF THE FIELD IS VALID AND REASONABLE. However, even if the system can provide REASONABLENESS CHECKS, it cannot be responsible for the ABSOLUTE VALUE OF THE DATA.
>
> System knowledge of context IS THE MOST IMPORTANT DESIGN CRITERIA OF AN INFORMATION SYSTEM. Another requirement or criterium is the SECURITY AND INTEGRITY OF DATA, i.e. protection against accidental, inadvertent loss or destruction and INACCURACY of sensitive data (DATA INTEGRITY) and protection against unauthorized access (DATA SECURITY). Equally important as prevention is the detection and correction of events violating security and integrity.

R.H. Lauren (1970)

IN THE CONTEXT OF RELIABILITY OF DATA BANK RECORDS

The problem of RELIABILITY is the problem of insuring and maintaining the ACCURACY of information contained in data banks, regardless of who has access to the data or whether the information is private or public.

In regard to reliability, two specific areas are identifiable for concentrated effort in the future:

- The problem of existing files.- How to CLEAN UP them to meet whatever STANDARDS will be ACCEPTABLE.

- How to increase the areas of CONTROLLABILITY for the input of information.

H.G. Lundin & B. Sundgren (1969)

IN THE CONTEXT OF A DEBATE ON PUBLIC DATA-BANKS AND NATIONAL INFORMATION CENTERS

In order to define the risks and responsibilities implied in the design and operation of data-banks, the authors use in the above context a matrix in order to visualize the interactions or consistencies among the goals-desires emanating from the government, the citizen as an individual, and organizations such as business firms, newspapers and political parties.

	Government				Citizen-Individual				Organi-zations	
	01	02	03	04	05	06	07	08	09	10
Follow-up 01	+	+	+		+	-	-	+		
Planning 02	+	+	+			-	-	+	+	
Obligation rep.03	+	+	+	+		-	-	+	+	+
High quality 04	+	+	+	+	+	-	-	+	+	+
Legal security 05					+		+	+		-
Low rep.effort 06	-	-	-	-		+			-	-
Integrity 07	-	-	-	-			+		-	-
Social service 08								+		
Marketing info 09		+			-	-	-		+	+
Data on others 10	+				-	-	-		+	+

In the "conflict matrix" above, the sign "+" at row 10 and column 01 shows that goal 01 has goal 10 as precedent, that is, the possibilities for follow-up control are improved by the contribution of detailed information on others (citizens-individuals and business firms). Blank positions stand for neutrality or independence. The goal-numbers mean the following:

01 - Possibilities to follow-up the implementation of laws such as on taxation and military service
02 - Basis for social planning
03 - Imposition, obligation to report to the data-bank in order to guarantee"automatic" flow of updatings
04 - High quality of data

05 - Legal security for the individual
06 - Low reporting effort, respect for the citizen's time
07 - Integrity, protection against discrimination
08 - Follow-up of right to social benefits

09 - Market information like addresses of possible customers etc.
10 - Detailed information on citizens, other organizations, competitors, etc.

The matrix proposes that high-quality is a desire emanating from the government. It gives positive contribution to all other goals except for the individual's goals 06 and 07 above. Furthermore, high quality is supported by (receives positive contribution from) goal 03, is opposed by goals 06 and 07, and is neutrally preceded by all others.

The authors go on using the matrix in order to roughly summarize the overall conflict or consistency of overall goals between government, citizen, and organizations. This is done by noting whether the sign "+" or "-" is predominant in each "sector" of the matrix above. This leads to the following sector-matrix:

	Gov.	Cit.	Org.
Gov.	+	-	+
Cit.	-	+	-
Org.	+	-	+

The authors suggest that the commonness of interests between government and organizations, and their conflict with the individual citizen's interests especially 06 and 07 require the set-up of official parliamentary controls.

In spite of HIGH QUALITY playing a role in the authors' approach, the term is not defined and an explicit justification is not given for its inclusion among the GOVERNMENT'S goals.

Two other authors, however, B.Hansen and A.Rickardsson have used the same matrix-approach in the context of an undergraduate paper presented year 1970 at the Royal Institute of Technology of Stockholm, Dept. of Information Processing. They analyze the goals of an official public data-bank on the country's business organizations, and they suggest that HIGH QUALITY of data is

- HIGH CURRENCY (i.e. low"age")
- CORRECT CONTENT
- COMPLETE COVERAGE

The problem of currency is seen to be affected by the sources of information that are used for the updatings.

The coverage of the target population is seen to be incomplete to the extent that there are no possibilities to add new sources in the systems design.

The correctness of the information is seen as the result of proper COVERAGE and IDENTIFICATION of the target population. As in the two previous statements, the definitions are not explicitly given but they are in our own opinion rather implied by the text. What we called correctness in the third statement corresponds to "satisfactory presentation of results (satisfactory from all points of view) to future consumers of statistics."

G. Montelius et al. (1970)

IN THE CONTEXT OF A THEORETICAL ANALYSIS OF ERRORS AND THEIR CONSEQUENCES IN AN INTEGRATED CONTROL SYSTEM

The authors develop some definitions of error based on the following:

> Consider a number of input-elements Xi, which undergo a process Fi, and give a result-element Yi.
>
> One can thus write Yi = Fi (Xi).
>
> By ERROR, in this context it is meant that Yi $\neq$ Fd (Xi) for at least one i, where Fd stands for the DESIRED, i.e. the "RIGHT" process. One can therefore also write the definition of ERROR as
>
> Fi $\neq$ Fd
>
> since the input-elements must be regarded as neutral from the viewpoint of the considered process.
>
> An extension of the above definition can be applied to defining
>
> RANDOM ERROR = The consequences of Fi not being identical to Fd for randomly distributed i
>
> SYSTEMATIC ERROR = The consequences of Ft not being equal to F t+1, and F t+1 is right. (t is a time index).
>
> THE PROBLEM OF DETERMINING WHETHER THERE IS SOME ERROR HAS NOW BEEN TRANSLATED TO THE PROBLEM OF DETERMINING WHETHER Fi is right, i.e. WHETHER Fi = Fd.
>
> In order to be able to start a system at all we must commit ourselves to a Fd on the basis of experience, and assume that it is RIGHT: sometimes we must terminate the search for the absolute TRUTH and start the system. Our assumption that the selected Fd is "RIGHT" does not actually imply that ERROR-CONTROLS are unnecessary - we have only prescribed a standard.

Eventually the authors consider the error-thinking suggested by numerical analysis: Input-element (the number) is equal to the result-element (the measured value + error). They state that such understanding of error is obviously better in the case of continuous variables, but it is not adequate to illustrate e.g. keypunch-errors. They state that the former concept of error can be translated to their proposed "right/wrong" concept by establishing control limits (error limits).

Orlicky (1969)

IN THE CONTEXT OF INPUT DATA INTEGRITY AS ONE ASPECT OF SYSTEM OPERATION

> The computer system functions with full success only in a "perfect" environment, which would include ERROR-FREE, COMPLETE, and TIMELY data. When data lack INTEGRITY, a computer system tends to fail. The seriousness of the consequences will vary with the application. It may be minor where the computer is used as an analytical tool or rapid-fire calculator. In these cases, resulting outputs are used for evaluation or as an intermediate step within some larger function, but they do not reflect operating decisions.
>
> In computer-based operating support systems, however, many such decisions are programmed for the computer to make and low quality input data heavily contribute to failures with far-reaching consequences!
>
> The QUALITY of input data varies with their source. Accounting data are, as a rule, the most ERROR-FREE followed by engineering, purchasing, production control, and marketing data, in roughly that order. The incidence of error is always highest in the labor and production data being generated in factory operations, particularly where production workers themselves report (by whatever means) their activities to the system.
>
> INPUT DATA INTEGRITY results from education, discipline, system checks, and the capability to investigate and correct. System checks against input errors may be classified as
>
> 1. The barrier or filter, i.e. programmed or manual capability to detect and reject incorrect transactions at the point of entry, by means of self-checking digits or diagnostic routines for comparison with other files.
> 2. Internal detection by checks made against the file being updated.
> 3. Washing out residues, i.e. detecting and removing the effects of undetected errors by reconciliation, purging and close-out procedures.

The author sees FILE or DATA BASE INTEGRITY as distinguished from the above mentioned input data integrity:

> A single change of e.g. departmental boundaries in a manufacturing plant, may "explode" throughout a routing file calling for thousands of revisions. This problem must be met by adequate staffing and budget for FILE MAINTENANCE

Among aspects of SYSTEM DEVELOPMENT, the author mentions FILE CLEAN-UP during conversion to new format. Such conversion should then include AUDITS FOR ACCURACY.

S. Owsowitz & A. Sweetland (1965)

IN THE CONTEXT OF A STUDY OF FACTORS WHICH AFFECT CODING ERRORS

> Information processing generally begins with making observations and recording them. Under modern information processing they are then keypunched. From this point on, the major part of processing is done by machinery which is almost ERROR-FREE. The errors occur in the inputs: the recording and keypunching.
>
> 1. As a first approach, to date, the major effort in solving the ERROR PROBLEM has gone toward DETECTING errors in the document themselves.
>
> 2. A second approach is to CONTROL error instead of eliminating it. The statistical methods used to randomize and balance error are a simple illustration of control, as in the computation of fiducial limits. Another way of controlling error is to reconstruct the erroneous information to yield a TRUE record.
>
> 3. A third approach is ERROR PREVENTION. This might be called "designing" human-factor elements into data-processing systems, in order to make the coding situation as error-free as possible.

The authors consider the third approach as a way of improving the VALIDITY OF THE DESCRIPTION of a system. They do so by concentrating the study on the coding-keypunching sequence of the overall coding process. They define these latter terms in the following way.

> Given that a component (system, black-box, bit or piece etc.) is in a status that can be described and coded, and given a sufficient and adequate code, the CODING PROCESS can be subdivided into a number of steps:
>
> 1. The human observer examines the component and judges what its status is.
> 2. Referring to his manual, he finds a word or phrase that describes his judgement.
> 3. After finding the APPROPRIATE description he enters the corresponding code on the form.
> 4. The form is reviewed by one or more people who may make corrections.
> 5. The form is keypunched and verified.
>
> The series of steps 2. to 5. of the overall coding process above is what was previously referred to as the CODING-KEYPUNCHING SEQUENCE.

The authors state that if the description keypunched on the card ACCURATELY describes the status of the component, then the description is VALID. If the system CONSISTENTLY records the TRUE statuses of a large number of components, then the system is a VALID recording mechanism. Thus, the validity of a system is vulnerable at a number of places. The reported study tries to answer the question: "what kinds of coding reduce the validity at the coding-keypunching sequence ?".

G. Rodin (1971)

IN THE CONTEXT OF DESIGN AND USE OF DATA BANKS FOR REAL-TIME SYSTEMS

DATA QUALITY is a measure of the deviation of the data from the IDEAL value. Quality may be further subdivided in four groups:

COMPLETENESS means that all information that should exist actually exists in the data bank. The concept also includes the requirement that there is no unnecessary, superfluous information stored in the bank.

PRECISION and declaration of the degree of precision is only of interest in the case of continuous variables like when specifving the width of a road: the data may be of no use if the PRECISION, i.e. the ERROR LIMITS are not known. Precision is particularly important if several users will have access to the information: the precision must then be good enough for the requirement of all users. For future requirements it is also necessary to specify how good the quality is.

CORRECTNESS. For most kinds of data which are stored in public information systems it can be said that they are either RIGHT or WRONG, e.g. birth date, social security number or marital status. For other continuous variables like e.g. temperature,the correctness may be affected by two types of errors: VALIDITY ERRORS when not measuring what is believed to be measured, and RELIABILITY ERROR of the measured value itself. For instance a validity error is made if one tries to establish the position of a house by measurements on a map that only shows the limits of the lot on which the house is built, and it is assumed that the house lies at the "analytical centroid" of the lot surface. The reliability of the measurement data is determined by the PRECISION with which this analytical centroid is measured.The reliability is then depending upon the precision: if all values fall within the error limits, the reliability is said to be great.

CURRENCY. In the course of time, depending upon updating procedures, different data become of different age. In certain statistical applications it is important to have information on the age of data.

The author goes on discussing as a separate point the issue of DATA SECURITY:

Security of a data bank system means:

- Protection against disturbances (interruptions) of system operation.
- Protection of data against loss of data, change of data and particularly against UNAUTHORIZED CHANGE AND DISSEMINATION OF DATA (SECRECY). The latter is to be regarded as a necessary condition of high quality of data.

The same author also discusses METHODS FOR OBTAINING HIGH DATA-QUALITY:

There are possibilities for checks of inputs both inside and outside the computer system. The outside check may consist of verifying that CODING IS CORRECT by requiring double input of the same data, possibly coded by two different people and input by two different people. Furthermore the system may be programmed to respond to the first input by requesting a confirmation and stating the importance that the particular input be absolutely right. The system may also furnish at some print terminal a hard copy of the on-line input for proper visual check against the original documentation.
The inside checks in the computer consist of the well known REASONABLENESS OR LIMITS AND VALIDITY TESTS.

QUALITY CONTROL OF THE DATA in the data bank may be performed on a continuous basis e.g. by means of sampling followed by the above mentioned types of checks. Statistics about the controls may be later used to detect ANORMALITY IN THE QUALITY which may be an indication of serious quality problems.

OBSOLETE AND UNNECESSARY data must be regularly deleted, leading not only to higher quality but also to economy in processing time.

One way to improve quality is to give a MEASURE OF QUALITY. It can be for instance a measure of some aspects of quality such as PRECISION and CURRENCY. A measure of the latter might be information about when the data was stored or updated the last time. Such measure will have to be specified and stored at the record or data-element level in case the quality is not the same for the whole data bank or file. Without such individualization the overall quality of the data bank will be determined by the weakest link, i.e. by the data with the lowest quality.

One way of checking the contents of a data bank is to furnish copies of the stored information to the inputters who have interest in its CORRECTNESS. Such procedure would also result in less fear or resistance against the development and use of data-banks.

C.J. Weinmeister III (1971)

IN THE CONTEXT OF PRACTICAL GUIDELINES FOR THE DEVELOPMENT OF MANAGEMENT INFORMATION SYSTEMS

> A successful management information system is a system designed to provide the operational management with ACCURATE information upon which to make sound decisions. Success is the object of such a system. It must be management-oriented and the data, whether it be manual or automated, must be ACCURATE and available to the manager.

The author develops the paper starting with two hypotheses one of which is that management information systems have failed because of inadequate attention to data-base construction. Prior to stating nine data-base design criteria, the author provides a basis of nine so-called "information theory statements" some of which are given here below since they apparently relate to the issue of quality of information.

5. The VALUE of information varies with its USEFULNESS. Usefulness changes with time. The degree of usefulness (from "critical" to "of marginal value") should be a prime determinant in choosing methods and frequency of collection, transmission and storage.
6. Information use changes with age. All information passes through a continuance of stages of CURRENCY, from absolute currency, through historical and to forgotten. The use of this data/information varies with currency.
8. The more PERTINENT the available information, the better the decisions. Having the CORRECT data in the correct place at the correct time is of paramount importance.
9. Most information contains some ERRORS. One of the paramount tasks of all gatherers of data and processors of information is to lower the error rate. Time injects errors into data, for data are constantly changing.

And among the nine data base design criteria:

6. The system design must ensure that the data are ACCURATE, CURRENT and accessible. Information users quickly lose confidence in data which is obviously inaccurate either because of IMPROPER data input or because of OUTMODED data which should have been replaced. Accuracy may be checked at input, by preprocessor checks and by manual comparisons. The more data are used the more accurate they will become. The most effective method of data purification reamins data use. Currency of data is a relative quality depending upon the function of the system. The update cycle is the key to currency.

Tiina Berglund & Brita Larson (1969)

THE EFFECT OF THE PUNCHED CARD LAY-OUT ON THE QUALITY OF STATISTICS

The following lay-outs were studied,

A. Fixed position and fixed length
B. Fixed length and variable order
C. Variable length, fixed order
D. Variable length, variable order

In former studies on punching errors, the authors observe, the FREQUENCY OF INCORRECTLY PUNCHED CARDS OR CARD COLUMNS has been used as a quality measure. In this study, the above measures were insufficient, since the same type of punching error might affect the information items quite differently depending on the type of layout (e.g. if the digit happens to be a field tag).

A new kind of measure related to the need of VERIFICATION is required. The AMOUNT of the EXACT DEVIATION between the VALUE written on the form and the punched value gives for each individual item on the form, a measure of the NEED OF VERIFICATION. However, such measure is time consuming to obtain manually, and therefore the NUMBER of incorrect items and of digits are used as approximations to the amount of exact deviation. The measure of the number of incorrect digits included all digits immediately to the right of the incorrectly punched one.

The investigation then relates the two new suggested measures to the total number of items and digits. In comparison with the measures conventionally used, similar measures were included - the number of punched cards with incorrect values and the number of punch errors committed. The study used field-filled forms of the Swedish Agricultural Survey in June 1964 consisting of 1340 forms with place for 70 items each leading to a total of 93,800 items out of which only 22,000 had been filled with a total of 41,200 digits. The following table summarizes the results:

ALL TYPES OF ERROR	TYPE OF LAYOUT			
	A	B	C	D
Wrong items				
- In percent of all items	1,2	0,3	2,7	0,9
- In percent of filled items	5,0	1,5	11,4	3,9
Wrong digits				
- In percent of filled digits	5,3	1,6	11,9	5,5

The study proved that different layouts might influence the quality of the statistics: in the case, B and C are the most respectively least favorable layouts. Moreover the results indicate that traditional quality measures are not able to discriminate between different punching layouts. The relative number of wrong items varied between 0,5 and 9,4 % for errors directly assignable to punching layout. The corresponding relative numbers for incorrect digits varied between 0,5 and 9,6 %.

At the conceptual level, the Berglund-Larson study is also interesting because of the error-classification scheme. Punch errors were investigated in order to differentiate the importance of the following influence factors, besides the punch layout itself:

ERRORS DUE TO THE NATURE OF ORIGINAL MATERIAL, such as bad handwriting, changes in the originally field-filled digits, and alternative forms of decimal figures.

ERRORS DUE TO PUNCHED CARD LAYOUT such as

IN LAYOUT A: -Displacement of item values to another place on the card
-No card number or wrong card number (this error is also influenced by the choice of punched medium: card, paper or magnetic tape)

IN LAYOUT B: -Missing or wrong item identification for the item values
-Displacement in some column (not whole field length) of the item value

IN LAYOUT C: -Missing field separation character between item values
-Too many field separators between item values
-Missing or wrong card number on the card (this error is also influenced by the choice of punch medium)

IN LAYOUT D: -Missing field separators between item values
-Missing or wrong identity for item values

ERRORS DUE TO MISCELLANEOUS such as transposed digits, wrong digits when the original was clearly readable, forgotten item values, wrong form identities and missing cards. The last kind of error is influenced by the choice of medium while the others may be related to the skill-degree of punch operators.

Bürotechnische Sammlung (1956)

ON THE NATURE OF ERRORS IN PUNCHING NUMBERS

As referred by M.Jönsson in Mekanresultat 71008 (1971), 12 million numbers were keyed with no specified equipment and procedures, resulting in 10,400 wrong numbers, i.e. 0.08 %. Analysis of the errors in terms of digit manipulation may be summarized in the following table; (average of percentages for adding and card punching machines):

- insertion of digits	4 %
- omissions	7 %
- single digit substitution	77 %
- multiple digits substitutions	12 %

B.L.Cardozo & F.F.Leopold (1963)

HUMAN CODE TRANSMISSION

The experiment was set up to study in terms of information theory (theory of signal transmission) some aspects of operations where the the operator's task is simply of a link or a "human code transmitter". The operator does not PROCESS the coded information but has simply to render TRULY both the SYMBOLIC CONTENT and the ORDER in which the symbols appear.

ERRORS were defined as any difference in each position of the code. Figures were however obtained also for ERRORLESS TRANSMISSION, i.e. for entries (whole codes) with no errors, compared with those with AT LEAST ONE error.

Independent variables were code forms (letter, digit, combined letter and digit), aural or visual presentation, information content in terms of information theory, rate of presentation and grouping of items inside the code.
Dependent, studied variables were the number of errors (loss of information) and the percentage of errorless transmission (100 minus the percent of codes with at least one error).

Special features of the experiment were e.g. the deletion of the letter M from auditory experiments to avoid its confusion with N; the adjustment of the number of digits in relation to the number of alpha - letters in order to be able to compare codes with the same information content but different alpha content; avoidance of codes which contain aids to the memory(such as for certain telephone codes), and advance information to the subjects of the experiment about the structure of the codes to be presented (quantity of digits or letters), and adequately long writing fields on the forms - which the subjects knew should be completely filled out.

The results show that errors began to occur for codes with an information content of more than 20 bits (about four letters or five digits). The experimentally determined frequency of errorless transmission for the entire code was higher than the calculated based on the assumption for probability of incorrect digits, derived from the number of errors in reproducing 7-digit codes. This suggests that errors are not uniformly distributed over the codes, but have rather a tendency to cluster.

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Typical figures for errors were e.g. 2 errors for 8 symbols in alpha codes, or equivalently 10 symbols in digit (numeric) codes. The figures were obtained by averaging over a heterogeneous group of subjects.
For e.g. an 8- digit code the calculated probability of errorless reproduction is about 35 % against the experimentally found 65 % (approximate); for a letter code the calculated probability of correct reproduction is about 70 % against more than 80 % experimentally found when considering a letter-code length of the same information content (10 exp 8 possibilities) as the 8-digit code.

G. Carlson (1963)

PREDICTING CLERICAL ERROR

A study aimed at predicting clerical error in EDP environment, reports some findings from analysis of input error in a highly automated bank central office.

Since error was an infrequent occurrence with regard to the bulk of behavior, a laboratory approach was economically prohibitive. The solution was to locate a large amount of historical data on errors made in encoding dollar amounts on money checks for further MICR (Magnetic Ink Character Recognition) processing.

The study gave some side-results, like indicating that errors per 1,000 items listed (checks) varied during a week between 1.002 and 1.203, the peak rate being on Tuesday, typically the day of the week with highest error rates. Furthermore the study confirmed the negative relation between error-rate and speed of listing, the fastest operators making the least errors. Finally, a classification of the kinds of listing errors showed that

digit substitution errors accounted for	62.4 %
omission errors for	20.7 %
insertion errors for	6.0 %
transposition for	1.5 %
double substitution	2.1 %
double omission	2.3 %
double insertion	1.1 %
miscellaneous	3.9 %

Besides the results above, the study actually aimed at the development of predictive routines indicating the item listed in error and the place within the item, such as the last digit, or the two first digits, etc. An explanation is now required for the often used term "listing".

The setting of the study was a central location where checks from outlying branches and banks are brought at the end of the day's work to be listed and then sorted to the maker's branch or bank. The equipment used was check proof machines of common make. The operator detects an error by noticing a discrepancy between the incoming tape total and her current master tape total. The predicting routine had a goal of using a heuristic approach to create a binary decision tree that by processing of the correct list would simulate human error and predict errors, to be used in the investigations in search of the actual errors. Out of 4,155 new errors, 46 % were correctly predicted by the developed set of routines. These 46 % should be compared with the 10 % corresponding to what should be expected from a straight chance prediction, or 20 % when considering certain obvious higher-probability errors such as that 3 is more often changed to an 8 than to a 1.

Note: as an implication to the initially mentioned side-results' figures, it may be suggested that the error rates (errors per 1,000 items listed), combined with the listing volumes per day (varying during the week between 232,000 and 385,000 for 54 operators), would imply - prior to correction procedures - the input of 240 to 420 errors per day into the system at that particular installation.

R. Conrad & A.J. Hull (1967)

COPYING ALPHA AND NUMERIC CODES BY HAND: AN EXPERIMENTAL STUDY

The identification of individuals or "items" in an information system, as well as other requirements for identification of e.g. transactions, implies use of CODES. These codes are often groupings of alphanumeric characters and they are likely to being copied into forms, etc. by an increasing number of people including the untrained general public.

Against this background a study was made for comparing error rates and speed when codes are presented to the "copier" in different ways. In varying degrees the following factors were investigated:
- distance between source code and copy
- length of code
- configurative grouping of digits within a code
- all alpha or all numeric codes.

The percent of wrong codes resulting from errors in simple copying was in this way shown to vary between 1.11 and 3.15 for codes of mixed lengths of 3,6,9, and 12 digits under various conditions of the other factors above.

When sorted in groups of same length, the codes resulted in error rates varying from 0.33 % (for length of 3 digits) to 4.19 % of wrong codes (for length of 12 digits). The copying errors were also analyzed by CRITERIA OF INCORRECTNESS and classified in classes below, under varying combinations of the earlier mentioned factors:
- Transposition 4.3 - 24.1 %
- Substitution 33.1 - 86.9 %
- Addition (+1) 1.9 - 7.2 %
- Omission (-1) 4.9 - 53.9 %

G.B. Davis (editor) - (1968)

ON THE ACCURACY OF OCR (OPTICAL CHARACTER RECOGNITION) IN THE CONTEXT OF AUDITING OF EDP SYSTEMS

In the context of discussing hardware features for control over equipment malfunctions, the author frames the OCR accuracy problem in terms of two rates: the REJECT rate and the ERROR rate.

> The reject rate is the percentage of documents rejected because the equipment is unable to recognize the character. At the state of technological development around years 1967-1968 typical reject rates were in the range 2 - 20 %.
> The error rate is the percentage of documents which were read but which contained one of more characters incorrectly identified. The typical rates ranged from less than 1 % of documents up to 2 %.

The reject rate is said to be significant in terms of handling time and reprocessing. The significance of error rate is dependent upon the application: 1 % error rate may be quite acceptable for one application but totally unacceptable for another.

EDP ANALYZER (SEPTEMBER 1971)

IMPROVEMENTS IN DATA-ENTRY: GENER L CONSIDERATIONS AND KEY-TO-TAPE DATA ENTRY SYSTEMS

In a report on developments of data-entry devices, the above issue of EDP Analyzer refers indirectly to experience on input error-rates. For example, the input data error rate is said to have been very good - less than $\frac{1}{2}$ % - for keypunching of cards at a specific installation. Conceivably it refers to rate after punch verification and from what follows it apparently refers to number of keystrokes rather than number of entries - in some sense.

In discussing the importance of easy correction capabilities at entry devices, a reference is made to a report by R.F.Carey who, in the June 1970 issue of Datamation, states that 85-90 % of keying errors were immediately sensed by the operators of specific entry devices which allowed keying of entire records into an intermediate storage device or buffer.

In discussing ACCURACY requirements, tolerable error rates are said to vary anywhere from an average of one error per 20 keystrokes up to and beyond an average of one error in 10,000 keystrokes.

Accuracy requirements appear to be considered high and demanding if they are set at about one error in 10,000 or more keystrokes in keypunching. When this error rate is attained in typewriting for OCR input, it appears that proofreading detects few of the errors. Accuracy is named as being especially important e.g. in dealing with legal documents.

The considered issue of EDP Analyzer is also interesting for its attempts to clear up the error issue at a more conceptual level. In discussing data-entry it separates the subject of verification from the subject of validation.

VERIFICATION is defined as the process of assuring (through detection and correction) that the data recorded on a source document has been TRANSCRIBED ACCURATELY to machine language.

VALIDATION is defined as the process of assuring that the SOURCE DATA WAS CORRECT, by such means as logical checks, control totals, check digit checking etc.,i.e. more generally by testing input data fields against some DATA DEFINITION for those fields.

Also at the conceptual level it is interesting to note that validation methods are considered as one of the types of verification, implying some kind of conceptual overlapping of the used words; it is stated for example that some validation checks also perform verification, "but it is incorrect to assume that all verification can be eliminated by validation checks" (EDP Analyzer,Oct.1971,p.8)

EDP Analyzer concentrates further on the subject of verification, while validation is to be discussed in the October 1971 -issue. Other mentioned types of verification, besides validation methods, are KEY VERIFICATION and SIGHT VERIFICATION. In discussing criteria of choice between these two methods, reference is made to a study by R.C.Turnblade which reportedly classifies input data in three types in terms of their MEANINGFULNESS TO THE READER:

> LANGUAGE TEXT such as name and address data, which is familiar and MEANINGFUL TO MOST PEOPLE.
>
> BUSINESS JARGON such as part names, part numbers, business form entries which take on meaning to the extent that a person becomes experienced in using such types of data.
>
> "NONSENSE" DATA, such as quantities and code numbers, which are essentially not meaningful to the casual reader in the sense that he cannot tell whether it is RIGHT or WRONG just by looking at the number.

As referred by EDP Analyzer, in discussing the criteria of choice of method of verification, Turnblade uses

1. Types of meaningfulness (listed above)
2. Allocation of functions in creating the data - versus entering it: also interpretable in terms of frequency of repetition of task/familiarity of the operator with the particular job.
3. Ease of correction
4. Accuracy requirements.

The criterium of type of meaningfulness interacts strongly with that of allocation of function in that Turnblade conceivably considers that meaningfulness is a function of both the type of data (in terms of meaningfulness) and of whether the person entering the data is the same who created the source document.

In summarizing part of the above discussion, in what concerns sight versus key verification, EDP Analyzer of October 1971 states that sight verification is useful for data that can be verified in terms of words or phrases while key verification is needed where the data must be compared on a character-by-character basis.

Eventually, especially in the context of key-to-tape systems, EDP Analyzer introduces a new terminology variant by defining UNCORRECTABLE ERRORS as those source data-errors which are caught by validation checks. When such checks,(e.g. to see that a value falls within a specified range, or is a member of a specific set of values),fails (i.e. detects an error) during data entry, it means that the source data is WRONG and it should be considered UNCORRECTABLE (possibly meaning "by the operator") at the entry stage. Attempts to correct such errors would heavily affect the effectiveness of the entry process; the offending field should be rather marked, bypassed and logged for later human analysis. UNCORRECTABLE errors must therefore not be confused with RESIDUAL when these refer to undetected at entry and introduced into the processing.

EDP ANALYZER (OCTOBER 1971)

IMPROVEMENTS IN DATA ENTRY, ESPECIALLY ON KEY-TO-DISC AND ON VALIDATION

One case is reported where 5 % entry error rate before verification (not more closely specified) was obtained with direct data entry system with CRT (Cathode Ray Tube) terminals. Switch over to using a particular key-to-disc system which also performed extensive validity checking resulted in the error rate going down to about ½ %.

Experience from another installation is reported showing that a 2 % error rate when using keypunch entry, dropped to below 1 % with the use of a key-to-disc system.

In the context of evaluating especially key-to-disc systems it is noted that some validation checks can also act as a verification check: check digit is an example. Control totals and inter-field relationships are worse examples because of the possibility of errors compesating each other and because of "legal wrongness".

In the context of VALIDATION FEATURES the following types of VALIDATION CHECKS are said to be possible with data-entry systems employing mini-computers:

1. Character-set check -
2. Value-set check
3. Range check
4. Check digit check
5. Control total balancing
6. Record count
7. Sequence check (if transactions have sequence numbers and have been sorted into that sequence)
8. Inter-field relationship checks
9. Field length check.

The author goes on to reporting of some findings which reduce SOURCE DATA ERRORS, since such reduction "... of course will reduce the number of cases where the validation checks will fail" (p.9). Apparently this refers to the familiar concept of prevention. Two methods for reducing source data errors are developed:

1. Field and code design
2. Design and use of source documents.

Besides of reporting extensive experience of the economy and the effectiveness of the entry process, the author refers to a report by R.C. Turnblade containing summaries of "nominal" error rates obtained from numerous sources, and restates the findings in the following table on NOMINAL ERROR RATES PER 10,000 KEY STROKES, where

	MANAGEMENT EMPHASIZES :	
	Accuracy	Speed
Language text	2	100
Business jargon	5	100
Nonsense data	100	200

Such data seem to be in line with other reported by Johanningsmeier, who is cited as reporting production error rates of 1 to 2 per 10,000 for text and jargon.

W.H. Emmons et al. (1970)

A COMPARISON OF THREE NUMERIC KEYBOARDS

An experiment is reported having the purpose of comparing the performance of inexperienced operators at different types of 10-keyboards with which they were unfamiliar.

Initially the experiment consisted in having the operators keying 1,000 sets of randomized 5-digit numbers on each of three keyboards. The numbers to be keyed were presented to the subjects via a CRT display connected to a computer. The computer was programmed to calculate the number of UNDETECTED ERRORS, i.e. errors not corrected by the subjects themselves: the subjects had the possibility of repeating the digit entry if they realized that they had made an error.

The percentage of keystrokes with undetected errors varied between 0.37 and 0.39 % while the keying speed was in the range of 1.29 to 1.33 keystrokes per second. After discounting for INVALID CHARACTER ERRORS, i.e. errors caused by the keyboard hardware, the percentage of errors (i.e. errors/EFFECTIVE KEYSTROKE, not counting keystrokes corrected by the operator) varied between 0.32 and 0.37.

Since the performance of the operators improved with time during the successive sessions of the experiment, the last sessions were dedicated to gather statistics on the performance of four keyboards of the same type (but with slight functional differences) as one of the previously used. The keying rate proved to vary between 1.31 and 1.49 (average number of effective keystrokes/second) while the % of errors (undetected errors per effective keystrokes) varied between 0.17 and 0.38.

E.T. Klemmer (1959)

NUMERICAL ERROR CHECKING

The author states the purpose of gathering some statistics on error-checking. The emphasis of some studies like e.g. Conrad & Hull's (1967) places emphasis on speed and checking is discouraged.

The study was performed trying to answer two basic questions:

1. What is the effect of grouping digits on the speed and accuracy of error-checking ?
2. How does the frequency of errors to be detected - affect the speed and accuracy of error checking ?

Only numerical material was used. Both experienced and "naive" i.e. unexperienced subjects were asked to compare numbers to be checked, which were printed on pairs of separate pages. The task was to mark those digits which were different.

Three different error probabilities were used: 0.1, 0.01, and 0.001 - where error probability is defined as the proportion of digits on one of the two sets of pages, that were different from the digits on the other set in the corresponding comparison-place. For example, for error probability 0.01 approximately one digit in a 100 was changed on one sheet of each pair. The following results were obtained:

Naive (N) Experienced (E)	Error Probability	Percent digits not detected	Percent residual errors
N	0.1	4	0.4
E	0.1	2	0.2
N	0.01	13	0.13
E	0.01	13	0.13
N	0.001	24	0.024
E	0.001	17	0.017

E.T. Klemmer & G.R. Lockhead (1962)

PRODUCTIVITY AND ERRORS IN TWO KEYING TASKS: A FIELD STUDY

The investigation aimed at measuring productivity and error rates for a billion responses by more than a thousand operators of card punches and bank proof machines in twenty different installations. The authors studied the influence of time on the job (experience) and of individual differences among operators.

The percentage of errors caught in an independent verifying procedure, for card punching were in the range 0.02 to 0.06. No data is reported on errors which the operator himself detected and corrected and it is not clear whether the verifying procedure was a punch verification. This is however probably the case in face of the nature of the studied environment; it also clarifies why no data were available on the residual, undetected errors after verification.

For bank proof machines, the figures are given in terms of percent of transactions (checks), and the errors averaged 0.03 % errors per check, not including errors caught by the operator himself in checking the total of his machine with the supplied control total.

Special features of the investigation were e.g. that no errors in the cents or dime positions were counted. The same applied for those errors which were conceivably caused by poorly written numerals or by certain PROCEDURAL MISTAKES.

E.T. Klemmer (Personal Communication) (1964)
(referenced in Smith, 1966)

HUMAN RELIABILITY: SOME OBSERVATIONS

W.A. Smith (1966, p.14) reports that E.T. Klemmer in 1964 indicated that the average telephone user dials one percent of digits incorrectly. Two thirds of these errors are detected by the user himself in the course of dialing while the rest (about 0.3 %) is caught by the system (e.g. as a "non-existent" number) or results in WRONG numbers. Of those errors not detected by the customer, two thirds can be allocated to the dialing of wrong digits (usually one unit off) and the other third to having the wrong number in mind or failing to dial enough digits.

E.T. Klemmer (1968, 1970)

GROUPING OF PRINTED DIGITS FOR MANUAL TELEPHONE ENTRY

One of the common problem areas underlying all manual entry of numbers (here defined as a linear array of digits presented simultaneously) is how to group them visually for optimum performance by the average user, says the author.

He reports six experiments whose purpose was to see if the major previous findings favoring groupings by 3's and 4's would hold for numbers of different lengths, users of different skills, and various orders of presentation.

> The different skills of subjects were: technical or professional job classifications, clerical-secretarial, and shop workers.

It is not clear to us whether errors were defined including or excluding those self-detected by the subjects. In some of the experiments, errors were immediately signaled by the experimenter to the subjects, allowing for correction, while this appears not to be the case in other of the experiments. The percent figures seem to stand for percent of cards with one or more errors per grouping or per subject. The study includes some figures about relationships between time per entry and error rates.

Error rates in the six experiments showed to be all less than 1 % when averaged over groupings and subjects. None of the experiments showed a statistically reliable difference in errors as a function of grouping nor there was any consistency over experiments. Large individual differences between subjects were however found with respect to rates of committed errors, in the course of the experiments which were all concerned with the overall process of looking at printed numbers and entering them on a push-button telephone.

J.J. Kramer (1970)

HUMAN FACTORS PROBLEMS IN THE USE OF PUSHBUTTON TELEPHONES FOR DATA ENTRY

In an attempt to uncover some of the basic human factor problem areas, Kramer reports some results of the analysis of user performance (in terms of speed and ACCURACY) in using pushbutton devices for data entry. First come three cases of analysis of FIELD data which describe observations of REAL use of pushbutton telephones for data entry.

1. IN A PRODUCTION REPORTING FIELD-TRIAL.

Worker ERRORS were classified as :

- PROCEDURAL - e.g. sending data before answer-back tones had ended.
- HAND KEYING - e.g. adjacent digit substitution and digit omissions
- OMISSIONS - i.e. failure to make a report

An analysis of entries of up to 19 digits (including pre-punched information) made by 44 workers revealed an OMISSION RATE of 8 % where the rate includes corrected entries (by the workers) and the percent is given in terms of entries. The PROCEDURAL ERROR RATE was at about 4 % and the HAND KEYING RATE at about 3 %. The figures should be considered with care since entering data before answer-back tones had ended had an exceptional effect on one of the several (10) studied locations.

About half of the procedural and hand-keying errors were corrected decreasing the total error rate from about 15 % to 11 %. It appears that the corrections were those motivated by immediate self-detection by the subjects, or thanks to error-answerback tones at the entry device.

2. ACCESSORY ORDERING - FIELD TRIAL

Omission errors could not be detected since NO INDEPENDENT SOURCE DOCUMENT was available to compare what the users ordered with what should have been ordered. This excludes from the error count also the ordering of completely wrong items or wrong quantities.

For order-messages of up to about 30 digits (including prepunched information), the PROCEDURAL error rate (e.g. failure to enter either or both of the prepunched card fields - for instance for station identification) was about 23 % giving a residual after corrections of about 9 %. The HAND KEYING error rate was 5 % leading to an uncorrected, i.e. residual rate of 0.3 % mainly due to the use of self-checking item-code numbers which made possible the returning of error-answerback tones to the user. The TOTAL ERROR rate went thus from 28 % to a residual 9 %.

3. AN OPERATIONAL CREDIT-AUTHORIZATION SYSTEM IN A DEPARTMENT STORE

Upon receipt of an inquiry message of up to 16 digits, a computer reviewed credit information about the indicated customer account and then commanded an audio response unit to compose the appropriate reply. A sample of the entries at one of seven possible input channels was analized and the voice response generated by the computer indicated that about 20 % were calls containing at least one user error. Because of the circumstances neither TRUE nor residual error rates could be determined in relation to the total set of users and input devices.

Upon analysis of the results from the three field studies Kramer identifies three basic human factors areas:

1. User instructions and training, which were quite insatisfactory in the studied situations.
2. Data entry formats and procedures.
3. Feedback and knowledge of results in form of e.g. answerback tones.

In addition, Kramer reports some LABORATORY experiments on aspects of user performance in transmitting combined alphabetic and numeric information using a keyboard containing only 10 or 12 buttons. Subjects were assigned to three groups using three different entry methods. Each subject entered about six orders for ten items each; the details of the study suggest that each subject group entered about 35,000 characters.

ERRORS (both corrected and uncorrected) were classified as

- PROCEDURAL
- TIME GATE OR TIME DELAY
- ALPHABETIC
- NUMERIC

The sum of uncorrected and corrected errors was related to the term "ORIGINAL" error rate while uncorrected errors were referred to by the term "RESIDUAL" rate.

The largest contributors to procedural errors were mode-shifts numeric/alphabetic showing a residual rate of one out of every 50 mode-shifts. The largest contributors to timing errors was keying letters too slowly: the residual rate for timing errors was one error for every 89 LETTERS. The maximum residual rate for alphabetic errors was 1:61 letters, and for numeric 1:384 numeric characters.

Kramer terminates his paper emphasizing the importance of motivational and procedural aspects of entry, for total system performance.

B. Langefors (1968a)

IN THE CONTEXT OF AN INTRODUCTION ON INPUT TO COMPUTERS BY MEANS OF PUNCHED MEDIA

The author mentions that investigations have shown that about 0.3 % of punched characters are in error. Punch verification done after card punching usually reduces the above figure to 0.03 %. If punch errors in the punch verification process were committed at random, the expected rate after verification would be much lower. The difference may be attributed to that certain kinds of substitutions of digits or misreadings of handwritten digits (or letters) have a higher probability of occurrence than others, says the author.

Langefors goes on observing that punch verification cannot catch errors made by the people who create the source document, in writing down the original figures. If it is assumed that source errors are made with the same rate as above, 0.3 %, they cannot be detected by e.g. control totals and punch verification will only detect 27 out of 60 erroneous characters in every 10,000 characters, i.e. less than 50 % of such errors.

Langefors gives an example where a data entry device working on punched media with 0.3 % error rate, would inject at least 18 errors per hour of operation, into the system, if no other checks were performed.

> Since such other checks are not performed in many administrative applications of EDP, one can ask how it has been possible to obtain meaningful results in such applications. The explanation is that administrative EDP is made on the basis of a LARGE NUMBER OF SEPARATE, SMALL TRANSACTIONS. An error rate of some tenths percent of the transactions is not a large burden in an administrative application where even OTHER ERROR SOURCES exist.
>
> On the other hand, the effect of occasional errors in a scientific EDP application may be of decisive importance for the results. Fortunately, in large mathematical complicated computations it is possible to design mathematical checks that detect most input data errors. It appears that THE VERY LARGE NUMBER OF DATA which are used in the computation is what also makes possible the mathematical checks.

In addition to other error detection methods, Langefors also mentions the well known check digits. In another work (1968b, p370) he refers to an investigation where the percent of wrong characters (in the case:digits) was proved to be 0.1 % in punching. The possibility of using a check digit detected about 99 % of the errors and consequently reduced the undetected punch errors by a rate of 1/100 compared with the verification reduction of 1/10 mentioned above. Furthermore the author notes that check digits, (whenever practical) also permit detection of some errors in writing the source documents, resulting in a further improvement of the overall detection rate.

J. Martin (1969)

TELECOMMUNICATIONS AND THE COMPUTER

Computer data may be transmitted through land-based and through high-frequency radio communication links. Such links introduce their own errors in the data, through distortion or noise. Martin offers some statistics which has been gathered in this respect.

Typical, most probable error rates are stated:

1. On 50-baud telex lines - one bit error per 100,000 or one bit error per 50,000 transmitted bits corresponding to between one and eight character errors in 100,000 transmitted characters. In terms of time this corresponds to between one error in half an hour - and one error in about four hours.

2. On 200-baud telegraph lines - somewhat better results than above, about one bit in error per 100,000 transmitted.

3. On 600 to 2,000 bits/second voice grade lines, further improved error rates, varying between 1/500,000 and 1/100,000.

4. On high-frequency radio circuits, which should be avoided in the transmission of computer data, a typical error rate is one character per 1,000 transmitted, before correction.

After usual detection and correction procedures (by code or by retransmission) many systems might improve the level of undetected errors from 1/100,000 to 1/10,000,000 bits. One available coding scheme for reduction of undetected error rate will reduce it to 1/ 1 x 10 exp 14.

For code-detected retransmission methods in high frequency radio circuits the undetected error rate may at certain bad periods of time rise to 1/16,000 characters or even 1/160 while the effective speed of the link would drop to perhaps 90 % respectively 50 % of the nominal speed.

Martin mentions that other components of a computer system (other than telecommunication links) such as tape or file channels have a much lower error rate than the rates of undetected errors of telecommunication links in conventional use today.

F.J.Minor & S.L.Revesman (1962)

EVALUATION OF INPUT DEVICES FOR A DATA SETTING TASK

A study evaluating a set of four types of numeric manual entry devices used the criteria of ERROR RATE, ENTRY TIME, and OPERATOR PREFERENCES.

Non experienced operators keyed 10-digits numeric data words in 10-key keyboards and attained an average of 0.6 % of entries containing one or more errors.

The subjects' own handwritten data word served as the criterion against which the manual entry was checked for ACCURACY. Therefore poorly written numerals could barely influence the error rate.

Janet L. Norman (1971)

REDUCING TELEPHONE NETWORK ERRORS

> The technical feasibility of a data communication system depends upon its FREEDOM FROM DATA ERRORS, probability of detecting errors that do occur, and its efficiency in overcoming the effects of errors.
>
> Errors are introduced into data systems by both HUMANS and HARDWARE. Those errors which are attributable to hardware may result from either EQUIPMENT MALFUNCTIONS or RANDOM TRANSMISSION INACCURACIES.
>
> This study limits itself on errors due to TRANSMISSION INACCURACIES in normal voice band data transmission over the USA switched telephone network. Furthermore, the report deals only with statistics on error-free reception of long blocks (message formats) of length from 10,000 up to 300,000 bits of data.

The paper mentions previous available statistics of an average error rate of about 3/100,000 bits. However, since errors happen to be clustered, i.e. not uniformly scattered throughout the data, there are frequent long intervals of time which are completely error free. This explains why the error free percent of long messages is much higher than would be theoretically expected in the case of uniform distribution of errors. Figures are given of e.g.

18 % for messages of 2 million bits
65 % for lengths of 200,000 bits
74 % for lengths of 100,000 bits

In summary, the report mentions that the probability of error-free reception is reasonably large, i.e. in the range 0.6 to 1.0 and that those messages which do have errors tend to contain most such errors. A study of the effect that time of the day has on errors shows that calls placed at night contained twice the percent of error-free messages as those calls made during daytime.

The report gives some detailed calculations which illustrate the kind of error-thinking in the context of data transmission:

The above error rates refer to"TRUE" ERRORS as verified in experimental situations. In practice one works with additional concepts such as RATES OF UNDETECTED ERRORS which refer to messages that are free from PARITY-CHECK FAILURES; i.e. messages with errors undetected by parity check procedures. This,by the way, introduces a new specific meaning of UNDETECTED in quality-terminology.

It is interesting to note in this context that due to the characteristic clustering of errors both inside a character and inside the whole message, long messages accepted without parity failures are likely to show lower rates of hidden (undetected) errors than the rates obtained in retransmitting individual characters or short blocks until they are accepted free from parity failures.

In a typical calculation, for 200,000-bits messages consisting of 25,000 8-bit characters:

The probability that the message is TRULY error-free	0.65
The probability of undetected errors existing in the message without parity failure	0.02
Consequently the probability of a message APPEARING to be error-free	0.67

Since the incidence of undetected errors in messages free from parity errors is known to be quite low, the author mentions that such statistic may be difficult to obtain since it is difficult to discriminate them from what are designated as DATA HANDLING ERRORS.

Illustrating further the use of the above figures in a typical calculation, the author mentions that if the above messages of 200,000 bits are repeated until received without parity failures, then each call must be made on the average 1/0.65 or about 1.5 times. Once all messages are received without parity failures, one will still have a residual probability of 0.02 of each message containing undetected errors.

The OVERALL CHARACTER ERROR RATE IN ACCEPTED DATA then would be 0.02/25,000 = 8 x 10 exp -7 which is two orders of magnitude smaller than the achieved by retransmitting individual characters until received without parity failures. This advantage is obtained at the cost of longer everall transmission time.

J. Orlicky (1969)

IN THE CONTEXT OF INPUT DATA INTEGRITY FOR SUCCESSFUL OPERATION OF EDP SYSTEMS

Orlicky, without giving some specific definition of errors, states that typical error rates run between 1 % (very good) and 3 % of collected transactions. Thus a job shop with 1,000 employees, which may report, say, 7,000 labor, production, and material movement transactions per day, can be expected to generate 100 or 200 errors every day.

S. Owsowitz & A. Sweetland (1965)

FACTORS AFFECTING CODING ERRORS

This is a research memorandum related to a project concerned with USA's Air Force so-called maintenance management. It reports the results of a number of experiments which, the authors say, explore the possibility of "designing" human factors elements into EDP systems. Human subjects coded a variety of data in a number of ways with the purpose of determining which methods resulted in the fewest errors.

Air Force maintenance personnel were used as subjects of the experiments, in which their coding routine resembled their method of recording real-world maintenance data. Their coded information was keypunched and the resulting decks were analyzed to determine what factors led to the highest and lowest error rates.

Coding was in this context defined as the translation of a judgement into a form suitable for machine processing and the study limited itself to three-digits (alpha and/ or numeric) codes. INDEPENDENT VARIABLES in the various series of experiments were e.g. alpha content (i.e. the proportion of code digits that were alphabetic), positioning of the alpha-numeric content, knowledge on the part of subjects and keypunchers about the allowable ("legal") content alternatives, use of mnemonic codes or letter-pattern familiar codes.

In experiments as these it is possible to speak of TRUE (rather than DETECTED) error rates after keypunch and verification, varying between 1.2 % and 16.4 % wrong entries as proportion of all code entries. Error analysis in practical applications usually refers to DETECTED (and therefore IDENTIFIABLE) errors with rates typically in the range 1 % - 5 %. Such detections usually refer to detections through programmed validity checks. Since such checks are based on the "legitimacy" of certain digit combinations, in terms of communication theory this indicates that to machine-detected error rates may in fact correspond 2-3 times higher TRUE error rates, the difference being due to the UNDETECTABLE errors.

J.A. Perlman (1963)

IN THE CONTEXT OF DISCUSSING DATA COLLECTION FOR BUSINESS INFORMATION PROCESSING

In a report on data collection devices available on the market, Perlman points out that experience at one installation using equipment with error-detection capability of lesser sofistication, indicates a RETRANSMISSION RATE (error detected while the operator is still at the remote station) of around 0.5 % and an UNDETECTED rate (that in this context refers to detection by the system after the data collection step) of less than 0.1 %.

Another installation using data collection devices of a higher sofistication is reported as having operated with an undetected error rate of less than 1/100,000 characters. It is not clear whether the above figures are in terms of characters too, or rather in terms of entries.

R.T. Root & R. Sadacca (1967)

MAN-COMPUTER COMMUNICATION TECHNIQUES: TWO EXPERIMENTS

This study recognizes that present computer technology no longer requires man to communicate indirectly with the computer through the medium of punched cards or tape. The two related experiments evaluated alternative man-computer communication techniques relevant even for on-line communications.

Five primary variables affecting man-computer interaction were isolated and manipulated to various degrees:

- word form (full word or abbreviations)
- syntax
- format (fixed or variable length, tagged field)
- equipment (written, voice, teletype transmission)
- procedures (allocation of work between the interpreter-coder and the communicator-operator)

Subject performance was analyzed in terms of time and of errors. ERRORS WERE CLASSIFIED in:

- spelling: any misspelled word
- omission: failure to enter a required item of information
- content: wrong information, e.g. incorrect identification or coding of event
- sequence: information items in the message not in proper sequence.

One experiment involved 20 subjects using real system messages and being trained interpreters of aerial photographs. They composed target reports from simulated pictures, and then either teletyped them immediately while composing (direct entry), or handwrote or voice tape-recorded them for subsequent teletyping either by themselves or by another "communicator". The messages had a maximum of 224 characters if in fixed field format but otherwise their length is not stated. The subjects were all trained teletypists above a minimum speed of 35 w.p.m.

Errors are presented in terms of average number of errors per image-frame to be reported as military intelligence information. The average of UNDETECTED errors per image in the experiment varied between approximately 1.4 and 2.4. Detected errors were defined as those detected (and corrected) by the person entering the report in the computer-readable mode.

> Some degree of leniency was used in scoring errors. Although the transcribed reports would no doubt have been found to contain more errors than reflected in the present analysis if subjected to a computer input edit program, it was felt that several steps would be taken in an operational system (such as increased training time) which would overcome a major portion of the ERROR PROBLEM. IN PARTICULAR, CONTENT AND OMISSION ERRORS WERE SCORED LENIENTLY with only MISIDENTIFICATION OR OMISSION OF TARGET items or other critical information being scored as errors.

The authors present no error figures for the second of the two experiments since no meaningful differences were found between the effects of two word form variations and three format variations.

<u>W.A. Smith Jr. (1966)</u>

ACCURACY OF AUTOMATED DATA COLLECTION IN PRODUCTION INFORMATION SYSTEMS

The figures reported by Smith refer to a more complex situation which includes many types of "errors" which are outside the frame of reference- in some sense - of most other investigations.

Smith's findings indicate that the percent of wrong entries varies in the range 6.8 % - 26.1 %.
AFTER APPLYING THE OPERATOR'S OWN, AND THE SYSTEM'S DETECTION AND CORRECTION PROCEDURES that were available, the percent of RESIDUAL ERRONEOUS ENTRIES varied in the range 3.4 % - 5.6 %.

The definition of errors in this investigation included
- omitted entries (failure to record an event)
- misidentification
- miscount
- wrong sequence (of partial entries in a complex message)

The field study to which the above figures apply, displayed the following independent variables of environmental parameters:

- individual recorder differences (combinations of worker and device, accuracy of entries of the same worker as function of time)
- differences between work shifts (implying different workers, supervisors and recording procedures)
- differences between work sites (continuous assembly line versus job shop with variable operations and routing, each having messages of different complication and length)
- use of pre-assigned media (e.g. pre-punched cards and worker's identification badges to be inserted in a shop terminal) versus manual entry.

The field study was complemented with an experiment with the purpose of studying the effect of different message lengths and of time pressure on making entries.

The dependent variables studied were especially the total number of errors (entries) and the RESIDUAL number of errors, i.e. after detection and correction were applied. The results of the experiment were also used to determine the kinds of manipulation recording faults in copying digits. It appeared that about 60 % of such faults were caused by single digit substitution, another 20 % by single digit omission while the rest consisted of double substitutions, double omissions, insertions, transpositions and miscellaneous.

The conclusions of the overall study emphasize the heavy contribution of so-called CONTENT and EVENT DESCRIPTION MISTAKES to the residual rate, especially OMITTED entries. They also emphasize the need to reduce message length and complexity.

<u>J.E. Talbot (1971)</u>

ON THE HUMAN SIDE OF DATA INPUT - OCR INPUTS

The author frames the OCR ACCURACY problem in terms of trade-off between two forms of RECOGNITION ERRORS: rejecting GOOD DATA (handwritten, typewritten, printed), and accepting BAD DATA.

The report refers to an installation where the document reject rates caused by recognition errors were less than 6 %. In the light of the above framing of the accuracy problem, this could mean that 6 % includes both rejections and acceptance of bad data and that the figure is in terms of entries or characters. The author mentions another installation where by careful typewriting of originally handwritten data, rejections at the equipment were negligible while the error reject rate (presumably accepted data that on subsequent processing proved to be wrong) zoomed to 35 %.

J.P. Van Gigch (1970a, 1970b)

A MODEL FOR MEASURING THE INFORMATION PROCESSING RATES AND MENTAL LOAD OF COMPLEX ACTIVITIES

The author suggests that there is an alternative way to look at the problem of HUMAN ERROR when regarding the human as a communication channel and information processor. Van Gigch aims at the calculation of the total amount of information transmitted from input stimuli to output responses, and to the determination of an information processing rate which characterizes the mental content of the work performed.

> The calculation of information processing rates can be applied to any industrial operation and process, and is particularly well suited to jobs where the degree of automation is such that the physical aspect of work has been practically eliminated.
>
> The mental content of work, i.e. the total demand it makes upon the worker, should appropriately take into account both the complexity of the job, as measured by the entropy or degree of variability per step of cycle sequence, and the repetition rate of the operation cycle i.e. the number of times the operation has to be performed in a given period of time. Each of these two elements can be evaluated separately and combined by means of the model in a resulting informational load. This amounts to measuring the mental content of work in terms of information processing rates.

The reported research indicates that the rate of 7.5 bits per second (peak) corresponding to an average sustained rate of 4.5 bits, as defined through the proposed model, might come to be considered as close to the maximum capacity of the human communication/processing channel in industrial jobs.

> Although it would have been useful to determine the level of ERRORS which accompnied different processing rates in the study of some jobs in the forest product industry, this information was NOT obtained.

Disregarding eventual scientific-methodological problems of the approach, one might assume that human error rates exhibit important variation when the mental load approaches what comes to be considered as the maximum capacity of the human information channel. The approach might permit taking into account the mental load of specific CODING PROCEDURES used in translating so-called real world events to the computer system language.

G.G.Neill Wright (1952)

THE WRITING OF ARABIC NUMERALS

As referred by M. Jönsson in Mekanresultat 71008 (1971), one of the author's reported investigations consisted in having 93,320 arabic numerals to be written by 352 and read by 130 people. Out of these numerals, 1,579 digits were confused with others (mostly confusions between 0 and 6) in reading, leading to an overall error rate of about 1.7 %. Jönsson presents a table on the nature and frequency of found transpositions.

Besides some other data illustrating eventual influence of digits on the perception of those following them, Jönsson refers another of Wright's investigations aimed at determining the frequencies of unreadable and ambiguous digits in the reading of 44,250 digits which were written by 212 people. A table shows that 0.5 % of the digits were UNREADABLE and 2.2 % were AMBIGUOUS, leading to what we might call a TOTAL ERROR RATE of about 2.7 %.

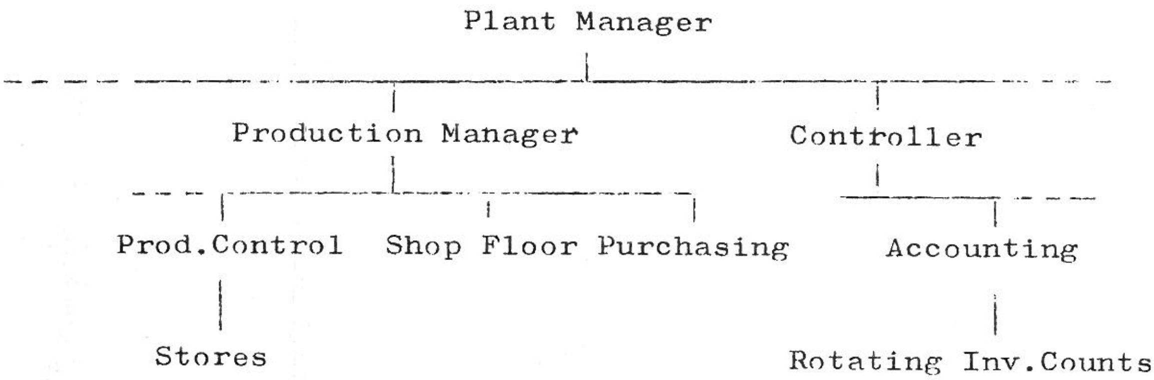
This last mentioned investigation also indicates that the digit 4 was the most frequently found to be unreadable, 0 and 6 were the most frequently ambiguous, while 1 and 4 where the least frequently ambiguous. No explicit recommendations are given on how to use these findings in the design and operation of EDP systems.

CASE STUDY ON DIFFERENCES BETWEEN PERPETUAL INVENTORY RECORDS AND ROTATING INVENTORY COUNTS

of completed parts in stock in a manufacturing company.

INTRODUCTION

This study refers to the completed parts stock of a company manufacturing electro-mechanical machines. The company consists of, among other units, a PRODUCTION UNIT, and a CONTROLLER'S UNIT.
The former consists of several departments such as Production Control, Purchasing, Shop Floor and Stores while the latter includes the Accounting dept. which shares with Production Control the responsibility for the accuracy of inventory control (stock figures).



The operations of the plant are supported by interdependent programs run on the local computer system, and utilizing common files for purposes of inventory control, operation scheduling, control of engineering data etc.

The rotating inventory counts show that there are differences between the quantity of parts that should be found in stock, according to the program-maintained perpetual inventory records, and the quantities reported to be found through the rotating physical counts. Such differences were often judged by auditors and managers to be too great especially in face of the risk that the overall differences be still greater because of difficulties of estimation from the counted sample.

This perceived danger motivated in the course of the years the three investigations which will be summarized here. They were done respectively by the staff of the assistant plant manager (1964), the staff of the Production Control manager (1968), and by internal auditors (1969). This third investigation by internal auditors can be said to have been perpetuated in terms of present classification of causes of differences and in terms of the organization of follow-up statistics which are presently produced by a set of EDP application programs.

The clerical personnel performing the rotating inventory counts (control) are physically located in the stock room but report directly to Accounting. Their findings are the source of information used in producing the statistics analyzed in this our context.

EXPLANATION OF SOME OF THE USED TERMS

The purpose of the PERPETUAL INVENTORY, i.e. an EDP-implemented model of the stock, is to have an ACCURATE image of the flow of parts in the plant. This is accomplished by maintaining a perpetual stock record for each part in stock. This record is said to show the entries into stock, withdrawals from stock and the current balance, i.e. the number of parts that are (supposed to be ?) currently available in stock.

The purpose of ROTATING INVENTORY CONTROL is to keep a so-called running"check on the ACCURACY" of the perpetual inventory records and to correct them when necessary. This is done by having regular counts made of various parts and comparing the actual count to the perpetual inventory record. Minor differences, or variances, are usually attributed to the use of scales in counting and to the so-called human factor. Greater differences are investigated for determination of causes and proper correction. The label of "error" may be given e.g. to those differences with a quantity variance of plus/minus 5 %, or the value of which exceeds U.S. $ 100.

The operation of rotating inventory (RI) control is performed by RI-clerks who each morning visit the locations in stock where there are parts they intend to count. The clerks mark these locations by leaving in the stock bin a well visible "control card", that is later picked up when the clerk returns in the course of the counting tour. Stores personnel are expected to indicate on the card all transactions taking place prior to the control count by the RI-clerks, in order to enable the count result to be reconciled back to the previous night's closing balance.

Here follow some selections from our case study, chosen with a view on the purpose to illustrate the issue of accuracy, or quality of information. The study consisted in assembling and organizing the results obtained by the three special investigations on inventory differences. It must be noted that our purpose was not to make an own investigation on the causes of differences but rather to evaluate the traditional practical way of approaching the problem of accuracy in a specific, supposedly simple, very concrete and realistic environment. This implies also that the material presented below does not pretend to have been gathered according to any precepts of scientific methodology: it is rather an evidence of traditional investigation technique or trouble - analysis in an industrial environment. In any case this material does not supply a complete evidence since some details of our study were omitted here because they are not required for the present purpose.

(1964): FIRST INVESTIGATION

The investigator investigated every day during a period of some weeks, for a set of selected parts, the cause of differences detected through the reports of the RI-clerks. He summarizes his findings in the following table

CAUSES	NUMBER OF CASES	VALUE IN MONEY +	VALUE IN MONEY -
1. Placement of parts in the stock-room	3	-	28.852
2. Placement of "control card"	3	-	3.480
3. Erroneous counting	10	16.266	75.048
4. Erroneous date	2	18.875	75
5. Misunderstanding of verbal information	4	35.000	11.547
6. Handling of invoices etc. e.g. punch error	2	370	6
7. Unidentified causes	2	-	-
Totals during investigated period		70.511	119.008
Gross differences		189.519	
Net differences		48.497	

(1968): SECOND INVESTIGATION

The investigator does not summarize his findings in a table. A review of his report, however, reveals that he has found the following causes (values of differences are not reported here)

1. Multiple stock locations, but only one was reported
2. No stock location was assigned to the part
3. Error committed because personnel was inexperienced
4. The "control card" was not properly placed by RI-clerk
5. Control card was placed,but not used by stock personnel
6. P.I.(perpetual inventory) balance not filled on manually generated RI-control card (see note 1 below)
7. Partial delivery was reported as complete delivery

(1969): THIRD INVESTIGATION

We said earlier that this third investigation was made by internal auditors. We mean more specifically that they organized the scheme for classification of errors and recommended the types of desirable follow-up statistics on inventory differences and their causes. In this sense we can add that the third investigation became a running investigation since it is continuously performed up to now.

An year-end summary of this running investigation consisted of a table including the following causes and percent figures (percent out of a year total of about 900 found causes)

CAUSES	PERCENT OF CASES
1. Part out, but was not reported out (of stock)	5
2. Reported out, but in fact still in (stock)	9
3. Part in, but not reported in	13
4. Reported in, but still out	1
5. Partial delivery, reported as complete (see note 2)	8
6. No delivery, reported as complete (see note 3)	9
7. Wrong card punch, in delivery-out	1
8. Wrong card punch, in delivery-in	1
9. Error in handwritten transaction	6
10. Error in the reporting of stock location	1
11. Wrong count, delivery of wrong quantity	40
12. Other	6
Total (corresponding to about 900 found causes)	100

NOTES

1. RI-control cards are normally computer generated by means of a program following the schedule: each part at least one RI control per year, high-value parts 4-times per year. On manually generated control-cards, however, if the last PI (perpetual inventory) balance in not handwritten on the appropriate field of the card, it will not be punched and the EDP program will calculate the new balance as the PI balance before the RI control PLUS the quantity found in stock on occasion of the control.
2. The stock clerk forwarded the pre-punched card generated by the computer for stock-requisition, without thinking in the fact that he had found only part of the punched quantity. The card should have been marked,corrected or changed.
3. Incapability to deliver because of stock-out condition requires that the stock-requisition card which was computer--generated be especially marked before forwarding to the computer center for data-processing. If not, the pre-punched card will be processed under the assumption that the delivery of the pre-punched quantity was done.

Let us now go over to a summary of the contents of follow-up statistics, manually and computer generated, administere by Accounting and distributed to responsible managers and other personnel with the purpose to enable improvements in the accuracy of inventory records.

SUMMARY OF CONTENTS OF FOLLOW-UP STATISTICS ON INVENTORY DIFFERENCES, ORIGINATED ON OCCASION OF THE THIRD INVESTIGATION (1969).

1. Number of different part numbers (completed parts in stock) that are left and have still to be RI controlled before the end of the current year:
   1.1. Actual number of performed controls versus planned number (e.g. all parts are to be counted at least once per year)
2. Results of RI activity - RI differences per month, year-to--date (y-t-d that is up-to-now this year) for each month:
   2.1. Value of positive differences
   2.2. Value of negative differences
   2.3. Value of net differences
   2.4. Value of gross differences
   2.5. PI balance value of all RI controlled parts
   2.6. Gross value of RI differences in % of 2.5.
   2.7. Net Value of RI differences in % of 2.5.
   2.8. Number of accepted RI controls
   2.9. Out of 2.8. above, number with value higher than limit
   2.10. Percent value that 2.9. is of 2.8. i.e. percent of accepted RI controls with value of difference higher than limit, e.g. 100 money units.
   2.11. Sums of the above, or accumulated value, for each one, each month, y-t-d.
   2.12. Same as 2.11 but for past year (for comparison).
3. Acceptance of RI controls:
   3.1. Total number of RI controls (both new and repeated for the same part number) performed this month, past month and y-t-d.
   3.2. Number of accepted RI controls and what percentage they are of corresponding total number of RI controls as per 3.1. above.
   3.3. Number of accepted RI controls with value of difference greater than 100, and what percentage they are of the number of accepted controls (3.2.)
   3.4. Out of 3.2. and 3.3. number of those with value of difference greater than 500.
4. Specifically per distinct part-number; for all part numbers with accepted differences with value greater than 500, specification of the following figures:
   4.1. Value of positive difference
   4.2. Value of negative difference
   4.3. Value of net difference
   4.4. Value of gross difference
   4.5. PI balance
   4.6. Sums of the above for all part numbers in the report
   4.7. Sum of gross differences in % of sum of PI balances
   4.8. Sum of net differences in % of sum of PI balances
   4.9. Display of 2.1. to 2.7. above, for the current month, to allow the reader's comparison with corresponding figures in 4.6. above.
   4.10. Percent value that figures in 4.6. are of related values in 4.9.

(continues)

5. Negative balances per month.

5.1. Number of distinct different part numbers with open (i.e. not yet accepted) negative balances at end of each month, y-t-d.
5.2. Money value of negative balance (sum for all part numbers in the referenced month).
5.3. Percent of part numbers for which causes of difference were found during the referenced month (i.e. did not have to be "accepted"-without cause)

6. Negative balances per week-end during ending month

6.1. Number of disctinct part numbers with open negative differences at end of referenced week.
6.2. Money value of the negative differences.

7. Negative balances - other than above

7.1. Number of part numbers that during a referenced month showed some negative PI balance.
7.2. Average per day of that month, calculated from 7.1 above.
7.3. Money value of 7.1 above.
7.4. How many distinct part numbers, during the referenced month, showed a negative PI balance, during how many weeks before correction (reconciliation with knowledge of cause) or acceptance (reconciliation without knowledge of cause).
7.5. List of particular part numbers that show negative PI balances at the end of the month, not having been yet closed.
  7.5.1. For the above: for each part number, the number itself, name of the part, quantity of the difference and its money value.
7.6. Diagram over negative balances - curve showing the development of the variable defined in 7.2., for each month y-t-d.

8. Repeated RI controls

8.1. Curve showing the development per week y-t-d of the percentage that repeated RI controls represent of the "first time" RI controls. (Objective may be e.g. 10 % for current year).
8.2. Money value of the repeated RI counts above.

9. Causes of differences

9.1. For each cause-code, the number of part numbers whose investigation led to correction of differences attributed to respective cause.
9.2. The percent of all causes that each particular cause stood for.
9.3. The percent distribution of causes y-t-d for this year and past year (for comparison purposes).

We shall now go over from this"EDP-oriented" summary of the quality of inventory records, to background of these quality problems: so-to-say the "causes of the causes" of the differences i.e. errors that were found in the course of the investigations.

Such errors were not assembled and organized for analysis in nearly the same degree of formalization as the above statistics. A major part of our study consisted in identifying and gathering descriptions of errors from the three investigations, deleting as far as possible duplications of same descriptions,and trying to maintain the description formulated with the same words used by the original investigator.

SUMMARY OF ERRORS
IDENTIFIED AND DESCRIBED IN THE COURSE OF THE INVESTIGATIONS, LEADING TO INVENTORY DIFFERENCES

1. WRONG CODE was used for the particular stock-transaction. Such transaction codes are used in related cost-accounting procedures and vary with the origin/destination of deliveries to-from stock. A wrong code may unintentionally generate double as many transaction cards as actually required, leading to secondary errors such as negative balances etc.
2. DELA D PARTS arrive physically after close-out of earlier inventory difference. In this way the earlier "correction" of a difference without knowledge of its real cause, causes a new difference.
3. ERRONEOUS DATE. A set of parts is being manufactured in the shop floor: as soon as the first two pieces are completed, they are transported to stock. The stock clerk, however, waits for reporting their arrival to stock until the rest of the set arrives, since the pre-punched transaction card accompanying the first parts refers to the whole quantity of the set (same job number). In the meantime a stock requisition arrives for one of the two pieces already physically in stock and it is delivered with an own transaction leading to e.g. a negative balance in the PI file.
4. WRONG COUNT. Missing one box out of many boxes stapled on each other, and a great number of parts is packaged in the missed - hidden box.
5. WRONG COUNT. Assuming that one box behind or below many unopened boxes is also unopened containing a definite number of parts, while this is not true.
6. WRONG COUNT. Assuming that the quantity in a box is the quantity declared by the vendor or printed on the box. Sometimes there are instructions forbidding the opening of boxes except in certain circumstances, because of contamination problems or difficulty of later controllability, e.g. in rotating inventory control.
7. QUANTITY EXCHANGED with department number when manually filling-out a stock-requisition card. The wrong "quantity" exceeds the physical stock balance resulting in an unexpected stock-out. This leads to detection of mistake in the delivery moment, resulting in that the originally intended quantity is actually delivered, but the requisistion card is not corrected.
8. PART NUMBER EXCHANGED with another while copying from a document where both appear near each other.
9. WRONG PUNCH of quantity 100,001 instead of the intended 1; same for part number 856032 instead of the intended 856037 (unclear handwritten digit 7).
10. WRONG PART DELIVERED to a correctly filled requisition.
11. PARTS ARE NOT FOUND because they are placed at locations that are not yet numbered because of shortage of manpower.
12. PARTS ARE NOT FOUND because they are placed at stock locations which were not reported as intended locations for that particular part number.
13. PARTS ARE NOT FOUND because located in a "third" stock location. The EDP stock-updating application allows for registration of a maximum of two stock locations. Additional ones must be tracked by means of manual methods.
14. PARTS ARE NOT FOUND because too many different parts are stocked at the same one numbered stock location, and it is easy to overlook them.

15. CONTROL CARDS are not placed in certain stock locations because they are kept locked early in the morning for security reasons.
16. CONTROL CARDS are not filled by stockroom personnel. They do not note them when expediting some parts requisitions, or they are not motivated to fill them, or they are not instructed to do so. The RI personnel sometimes forgets to pick-up at the end of the day those cards placed in locations which they intended to visit but had no time left to. This has occasionally spoiled the confidence and motivation of stockroom personnel. On the other hand such follow-up of left--over cards places an additional unappreciated burden of clerical duties on the RI personnel.
17. CONTROL CARDS. Stockroom personnel forgets to fill them. Compare with number 16 above.
18. WRONG COUNT. The number of parts physically delivered from stock is not the same as the number on the requisition.
19. MIXING OF SIMILAR PARTS. Upon closer examination, as for quality control purposes, it is discovered that an open box actually contains two different parts of similar appearance. Several prior causes may be immagined.
20. MISUNDERSTANDING OF VERBAL INFORMATION in the course of indirect observations, as when the question or the answer is misunderstood regarding the date of arrival or the quantity of certain parts or boxes.
21. WRONG STOCK LOCATION is reported because the numbering system for stock locations is misunderstood by inexperienced personnel.
22. PARTIAL DELIVERY REPORTED AS COMPLETE since the pre-prepared transaction is not changed or complemented with an additional transaction upon verifying that the observed event does not conform to the planned event.
23. PI BALANCE NOT FILLED on manually generated control card, since this is normally not necessary with computer-generated cards where such information is prepunched by the EDP application. The updating program calculates then the new balance as the last calculated in the PI file plus the balance reported by the RI count on the manually generated card.
24. NO DELIVERY REPORTED AS COMPLETE. When stock personnel is unable to deliver a single piece of a requisitioned quantity because of stock-out condition (zero quantity in stock), the requisition card should be especially marked and put apart for special EDP handling (emergency because of danger for line-stop). If the special handling-marking is not performed, the system assumes that the whole quantity was indeed delivered.
25. LOSS OF DOCUMENT in handling as when an invoice is put among other kinds of documents or forgotten at the bottom of a box which was opened for control of the quantity of parts in it.
26. PARTS ARE NOT FOUND. A "third" stock location was reported to the system in belief that it was the second one. The EDP program accepts only a maximum of two locations for the same part number. Upon reporting of the third one, the whole record for the first location was lost (erased).
27. WRONG IDENTIFICATION of the part - misunderstanding. The unit of a certain printed label was occasionally believed to be the label itself, a foil with glued a set of many of the labels, or a set of such foils.

28. WRONG COUNT. Small parts which are delivered in great quantities are counted indirectly by weighing them and relating the total weight to the unit weight. This introduces scale errors and related human factors. One of the investigators suggests that a percent difference in quantity up to about 3 or 4 % could be normally ascribed to scale and such human factors.
29. EXCHANGE OF MEASUREMENT UNITS. A very long cable arrives in a box marked with "length = 550" and it is assumed to refer to meters while it later prooves to have been feet.

Note: No investigation refers to another remarkably obvious source of differences which we will note for the sake of completeness:

30. THEFT. Equivalent to a lie or deliberately given false information.

HISTORY OF QUALITY IN MANUFACTURING

Technological stability in industrial operations: historical background of quality in manufacturing.

Since the earliest days of man, artisans, engineers, and industrial administrators have undertaken the development of certain aspects of manufacture such as production method, production rate, and product quality, with the general aim of GETTING MORE OUTPUT, in some sense, for a given input. The most highly publicized and the most widely practiced of these techniques have been ascribed to F.W. Taylor who emphasized the planning of productive effort in such a manner that the outcome, output, of this effort was PREDICTABLE IN TERMS OF QUANTITY. Although Taylor also had in mind the QUALITY of product - in perhaps some vague sense, he was primarily concerned with predictions of quantity.

Taylor stressed the ELEMENTIZING of operations and modifying methods. He further stressed the elimination of worker initiative and he proposed manufacturing procedures to better guarantee high output of mass production. While Taylor did stress wage payments in relation to rates of output, he seemed primarily concerned with establishing standardized RATES OF PRODUCTIVITY. And, in spite of his stress on standard production methods and his monumental technical job in "The Art of Cutting Metals", the heritage of his influence is largely to be found in the superabundance of persons in industry engaged in setting up rates of production based in part on time measurements, in part on individual judgement, and, in part on collective bargaining. For a half century or more, disciples of Taylor and other propounders of "efficient" manufacturing procedures, were concerned with devising "methods" by which they could predict MAXIMUM OUTPUT for given input (production RATES), with some vague notion of the "one best method" and so-called "fair day's work".

About year 1925 it was openly realized that PRODUCT QUALITY HAS A DEFINITE BEARING ON OUTPUT IN THAT A PRODUCT WHICH DOES NOT CONFORM TO DESIGN SPECIFICATIONS CANNOT BE COUNTED IN THE OUTPUT. Product that is scrapped or reworked reduces the overall production rate. Also, if considerable inspection of product is necessary, the over all man-hour input for the accepted product is increased.

About that time, W.A. Shewhart, of the Bell Telephone Laboratories, recognized the fact that ATTAINEMENT OF SPECIFIED PRODUCT QUALITY IS A FUNDAMENTAL PROBLEM OF SCIENTIFIC METHOD, A PROBLEM OF PREDICTION. Dealing with the problem of quality in mass-manufactured products, he recognized the INHERENT VARIABILITY IN REPETITIVE PROCEDURES and formulated a set of ideas which yielded operationally verifiable criteria for the attainement of specified product quality. He also noted that such criteria can be established only within the framework of an ACCEPTED GOAL OR SET OF CONSTRAINTS. This goal was essentially economic in nature, in terms of impact of quality on cost of input and VALUE OF OUTPUT.
Prediction of a quality characteristic within LIMITS was considered possible when a "constant system of chance causes" exists, or when equivalently "assignable causes" do not exist. The latter were those which could be

ECONOMICALLY identified and eliminated. Criteria for discrimination between the two types of causes were based on principles of statistical inference and associated precepts of probability, ("STATISTICAL CONTROL").

Fundamental to the attainement of quality, i.e. to the attainement of a state of the production process wherein it is possible to PREDICT WITHIN SPECIFIED LIMITS the quality that will be realized, is the following three-step continuing sequence as conceptualized by Shewhart:

1. QUALITY SPECIFICATION. It is the HYPOTHESIS of the quality to be obtained.

2. PRODUCTION METHOD OR THE PROCESS. It is equivalent to the EXPERIMENT in science, whose results are to be examined to determine whether the hypothesis is verified in fact.

3. QUALITY EVALUATION, equivalent to the TEST OF HYPOTHESES in science. The results of the production process are inspected or tested and the inpection or test results are evaluated to determine whether the specified quality has been attained.

Until about the middle of the forties, statistical inference had only rarely been applied in testing hypotheses in the engineering sciences. Criteria of acceptance of physical hypotheses had usually been the JUDGEMENT of the individual engineer or scientist. While manufacture and scientific inquiry are quite parallel in respect to experimental inference, the requirements of attaining quality in mass production differ, in that FAILURE MAY DESTROY THE MANUFACTURING ACTIVITY. The failure to attain predicted quality may mean SUCH LOSS AS TO PREVENT FURTHER MANUFACTURE.

The three-step sequence in attaining industrial quality, therefore, must be continuing and self-corrective and must lead to the ralization of a constant chance cause system in the production process whereby the desired quality can be assured.

(S.B. Littauer, 1950)

BASIC CONCEPTS OF QUALITY IN MANUFACTURING

THEORY OF ERRORS AS VERIFICATION THROUGH PROBABILITY.

VERIFIABILITY requires that any theory predict certain numbers which can be compared with the numbers gained by actual operations of measuring.

In actual practice these numbers, which may be called THEORETICAL MEASURABLES and OPERATIVE MEASURABLES respectively, never correspond. It becomes necessary, therefore, for the scientist to SPECIFY WHEN THE DEVIATION BETWEEN THEM IS SUCH THAT VERIFICATION OCCURS. These specifications are defined by the THEORY OF ERRORS in which the concept of probability has an essential place. (Northrop, 1947, p.200)

ACCURACY AND PRECISION IN THE THEORY OF ERRORS.

In the theory of errors we customarily assume that we may repeat the measurement of the length of e.g. a line AB (a segment), again and again at will, obtaining an infinite sequence of observations

$$X1, X2, \ldots, Xn, \ldots$$

We then assume that the segment AB has a TRUE length X' which is constant for all time. Then we introduce the concept of an ERROR $e'i$ of a SINGLE observation Xi, defined by the relation

$$e'i = Xi - X'$$

Now we come to the question of what is the meaning of the ACCURACY of the METHOD OF MEASURING the length of the segment AB by means of an engineer's scale. One of the things that are done in the theory of errors is to assume that the infinite sequence above has a LIMITING AVERAGE VALUE $\bar{X}'$ which defines the CONSTANT ERROR

$$d' = \bar{X}' - X'$$

This constant error provides a kind of measure of the ACCURACY of the TEST METHOD or METHOD OF MEASUREMENT in somewhat the same way as $e'i$ above provides a measure of the accuracy of the SINGLE OBSERVATION Xi.

Usually, however, we go further and conceive of the accuracy of a given method of measurement as being determined by the frequency of occurrence of the numbers in the infinite sequence above, within some specified RANGE $X' - L1$, $X' + L2$. If we make $L = L1 = L2$ then the distance L may be associated with the concept of PROBABLE ERROR.

PRECISION seems to differ from the concept of accuracy, principally in that the clustering of the members in the infinite sequence is measured in terms of the fraction of these members within the range $\bar{X}' - L$, $\bar{X}' + L$, this range being related to the average $\bar{X}'$ of the infinite sequence instead of the TRUE VALUE X' being measured.

In the context of manufacturing, a SPECIFICATION may be seen as fundamentally the statement of requirements as means to an end, which we idealize in terms of the classic concepts of accuracy and precision.

ACCURACY involves in some way the difference between what is observed and what is TRUE.

PRECISION involves the concept of REPRODUCIBILITY of what is observed.

We could then say that accuracy is a measure of correctness, while precision is a measure of reproducibility. (Shewhart, 1939, p.124, 146)

ESTABLISHMENT OF TOLERANCE LIMITS, AND "MEASUREMENT ERROR".

When speaking of tolerance limits in terms of MEASUREMENTS of some quality characteristic, it is often tacitly assumed that the measurements themselves are "RIGHT" or "TRUE". Obviously, however, this assumption may not be justified and hence we need to take into account the DIFFERENCE BETWEEN THE CUSTOMARILY ACCEPTED CONCEPT OF THE TRUE VALUE X' of a physical quality, AND A MEASUREMENT X OF THIS TRUE VALUE. (Ibid. p.71)

In practice, however, we cannot discover the "true value": we can simply make measurements and draw inferences from such measurements ABOUT OTHER MEASUREMENTS NOT YET MADE, if we are to limit ourselves to inferences that can be operationally verified. (Ibid. p.87)

The concept of TRUE VALUE leads us to CHOOSE operationally verifiable criteria that measurements must satisfy in order that they MAY BE CONSIDERED TO BE MEASUREMENTS OF THE TRUE VALUE X'. These criteria include those for CONTROL of any method of measurement (i.e. the sequence of measured values according to a given method must represent a statistically controlled condition), and those for checking the consistency between measurements by DIFFERENT METHODS (i.e. the statistical limits of the averages of the first n terms of the sequences from different methods, as n approaches infinity - must be equal). IN PRACTICE, IT IS CUSTOMARY TO CHOOSE ONE OF THE METHODS OF MEASUREMENT AS A STANDARD, AND TO CONSIDER PRACTICALLY VERIFIABLE OPERATIONAL MEANING FOR THE REQUIREMENTS OF CONSISTENCY. (Ibid. p.72)

As a final note, it should be understood that the setting of tolerance limits on the measurement of a so-called physical constant (such as the velocity of light) is analytically the same problem as the setting tolerances on the true value of quality of pieces of a product of a given kind. The tolerance limits on a quality must take into account not only the variability of the "true" quality, but also of the method of measurement. HENCE, THE PROBLEM OF SETTING TOLERANCES ON THE MEASUREMENT OF A PRESUMABLY CONSTANT VALUE OF A GIVEN QUALITY ALWAYS CONSTITUTES A PART OF THE JOB OF SETTING TOLERANCES ON A QUALITY CHARACTERISTIC. (Ibid. p.116)

OPERATIONAL MEANING OF ACCURACY AND PRECISION

The impossibility of determining a "true value" in the sense of the theory of errors introduces the need of an operational meaning for accuracy and precision:

We meet indefiteness in the definition of accuracy as a measure of CORRECTNESS; what measure is implied and what is this degree of correctness that we are supposed to measure ?

Likewise for precision - AGREEMENT OF RESULTS AMONG THEMSELVES is not definite because there is a large number of senses in which results might be said to agree among themselves. Precision as a measure of REPRODUCIBILITY is definite only if we know what measure is implied and if we know what is this measure of reproducibility that we are to measure. Furthermore: to what portion of the infinite sequence of measurements with a given method do such statements as "agreement of results among themselves" or the "reproducibility of the observed values" refer ?

When trying to give operational meaning to accuracy and precision, the first thing to recognize is that there are two aspects of an operation of measurement: the quantitative-numerical (pointer reading),and the qualitative-physical. They both are required for a complete description of the operation of measurement. Likewise the interpretation of experimental results must take into account both aspects of the operation in order to avoid ERROR OF JUDGEMENT based upon the observed results.

Hence, to make any practically verifiable statement about a quality characteristic we must (at least):

1. Specify each of the PHYSICAL operations of measurement to be considered.
2. Specify the number of terms to be considered for each infinite sequence of observations corresponding to a method of measurement.
3. Define the functions to be computed in terms of the set of observations.
4. Specify for each such function the interval within which the value of the function must lie if the judgement-statement involving that function is to be considered true.

The OBJECTIVITY of a quality characteristic in terms of the concepts of accuracy and precision will in any case exist only in the CONSISTENCY BETWEEN THE INDEFINITELY LARGE NUMBER (METHODS) OF POTENTIALLY INFINITE SEQUENCES (OBSERVATIONS) constituting the numerical aspects of the operations of different methods of measurement

Finally it is important to note that there is not "the one" verifiable operational meaning of ACCURACY and PRECISION, but rather A CHOSEN such meaning. However we are not free to choose arbitrarily ANY verifiable meaning since we must limit ourselves to those alternatives that are ECONOMICALLY ATTAINABLE. In other words, tolerance requirements for accuracy and precision must be economic. (Shewhart, 1939, p.125-140)

OTHER ECONOMIC ASPECTS:
IN THE CONCEPT OF TOLERANCE LIMITS

We may think of the "go, no-go" tolerance limits as constituting a means of screening a given product in respect to some quality characteristic.

In this sense, TOLERANCE LIMITS ON A QUALITY CHARACTERISTIC X fix the range within which the quality X of a piece of product must lie in order to conform to specification and in order to fit into some mechanism that the engineer wants to make. The choice of the tolerance limits depends then upon the particular design.

However, they will also be determined by the consideration of the percentage of the product made under commercial conditions that MAY BE EXPECTED to have a quality falling within that range.

Another reason why the engineer under certain conditions must be concerned not only with the tolerance range but also with the PROBABILITY ASSOCIATED WITH THAT RANGE is in the case of DESTRUCTIVE TESTS. If the inspection test to determine whether the quality of a piece of product lies within the specified tolerance range is destructive, then it is only through a KNOWLEDGE OF EXPECTED VARIABILITY of quality that an engineer can determine what assurance he has that the quality lies within its tolerance limits.

So long as we think of a tolerance range simply as go, no-go limits, our attention is centered primarily on the limits themselves. However, just as soon we begin to consider the establishment of tolerance limits from the viewpoint either of making EFFICIENT USE OF AVAILABLE MATERIALS or of maintaining an adequate degree of QUALITY ASSURANCE (especially needed when the inspection test is destructive), we must think not only of the tolerance limits but also of the probability associated with these limits. (Shewhart, 1939, p.50-51)

BASIC CONCEPTS OF QUALITY IN PHYSICS

Measurement of some PROPERTY of a thing, of the "fundamental physical constants", and of other basic properties of nature, in practice always takes the form of a sequence of steps or operations that yield as an end result a number that serves to represent the amount or quantity of some particular property of a thing - a number that indicates how much of this property the thing has, FOR SOMEONE TO USE FOR A SPECIFIC PURPOSE.

PRECISION AND ACCURACY are inherent characteristics of the MEASUREMENT PROCESS employed and not of the particular end result obtained.

ACCURACY is determined by the closeness to the TRUE value characteristic,of successive independent measurements of a single magnitude generated by REPEATED applications of the process under specified conditions. The true value is defined conceptually by an exemplar measurement process or the target value intended in a practical measurement process. Accuracy may be measured in terms of BIAS, or SYSTEMATIC ERROR, i.e. the magnitude and direction of its tendency to measure something other than what was intended. Strictly speaking, the ACTUAL ERROR of a reported value, that is the magnitude and sign of its deviation from the truth, is usually unknowable. Limits to this error, however, can usually be inferred - with some risk of being incorrect - from the PRECISION of the measurement process by which the reported value was obtained, and from REASONABLE limits to the POSSIBLE bias of the measurement process.

Although the accuracy REQUIRED for a reported value depends primarily on the INTENDED use, or uses, of the value, one should not ignore the REQUIREMENTS OF OTHER USES to which it is likely to be put. A REPORTED VALUE WHOSE ACCURACY IS ENTIRELY UNKNOWN IS WORTHLESS.

PRECISION refers to the typical closeness TOGETHER of successive independent measurements of a single magnitude generated by REPEATED applications of the process under specified conditions. Precision may be measured in terms of STANDARD ERROR of the reported value, which measures (or is an index of) the characteristic DISAGREEMENT of repeated determinations of the same quantity by the SAME METHOD. The standard error is the standard deviation of the probability distribution of estimates (that is, reported values) of the quantity that is being measured.

In general the purpose for which the result is needed determines the precision and accuracy REQUIRED, and ordinarily also the method of measurement employed.No single form for stating credible LIMITS to likely inaccuracy-imprecision is universally satisfactory. It is important to give a detailed account of the various components of imprecision and systematic error, so that EACH INDIVIDUAL USER OF THE FINAL RESULT MAY DECIDE FOR HIMSELF WHICH OF THE INDICATED COMPONENTS ARE, OR ARE NOT, RELEVANT TO HIS USE OF THE FINAL RESULT. (C.Eisenhart, 1968)

ORIGIN AND MEANING OF ACCURACY AND PRECISION

R.L. Ackoff (1962)

The application of the concept of "best decision" (as it is commonly understood) to pure research, requires the evaluation of the losses (and gains) from falsely (or correctly) rejecting a "pure" research hypothesis or the evaluation of the losses due to ERROR in estimating the value of a parameter WHEN THIS ESTIMATE MAY BE USED FOR MANY PURPOSES OF WHICH THE RESEARCHER CANNOT BE AWARE.

Since these evaluations do not seem possible, it appears that the pure researcher requires A CRITERION OF "BEST ANSWERS TO QUESTIONS" WHICH HAS NO REFERENCE TO OUTCOMES OF DECISIONS AND THEIR VALUES.

Every concept of ERROR contains an implicit set of assumptions concerning the value of the consequences. From this we will not conclude that the pure researcher must explicitly formulate consequences and their values - for this he clearly cannot do in many circumstances- but that HE MUST MEASURE AND REPORT ERRORS IN SUCH A WAY THAT THEY CAN BE ADJUSTED TO SUIT CIRCUMSTANCES IN WHICH THE VALUES OF CONSEQUENCES DIFFER FROM THOSE IMPLICIT IN HIS MEASURE OF ERROR.

In the context of estimating the true value of a parameter, ERROR MUST BE MEASURED IN A WAY WHICH DOES NOT PRESUPPOSE KNOWLEDGE OF THE TRUE VALUE OF THE PARAMETER BEING ESTIMATED. This is done by measuring properties of the set of estimates yielded by an ESTIMATING PROCEDURE, rather than by measuring the properties of any one specific estimate.

Generality of scientific results - their applicability over a wide range of conditions - is not possible with any single estimated value of a parameter. DIFFERENT ESTIMATES DERIVED FROM THE SAME DATA are required for different circumstances. Consequently, the objective of an estimating procedure should be to provide the information necessary for PREPARING THAT ESTIMATE IN ANY SPECIFIC SITUATION WHICH MINIMIZES THE EXPECTED COSTS OF ERRORS DUE TO ESTIMATION.

Ultimately, then, the best answer to a question is one which can be used in any problem situation to obtain a best solution.

TRUTH AND ERROR OF INFORMATION HAVE NO MEANING INDEPENDENTLY OF THE WAY IN WHICH INFORMATION IS APPLIED. "Correspondence with reality" cannot be used to measure error, since reality is not known in a way which permits such computation. Information corresponds to reality in any specific situation to the extent that it can be used to accomplish somebody's objectives in that situation; that is, to obtain best solutions to problems. (p.61-63)

C.W. Churchman (1948)

> The TRUE measure of a given distance will be the limit ("stochastic limit") of an infinite set of observations, all in "STATISTICAL CONTROL". When lack of control results, the scientist changes his theory, so that theory depends on observation, and yet no observation can be made without some presupposed theory. (p. 57)

> All questions requiring a QUANTITATIVE answer (i.e. a number of some sort) are not questions receiving an immediate answer. For to measure anything, an instrument of measurement is required, and all such instruments presuppose the principles by means of which they were constructed. Even discrete counting presupposes laws of addition and certain principles of succession. Similarly it can be shown that also questions concerning qualitative relationships between objects cannot be answered immediately since they presuppose the answering of other questions. (p.121)

In the context of discussing experimentalism, Churchman describes the experimental process, usually called the PROCESS OF EXPERIMENTAL CONTROL. The nature of such control is formalized in order to describe science's way of approaching its ideal of absolute PRECISION. To summarize, an experiment is said to be CONTROLLED if we state all the formal conditions under which a mathematical function of a series of observations approaches a limit stochastically. Such definition of experimental control is then made the criterion of MEANING: No question of FACT can be said to have meaning unless there exists a CONTROLLED EXPERIMENT for its answering.(p.182)

> Granted postulates of experimentalism, it is always possible to find a formal image of nature that will enable us to reduce the "ERROR", with an increase in the number of observations, to a quantity less than any given amount. Furthermore, the DEGREE OF PRECISION (corresponding to an "error of the error") can also be thought to be measurable. In terms of the basic methodology of experimental science we can then define the concepts that are fundamental to any theory of knowledge, meaning, TRUTH, and REALITY. Two of the concepts are:
>
> 1. The TRUE ANSWER TO A QUESTION OF FACT - is that single value for which the ERROR OF OBSERVATION is zero.
> 2. The TRUE IMAGE OF NATURE - is that image which will produce EXPERIMENTAL CONTROL for all series of observations, finite or infinite. (p.183)
>
> Progress in the accomplishment of the scientific purpose may be measured by the reduction of the ERROR OF MEASUREMENT. The ideal of errorless measurement can only be approached by taking observations in indefinitely increasing number, and there is a constant demand for the experimenter to decide whether the ideal is approached satisfactorily, i.e. whether the observations are "IN CONTROL". (p.267)

C.W. Churchman (1959)

PRECISION is one of the needs satisfied by STANDARDIZATION in the context of measurements. This is the need to DIFFERENTIATE ASPECTS OF THE WORLD WE LIVE IN. The planning of a large meeting only demands a rough notion of the size of the crowd, say, between 2000 and 3000, in order to select a meeting hall economically; but the planning of a dinner meeting requires much greater precision. (p.90)

Without standards, one would have to report all the relevant information about time, place, observers, procedures, etc., in addition to the DATA REPORT itself. Otherwise, no one would know what values to assign to the variables in the laws that enable one to use the report IN OTHER CIRCUMSTANCES. But once a standard has been given, then all data reports can be adjusted to the standard, and all that is needed is the data report itself. THUS, THE STANDARD CONDITIONS CONSTITUTE A DATA-PROCESSING DEVICE THAT SIMPLIFIES THE AMOUNT OF REPORTING REQUIRED. (p. 91)

The aim of minimizing the effort to adjust data usually CONFLICTS WITH THE AIM OF PRECISION. In effect, the "cost" of adjusting data rises as more precision is attained, just as the cost of absence of precision goes up as we attempt to find "simpler" data. Experience has shown that it is possible to be naive with respect to precision in an attempt to be SIMPLE IN PROCEdures. ALL OF THE SUPPOSEDLY "SIMPLE" INSTANCES, - A REPORT OF A WITNESS, OF A LABORATORY TECHNICIAN, OF A STOCK CLERK - ARE NOT SIMPLE AT ALL IF THE DECISION ON WHICH THEY ARE BASED HAS ANY IMPORTANCE. Many "checks on the accuracy" of the data amount to setting up standards to which the data can be adjusted.(p.90)

Besides of standardization etc, two other most important aspects of measurement are the accuracy of the measurements and the control of the measurement process.

ACCURACY is itself a measurement - the measurement of DEGREE TO WHICH A GIVEN MEASUREMENT MAY DEVIATE FROM THE TRUTH. Since truth is related to the uses to which measurements are put, and since measurements are pieces of information applicable in a wide variety of contexts and problems, it MUST BE POSSIBLE TO FIND ACCURACY MEASUREMENTS which ARE APPLICABLE IN SUCH A WIDE VARIETY OF CONTEXTS AND PROBLEMS. The problem of accuracy is then to develop measures that enable the user of the measurement to evaluate the information contained in the measurements. (p.92)

CONTROL is the long-run aspect of ACCURACY. It provides the guarantee that measurements can be used in a wide variety of contexts. In other words, a control system for measurement provides OPTIMAL INFORMATION ABOUT THE LEGITIMATE USE OF MEASUREMENTS UNDER VARYING CIRCUMSTANCES. (p.93)

C.W. Churchman (1961)

One of the most significant aspects of modern science is the realization that one does not measure unless one also measures the ERROR of measurement. (p.101)

A scientist realizes that without some estimate of error HIS MEASUREMENTS ARE MEANINGLESS. But accountants and managers want their cost data "exact". They think of "cash on hand" as the most PRECISE measurement because there can be relatively little error in this figure. What they do not seem to realize is that a precise figure in this sense of precision also contains very little information about the state of the system. Or, rather, if a firm's goal is to learn, it learns least from precise figures. One might try to conceive of independent judgements of costs as the "elementary observations" that statistical theory requires, in an attempt to use statistics in other than its strong orientation towards statistical deviations in controlled experiments. (p.335)

Measurement includes the process of CONTROL. In other words, measurement is an organization of experience in which information is "fed back" concerning the ACCURACY of the measurements. "Accuracy" entails information about the possible deviations of the measurements from reality. This may be interpreted as meaning that ACCURAGY is information about the VALUE OF THE MEASUREMENTS FROM THE POINT OF VIEW OF THE OUTCOMES OF THE ACTIONS WHICH HAVE BEEN PARTIALLY DETERMINED BY THEM. One of the most significant results of modern scientific method has been the ABILITY TO ESTIMATE ACCURACY WITHOUT KNOWING EXACTLY WHAT REALITY IS, THAT IS, WHAT THE BEST ACTION IS.(p.101)

ACCURACY AND CONTROL are the concepts which define the consistency of measurement reports. The concept of ACCURACY OF MEASUREMENT can be used in at least two senses. First, a measurement process may fail to be accurate in the sense that it is not consistent. For example, REPETITIVE OBSERVATIONS DIFFER "TOO MUCH" OR FAIL TO AGREE SUFFICIENTLY WELL WITH THE FORMAL STIPULATIONS. Second, a measurement process, though consistent, may have VERY POOR ACCURACY FOR A SPECIFIC PURPOSE. Thus, we can say that a set of data are inaccurate and mean either that the set is inconsistent relative to certain formal rules, or that the set has a very low measure of accuracy.(p.127)

CONTROL is the process of deciding when to test for ACCURACY and what corrective action to take when it is decided that the accuracy requirements are not met.(p.128)

Normally, control is said to exist only if the adjusted observations are statistically consistent (statistical control). But it may be that control defined in terms of many repetitions of adjusted observations is too narrow for measurements made outside of the laboratory or outside a precisely controlled production line. IF SCIENTIFIC METHOD IS TO BE EXTENDED TO DECISION-MAKING IN GENERAL, THE IDEALS OF ACCURACY AND CONTROL WILL ALSO HAVE TO BE REDEFINED. (p. 129)

C.W. Churchman (1968a)

Measurement is sometimes described as the assignment of numbers to things, but it may be far more useful to define it as the activity of creating PRECISE, ACCURATE, and GENERAL information.

PRECISION and ACCURACY enable us to make refined choices and hence reduce the risk of ERROR. If I say to you, "Take the bus to get to my home", I am being imprecise though perhaps accurate because taking some bus is the only feasible way to get there. If I say, "Take the 43 bus at Market and Fillmore leaving at 5:00 P.M. weekdays", I am being precise, but perhaps not accurate if no such bus runs at that time.

"GENERAL" information is information that can be used in a wide variety of times and places. If the bus schedule changes each day, my precise information may not be general; I could make it general by giving you a day-to-day schedule, so that no matter when you arrived you would know when to catch the bus. (p.161)

A. Kaplan (1964)

In the context of VALIDITY of measurements: the root meaning of the word validity is the same as that of the word VALUE - both derive from a term meaning STRENGTH. The usual characterization of a valid measurement is that it "measures what it purports to measure". The validity of a measurement refers then to its VALUE or in WHAT SOMEBODY IS ABLE TO DO WITH IT. Close to the latter meaning is the possibility to regard THE VALIDITY OF A MEASUREMENT AS A MATTER OF THE SUCCESS WITH WHICH THE MEASURES OBTAINED IN PARTICULAR CASES ALLOW US TO PREDICT THE MEASURES THAT WOULD BE ARRIVED AT BY OTHER PROCEDURES AND IN OTHER CONTEXTS. (p.198-199)

The ERROR of measurement is itself a measure of our failure to achieve what we aspired to; validity is a matter of the scientific significance of our aspiration. The study of sources of error affecting the validity of measurements introduces new concepts such as sensitivity, reliability, accuracy and precision.

One source of error is insufficient SENSITIVITY, which is a measure of the discriminating power of an instrument or procedure of measurement.

A second type of error is associated with the concept of RELIABILITY, which is a measure of the extent to which a measurement remains constant as it is repeated under conditions taken to be constant. Among these conditions the observer making the measurements is of particular importance. Accordingly, reliability is often interpreted as a kind of INTERSUBJECTIVITY: the AGREEMENT OF DIFFERENT OBSERVERS on the measures to be assigned in particular cases. But changes in the circumstances of measurement other than the identity of the person making the measurements are also involved in reliability.

A measurement which is free of systematic error is said to be ACCURATE. This is not to be confused with PRECISE, an attribute which depends on reliability as well as on sensitivity.

What is RANDOM ERROR and what is SYSTEMATIC ERROR depends on what we are taking into account in the assignment and interpretation of our measures. As Coombs puts it, "the measurement theory assumed in analyzing data becomes a part of those data, and such portions of the data which are incompatible with the a priori abstract system are rejected and regarded as constituting (random) error variance." A systematic error, in short, is one due to a factor whose effect was presumed to be already incorporated in the theory of that measurement; effects due to other factors are called random. (p.199-201)

What was said above suggests the need of a concept of truth and of true measure. What we can say is something along the following lines.

As we increase the sensitivity, reliability, and accuracy of our measurement of some magnitude, we find (or hope to find) that the measures increasingly exhibit a CONVERGENCE TOWARD SOME PARTICULAR VALUE. This value can usefully be dealt with as the mathematical limit toward which the measures tend. THE "TRUE MEASURE" OF THE MAGNITUDE IS NOTHING OTHER THAN THIS LIMIT.

Instead of saying that a new procedure or instrument of measurement is an improvement over the old because it comes closer to the "real value" of the magnitude, it may be less misleading to say that it is an improvement because the "true measure" specified in its terms is more useful scientifically than the old "truth" was. (p.201-216)

Even if a particular measurement were quite free from error and wholly exact, replications of the measurement would almost certainly fail to yield always identical measures. Both our concepts and the contexts in which they are applied are open to some extent: DIFFERENT OBSERVERS WILL HAVE SOMEWHAT DIFFERENT CONCEPTIONS, AND WILL VIEW SOMEWHAT DIFFERENTLY WHAT WE CALL THE "SAME" SITUATION. TO OBJECTIFY THE RESULTS OF INQUIRY WE MUST PROVIDE SOME DEGREE OF INTERSUBJECTIVE CONSTANCY. As Savage suggests, statistics may be seen as dealing with VAGUENESS AND WITH INTERPERSONAL DIFFERENCE IN DECISION SITUATIONS, EXPLOITING SIMILARITIES IN THE JUDGEMENTS OF CERTAIN CLASSES OF PEOPLE, and in seeking devices, notably RELEVANT OBSERVATION, that tend to minimize their differences. A NUMBER OF OBSERVERS EACH MAKING HIS OWN ESTIMATE OF A CERTAIN MAGNITUDE, OR A SINGLE OBSERVER MAKING ESTIMATES ON SUCCESSIVE OCCASIONS, provide findings to be reduced to some underlying unity, or less divergent set.

REVIEW OF EMPIRICAL RESULTS FROM THE REVIEWED LITERATURE ON INPUT QUALITY

SUBJECT: / AUTHORS:	01	02	03	04	05	06	07	08	09	10	11	12	13
Error classification	x	.	.	.	.	.	x	.	.	.	.	.	.
Entry equipment													
Punch	x	x	.	.	.	.	x	x	.	.	x	.	.
Telephone	.	.	.	.	.	.	.	.	.	.	.	x	x
Bank proof/encoder	.	.	.	x	.	.	.	.	.	.	x	.	.
OCR, MICR	.	.	.	.	.	x	.	.	.	.	.	.	.
Communication	.	.	.	.	.	.	.	.	.	.	.	.	.
Typing	.	.	.	.	.	.	.	.	.	.	x	.	.
Shop terminals	.	.	.	.	.	.	.	.	.	.	.	.	.
Keyboards only	.	.	.	.	.	.	.	.	x	.	.	.	.
Hand copy, read, write	.	.	x	.	x	.	.	.	.	.	.	.	.
Sight verification	.	.	.	.	.	.	.	.	.	x	.	.	.
Key-to-disk/tape	.	.	.	.	.	.	x	x	.	.	.	.	.
Other:	.	x	.	.	.	.	.	.	.	.	.	.	.
Applications													
Manufacturing	.	.	.	.	.	.	.	.	.	.	.	.	.
Sales	.	.	.	.	.	.	.	.	.	.	.	.	.
Banking	.	.	.	x	.	.	.	.	.	.	x	.	.
Other:	.	.	.	.	.	.	.	.	.	.	.	.	.
Choice of entry equip. codes, transactions & forms													
Choice entry equip.	.	.	.	.	.	.	x	x	.	.	.	.	.
Forms design	.	.	.	.	.	.	.	x	.	.	.	.	.
Alpha x numeric	.	.	x	.	x	.	.	x	.	.	.	.	.
Length	.	.	x	.	x	.	.	x	.	.	.	.	.
Grouping	.	.	x	.	x	.	.	x	.	.	.	.	x
Aural x visual	.	.	x	.	.	.	.	.	.	.	.	.	.
Fixed/variable field	x	.	.	.	.	.	.	.	.	.	.	.	.
Check possibilities	.	.	.	.	.	.	x	.	.	.	.	.	.
Pre-assigned media.	.	.	.	.	.	.	.	.	.	.	.	.	.
Memory aids	.	.	.	.	.	.	.	.	.	.	.	.	.
Time pressure	.	.	x	.	.	.	.	x	.	.	.	.	.
Characters, symbols.	.	.	.	.	.	.	.	x	.	.	.	.	.
Human element and procedures													
Person	.	.	.	.	.	.	.	.	.	.	x	.	.
Preferences	.	.	.	.	.	.	.	.	x	.	.	.	.
Training	.	.	.	.	.	.	.	.	x	x	x	.	x
Allocation of function	.	.	.	.	.	.	.	.	.	.	.	.	.
Supervision methods	.	.	.	.	.	.	.	x	.	.	.	.	.
Digit manipul. errors	.	x	.	x	x	.	.	.	.	.	.	.	.
Checking techniques	.	.	.	.	.	.	x	x	.	.	.	.	.

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12 - Klemmer (1964)
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(continued)

REVIEW OF EMPIRICAL RESULTS FROM THE REVIEWED LITERATURE ON INPUT QUALITY

SUBJECT: / AUTHORS:	14	15	16	17	18	19	20	21	22	23	24	25	26
Error classification ...	x	x	.	.	.	.	x	.	x	x	.	.	.
Entry equipment													
Punch	.	x	.	.	.	.	.	.	.	.	.	.	.
Telephone	x	.	.	.	.	.	.	.	.	.	.	.	.
Bank proof/encoder	.	.	.	.	.	.	.	.	.	.	.	.	.
OCR, MICR	.	.	.	.	.	.	.	.	.	.	x	.	.
Communication	.	.	x	.	x	.	.	.	.	.	.	.	.
Typing	.	.	.	.	.	.	.	.	.	.	.	.	.
Shop terminals	x	.	.	.	.	.	.	.	.	x	.	.	.
Keyboards only	.	.	.	x	.	.	.	.	.	.	.	.	.
Hand copy,read,write...	.	.	.	.	.	.	.	.	.	.	.	x	x
Sight verification	.	.	.	.	.	.	.	.	.	.	.	.	.
Key-to-disc/tape	.	.	.	.	.	.	.	.	.	.	.	.	.
Other: .	.	.	.	.	.	.	.	.	x	.	.	.	.
Applications													
Manufacturing	x	.	.	.	.	x	.	.	.	x	.	.	.
Sales	x	.	.	.	.	.	.	.	.	.	.	.	.
Banking	.	.	.	.	.	.	.	.	.	.	.	.	.
Other: .	.	.	.	.	.	.	x	.	x	.	.	.	.
Choice of entry equipment, codes, transactions and forms													
Choice of entry equip..	x	.	.	x	.	.	.	.	x	x	.	.	.
Forms design	.	.	.	.	.	.	.	.	.	.	.	.	.
Alpha x numeric	.	.	.	.	.	.	x	.	.	.	.	.	.
Length	.	.	x	.	x	.	.	.	.	x	.	.	.
Grouping	.	.	.	.	.	.	x	.	.	.	.	.	.
Aural x visual	.	.	.	.	.	.	.	.	x	.	.	.	.
Fixed/variable field ..	.	.	.	.	.	.	.	.	x	.	.	.	.
Check possibilities ...	.	x	x	.	.	.	x	.	.	x	.	.	.
Pre-assigned media	x	.	.	.	.	.	.	.	.	x	.	.	.
Memory aids	.	.	.	.	.	.	x	.	.	.	.	.	.
Time pressure	x	.	.	.	.	.	.	.	.	x	.	.	.
Characters, symbols ...	.	.	.	.	.	.	x	.	.	.	.	.	.
Human element and procedures													
Person	.	.	.	.	.	.	.	.	.	x	.	.	.
Preferences	.	.	.	x	.	.	.	.	.	.	.	.	.
Training	.	.	.	.	.	.	.	.	.	.	.	.	.
Allocation of functions	.	.	.	.	.	.	.	.	x	x	.	.	.
Supervision methods ...	.	.	.	.	.	.	.	.	.	x	.	.	.
Digit manipulation error	.	.	.	.	.	.	x	.	.	x	.	.	x
Checking techniques ...	.	x	.	.	x	x	.	.	.	.	.	.	.

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STATISTICS AND THE "REJECTION OF OUTLIERS"

If, in an experiment, one value obtained by the particular measurement process is a long way from the other values in a SERIES OF REPLICATE DETERMINATIONS OF THE SAME CONSTANT MAGNITUDE, or if for instance in a least-squares analysis one reading is found to have a much greater residual than the others, THERE IS A TEMPTATION TO REJECT IT AS "SPURIOUS" OR "OUTLIER".

The temptation arises from the experimenter's feeling or JUDGEMENT that in this way he can minimize the loss of so-called ACCURACY of the experiment due to the two possible ERRORS: rejecting a VALID observation or accepting a defective one.

Several outstanding statisticians have given attention to this problem which has been recognized since more than hundred years ago. Some of their thoughts may be summarized as follows.

SOURCES OF VARIABILITY IN READINGS

Variability or dispersion in a set of observations can be seen as arising from several different sources. If we are for instance investigating the height (stature) of persons employed at a particular place we may have variability due to:

1. INHERENT VARIABILITY. It would be observed in the population even if all measurements were PERFECTLY ACCURATE. It cannot be reduced without changing the population itself, THE OBJECT OF THE STUDY. If we are interested in the MEAN stature of the population, we may refer to the variability as "error" since it gives rise to estimation error; but the name is misleading. In connection with the concept of "population appears also what statisticians may call "error of contamination": it occurs when a certain proportion of the observations came from a population which is SIGNIFICANTLY DIFFERENT from the one in which the experimenter is interested, and there is no way to discover which populations yield which observations.

2. MEASUREMENT ERROR. It is due to the measuring instruments. In measuring height, if readings are made to the nearest centimeter, it is usually assumed that measurement error should not exceed half a centimeter, but in fact it sometimes does. One may count as a measurement error also any ARITHMETICAL MISTAKE in reducing the original notebook entries to the form in which they are quoted as observations (e.g. "clerical errors").

3. EXECUTION ERROR. It is intended to denote any DISCREPANCY BETWEEN WHAT IS INTENDED TO BE DONE AND WHAT IS ACTUALLY DONE, other than error in the use of measuring instruments. Here should also be included the above mentioned errors of "contamination", for example

including in the sample of measurements the height of some person not belonging to the population, to measure something other than height, or to select a biased sample of the population.

CRITERIA FOR REJECTION

One of the most important results of finding an apparently "wild" or otherwise anomalous observation, i.e. an "outlier", can be the CORRECTION OF A FLAW IN THE MEASUREMENT PROCESS, or - even better - the creation of NEW INSIGHTS INTO THE PHENOMENA UNDER STUDY.

This presents one basic difficulty in finding criteria for rejection of outliers. Furthermore: can realistic rejection models be worked out for cases when the probability of a blunder, e.g. missing an observation, depends on the value that would have been observed if the blunder were not present ?

IT APPEARS THAT THE BASIC CRITERIA FOR REJECTION IN STATISTICAL MATERIAL DEPENDS ON WHAT WE ARE AFTER AND ON THE NATURE OF OUR MATERIAL. If our observations are five determinations of the percent of chemical A in a mixture, and one observation is badly out of line, A CHECK OF THE EQUIPMENT MAY SHOW that the outlier stemmed from an equipment MISCALIBRATION that was present only for the one observation. If the GOAL OF THE EXPERIMENT is only to estimate the percent of A in the mixture, it would be very natural simply to omit the wild observation in case we cannot correct for the magnitude of the miscalibration. However if the goal of the experiment is that of INVESTIGATING THE METHOD OF MEASURING the percent of A (say in anticipation of setting up a routine procedure to be based on one measurement per batch), then it may be very important to keep the wild observation in. IN THIS WAY WE CAN LEARN SOME LESSON ABOUT THE METHODS OF SAMPLING, MEASUREMENT, AND DATA REDUCTION (as opposed to the underlying physical phenomenon).

As another example suppose that 50 bombs are dropped at a target in a military operation, that a few go wildly astray, that the fins of these wild bombs are observed to have come loose in flight and that their wildness is unquestionably the result of loose fins. IF WE ARE CONCERNED WITH THE ACCURACY OF THE WHOLE BOMBING SYSTEM, we certainly should not forget these wild bombs. BUT IF OUR INTEREST IS IN THE ACCURACY OF THE BOMBSIGHT, the wild bombs are irrelevant.

Another approach to the problem of outliers recognizes that it is not basically a problem of rejection, which may typically be treated with the method of significance tests. It is not so often a matter of studying whether and how often outliers occur in a certain field, but rather a study of guarding oneself from their adverse effects by answering the typical "insurance policy" questions:

1. What is the "premium" ?

2. How much protection do I get in the event of error ?

3. What is the probability of error ?

leading to a compromise between rejecting a valid observation or accepting a defective one. Many studies about rejection of outliers have focused on the third question while obviously all three are important since e.g. low premium and good protection decrease or eliminate the need of an answer to the third question.

Seen in still another dimension, the problem of rejection of outliers is one of increasing complexity according to the following scale based on degrees of KNOWLEDGE ABOUT APPARENTLY WILD OBSERVATIONS:

1. We know even BEFORE an observation that it is likely to be wild, e.g. because of a physical incident that occurred to the equipment.

2. AFTER the observation we can reconstruct a causal pattern by checking with e.g. a laboratory notebook or by retrieval from memory of historical data.

3. WITH NO OTHER EVIDENCE, we want to reject the outlier only based on the PATTERN OF THE OBSERVATIONS THEMSELVES.

Eventually, besides of the previously mentioned errors of so-called contamination, measurement and execution, statisticians may also justify treating the data by some method of outlier rejection on the premise that OUTLYING OBSERVATIONS ARE INHERENTLY MORE DIFFICULT TO OBSERVE AND RECORD so that their PRECISE VALUES are less TRUSTWORTHY. It is usual in such cases to speak of observations that are INACCURATE rather than SPURIOUS. Statistical techniques have been developed for treating or "censoring" a few values on each extreme ("tail") of the distribution.

(F.J. Anscombe, 1960; T.S. Ferguson, 1961; W.H. Kruskal, 1960a and 1960b)

HISTORICAL CRITICISM

It is an aim of historical research to DRAW INFERENCES ABOUT THE PAST THAT ARE IN SOME WAY VERIFIABLE. With this purpose it utilizes several kinds of remnants, like in archeological research, but also many available reports in narrative form, etc.

SOURCE CRITICISM

Typically a historian recognizes the need to evaluate a historical SOURCE on the basis of three main dimensions:

1. GENESIS. That is its coming into being: when and how, WHO determined such an event - what person, private or public organization WITH WHAT INTERESTS. The situations around the origin of the source lead to a common classification of the information along its DEGREE OF PRE-PROCESSING:
   a) ORIGINAL DATA, which are the oldest data available, e.g. accounting information in a firm, on which the
   b) RAW MATERIAL or PRIMARY MATERIAL is based on, e.g. the filled forms that the firm has prepared on request of some state agency.

   The raw material is furthermore seen as originating
   b1) PRIMARY STATISTICS for which the material was expressely obtained, and
   b2) SECONDARY STATISTICS which is the result of processing that was not envisaged at the time of obtention of the material.

2. CONTENT. The source is classified as a
   FIRST-HAND SOURCE or as a
   SECOND-HAND SOURCE
   according to its DISTANCE TO THE HISTORICAL SITUATION. Does the information refer to something that the reporter himself has seen or heard, or are there several links between the event and the reporter ? It is also important to consider what FORM OF EVIDENCE is offered by a second-hand source: a picture, a copy of a document or barely a repetition of a rumour.

   The above classification of sources overlaps with the previously mentioned classification according to the degree of pre-processing: ORIGINAL DATA AS WELL AS RAW MATERIAL MAY BE EITHER FIRST-HAND OR SECOND-HAND SOURCES' PRODUCTS. For instance, advertisements for political meetings - appearing in available copies of newspapers are original data, however they are first-hand for an investigation of volumes of political advertisements while they are second-hand for an investigation about times, places, and speakers at the meetings. Analog points can be raised regarding Custom's reports on quantities and values of goods exported or imported to-from certain countries.

Quantitative analysis of source contents gives rise to certain definitions of so-called RELIABILITY, RELEVANCE, and VALIDITY. For instance, in an investigation of written material published by the press on political questions, the articles are coded in CLASSES OF POLITICAL MATTERS and the VOLUME of the writings is measured, for example, in number of lines.
The RELIABILITY of the investigation is then said to MEASURE THE PRECISION of the measurements, and it is a FUNCTION OF DIFFERENCES OBTAINED BY DIFFERENT RESEARCHERS performing the same investigation. If the same investigation also aims to measure the INVOLVEMENT of the political parties in the political debate, it might attempt to measure the frequency of the PARTIES' NAMES per e.g. 100 lines of press-text. Is such a measure an expression of involvement ? Are such names a source with RELEVANCE for the question that was asked ? If not, the investigation will have low VALIDITY.

3. FITNESS FOR USE. This refers to the use to answer the posed questions. Such evaluation is based on two dimensions: relevance and credibility.
   a) RELEVANCE. An example is the reporting of Customs' authorities about charge and receipts of duties. They are directly relevant for an investigation of incomes to the State, while they must - if at all possible - be adjusted for smuggling and dutyfree goods when used in investigations of volume of trade. THE RELEVANCE IS THEN RELATED TO THE USE AND GOAL OF THE USE OF DATA.
   b) CREDIBILITY. It is evaluated on the basis of the INTERNAL CONSISTENCY of the report, its "probability" (based e.g. on commonly accepted truths), the reporter's judged possibilities to understand, notice, and reproduce what is described, and eventually his subjective qualifications, reputation. It is, for instance, barely credible that in an armed conflict one party can count at the end of each day the enemy's casualties down to the last man or airplane.

Most other problems related to source criticism which appear in historical research literature are known in the context of statistical method. One outstanding problem appears to be the DEFINITION OF THE POPULATION in terms of TIME, SPACE and the ATTRIBUTES OR QUALITIES of its ELEMENTS OR INDIVIDUALS. This problem is the background of some of the main difficulties and errors in investigations e.g. related to CHANGES in geographical-administrative limits of territory, in classification-allocation among categories-codes, or related to so-called "non-responses" or "missing" observations.

We will now illustrate the application of this theoretical framework to some concrete examples and develop such examples in the context of sources of ERRORS in case studies.

SOURCES OF ERRORS IN CASE STUDIES

To take the terminology question first, case studies on the FITNESS FOR USE of a source (was seen to be evaluated in terms of RELEVANCE and CREDIBILITY) show that both relevance and credibility are affected by specific types of errors.

RELEVANCE may be affected by ERRORS in, or simply by CHANGES in data-collection or classification procedures: an increased reporting of rate of crimes may be caused by a more efficient reporting system rather than by an actual increase in the number of committed crimes. Or the definition of "crime" itself might have changed in the meantime leading to the inclusion among crimes of events that earlier were not considered as such, in spite of occurring as often as now. Or the rate may stay constant in spite of the crimes leading to more serious consequences.

CREDIBILITY is said to depend partly on the COMPLETENESS and partly on the CORRECTNESS of the statements.
a) COMPLETENESS is said to be affected if for instance when trying to count the population in a region by means of direct method, a great number of the people hide outside the region with the intent of not being registered (e.g. because fearing a heavier taxation).
b) CORRECTNESS is said to depend on the goodwill and capability of those who gave the statements or delivered the data: peasants will report greater numbers of live-stock if they believe that the report will be used for allocation of fodder or financial support, rather than if they suspect that it will be the basis for taxation; furthermore it may be impossible to count the live-stock down to the last unit at the end of a given day.

The evaluation or estimation of ERRORS in historical statistics' material is said to be possible by means of two methods:
a) CONFRONTATION OF INDIVIDUAL STATEMENTS, as exemplified in investigations that compare the live-stock figures in taxation records with corresponding figures in documents on the distribution of inherited stock among heirs.
b) STATISTICAL ANALYSIS of the so-called "REASONABLENESS" of sums and results. It is typical of population statistics and is based on well known probability-distribution thinking.

(As an additional case, Morgenstern cites Hans Delbrück who found that if the Greek claims regarding the strength of the Persians at Thermopylae were true, there would not even have been room for the Persian troops to occupy the battlefield. Or, given the roads of the time, the last Persian troops would have just crossed the Bosporus when the first already had arrived in Greece).

We will now take a look at errors in population, social and economic statistics from a historical perspective. What is named as "political statistics" overlaps in many respects with economic statistics and will be included by us in the latter.

POPULATION OR DEMOGRAPHIC STATISTICS

It deals with births, deaths, marriages, fertility, and migration. Historical research in this area has dealt with e.g. size and changes in size, and mobility.

When trying to determine past yearly changes in size of population, based on registry hold by national or local authorities, it has been proposed on one occasion that the agents of the authorities deleted the poorest people from the registry in years of bad economic situation: such people could then be temporarily relieved from taxes. A measure of the size of the population may in this case be looked upon as an economic indicator !

Later investigations of such problems have considered technical aspects of the registration such as substitution of clerks, issuance of new rules for registration, local differences in accounting rules or inflexibilities in rules of cancellation, writing off etc. Figures on migration were obtainable only in those cases when registration was supplemented by a continuous system of transactions, rather than exclusively based on periodical counts. Many errors in population registry have been assigned to the registrators' insatisfactory training in bookkeeping, dullness of work, or lack of motivation to register people who were regarded as "DEVIANT" RELIGIOUSLY OR POLITICALLY. Clerical misunderstandings included cases when stillborn children (dead at birth) were registered as dead but not as born. It is estimated that during the 18 th century's Danmark and Norway about 5 to 10 % underregistration may be related to the numbers of born and dead people.

Deviances between the situation in which the original data appeared, and the situations in which later such data are interpreted, occur when population dynamics must be inferred from available documentation. Registry on burials stands for mortality, clerical registry on marriage ceremony stands for marriages, and baptism stands for births. Summary tables of data WERE SYNTHETIZED from partial tables preventing the kind of checks possible through comparison with actually original data lists. Special inconsistencies were caused by the earlier habitude of not using "non-existence" or "absence" files for people who had disappeared without trace.

SOCIAL STATISTICS

It is usually concerned with either the SPECIFIC INDIVIDUAL (language, education, family relationships, income, property), or with SOCIAL ACTIVITIES (such as health assistance, economic support, education, judicial system), or finally with data concerning the SOCIETY IN FUNCTION (e.g. unemployment, cost of living, salary trends, housing).

Errors in such statistics could in some cases be traced back to data-collection forms which were changed for the purpose of certain kinds of improvements, (such as decreasing misunderstandings in the process of filling the forms) at the cost of destroying the possibility of comparing data from successive periods of time. "Language" could be in one case filled upon statement of the respondent while in another case it was the registrator's own opinion. "Profession"could be dependent on the kind of branch - industry, or alternatively on the content of the work - in some other sense.

ECONOMIC STATISTICS

POLITICAL STATISTICS, specifically is said to deal with national and local financial statistics, with elections (including voters, elected, and press). Specific problems arise because of the SECRECY of certain financial data, the earlier non-existence of fiscal unity in financial transactions, difference in currencies. Special pitfalls come e.g. from the use of files on national revenues from taxation for the purpose of inferring the distribution of income and property.

ECONOMIC STATISTICS,properly defined, is said to deal with PRODUCTION, LABOUR, and CAPITAL as descriptors of the economic situation. It is found that original data having LEGAL IMPORTANCE (such as proof of property) was the one that is most carefully conserved. It is also found that those documents which were most suited for quantification offered pitfalls because of NON-COMPARABILITY between successive periods of time, or because they had low relevance for the purpose on hand.

In agricultural statistics, figures on cultivated areas were affected by errors because of inconsistencies in data-collection from one period to the next, or because of shifting definitions which were hidden by the AGGREGATION OF FIGURES prior to the analysis. Estimates on volume of harvests were affected by variations of money value, since original documents evaluated harvests on the basis of the at-the-time actual values. In modern statistics, special controls are made through individual interviewing of sampled farmers.

In foreign trade statistics the original data may be obtained from Customs' files on import and export. Control of smuggle's effect on the figures is performed through comparison between the files of different Customs stations or between the files of export and import firms. Foreign trade value figures were inferred from quantity figures since Customs duties were related to quantities. The values shown in Customs files were determined through a central or local estimate, or through a request of data from the exporter-importer, leading to inconsistencies about whether the value referred to was at sending or at destination. Land of origin was often found to have been equated to last land touched at,prior to arrival. Land of destination was in an analog way erroneously equated to first land touched at, after departure.

Statistics on handicraft and industry was plagued by inconsistent classifications, resistance by respondents to furnish the requested information, and uncontrolled data-collection procedures.

Statistics on prices became necessary for national authorities when taxes "in natura" were to be evaluated in money or when foreign trade quantities were to be translated to balance of payments. Prices may be inferred from private bookkeeping, and from price tariffs or quotations whose interpretation is strongly dependent upon the particular method of calculation.

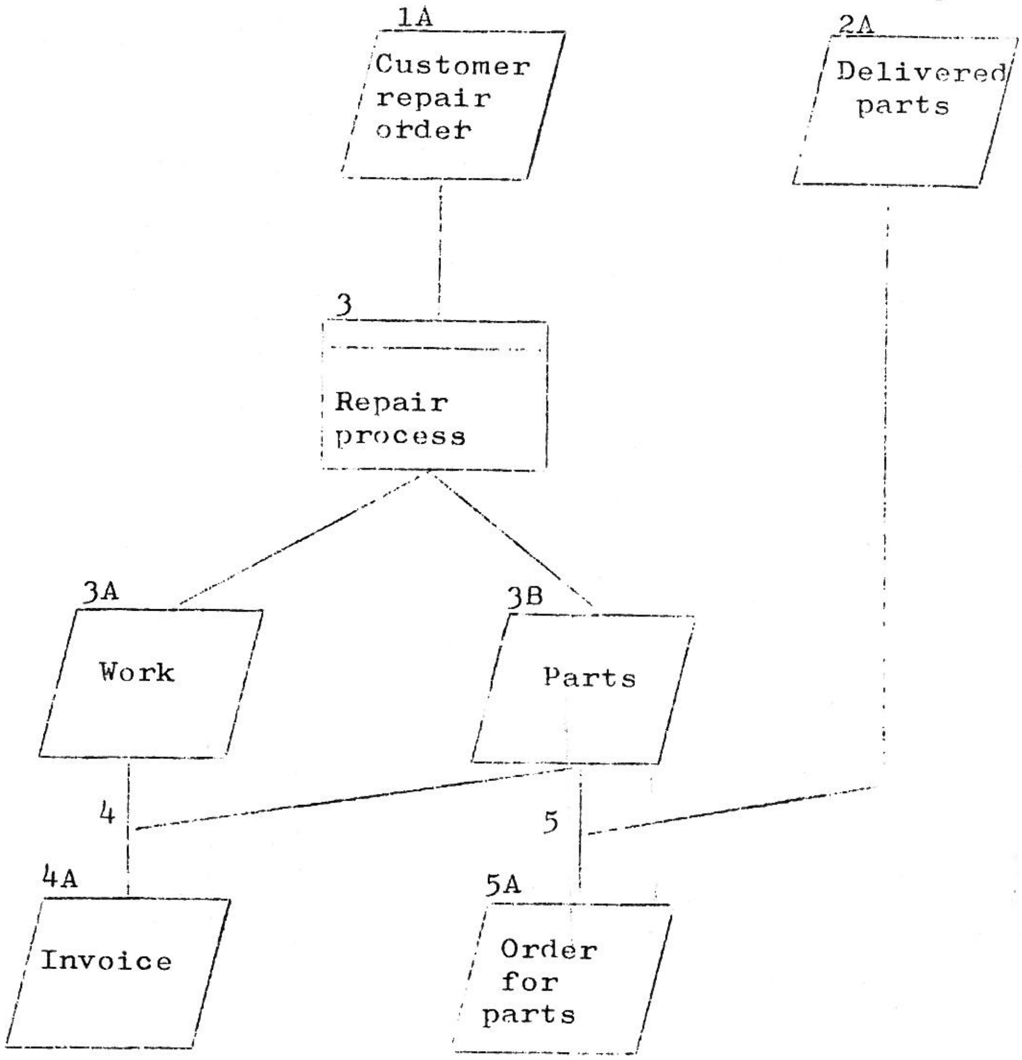
Ambitious data-collection was possibly associated with great volume of collected data, but also with loose rules and control.

(B. Schiller & B. Odén, 1970)

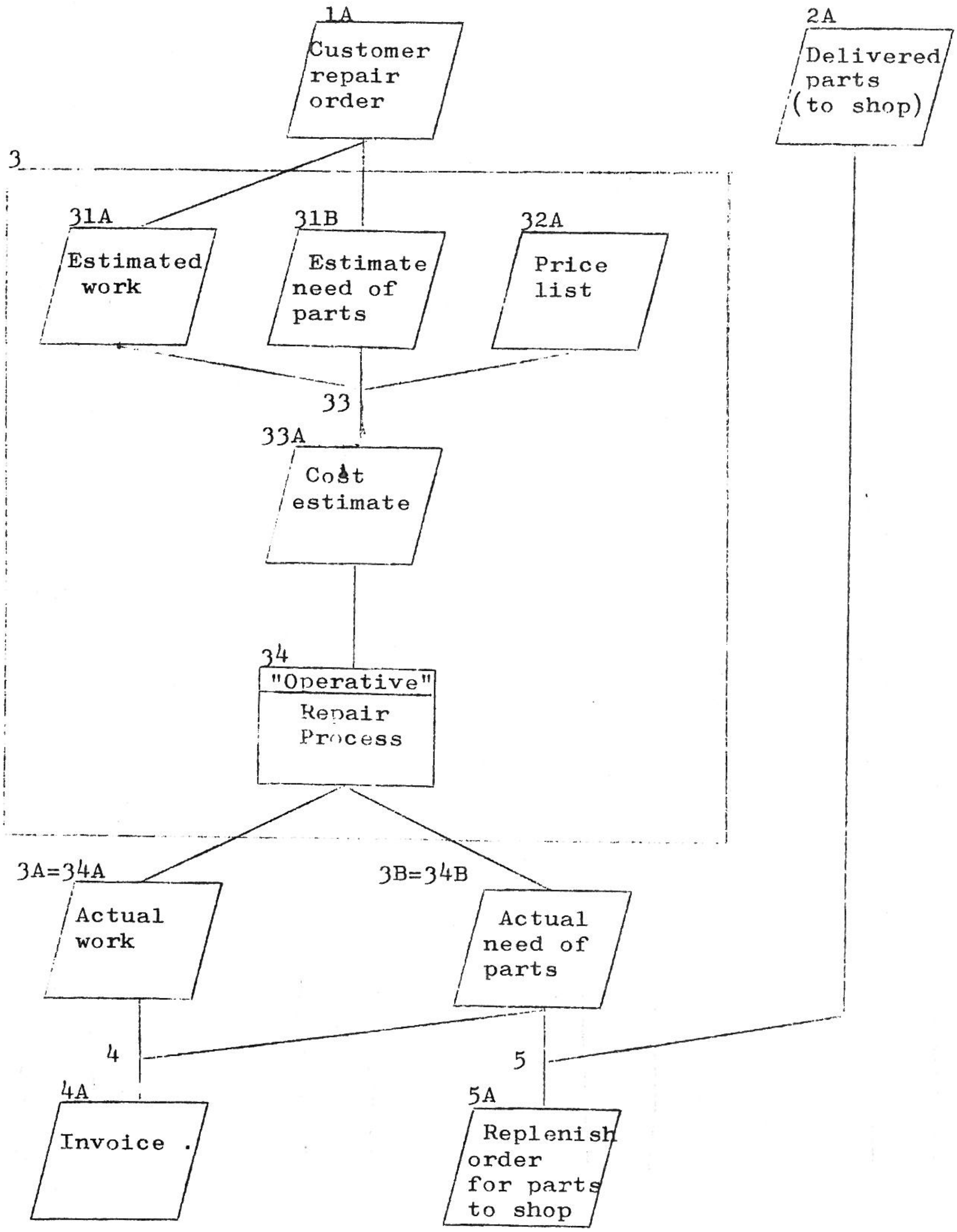
SUGGESTIONS FOR FURTHER ACTION AND RESEARCH

METHODS FOR SYSTEMS ANALYSIS

We already mentioned in chapter 5 the need to complete the structure of an elementary message (in the Langefors' sense, 1968b,p.183) with the ERROR of the measure as a characterization of the measurement or observation process that produced the particular value. We also mentioned the need to include in the Langefors' precedence analysis (1968b, p.67) some "redundant" precedents along the lines of our proposal, in order to allow computation of error. We will now illustrate particularly this last point with a simple example of systems analysis applied to the description of data-processing for a car-repair shop. We shall use the lately developed methods for drawing of precedence graphs, extended from M.Lundeberg's illustration (1970,p.180) of Lagefors' ideas.



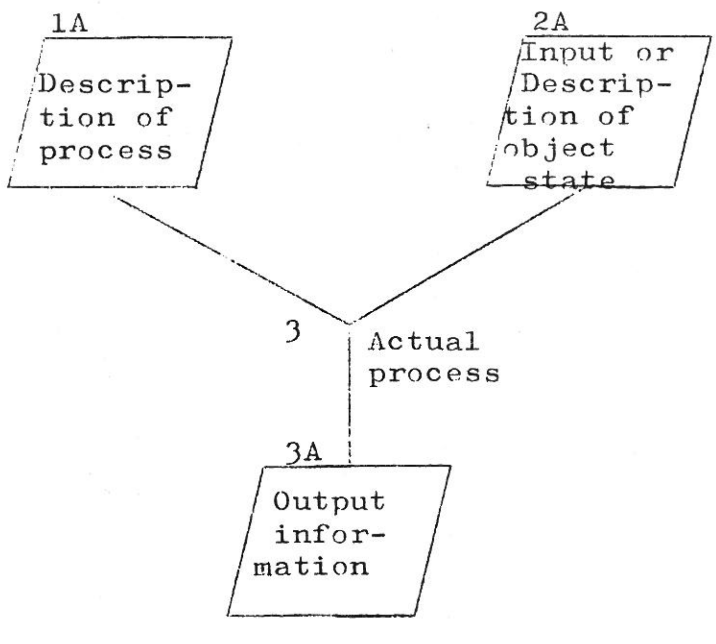
A detailing or "amplification" of process 3 leads to the following partial enlargement of the previous figure



An interesting implication of our paper which we suggest as object of further research is the possibility of regarding 31A essentially as the same thing as 3A, and 31B as the same as 3B. They both are computed by means of certain rules or measurement processes and their relation could be used for computation of error of the cost estimate. This amounts to recognizing that the fundamental nature of data-processing is to predict. According to our proposal the enlargement of process 3 in the second figure has simply introduced the "control observation" of an independent observer, the customer, who is allowed to negotiate on the magnitude of 31A and 31B.

The information sets 31A and 31B, then, correspond to the information 5A in figure 4.10, while further analysis of the figures would possibly uncover the nature of the negotiation process and of the "objective" predicted or measured cost (invoice) in this simple case. It should be noted that similar analysis may be made on other information sets of the graph for the repair-shop. As in the case of results of requirement generation in a manufacturing plant, the replenishment order for parts to the shop, as computed by the data-processing system (5A in the enlarged second figure) is itself only an "estimate" which may be submitted for negotiations to the purchasing department, prior to being sent to the vendor. The information sets 3A and 3B are the only available description of 34. It"exists" only in terms of descriptions.

In order to generate further suggestions for research, we will explore the meaning of the graph-language for description of information processes. With a view on the group of information sets and processes 2A,3A,5,5A of figure 4.10, or alternatively the group in the first, overview of data-processing for the repair shop, we abstract the following basic block



Some interesting questions arise if we ask ourselves what are the implications of 3A being "wrong". Then, using the figure we come to wonder whether the cause is wrong 1A, wrong 2A or wrong 3. If we concentrate on 3 we may ask ourselves how can the "actual" process be wrong. If the process is performed by a computer rather than in a human mind then we will say that the actual process was wrong because of a hardware failure. But "3" in the figure is a symbol that refers to something, it is a description of something, it is information too. Does it describe what should have happened according to some other description (process specifications) ? In such a case, what is the difference between 3A and 1A ? Maybe 1A is the MATHEMATICAL description of the process, while 3 is the PHYSICAL (for instance in terms of electronics) description.

This kind of reasoning takes us back to chapter 4 and to the Von Neumann-Goldstine approach that was one of the basis for our proposal. Maybe 1A is the mathematical function and/or its translation to numeric-analytic terms. Perhaps then, process 3 is the physical translation of the numeric-analytic-binary description to the electronics-physics description. In chapter 4 we named that such translation was only allowed because of the integration of the theory of physics with arithmetics, geometry etc. This is what permits in some sense to "test" the truth of the overall set 1A,3. The extension of this reasoning to the rest of the figure suggests that 2A refers to the"concepts" and measurement of the state of such concepts or objects.

It is obvious that we cannot discuss at one in terms of several different "models" like the mathematical, physical etc. When the output is "wrong",however, or in order to test whether it is wrong we MUST in some way integrate the partial models. This is perhaps the intent of H.Simon when stating that one poses a problem by giving the STATE description of the solution in the SENSED WORLD. The task is then to discover a sequence of PROCESSES in the ACTION WORLD that will produce the goals state from the initial state."Problem solving requires continual translation between the state and process descriptions of the same complex reality." (1969,p.112)

This relates the whole issue to the discussion by Margenau (1966,p.332-341) and his emphasis on that the difference between primary,perceptory experience and the concept or constructs of the cognitive experience, is not merely semantic or linguistic (p.334-335). Actions of the instrumental or operational definitions relate our perceptory to our cognitive experience. In order to apply Simon's problem-solving phylosophy and Langefors' precedence-component analysis to social phenomenon one should investigate which are the possibilities that aggregations of information sets may result in the social or psychological CONCEPTS equivalent to Margenau's cited eigenfunctions of quantum mechanics. Such possibilities may also determine the applicability of precedence graphs to information processes in social environments.

We think that what was said justifies our restraint from drawing precedence-graphs in this study of quality of information, and it appears to be consistent with several remarks that we found in the literature.

M.E.Maron, for example, (1964,p.15) cites Uspenskii as pointing out that "in order to create an information language for a given subject, one must have a theory of that subject; one must know about the things in question, about their properties, properties of those properties, and so forth."

Churchman (1963,p.8) after stating that the observing mind partitions the class of meaningful assertions into those that describe the reality of the observed mind, and those that do not continues: "Often, without loss, the observing mind may take the set of assertions to be the reality of the observed mind rather than a description of it."

Several authors describe how particularly in social environments, the meaning of input, output, and process becomes vague or breaks down leading to false results. See J.Schlesinger (1971,p.400), Gross (1971,p.367), Buckley (1967,p.54,168). Particularly worthy of meditation is the elaborate construction that H.H.Goode & R.E.Machol attempt to explain in order to differentiate between INFORMATION versus MATERIAL systems(1957,p315). The kind of conceptual difficulties that it uncovers are characteristic of later positivistically oriented literature. The same is noticed in Chapanis (1951).

The alternatives may be seen in terms of the generalized concepts of precedence and production as set forth by e.g. by Singer and found in the work of Churchman and Ackoff (See Ackoff, 1962, p. 156,172). It is possible that also A.Danielsson's approach gives some hints in this direction (1963). Much hard work is apparently required in order to translate such thoughts to guidelines for systems analysis aimed at computerized applications. Perhaps some further hints will be contained in the latest book by Churchman (1971) which we have not yet available at the time this is written.

A final note to suggest that mentioned possible developments in methods of systems analysis may be relevant even for more technical software matters. In a personal communication (April 13,1971) Prof.David L.Parnas emphasizes that the"interface" between subsystems or modules of software operating systems does NOT consist only of their input/output flows of data. In Parnas' own words, such interface consists also of the ASSUMPTIONS that the modules make on each other. This means that we can actually change a module without changing others only to the extent that we do not affect the assumptions that the others assume (See information set 1A of figure 4.10). Thus, it appears that such assumptions may be considered as part of the factual content of boundary flows.

HUMAN THINKING AND MANIPULATION OF SYMBOLS

There is apparently something in common between much work going on in so-called artificial intelligence, simulation of human thinking, automatic problem solving, question-answering and fact-deducing systems, data management, quantitative linguistics, etc. This common thing is that they are regarded basically in terms of manipulation of symbols and that the writings about such topics are often divorced from any philosophical considerations or evaluation in terms of scientific method. "Symbols" and "manipulation" have apparently acquired a primary, self-sustained meaning that makes us wonder how it is related to e.g. Margenau's statement on the difference between primary-perceptory experience "P" and conceptual "C" cognitive experience (1966,p.335): "The difference between P and C is not merely semantic or linguistic; in fact language frequently obscures the difference. To note this is especially important for a fuller understanding of the method of science..."

The implications of the above may be essential in order to understand the implications and THE DANGERS of symbol manipulation which is often believed to create knowledge by manipulating a number of related "facts" plus their relationships. Knowledge and understanding is then seen as limited by our computer-programming capabilities as well as time-economic limitations of hardware, memory,etc. Truth is often seen in terms of logic truth, as implied by the VALIDITY of deductive arguments or by TRUTH-FUNCTIONAL PROPOSITIONS. Validity is predicated of any deductive argument in which it is impossible to make the premises true while the conclusion is false. Truth-functional proposition is a compound proposition whose truth-value is completely determined by the truth values of its component propositions: thus, if we know the truth values of "p" and of "q" we can decide the truth value of "p implies q". One may, then, also conceive of the validity of CONDITIONAL PROPOSITIONS which are propositions of the form "if p then q" where p is the antecedent and q the consequent. (For an introduction see "Logic" in The Encyclopedia Americana, 1958).

And so go the arguments which the reader will probably relate to propositional or sentential calculus, to some of our reasoning in chapter 2, and to our discussions of truth relations among input, method, process and output. This appears to be the only possible discussion about "truth" that symbol-manipulation allows. The need for formalizing logic descriptions of complex reality, apparently lead to elaborate reconstructions like Carnap's modal logic incorporating "necessary" to the "and", "or", "not" terms. Then we get also a "temporal logic" which incorporates time. "Nuances in input" perhaps will be taken care by the "Theory of Fuzzy Sets",while in our approach we think they represent the scientific problem of measurement.

We urge the reader to think about the implications of how "decision-making in a fuzzy environment" (R.E. Bellman & L.A.Zadeh, 1970) takes care of the the problem of quality of information: "Specifically, our contention is that there is a need for differentiation between randomness and fuzziness, with the latter being a major source of imprecision which is associated with fuzzy sets,...that is, classes in which there is no sharp transition from membership to nonmembership. For example, the class of green objects is a fuzzy set. So are the classes of objects characterized by such commonly used adjectives as large, small, substantial, significant, important, serious, simple, accurate, approximate, etc."(p.B-141). Compare this approach with Ackoff's discussion of definition of red color (1962,p.160, 170).

It appears to us extremely important that all research relying on logic realizes the role and limitations of logic. "Logical consistency has no necessary priority." (Churchman, 1948,p.192). Further discussion of the limitations of logic are found in Kaplan (1964,p.3-18), Shapere (1966,p.42), Churchman (1968b,p.31-36,68,108-119). It is not a question of "plugging the information into the machine." It is not either a question of, as a top business executive once said, considering items of information or "facts" as the material parts to be combined by the computer "tool", requiring therefore to be standardized to obtain low cost and quick delivery of machined information.See also Ferry(1971,p.211) and Churchman (1968b,p.200) on education as "production".

In the same context we feel that a great danger is represented by the so-called simulation of human thinking. To illustrate the following point consider the following statements.

"A man, viewed as a behaving system, is quite simple. The apparent complexity of his behavior over time is largely a reflection of the complexity of the environment in which he finds himself." (Simon,1969,p.25)

"I do not propose here to develop in detail the idea that the core of the behavior we call emotional derives from a mechanism for interrupting the ongoing stream of activity. However, this notion is consistent with a good deal of empirical evidence about the nature of emotion and provides an interesting avenue of exploration into the relation of emotion to cognitive activity. It suggests that we shall not be able to write programs for computers that allow them to respond flexibly to a variety of demands, some with real-time priorities, without thereby creating a system that in a human, we would say exhibited emotion." (Simon, 1966,p.18)

We suggest that the above two statements being capable to direct coming research in psychology and "artificial intelligence", be submitted to deep criticism.

We think that a starting point for such criticism may be found in the following cited work.

"...we have found it expedient to refer, somewhat vaguely, to another metaphysical principle which I shall call the requirement of simplicity and elegance. This has replaced to some extent the older criterion of mechanical intuitability or visual clarity of explanatory constructs. Great scientists have always been impressed by it, for they have sought simple laws, differential equations of low order, spherical shapes for fundamental entities, small and where possible integral numbers for basic constants, and so forth. True, they did not always get away with simple choices, and they replaced the naive maxim of the simplicity of nature by the methodological injunction that simplicity must always be sought but ultimately distrusted. We should also note the logical ambiguity of terms like simplicity and mathematical elegance." (Margenau, p.340)

Churchman (1968b,p.123) cites Ashby:"Science has, of course, long been interested in the living organism; but for two hundred years, it has tried primarily to find, within the organism, whatever is simple...".
In another context (p.97)Churchman remarks that "reason is not equivalent to what might be called calculation; for example, the processes carried on by a computer do not express all there is to be said about the concept of reason." And this may be related to Shapere's remark (1966,p.45) that "Wittgenstein warned that a great many functions of language can be ignored if language is looked upon simply as calculus..."

It is difficult at this point to disregard the the idea that language as an expression of thought serves particularly as a vehicle for a relationship to another person ! Additional criticism is implied, if read carefully, by U.Neisser's remark on the two phases of the popular (and we might add "and many scientists' ") attitude towards "artificial intelligence" (1963) "Yesterday's skepticism was based on ignorance of the capacities of machines; today's confidence reflects a misunderstanding of the nature of thought."

Churchman, commenting on a possible attitude of the scientist writes "He acts as though he believed that people are information-processing machines. Indeed, in one area of scientific research, called "artificial intelligence", it is clearly assumed that intelligence is a type of information processing, and hence computers can think because we can get them to simulate the information processing of people. It's strange how often the critics of artificial intelligence object to the wrong thing here; they are horrified at the suggestion that computers can think, whereas they should be horrified at the suggestion that people are information processors. (1968a,p.124).

After a passus where he shows that reduction of biology or psychology to physics may imply the disregard of all those problems that historically originated the sciences of biology and psychology (1968b,p.155), Churchman writes "...If science can construct realistic descriptions in a nonhuman manner, then the way it describes is really inhuman." (p.189). This may be the background of the apparent bankruptcy of the debate on"subjective"versus "objective" in the context of scientific method, as suggested in chapter 4 and by Churchman (1970,p.B-47). See also Churchman's discussion the "disinterested observer" and his emotional life (1968b,p.188-189) where he writes:"Some knowledge of the emotional life of every observer must be understood to make sure that the observer's world is separable from this other world." That same chapter on "Realism and Idealism" (p.171) is recommended to those who feel that these matters are "too theoretical" in the context of design and use of information systems.

In spite of our frequent citations, Churchman is not alone in the deep and intensive criticism. Wilensky, Downs and other contributors to Westin (ed.) (1971) put these viewpoints in a concrete and broad socio-political perspective. Shortly before his death, the"father" of cybernetics, Norbert Wiener gave a cybernetic interpretation of the dangers of narrow-minded use of computers (1960), and Johnson & Kobler expand those views in other terms in a later paper (1962).

If we relate all the above to Margenau's remark(1966,354) on simplicity of physics'invariances, and to Churchman's comments on the meaning of social invariances (1968a,p. 224; 1968b,p.188) we think we have enough material for expressing the hypothesis that the search for"simplicity" in human matters may be dangerously biased. By this, we mean that if the search after so many expensive efforts turns out to be "successful" it may result in the discovery of constants and invariances which will further direct inquiry in inhuman ways.

In a recent presentation of the work on a symbol-manipulation project we asked the lecturer what would be the applications of future advances of the project. We were informed that at a higher level of sophistication it might be useful for social planning and military applications. Our next question was how the system would be tested,

We did not get any answer;but we think that the question was not properly understood since symbol-manipulation has no "frame of reference" for discussing test and quality in the sense of our paper. We think, however, that such a question must be thoroughly answered if we are going to place any confidence in practical uses of such systems.

INFORMATION QUALITY AND LAW

In the course of our paper we pointed to the importance of tying down the accuracy of information to particular humans. Research is necessary in order to refine the possibilities to define decision-makers.

We want now to emphasize the possibility that all concern with security, secrecy, privacy, integrity, and confidentiality, may indeed be a subproblem of the general issue of quality. Maybe 90 % of all evils, in some sense, will derive from authorized use of information which is misused because of our limited knowledge of its quality, or of its right processing. Is it possible that the present concern with security etc. is a symptom of the "communication" approach to information systems ? As if the whole question amounted to guarantee that the information is "plugged" into the right mind with the GOOD JUDGEMENT ? The mind of an EXPERT ?

We feel that our study suggests that the basic human right in the context of data-banks and information systems is that EACH CITIZEN BE INFORMED ABOUT WHAT IS RECORDED ABOUT HIS OWN PERSON AND ABOUT WHO HAS USED THIS INFORMATION FOR WHAT PURPOSE, AND FINALLY THAT HIS OWN DISAGREEMENT ABOUT THE RECORDED INFORMATION BE RECORDED AND ALWAYS RETRIEVED TOGETHER WITH IT.

The above minimum requirements just allow for the possibility to control the quality of information. The next recommended step could be to implement control of the quality of that information by guaranteeing that each individual has the right to "sign-off" BEFORE information about him is given to somebody else. The sign-off would imply AT LEAST the right to negotiate in the sense developed in chapter 4.

In this same context we want also to remind our discussion of Churchman's claim for the need at least of a system of legal controls so that the user of the information center cannot simply retrieve the datum "Jones was convicted of burglary" (Churchman, 1968b, p.196). As Buckley expresses it (1967, p.44) "individuals" are not discrete. What is discrete to the human observer's limited sensory apparatus is simply the physical organism. Or again Churchman (1968b, p.123): "From the point of view of synthesis, rather than analysis, the so-called simple component, so clear to the heart of the empiricist, is not simple at all. It is a component only because someone has had the imagination to construct the system of which it is a part; it is highly complicated because to show in what way it is a component at all is a long and tedious task. The issue is not whether the system exists; the issue is whether a component exists." Compare this with the discussion by Shapere (1966, p.47), Margenau (1966, p.335, 343), and the concepts of "eigenfunctions" and "field functions" in physics.

Thus, the problem is much more complicated than, as sometimes mentioned in the context of data management, "to guarantee that access to"data"be limited to those capable of using it correctly". Sometimes in organization-literature is mentioned that one important problem of "source-(of information) evaluation" is that of falsification of performance measurements. This view runs counter the spirit of our paper. We think that our previous discussions of judgement etc. may be further stimulated by referring to the literature on LIES, versus FALSIFICATION, versus POOR JUDGEMENT (for example, Morgenstern 1963, p.25,81). Maybe the denomination varies depending upon which organizational level they are committed at ? Legal equality may indeed require judicially binding responsibilization of "decision-makers".

The definition of decision-makers may also be a step towards control of abuses of statistical techniques for "predicting" behavior in minority groups. "Dagens Nyheter" Dec.5 1970,Feb.6 1972,Feb.11 1972 reports that for the purposes of research or"preventive" control,data are collected on people who e.g. live together without being married, take tranquilizers, have tendency for alcoholism, have problems at work or with relatives, what language do they speak, whether the mother of a child lives together with the child's father,or whether she has interrupted earlier gravidity, whether the subject is sexually deviant, or suspect for infidelity in marriage, or whether he has particularly weak financial position. Instead of the original idea that the citizens control the public servants by means e.g. of an "ombudsman" the opposite may be happening. This fits, at least, into the pattern of several contributions to Westin (ed.) (1971). See also Churchman (1968a,p.110).

Is it conceivable to legislate about the legitimacy of particular statistical techniques for the purpose of "predicting" and preventing undesirable individual behavior ? See our discussion on statistics in chapter 5.

The recent emphasis on secrecy etc. in Sweden raises interesting questions if seen against Boguslaw's citations: "One of the most powerful tools available to a bureaucracy is secrecy... Perhaps the most significant implication of bureaucratic organization is the tendency to convert all political problems into administrative problems." (1971,p.426). And Ferry writes: "Technology is already tilting the fundamental relationships of government, and we are only in the early stages." (1971,p.213) Churchman is also particularly critical of the orientation of security and secrecy thinking and concludes, "... one comes to recognize that our society has succumbed to the vile disease of clogged information processing." (1968b,p.85)

We have emphasized here public systems. Is the present kind of secrecy-effort a symptom of reducing quality to technical and positivistic terms ? Such approach deviates from the basic ideas of disagreement and negotiations.

We think that our study indicates some other important aspects of the privacy-integrity issue. Sometimes distinction is made between STATISTICAL versus INTELLIGENCE systems or between DATA-BANKS versus INFORMATION PROCESSING SYSTEMS, regarding the requirements and possibilities of privacy.

In statistical systems privacy is sometimes conceived possible by means of aggregations of data on many people in such a way as to prevent identification of any particular individual. As E.M.Brooks (1971,p.53) and A.F.Westin (1971,p.307) point out, however, original stored data cannot be aggregated if they indeed are to be of any use for research or advanced social planning. It is a basic scientific-conceptual requirement that attributes be kept related to the particular objects on which they were observed. If this is not done, the menace on privacy decreases but at the expense of increased menace on the quality of planning: the aggregations may only help to answer certain questions but not other, and the individual who was rescued from an invasion of privacy may become victim of a self-fulfilling "prediction" of the behavior of the minority group to which he is assigned. The problem of aggregation is also evident from the work of Verba (1969).

The second distinction between data-banks and information processing systems would suggest that the privacy-integrity problem is more simple in data-banks since there we at least know that we have only true "facts" and the problem reduces to "AUTHORIZATION" in the sense of making sure that only the right people get the facts. In information processing systems we have the added problem of evaluating the quality of the processing. We hope that our study has made clear, however, that the issue is much more complicated than so and that there is no conceptual difference between data-banks and information-processing systems in this respect. See the penetrating analysis by Churchman (1968a,p.113-116,119-125).

Finally we want to remark that many of the above problems are compounded in the context of the recent projects to "computerize" law by classifying and storing judicial data. See for example the swedish newspaper "Dagens Nyheter" of March 3, 1972 referring to a recent article in "Zeit". Political aspects of information processing leading to self-perpetuating decisions, disregard of relevant undefined attributes etc., are all matters which may be object of research in cooperation e.g. with historians. See Rokkan et al. (1969), the contributions to Westin (1971), Ch chman (1961,p.167), Ackoff (1962,p.174)

SOME POSSIBLE IMPLICATIONS OF "COMMUNICATION" THINKING

One of the most interesting examples of applying our proposal is the insight that figure 4.10 reduces to figures 2.1 or 2.2 (with the possible exception that computed error is not recorded in memory), to the extent that the controlling observer is identical to, or depending on those who state the assumptions, specify the action-inputs (operational definitions of measurements) or design the programs or system.
It appears that in this case, the controlling observer may also be seen as setting the "standard" in a sense like that discussed in the section on statistics when reviewing the paper by Hansen et al. Negotiations according to figure 4.11 are then not necessary or they are simplified since the controller may "enforce" the contract, or standard.

The above insight is consistent with what is sometimes experienced in the context of simulation conceived as composed of model-making, decision-making, and model-analysis. These terms may roughly correspond to system-design and statement of assumptions including specifications of inputs in terms of operational definitions (see "feedaback from 2A to 3 in figure 4.10), system operation or problem solving or implementation of designed programs in terms of "action-inputs" (see our reference to Danielsson's discussion, in chapter 4's section on"review in administrative processes"), and outputs to be analyzed. What has been experienced in computer simulation problems, then, is that it is better to unify model-making and decision-making under one same responsibility, and isolate model analysis, rather than to unify model-making and model-analysis leaving decision-making "isolated",that is under separate responsibility. The reason for this preference is that in the latter case the analysts have tendency to design too simple models since they are "easy to analyze".

In terms of our suggestion, "easy to analyze" means that it is easy to assign errors to input values and indirectly to the actions that correspond to the operational specifications of the input measurements: recall our references to the list of "source errors" in our appendix A3. On the other hand, if model-making and decision-making are unified under same decision-maker, it may be easier to make a trade-off for allocation of error between model with specifications and assumptions, and input values. This appears also consistent with Churchman's statement on the organizational implications of his proposed concept of reality,that we applied to our approach to quality: the controlling observer, decision-maker or researcher who "authenticates" the input or output data should have also the responsibility for the system design: the idea is the same, of facilitating trade-off, but Churchman's emphasis appears to be against the uncritical acceptance on "authoritatively" given inputs like design parameters.

"facts" or operational specifications of input measurements (1963, p.12). Since there are in this context some problems of at least terminology, it should be interesting to have this interpretation substantiated by future research. Just to stimulate thinking and to illustrate possible correspondence of concepts, we propose the following visualization of modeling traffic accidents with emphasis on traffic signs (roughly):

Input actions, measured values	Decision-making, data collection	"Measured", noticed traffic signs by driver
Design model, program, operational input specific.	Model - making, predict output	"Be careful", look around, placement & layout
Output, control observation	Model - analysis, Why error ?	Measured number of accidents, and investigation

The idea, then, is that to the extent that the model maker is not the same responsible as the decision-maker, the model will turn out too simple in terms of naive exhortations "to be careful" or detailed specifications of the driver's actions in order to make him notice traffic signs. To the extent that any accidents happen, the model analyzer who is the same as the responsible for the model making, will conclude from his own investigation that the "cause" was (error allocated to) that the driver did not follow the specifications which would have allowed him to notice the signs. The conclusion may be drawn that more severe police enforcement is desirable to make driver follow the specifications.

If the model-maker were the same as the decision-maker, he may realize the psychological constraints which prevent noticing and differentiating too-many, poorly designed or improperly placed traffic signs. When allocating the error detected and investigated by the model analyzer he may choose between attempting to be more careful, change the layout and placement of signs, or question the assumptions of the operational specifications (their scientific-theoretical basis) that is the conditions under which he must notice the signs (too high traffic intensity, traffic planning etc.).

The above is to be regarded simply as an illustrative hypothesis for explaining the importance of having the design and operation of a system not under the control of analyzer for proper allocation of inaccuracies.

If not, inaccuracies may happen to be defined and computed in such a way as to be allocable to wrongly performed measurement processes, that is, "observation" errors, without questioning the basis for the operational specification of the measurement process. As suggested by our discussion in chapter 1, this is related to the empiricist-positivist approach and may amount to not questioning the factual content of the input, being then equivalent to the "communication" approach discussed in the context of figures 2.1 and 2.2.

Of particular interest in the context of such research, exploring the justification of the thoughts above, would be to analyze the scientific meaning of Emery's statements on accuracy of estimates of input data for analytic or simulation models (Emery, 1969, p.97). Recall from app. no.1 that Emery suggests that somebody MAKES STRUCTURAL CHANGES IN THE PHYSICAL PROCESS BEING MODELED, whenever the INHERENT STATISTICAL VARIABILITY in the process precludes narrowing the range of an estimate to within the region of relative insensitivity. What would this approach imply if applied to SOCIAL processes? The question is whether structural changes would be made in the social processes in order to make them fit, say, the models used for social planning. In such a case one would regard the inherent statistical variability as the error, caused by random influences. Compare this concept of RANDOM ERROR with our discussion of systematic and random error when redefining quality in chapter five.

The whole issue above bears intuitively an interesting relationship to J.Marschak's approach to the economics of information and his suggested conceptualization of "OBJECTIVE" versus "SUBJECTIVE" ranking of so-called information structures (and instruments) according to their values. (See Marschak, 1959, p.86). Information structure is by him defined as the way in which an informant or an information instrument PARTITIONS THE SET OF ALL POSSIBLE STATES OF NATURE (which he apparently considers as a given fact - the set). Information is by him defined as a set of all potential messages associated with a given instrument (source or channel) of information.

Marschak goes on stating that whether a particular information structure yields a greater expected payoff than another structure depends in general on the PAYOFF function. Payoff is defined as that function of the ACTION and of the STATE of nature whose expected value is being maximized by the decision-maker. It is then noted that the ranking of information structures is a "SUBJECTIVE" matter, inasmuch it depends on the usefulness of information for a given user.

Marschak then poses the question whether there are pairs of partitions (information structures) such that the ranking of their values is not influenced by the payoff function. He notes then that "It is easily seen that such ("objective") ranking is possible if and only if one partition is a sub-partition of the other in the sense that each of the subsets in the former partition is contained in some subset of the latter." (p.86)

It appears to us that it is an extremely interesting object of further research to compare the above approach with ours in this paper. We did not start from a given set of states of nature but we rather saw such states as the result of CODING AS MEASUREMENT. It appears to us that coding structures are equivalent to the partitions or information structures above. Coding schemes may also be seen as specification of alternatives.
We can now relate this to what R. Boguslaw writes (A.F.Westin, editor, p.425): "...the exercise of force is related to the range of action alternatives made possible. The person with the ability to specify the alternatives...is the one who possesses power. And so it is that a designer of systems, who has the de facto prerogative to specify the range of phenomena that his system will distinguish, clearly is in possession of enormous degrees of power (depending, of course, upon the nature of the system being designed). It is by no means necessary that this power be formalized through the allocation of specific authority..."

The most remarkable conclusion from the all above, is that the Marschak's approach then may suggest the definition of "OBJECTIVE" ranking of values as a ranking which somebody obtains when, for example, he is forced to fit his view of the world as a sub-partition of the view established by somebody more powerful than him !

This hypothesis suddenly pushes us from the confortable realm of Shannon's mathematical theory of communication into sheer political science and gives added emphasis to what Churchman states (1961, p.167) "...the basis for a decision about the "next event" may very well have been already inherently established in decisions about the relevance and accuracy of the data." In this case what may be already established is the relevance and accuracy of the states of nature, information structure, and set of possible actions associated to payoffs. Compare these concepts with model or program, and operational specification of measurement actions.

We propose then that further research develops the above ideas and applies them to the analysis of a particular problem. It could be seen as a test of whether the "communication" type of research is biased in the sense that encourages agreement at the expense of certain types of disagreements. Is it from this point of view motivated to analyze public reaction and social implications of information systems or data-banks in terms of similar experience from the implementation of telegraph, radio and telephone systems ? Are we right in suggesting that Marschak's approach offers no alternative to the specification of quality of information ? See for instance his concept of "faulty information" as related to the concepts of external and internal environmental states (1959,p.89).

Consider the following concrete illustration suggested by our own experience. CODING STRUCTURES for input to manufacturing information systems may tend to grow in a disordered way. Immagine that a CODING DECISION , that is, like a decision on which code should be assigned to a particular part used in the manufactured product, is indeed a "description of the nature" of the part in terms of an implicit specification of how its attributes or properties should be data-processed. To the extent that this is so, the human coder may feel the need to be assisted by a "decision-table" (of the type used for computer programming) since each coding decision tends to look like an alternative outcome out of a complex decision-table.

Coding under such circumstances is no more a reasonably simple determination of an attribute or property of an object, class or event. Objects and events loose identity as in the case of weak or non-existent theory building. Coding instructions resemble more and more a series of operational (instrumental) definitions instructing the human coder on how to measure the reality structured by the information system.(For details refer back to our example in chapter 3.) The coder or input agent or "decision-maker" is actually forced to follow the instructions if he is to describe and code "correctly and objectively" the observed event. If the coder is dissatisfied with the coding structure he may meet economic-technical objections of the type described for example by R.Boguslaw (1971,p.421). In order to prevent total system breakdown, the coder may, with time, have to follow more and more complex and detailed coding instructions that require, in fact, that the coder implicitly describes in detail the nature and order of one processing sequence (out of the set of sequences allowed by the system). The system then processes the input.

Does this description fit both the material of chapter 3 and of the paragraphs above ? Does this situation in some sense imply that the system"predicts" ex-post by requiring that the input bears with itself much relevant information ? What are the implications for more complex information systems for public planning ?

Important aspects of the broad coding problem are covered by Oettinger (1971, p.250) and by Boguslaw (1971, p.419). Which possibilities exist to build into the system features for detection of poor coding structures ? Do such possibilities meet the criteria for meaningful operational definitions as implied for example by Ackoff (1962,p.146), Churchman (1948,p.112), Margenau (1966, p.336), Shapere (1966, p.44), Northrop (1947,p.126) ?

It should be noted that a meaningful operationalism, must be tied down to some theory or equivalently to some committment (Morgenstern 1963,p.304; Churchman 1961, p.344). This is what allows specification of requirements as when one specifies the required characteristics of an electric motor: such specification is possible because we have a meaningfully operationalized theory of physics;and it is naive to believe that one can specify the required information system without having a theory on the subject matter of the system.

As Buckley suggests (1967, p.92-93) committments and theories require a common acceptance and agreement on concepts,(probably related to the fact that one cannot define information as independent of the subject on whom it acts; communication may be regarded as an extension of the process whereby one organism attempts to influence another organism; see Buckley 1967,p.49,54). This may be the reason why the NAMING OF DATA-ELEMENTS OR TERMS is a so important aspect of the"DATA-MANAGEMENT" problem (see CD, 1970; IBM Form SC20-8096) in appendix A1. It may, therefore, also be naive to expect that data-management can be accomplished without having disagreement and negotiation built into the system design. The reader will recall that our proposal in chapter 4 puts emphasis on such features. If our understanding is right, we have reasons to expect that alternative implementations of data-banks and information systems on a national basis will meet immense difficulties in the above respect.

Under such circumstances WHAT ARE THE IMPLICATIONS OF "FAILING IN MANAGING THE DATA" ? Are there any social and political implications ? Since the positivistically oriented literature does not recognize the impact of these issues in systems design and operation, it may be legitimate to ask for more precise operational definitions for all those terms like distortion, absorption, screening, condensing, sampling, compiling, aggregating, compression, filtration, amplification, etc. of information that is said to occur in business and social organization structures. And there are some highly political-economic applications of positivistic thinking: an example may be O.E. Williamson's comments and conclusions, in the context of antitrust, about the beneficial effects of private multidivisional organizations (1970,p.178).

Several important contributions to the interplay between information, economics, politics and sociology may be found in the August 1970 issue of "Management Science". See especially the comments by J.F. Collins. The whole issue dealt with urban management problems, mostly, in its relation to information systems. See also parts 3 and 4 of A.F. Westin (ed.) (1971), especially the contributions by Gross and by Boguslaw but also others like Ferry, Wilensky, Downs, and Hoos. A dissertation by G.D. Brewer about management of cities and information systems (1970) shows the immense complexity of the problem and the immense naiveté of the expensive and fashionable "simulation of society" etc. As we earlier mentioned, Churchman summarizes many political matters (1968a, p.40,45,90-94,100,159, 169,211; 1968b, see index) and ethical ones (1970; 1968b, part 3).

D.T.Campbell from a different point of view, analyzes many important political realities and refers to "socially relevant data-banks" in a paper from 1969. W.Buckley (1967,p.173) summarizes a cybernetic interpretation of social and political problems. Swedish readers find in Ekecrantz (1971,1972) some extensive discussions of the relation between information and sociology: his views may be regarded as politically militant and therefore we looked for opposing views that would give a more complete image of the state of the debate in the country. We were not able, however, to find any such alternative views. This reminds us of Westin's experience in U.S.A. :

"Interestingly, I have not found any treatment of information technology in the writings of the American radical-right. They may simply take it for granted that computer technology is tightening the hold of a "pro-communist conspiracy" in business, government, and the intellectual community. Or, they may see information technology as a minor element in the larger moral confrontation between their poles of "godless communism" and "american values ". In any event, I have found no radical-right commentaries to include in this section on the larger setting of advanced technology in democratic society." (1971,p.151)

An interesting object of research, in Sweden, would be to investigate the implications of the non-existence of such a debate in the country.

SOME NOTES ON THE METHOD FOR THIS STUDY

In reading this paper, it is justified to question the scientific method and the exposition of our own work, as a basis for confidence in our conclusions.

Because of the nature of information, and because of the large scope of, particularly, public information systems, we want to see our own work in the context of the general issue of the management of inquiry. A summary on this issue is presented, for example, by F. Betz (1971).

This leads us to recognize the fundamental considerations which first arise when regarding professional control or scientific methodology as decision activities: the kinds and extent of agreement which determines scientific judgements. In reviewing classifications of different modes of scientific emphasis and evaluation, that is, of decision methods of institutional science, we felt that the most appropriate mode for this study is the one that Churchman names as NONCONVENTIONAL, NONFORMAL, DEDUCTIVE (1961).

Without going into further details here, we will point out that this mode implies, for example, that the agreement leading to scientific judgements, i.e. conclusions accepted by a disciplinary group of scientists, is not depending on the acceptance of any conditions or rules for membership in the group. Furthermore, the emphasis of the group is not on the study and awareness of inferential rules: it is felt that attempts to formalize may imply premature methodological commitments, as suggested by some literature mentioned in appendix A11. And finally, the presentation of the material is in "essay" form and it is not essentially an inductive generalization on a report of empirical data: factual support is only one of the basis for acceptance of principles or postulates.

In order to meet the questions raised by e.g. the material reviewed in appendixes A1, A2, and A11, we attempted to give to our work a stronger methodological basis. Thus, we also tried to satisfy several of the requirements for form and content in conceptual and operational definitions (Ackoff,1962; Churchman,1948). We have also relied on extensive citations, sometimes from more summarizing literature.

Our whole study draws upon a large body of literature whose authors we acknowledge and thank for having been able to edit, translate, or cite the contents. Our whole study, however, may be seen as essentially based on:

1. Shewhart (1939) who ties the study down to the concrete and well-established realm of manufacturing, physics, and statistical method.
2. Churchman (1948 and 1961) who extends Shewhart's insight into other areas of activity and relates the whole to the developments of scientific method.
3. Morgenstern (1963) who on the basis of extensive experience furnishes a valuable testimony of the importance of accuracy in economics, and clearly illustrates the limitations of information-processing.

We feel that Churchman's summary of his work up to about year 1968, as presented in "Challenge to Reason" (1968b), provides a rough theoretical frame for both the above literature and this paper of ours. We expect that this integrating function will also be possible in terms of Churchman's latest book "Design of Inquiring Systems" (1971) which we have not yet available at the time this is written.

The reader may find that it is remarkable that our study relies so heavily on Churchman's work. We felt that the remarkable thing was to notice,after several months of fruitless study, that his work for the first time allowed us to discuss the quality of information in information systems. Other literature does not even permit to frame a statement of the problem !

Our reliance on Churchman's work might be a serious weakness of our study if it implied that we have relied on the ideas of one only "expert". We think, however, that Churchman is one of the few "experts" related to operations-research and information-systems who has indeed bothered to pay due attention to various past and contemporary scientific-philosophical contributors. This is a far cry from the individual systems-analyst who, after some fifteen years of professional experience with computer systems combines his ideas with those of other peers, puts it down in a book, and then claims to have created a novel "philosophy" of data-processing and organizational control. The implications of this image appear well captured by Margenau (1966) in discussing the philosophical neutrality of newer branches of science in Western Nations. Computer science is not alone: what Margenau says may be as well applicable to, say, psychology as applied to validation of the accuracy of testimony in judicial contexts.

Because of the importance of Churchman's work for our study we have looked for the strongest possible criticism on it. Radnitzky (1970) and Kyburg (1962) attribute to Churchman viewpoints most of which appear explicitly contradicted in most of his writings. In general we feel that the criticism should be based on a deeper familiarization with his work. In particular, a proper understanding of "Prediction and Optimal Decision" (1961) is enhanced by a prior reading of "Theory of Experimental Inference" (1948).

For a further appreciation of the criticism against Churchman we deem it valuable to compare his exposition of the philosophy of science with Kyburg's own in a recent book (1968). We recommend also Shapere's discussion of meta-scientific and formal-logic approaches (1966), and Ackoff's criticism of the so-called general systems theory (1964). We feel that a methodologically justified use of system-concepts requires a much deeper understanding of the possible meaning of systems,as probably presented by Churchman himself in his latest book (1971) or as found in the text and references of Mason (1969), Mitroff et al. (1970), and Mitroff (1971).

In summary, the criticism that we could raise against the basis of this study appears to be irrelevant for its purposes and has strengthened our confidence in the conclusions.

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