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QUALITY-CONTROL OF INFORMATION

On the Concept of Accuracy of Information in Data-Banks and in Management Information Systems

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QUALITY-CONTROL OF INFORMATION:

On the concept of accuracy of information in Data-Banks and in Management Information Systems.

ABSTRACT:

This paper is intended to assist those who develop, use, maintain, audit, or in general may be affected by so-called Data-Banks and Management Information Systems.

One purpose of the paper is to recognize the importance of accuracy, or more generally of quality of information. Data-Banks and Management Information Systems may typically imply some processing performed on externally obtained measurements and pre-processed inputs, while their outputs may be stored and used by people in unknown contexts.

To the extent that this happens it becomes more difficult to expect that the quality of information can be represented by a measure of effectiveness of system and subsystems in relation to operational goals. Thus, a second purpose of this paper is to suggest some possibilities of attaching a measure of quality to discrete items of information, such as coded observations and intermediate computational results.

The paper consists of five chapters supporting five sets of statements regarding the consequences of present practices, and what can be done to implement the most necessary improvements. Illustrative examples emphasize administrative applications such as in public planning and in industrial manufacturing.

KEY-WORDS

Accuracy, Integrity, Privacy, Secrecy, Quality, EDP-Auditing, System-Management, Data-Management

FOREWORD

I started the study reported in this paper with a feeling of curiosity and personal challenge originated from particular problems experienced during my professional activity in industry.

After many months of work I felt disappointment and amazement for not being able to frame a scientific statement of the problem, and of course, much less a solution to it. The problem apparently "did not exist" according to the available literature and reports on current research.

My fortuitous contact with the writings by C.W. Churchman initiated a period of deep satisfaction and allowed me to organize my subsequent work with a feeling of being on the right way.

I terminate this study in a fourth mood: strong apprehension, because of the implications of my conclusions, with respect to the possible social impact of information systems for public planning and administration. The same applies with respect to the possible social impact of certain directions of current sociological and psychological research.

I hope that I will be proved to have been wrong. In the meantime my strongest desire is to stimulate others to further study of these issues.

I want to thank all the numerous people who in many different ways helped and encouraged me to accomplish this work. An attempt to enumerate them would probably result in neglecting unintentionally somebody.

Therefore, I will explicitly thank only Börje Langefors who first showed to me the need and possibility of a scientific systems thinking, and whose intellectual courage and open-mindedness made this work possible.

Secondly, I want to acknowledge my intellectual debt to C. West Churchman whose writings opened my way towards a scientific and human understanding of the issues related to this study.

March 1972

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CONTENTS

APPENDIXES:

INTRODUCTION

The motivation to start this study originated from the results of an investigation led by the author at the time he had managerial responsibilities in the engineering department of a manufacturing plant.

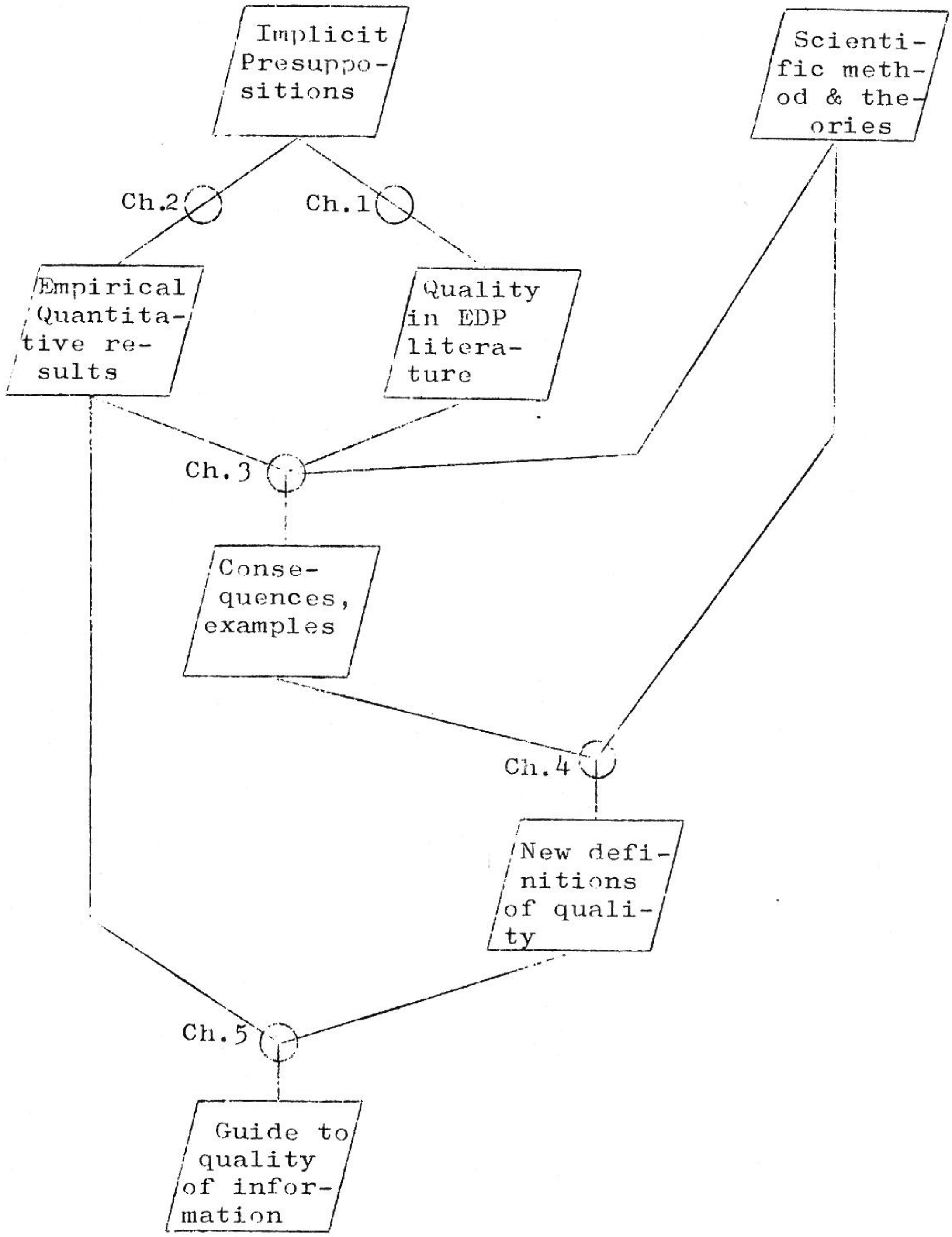
The investigation was directed towards the analysis of errors in the data-base describing the manufactured products. Many of the errors turned out to be other than the conventional "input" errors like transposition, substitution of digits, etc. As a matter of fact we felt that many of these errors had at some time to be committed in order to keep the system going, and they should perhaps not be called "errors" in the conventional meaning of the word. A proper appreciation of their nature led us to the domains of systems design, integration, data identification, etc.

This implies that our study is CRITICAL, that is,it presupposes that things are NOT going well in the area of systems design and operation. Thus, our experience has determined the general orientation of our work and it has furnished rich unstructured empirical material which was not explicitly utilized in this paper.

The graph on the next page gives an overview of the structure of this paper. Chapter 1 - based on our presuppositions, experience and observations results in summaries of what the conventional literature on electronic data-processing (EDP) says about errors and quality of information. In a similar way, chapter 2 results in summaries of empirical quantitative results on error rates. With the assistance of some more theoretical and scientific literature, chapter 3 integrates the results of the two earlier chapters suggesting the typical consequences and nature of a limited understanding of the error-quality issue as evidenced by the reviewed literature.

Chapter 4 draws heavily upon scientific literature in order to allow a scientifically justified definition of some aspects of quality of information in a way that is consistent with the suggestions set forth in chapter 3. Finally, chapter 5 uses the newly defined aspects of quality, refines them, and evaluates them in the light of the earlier practical-empirical results of chapter 2. The chapter results in particular recommendations on how and where to concentrate the quality effort of an organization, and may therefore be seen as the core of a "handbook for quality-control of information" assisting the designers and users of a data-bank or management information system.

More detailed contents of this paper may be found in the previous list of "contents".



Information-precedence graph illustrating a rough overview of this paper in terms of relations between the presuppositions of this study and the conclusions from chapters 1 to 5.

This paper contains also several appendixes containing both material originated by us and material written by other authors which was selected and sometimes heavily edited by us. This should be kept in mind when evaluating the material of others, since our editings are out of context and can never do full justice to the authors of the original text.

Exact citations are always enclosed between quotation marks. Both the extensive citations and the appendixes are judged by us as necessary for a proper understanding of this paper, which spans over a very wide range of professional literature, most of it not readily available at minor locations. Our references to " (Casual) Documents ", sometimes abbreviated "CD", refer to the corresponding items in appendix A1. They originate from personal notes that we wrote in the course of the years, based on literature which we are not able to identify. We included them because they are valuable as testimony of thinking found in the business and administrative community.

A discussion of the method for our work is presented in appendix A12. We feel that the full implications of the discussion are better realized after having read the main body of this paper. At this time it will suffice to remark that we did not judge convenient to attempt the use of a precise terminology. Our understanding of what is meant by information systems corresponds to the ideas set forth in Sweden by B. Langefors and in the USA e.g. by C.W.Churchman: information is used for decisions. For the rest, the reader should not assign any particular importance to the shifting use of terms except for what may be inferred from the context: the meaning of used words will emerge in the course of the arguments in the paper.

For example, we use alternatively the words Data-Banks, Information Systems, Management Information Systems; Accuracy, Quality; Model, Theory; Measurement, Observation; Administration, Organization, etc.

More explicit statement in the text are emphasized with the mark ▷ at the left hand margin. Such statements are often the basis for the specific conclusions in the corresponding chapter.

QUALITY IN THE EDP-LITERATURE

1.1 ON ACCURACY

There is one concept in the litterature on electronic data-processing which appears to be of fundamental importance, especially in the context of information systems for administrative applications.

It is the concept of ACCURACY.

We say that it appears to be of fundamental importance because the word is found whenever somebody wants to declare the importance or value of a so-called information system to be developed, as well as of such a system that is already installed and operational. Furthermore, the word is also found in the context of emphasizing the importance of correct input to an already developed and installed system.

In order to determine the desirability of further research on the nature of accuracy, a review was made of the professional literature dealing specifically with electronic data-processing. The review included books, periodicals, research reports, instructional booklets of computer manufacturers and internal company reports from places to which the author had access in the course of his professional activity.

No intentional "a priori" selection was made of which literature out of the above would be more closely examined. Through browsing the focus of attention was put on those publications that had something stated about the nature of accuracy or about concept intuitively related with the accuracy issue.

1.2 ON ACCURACY AND QUALITY

Appendix A1 displays an edited selection of such a review with a view towards answering the question "what is accuracy ?", and "is it in some sense important - justifying further research ?".

The appendix was created for the convenience of the readers, bringing together some material that was spread out in many different sources. The text had to be taken out of context and edited, which should be kept in mind because of the danger of misunderstandings and of not doing justice to the authors of the original text.

Consideration of appendix A1 introduces a multitude of new concepts intuitively related to accuracy. They are listed here below. We have completed the list with those terms which are known from other occasions, including those which denote aspects intentionally excluded from our main study, like security.

Accuracy	Usefulness	Trueness
Value	Confidentiality	Relevance
Validity	Consistency	Reasonableness
Dependability	Authenticity	Pertinence
Integrity	Completeness	Acceptability
Correctness	Reliability	Refinement
Precision	Degree of Detail	Approximation
Timeliness	Recency	Currency
Freedom from Error	Controllability	Rightness
Exactness	Goodness	Accessibility
Quality	Availability	Security
Secrecy	Privacy	Coverage

For the purpose of further reference in this paper, we will often choose the word QUALITY for representing roughly the set of all above words. In this sense, Quality stands for a generic attribute of information.

1.3 ON THE THIRTY-SIX PROPOSED ATTRIBUTES OF INFORMATION

A closer analysis of the material in the appendix A1 may be performed in attempting to answer the following questions.

1. Is the particular concept defined ?

2. Is any justification given on whether it is, in some sense, important ?

3. Are any recommendations given about what can be done in order to improve the quality ?

▷ Out of the about twenty sources in appendix A1, less than ten appear as having attempted to define quality. The attempts appear done in terms of conceptual rather than operational or functional definitions: i.e. the definition relates the concept being defined to one or more other concepts and generally takes the form similar to that of dictionary definitions.

For instance, Carr (1970) apparently equates RELIABILITY with CONSISTENCY. Lauren (1970) suggests that RELIABILITY is the same as ACCURACY. On the other hand IBM (F20-0006) suggests that RELIABILITY and ACCURACY are two distinct concepts.

Orlicky (1969) implies that QUALITY is FREEDOM FROM ERROR but he does not offer a further definition of error. Since INTEGRITY is mentioned by him as freedom of error, completeness, and timeliness, one could conclude that quality is only one of the aspects of integrity.

Rodin (1971) relates quality to the concept of IDEAL. The ideal value corresponds to the COMPLETELY EXACT AND CURRENT value. Since he defines quality also by its components COMPLETENESS, PRECISION, CORRECTNESS, AND CURRENCY, we could conclude that his concept of exactness is equivalent to a synthesis of the three concepts of precision, completeness, and correctness.

Montelius et al. (1970), Rodin, and a Casual Document (1964) make use of statistical terms such as RANDOM, ERROR LIMITS, and STANDARD DEVIATION. They do not, however, develop the meaning of these terms in the particular application. Since such words refer to very elusive and misused ideas, their use by the authors should be submitted to a critical evaluation. It should have been necessary to have, for instance, a reference to scientific-statistical literature or a closer specification on how to obtain the relevant observations.

Blumenthal (1969) in a book wholly dedicated to planning and development of management information systems does not make any reference to the problem of quality, or we were not able to find any such reference, unless it is considered as implied by a successful design. Quality is not included neither in the input data definition nor in the analysis of user requirements. The author apparently considers quality specification of data as a meaningless question since data are by him defined as "uninterpreted raw statements of facts".

Carr (1970) implies that legal and administrative applications of data are not decision making and that their data requirements do not generate data with good quality. From his formulation one is led to think that bad quality in terms of observation errors results to a large extent from the implied applications of such data. In spite of the vagueness of the statements this suggests important objections against Blumenthal's conceptualization of DATA, without however assisting in the definition of the terms.

J.C. Emery makes quality dependent on ACCURACY. Accuracy is seen as a QUALITATIVE characteristic of information which attempts to substitute the quantitative estimates of information value at lower levels of decision-making. Emery seems to imply that at high levels of decision-making neither accuracy nor information value can guide design decisions for development of information systems. The author apparently differentiates between accuracy of input data and REFINEMENT of the estimates of input variables that are critical in determining payoff. For the former, PERFECTION or absolute accuracy is only a question of costs and not limited by the nature of human knowledge; this is apparently what Emery implies. For the latter he suggests that it may be more economical to force reality to fit the model rather than to bear the costs of REFINEMENT of estimates, that is, improve accuracy which by the way may also be limited by the INHERENT STATISTICAL VARIABILITY of reality. Emery, however, does not define accuracy, errors and other used terms.

W.Edwards et al. propose that quality of information be substituted by quantity but,as far as we could see, do not define quality. This is particularly troubling when one knows that there are cases in which the proposed Bayesian probabilistic models are being used in military information systems. It is legitimate to wonder what do the assurances mean that, for instance, a nuclear attack cannot be triggered BY MISTAKE or BY ERROR!

Sundgren & Lundin do not either define quality but they attempt to consider it as one among other goals of a public data-bank, and then they proceed showing implicitly its nature by means of its relationships to the other goals. The authors, however, do not justify their allocation of the quality goal to the government: it could be conceived as being originated also by the citizen or by the organizations.

Montelius et al. (1970) state that the input elements must be regarded as NEUTRAL from the VIEWPOINT of the information process, where the process is chosen on the basis of experience and error-controls will be based on CHALLENGING in some way the the PRESCRIBED STANDARD PROCESSES. The authors, however, do not develop the ideas of neutral, control of standards etc. Therefore,their definition of error is also indetermined, vague.

Owsowitz & Sweetland (1965) in spite of adopting an ambitious approach in terms of PREVENTION of errors, apparently consider it possible to limit their study on INPUT errors and disregard the correctness of the information processes. Their definitions of accuracy, validity, consistency are vague in the sense that for instance they do not explicitly state what procedures should be followed in practice,to determine the validity of a recording mechanism.

Vagueness and circularity of definitions is, in our opinion also characteristic of Weinmeister's approach (1971) and also in N.P.Edwards' approach.The latter, for instance refers to the ACCURACY of a cost estimate, ACCURACY of the command and control system and of its subsystems, ACCURACY of the raw data, ACCURACY of the value of timeliness, accuracy, reliability, ACCURACY of the knowledge of the exact present location of the target, and ACCURACY and age-quality of the knowledge of the target's last position.

1.4 ON THE IMPORTANCE OF QUALITY

Out of the reviewed literature, the Casual Document (Casual - Documents will be referred to,by the abbreviation "CD") from 1966 states, for example that accuracy is the fundamental objective of information systems.

IBM (F20-0006) states accurate processing of data means that the processing, besides of being performed without undetected errors and in accordance with management's policies and instructions, FULLY ACCOMPLISHES ITS PURPOSES.

CD (1964) seems to imply that accuracy as well as other attributes of information such as timeliness and dependability,is a component of its value.

The above thoughts lead us to the more general and interesting matter of the relation between the quality of information, its value and the goals of a system. Emery touches this by stating that it is our inability to make quantitative estimates of information value,that forces us to use the concept of quality in developing organizational information systems.

▷ It is apparent that from these points of view, the quality of information is of fundamental importance for information systems. This statement is made even more interesting by the possibility that the value-impact, or more specifically the economic impact, of quality problems may rapidly increase because of the proliferation of so-called data-banks and management information systems.

Especially to the extent that the sources of information are not the same as the users of such information after its processing by some system, and to the extent that the user or affected population itself cannot be limited and defined, no "data-management" will be possible. The impact of the quality problem may have serious consequences: this may turn out to be the case with many public information systems unless some scientific control is established proving the contrary.

Physics, as a science, enjoys high status and reputation. As an illustration, the importance of quality of information may also be appreciated by referring to the issue as it appears in the physical science's information system:

Assume an engineer retrieving from a data bank some technical data to be used in the construction of a bridge: if he gets for instance the tensile strength of a certain kind of steel, without any indication on the accuracy and precision of the figure, he will not be able to use such steel in his work. Or alternatively, if he uses the steel anyway, say nine out of every ten bridges he builds will prove to not bear the load for which they were designed !

Thus it is apparent that e.g. in "general" databanks, the quality of information cannot be assumed to be less important. We would rather say that, unless somebody proves the contrary, the quality of general, organizational or social, information is still more important that in the physical sciences since the weaker theory building prevents testing the consequences of the use of information with inadequate quality. It is difficult to show the collapse of a social or business "bridge" and to put it in relation to its cause or "steel". Nor can weaker theory be compensated always through more "pure or raw facts" or direct observations: a country's unemployment figures stored in a public data bank are not more direct or basic facts than the physical properties of steel, stored in a technical data-bank.

There are indications that quality is in bad shape even in the physical sciences: Branscomb (1968) now director at the USA's National Bureau of Standards makes this very clear when at the same time giving a hint about the importance of the issue. He refers to research on a particular physical problem, cross sections for electron collisions, and he suggests a method for saving a substantial part of 44 million dollars in the course of a four-year period: "Simply by not doing the work at all unless it is written up in such a way that it can be evaluated and therefore become useful" (1968). If applied to data banks and information systems the same statement would read: "Do not generate or store information for information systems at all unless its quality is specified in such a way that it can be evaluated".

In spite of its importance, then, the quality problem is not properly understood or is ignored in the context of well established sciences.

Also Eisenhart (1968) and Hallert (1968, 1970) show through their attempts to explain quality to natural scientists and technicians, that such explanations are badly needed in broad areas outside of our immediate concern with ADMINISTRATIVE data-banks and information systems. Their emphasis, however, is directly relevant to design of data-banks containing, for instance, information about physical quantities. Since much of the experimental and theoretical work in so-called ARTIFICIAL INTELLIGENCE and fact-answering or fact-deducing systems is aimed initially at the simpler and better known physical reality, one may wonder whether such projects make allowance for storing and processing quality specifications.

It comes, therefore, eventually as quite naturally to learn that the situation is much worse in national and business economic statistics. This comes very close to the emphasis which we have given to this study. It may be only of question of time before in all industrialized western countries such economic statistics is regarded as information processing of "facts" stored in public data-banks and information systems. A whole book by O. Morgenstern "On the Accuracy of Economic Observations", 1963, may be regarded as a qualified massive document on the immense importance of the quality of information.

1.5 SOME COMMENTS ON THE CONTENTS OF THIS CHAPTER. SUMMARY

In general, the above kind of reasoning is what we think that can be accomplished from an analysis of the EDP literature and its definitions regarded as CONCEPTUAL definitions, sometimes also called constitutive or contextual. It is apparent that there is no agreement among the various authors: each one of them brings his own particular experience and intuition without framing his ideas in basic consideration of scientific method.

It is difficult to see that a further analysis along the same lines as above would be fruitful for our purposes. We could go on showing that some literature, like EDP Analyzer (Feb.1968) goes about by listing major causes of poor data, other like Casual - Document (1970) or the auditing literature represented by IBM (F20-0006) and Davis (1968) just propose what should be done to improve quality in terms of detailed EDP validation techniques or principles of organization. The implied scope of quality thinking ranges from trivial keypunching errors to the almost "everything" of the broad and vague concept of DATA-MANAGEMENT. One wonders how such an ambitious and vague data-management as suggested by Casual Document (1970) can be enforced on an universal social basis for the purposes of public data-banks !

"Self-evident" truths turn out to be no self-evident at all. For example the elimination of the human element from the input data stream is often assumed to result in better accuracy of the input. This is suggested, for example, by Blumenthal (1969, p.175) and by J.C.Emery (1969,p.38). J.P.McNerney (1961), on the other hand, in a very well justified and interesting study suggests that the opposite may be indeed true in certain circumstances. How to define "the circumstances" ? C.W.Churchman (1968b,p.189) suggests some of the deep implications of this issue: "objectivity" obtained by putting more and more of the act of observation into hardware such as computers and physical instruments greatly limits what can be observed,to the realm of PHYSICAL reality.

▷ After a review of the EDP literature we find ourselves in a really bad shape. Nowhere is told us how to measure quality and for what purposes, in an explicit manner. We are not able to use the implicit definitions in their present form as a basis for binding negotiations on desired and committed quality levels between a "buyer" and a "seller" of information. To the extent that the authors offer recommendations on what should be done in order to improve quality, we do not know why we should place confidence in their advice; and even if we placed confidence and implemented their advice we would not be able to evaluate the results of their recommendations.

▷ We state, therefore, that the available EDP literature does not define QUALITY OF INFORMATION, in the sense that it does not explicitly support the formulation of operational definitions of the concept. The review gives at best some kind of insight: there appears to be some consistency among the authors in identifying a TIME-RELATED aspect of quality that goes under the denominations of timeliness, recency, currency; other aspects are not explicitly time-related. Furthermore it appears that quality may be either associated with the information itself or with the system generating such information. We are not capable, however, to use these insights in their present form.

In face of the discouraging results of our review, we turn to the literature on scientific method in order to see what is said about definitions and operational definitions.

In the context of discussing what the CONTENT of conceptual and operational definitions in science should be Ackoff (1962, p.146) states: "In the newer branches of science, in particular, it has become increasingly common to define one concept in terms of others which, if anything, are less well understood than the one being defined and whose operational significance is even more obscure." Later, (p.150), Ackoff suggests five instructions for the build-up of definitions, which we shall roughly follow in the spirit of this paper. The basic idea, as we see it, is that definitions cannot be created out of thin air; they must be anchored in some established scientific knowledge, theories.

As Churchman (1948, p.159) summarizes it: "traditional empiricism has misread the significance of conceptions or general ideas; it has connected them with experience of the actual world; it has connected the origin - and validity of general ideas with antecedent experience. According to it, concepts are formed by comparing particular objects, already perceived, with one another, and then eliminating the elements in which they disagree and retaining that which they have in common. Concepts are thus simply memoranda of identical features in objects already perceived" (cited from J.Dewey's "The Quest for certainty"- 1929). Traditional empiricism has thus failed to realize the important role of generalizations; its"ideas are dead, incapable of performing a regulative office in new situations." (same source).

Continuing his integrating discussion of empiricism versus rationalism Churchman continues citing Dewey: "the basic error of traditional theories of knowledge resides in the isolation and fixation of some phase of the whole process of inquiry in resolving problematic situations. Sometimes sense-data are taken; sometimes, conceptions; sometimes, objects previously known. An episode in a series of operational acts is fastened upon, and then in its isolation and consequent fragmentary character is made the foundation of a theory of knowledge".

We think that no comments are necessary except for putting the question whether what we witness in the EDP literature is a variant of traditional empiricism or positivism,extensively criticized by Churchman (1968b). If this is true then we have a basis for explaining why we felt that we come nowhere up to now, and a basis for expecting that a "practical" approach as attempted in the next chapter will also raise problems of interpretation and generalization. We terminate this chapter by consolidating earlier statements in this chapter into the following.

1.6 CONCLUSIONS FROM THIS CHAPTER

1. The reviewed EDP literature does not offer definitions of quality of information, in the sense that no explicit support is found for the formulation of operational definitions of the concept.

2. The quality of information is of fundamental importance for the development and use of data banks or information systems; this is the opinion implied in the available EDP literature and it is also implied by the lack of a scientifically justified method for cost-benefit analysis of data-banks and information systems.

This motivates an extension of our study into the next chapter. We will attempt there to bypass the theoretical issues by inferring on quality from what has been and is practically done.

EMPIRICAL QUANTITATIVE RESULTS ON ERROR-RATES AND QUALITY

2.1 WANTED: A PRACTICAL, REALISTIC, EMPIRICAL APPROACH

The statements, good advices,"theories" and definitions found in the previously reviewed EDP literature were shown to be based on shaky scientific foundations. However they presumably have originated from human experience with concrete problems. After all, everybody will agree that there are "errors" in the inputs to an EDP system, e.g. a wrong address of a customer, wrong quantity to be shipped etc.

The EDP practitioner may, therefore, in a specific situation ask for advices or investigations on how to improve the accuracy of inputs to the system. Something HAS TO BE DONE and CAN BE DONE, even without "understanding" the whole issue or being able to define what errors are.

In the context of our research it is therefore tempting to hop a plane and invade some business firm having accuracy problems with some installed information system. We can take an army of statisticians with us, who will gather lots of hard data on the problem, talk with the people who developed and use the system, and finally apply statistical techniques and common sense to the data in order to suggest improvements. The object of investigation could be the accuracy of card punching and verification. In more sophisticated installations the object could be the accuracy of procedures leading to the keying of input data into on-line direct entry terminals etc.

IT TURNS OUT THAT MANY SUCH INVESTIGATIONS HAVE ALREADY BEEN DONE. The results are however spread out in publications ranging from the subject of EDP to applied psychology and human factors. We have made a review of such literature which may be relevant to our purposes and an overview is presented in appendix A2 for the convenience of the readers.

If the literature shows in some sense reliable and valuable material, we will be able to consolidate it obtaining a set of guidelines for improving the quality of information, obtaining implicitly-at least- some theoretical understanding of the quality issue, and in any case concluding about the desirability and nature of further study of the quality issue.

2.2 LITERATURE WITH EMPIRICAL QUANTITATIVE RESULTS

The basic selection criterium for the literature reviewed in appendix A2 was that something should be stated on specific ERROR RATES in the context of information. This would hopefully take us to some implicit concept of ERROR and of QUALITY. Furthermore we vaguely expect, departing from the familiar context of quality control in industrial manufacturing, that we might establish some "normal" error rates which will assist us in the search of methods for decreasing such rates.

The appendix consists of edited selections from the referenced papers. The selection was made with emphasis on the ERROR RATES rather than on abstracting the whole paper. Although not always consistent, we attempted to keep our own comments and heavier editings aligned at the most left hand side of the page. To the extent that the authors applied advanced statistical techniques, our comments do not imply that we have critically analyzed the calculations and found them to be correct.

Since the edited text is taken out of context, no guarantee can be given that we make justice to the authors: the readers must refer to the given sources in order to evaluate the papers.

The review reached beyond the area of literature on EDP, including more general and scientific literature from such areas as theoretical analysis of information systems, applied psychology, ergonomics and human factors, statistical journals and research in education. As a self-imposed limitation to the scope of our work we have not included the area of statistics applied to censuses, surveys, validity and reliability of psychological tests etc.
We will later attempt to show that this does not detract from the conclusions of this chapter.

The reviewed papers and our overview may be appreciated in terms of e.g.

- the reference to quantitatively specified error rates (the basic necessary condition for being considered in the review)
- the level of ambition, ranging from keypunch errors as in Bürotechnische Sammlung (1956) to the consideration of subtle environmental influences as for instance in Smith (1966)
- the depth of the eventual theoretical approach, related to the level of ambition above and to the attempt to classify errors, discussing their nature, as in Langefors (1968a), Smith (1966), Root & Sadacca (1967), Owsowitz & Sweetland (1965).
  To the extent that such theoretical approach is found in EDP literature, it could be included in appendix A1, as we in fact did with the Owsowitz & Sweetland's discussion of approaches to error.

- originality of the approach, in considering influences which were ignored by most other reviewed investigations, e.g. the Berglund & Larson's study of punched card layout, Smith's or Root & Sadacca's study of so-called content or omission errors. Another aspect of originality of approach may be the use of original methods in detecting or correcting errors, as for instance the development of predicting routines by Carlson (1963) based on the decision-tree heuristics suggested by Newell, Shaw and Simon.
- generality of the approach, in covering many possible aspects of the error or quality problem, as done by Smith (1966) or by EDP Analyzer (1971a, 1971b). EDP Analyzer, however, obtains generality thanks to its overview approach, mostly referring to relevant sources of literature.
- clarity in the explanation of used concepts or performed investigations, preventing ambiguity in the mind of the reader. An excellent example of desirable clarity is given in the Berglund & Larson paper.

All the above modes of appreciation were determinant of the selective abstracting in appendix A2.

2.3 WHAT DOES THE QUANTITATIVE LITERATURE CONTAIN ?

Many of the reports result from the application of statistical methods.

Variables are generally related to
- types of entry devices, types of keyboards
- use of punch verification, check digits etc.
- skills or experience of operators at entry devices
- grouping, length, composition (alpha content, etc.) of messages, punched card layout etc.
- aural versus visual presentation of stimulus (original)
- rate of presentation of stimulus or time-pressure on entry
- use of mnemonic codes or letter-pattern familiar codes
- management or supervision emphasis on accuracy or speed of entry
- allocation of entry functions between the creator of source document and operator of entry device
- use of pre-assigned media such as pre-punched cards, badges for personal identification or identification of remote terminal.

Performance of the entry process or of the handling of information is generally expressed in terms of ERROR RATES which relate to the degree of identity between stimulus or original message and the output from the human subject or from the entry device activated the the human operator. Sometimes the check of identity is extended to the output from some editing routines in the computer system.

Whenever the nature of the information handling process prevents a simple one-to-one correspondence between input and output, new performance measures are proposed either in terms of communication theory applied e.g. by Van Gigch to models of "integrative behaviour", or in terms of especially developed error-classification schemes as by Berglund & Larson.

Smith offers an interesting list of alternative criteria for data collection performance:
- time per entry, would be meaningful only in those cases when a substantial portion of the subject's time is devoted to the entry process
- rate of information flow (as proposed by e.g. Cardozo & Leopold and by Van Gigch) has no frame of reference for inclusion of omitted or incomplete messages, but it is interesting for its combining of speed and accuracy in one measure.
- number of consecutive good entries between mistakes would be of no practical utility because, Smith says, the computer system normally has to analyze all input messages. Martin's and Norman's discussion of accuracy in communication networks and Langefors' reference to the importance of many small transactions for the impact of errors on administrative EDP systems, however, suggest that such measure may be meaningful in some respects.
- ratio of volume and time of supervisory (administrative)messages to system input messages is said to be too dependent on many environmental characteristics. It is however interesting since it seems to imply the important concept of error-correction.

Smith finally chooses the PERCENTAGE OF INACCURATE OR INAPPROPRIATE ENTRIES as the most UNIVERSAL CRITERIUM OF DATA COLLECTION PERFORMANCE.

2.4 QUESTIONS THAT ARE RAISED BY THE LITERATURE

While reviewing the literature, several questions are raised beyond the above discussion of the meaning of performance and error rates. The questions reside in how to compare and use error rates in face of differences and ambiguities in the nature of the reported figures.

Error rates are either in terms of errorless entries (i.e. all entries except those with AT LEAST ONE error), where entries consist of different amounts of symbols (message lengths), or they may be also expressed in terms of individual symbol errors. Symbols for message syntax (such as field separation or field and record identification) may or may not be included in the error statistics.

Error figures may include errors that were detected and possibly corrected by the operator himself during the entry process, but such figures may also refer only the undetected or residual errors. Uncorrectable errors may designate the same thing as so-called residual errors, i.e. those errors which were not corrected at the last step before entry into system computation. Uncorrectable errors, however, sometimes designate those errors which are detected by checks at the entry device but are amenable to error in the source document: the error is not caused by the operator and therefore is not correctable by him without heavy loss of so-called efficiency in the entry process.

Error rates after detection and correction by operator himself at entry, should not be equated to error rates at input to the computer editing and validation routines since sometimes entry verification (e.g. punch verification) is done by another operator in an independent entry procedure, and/or by verfication-validation checks by software incorporated to the entry device.

Comparison of error rates for messages of different lengths is furthermore complicated by the use of e.g. prepunched sections in the messages and by many ambiguities in the terminology. DIGITS may commonly denote arabic numerals but sometimes they are used in expressions like "10-digit numeric data words" in which case the term is understood to be used also for denoting alphabetic characters. In such case is "digit" equivalent to ALPHA-NUMERIC character or SYMBOL, but "symbol" may rather be used to include special signs and letters from foreign languages, not belonging to a particular alphabet. LETTER is often used as synonym to CHARACTER. Finally one meets ambiguities in the meaning of terms like DATA which may stand for all the previous concepts of digit, character, symbol etc., but also for CODE, MESSAGE, ITEM, and in general the ENTRY'S DATA REPRESENTATION.

The most serious difficulties of interpretation of results, in the sense of being able to compare and use the reported error rates, however, stem from the environment in which they were obtained. It may be e.g. FIELD or LABORATORY. If field, it can still be field trial or field experiment, and field operational (as in Kramer, 1970). If laboratory, it may

still simulate field inputs (as in Root & Sadacca, 1967). Eventually some results are a flat statement of experience, presumably based on field or laboratory reports (as in Orlicky, 1969). Carlson (1963) presents a study of historical field data.
Such different environmental conditions may explain the appearance of error rates such as percentages in terms of types of inputs (e.g. percent of messages of 10-digits length which were in error) or in terms of persons (e.g. percent of entries made by subject A,which contained at least one error).

Different environmental settings imply also many special handlings and exceptions in the processing of original error information: for instance sometimes errors in the "cents" positions of dollar amounts were not counted as errors - the same happening to those original errors which could be ascribed to have been caused by poor handwriting on the original source document. In other cases some symbols were not used which could be visually or aurally confused with other symbols (e.g. M can be aurally confused with N). In one case the investigators report that they did not count as errors those which would conceivably have been prevented or detected in an operational field environment, by means e.g. of better training or programmed validity checks.

2.5 WHAT CAN BE STATED ON THE BASIS OF THE RESULTS ?

It is apparent that any advices based on the reviewed literature must be qualified by "if", "possibly" etc., including recommendation of careful evaluation of the original literature.

▷ At the level of general advice we could gather guidelines like the following:

1. Errors increase as the number of characters in the data code (code length) increases. Longer codes should be avoided, if not possible,they should be devided in smaller units of three or four characters, e.g. 123-4567 instead of 1234567.
2. The characters used in data codes should avoid digits or letters that can easily be confused with each other, such as I versus 1, 2 versus Z, slash (/) or virgule (,) versus number 1, letter O versus Q, O versus 6, U versus V.
3. Nonsignificant codes should avoid characters that when pronounced sound alike, such as M versus N, B versus P.
4. Significant or meaningful data codes are preferred over non-significant since this facilitates recall by the human coder and reduces errors. For example M and F are expected to be more reliable for MALE and FEMALE than 1 and 2.

5. In the cases when the code is structured of both alpha and numeric characters, similar types of characters (alpha, respectively numeric) should be grouped and not dispersed throughout the code. For example, fewer errors eccur in a three character code where the structure is alpha-alpha-numeric (e.g. HW5) than alpha-numeric-alpha (e.g. H5W).
6. When designing a code number system, try to avoid the chance of double occurrences of a character. Repeating characters are a major source of transcription error: the chance of error is greater in transcribing 31146 than it is when transcribing 31046.
7. Use check digits whenever possible and appropriate.
8. Avoid the use of variable length, fixed order punch card layout unless the higher probability of errors are offset by other advantages.
9. In the design of number check routines in verification consider that most digit manipulation errors are caused by single digit substitution, followed by omissions.
10. In general, use sight verification when data is of language type, i.e. in terms of words and phrases, and key verification when the data must be compared on a character-by-character basis.
11. Consider that there are limits to the accuracy of human sight-verification capability: the lower the frequency of errors to be detected, the less percentage of them will be in fact detected by the human sight verifier.
12. In selecting punch machine operators, consider that the fastest operators are also those who tend to make the less mistakes. (In addition there are psychological tests for selecting such personnel).
13. Easy correction of operator mistakes at entry devices tends to enhance both the speed and accuracy of input. The same is true for easy detection in terms e.g. of answer-back tones at direct entry devices.
14. Confirmatory answer-back tones should not be too long since they can lead to other kinds of erratic behaviour by operators who get impatient.
15. The profitability of punch verification should be continuously questioned since it deletes a very limited proportion of punch errors.
16. Consider source errors, sometimes called content, event, omission, procedural, misidentification, miscount, etc., generally more important in percent and seriousness of consequences than other entry operator errors and hardware or communication-links errors.
17. No preference, in general, can be stated for the use of alpha or numeric codes in a particular system.

18. No preference, in general, can be stated on whether the person making the data-entry as operator of an entry device should be the same as the person creating the original source information.
19. No statement, in general, can be done about the effect of using pre-assigned media such as prepunched cards on the accuracy of input.
20. Coding errors can be reduced at the entry stage by providing keypunch operators with knowledge on the set of the possible codes. This effect is greatest with menemonic codes.
21. There seems to be a substantial advantage in accuracy by copying a code by hand immediately beneath the original. Forms, dockets,etc., should be designed in such a way that this is possible.
22. Ten-key keyboards yield a significantly lower error rate and are preferred by operators, compared to other devices such as levers, matrix keyboards, rotary knobs and telephone sets.
23. Speed of human sight-ckeck of errors is highest for groupings of 3 to 4 digits in numeric material, and it is inversely related to the frequency of errors to be detected. The percentage of undetected errors increases with the higher speed of checking but it is not influenced by variation in grouping.
24. For several tasks including keyboard entry and telephone dialing, grouping of digits by 3's and 4's is consistently best in speed with no tendency to differences in error rate. Users often state preferences for larger groups than those producing best performance.
25. For codes of a given length (number of characters) coding errors tend to be proportional to the alpha content.
26. It cannot be stated that the use of mnemonic codes reduces coding errors. However, letter-pattern familiarity affects coding errors: codes containing letter pairs in familiar sequences (e.g. AT, BY, OK) have lower error rates. (Example of mnemonic code: OVH for "overhead").
27. Time pressure on making data entries does not need to affect the rate of initial original errors of entry, but it may contribute to higher rates of residual errors by affecting the rate of both detection and correction of mistakes by the operator at the point of entry.
28. The rate of correct information that is retrievable from coded information depends not only upon the error rate of the coding process but also upon the detectability of errors. This latter concept includes consideration of the ratio of the number of codes used to the total number of possible codes which may obtained from all combinations of the allowable character set.

2.6 COMMENTS ON THE STATEMENTS OBTAINED FROM THE REVIEWED LITERATURE

The guidelines which were suggested in the previous section appear much more useful than any speculations about proper definitions of quality, accuracy etc. However this does not imply that we have bypassed the conceptual difficulties of the quality problem. Maybe the guidelines cannot be applied to the particular installation for which one wants to improve accuracy. Maybe they are not so useful as we wish.

Agreement among different authors terminates at a very low level of ambition indeed. For instance, Bürotechnische Sammlung (1956) , Carlson (1963), and Smith (1966) agree quite well on such a simple matter as the proportion of digit manipulation errors which may be expected to consist of single digit substitution, say more than 60 %. But concerning omissions, Bürotechnische Sammlung gives the figure 7 % while the other two give about 20 %. Conrad & Hull (1967) on their part show with their wide variation of percent figures that they require mcuh closer analysis for appro priate interpretation.

Wright (1952) suggests that 0,3,6 and 7 are those digits which lead to most unreadable and ambiguous readings (combined). Owsowitz and Sweetland (1965) suggest instead that 2 is the most incorrectly reproduced digit. Upon closer analysis it will be found that Owsowitz and Sweetland included even letters in their investigation, leading to the 2 being very often confused with the letter Z, and this explains the differences between the two findings.

Concerning the use of either alpha or numeric characters in the construction of codes, EDP Analyzer (1971b) refers to Davidson who advises the use of numeric codes only. On the other hand Conrad & Hull (1967) in the context of manual copying of codes, state that the conclusion that digit codes are preferable to letter codes "...must be thickly surrounded by qualifications." mainly because of the possibility of utilizing language habits. Furthermore, Owsowitz & Sweetland explicitly state that the fact that error rate for alpha codes is generally several times greater than for numeric codes, this does not mean that they should be avoided; the decision will depend upon several other considerations since alpha codes can transmit a good deal more information per character than numeric codes can.

The ambiguity of advices and guidelines does not decrease but obviously rather increase when reaching more subtle problems. Let's just illustrate the case of whether the operator making the data-entry at the entry device should be the same as the person who creates the original document or codes the event-observation:

A reviewer of Root & Sadacca's paper concludes that their findings seem to justify the following. The direct entry method (same person doing both jobs) seems to be recommended where the best total speed and accuracy are needed, where there is no reason to save the message generator's time by delegating the data entry task to another, and where he could be taught typing efficiency (e.g. more than 35 w.p.m. i.e. words per minute). Examples of this type of situation are mainly on the military field but could also be, for instance, the air traffic controller's task. However, where the message generator is a costly specialist (e.g. a hospital doctor), or where he is not and cannot be taught to be a fast typist, then his time could be saved by having a clerk to do the data entry. But in such a case, when ERRORS might sometimes be vital (e.g. drug prespriptions in hospital), it could well be advisable for the specialist to enter certain details directly, especially since the experiment showed significantly worse errors when transcription was by another person.".

Thus, the reviewer concludes, it seems clear that any decision on the method must depend on a DETAILED AND THOROUGH ANALYSIS OF THE DATA ENTRY TASK AND OF THE SITUATION REQUIREMENTS. CAUTION IS NEEDED IN THE INTERPRETATION OF THIS EXPERIMENT. More research would be desirable to enable better guidance. (Shackel, 1969, p.159).

Smith (1966) on his hand states that although his study"showed no clear preference for clerical, group or individual production worker reporting, the choice might be dictated by the NATURE OF THE PRODUCTION CYCLE OR FLOW. All other things appearing to be equal, it would be preferable for the person recording events to be the one most affected by the ACCURACY and TIMELINESS of the entries. The complexity of messages transmitted and the variety of types of transactions made by an individual can be limited by assigning him uniquely to a device at a single work station where his primary duties are related to a production task rather than data collection. If personnel are required to make only occasional entries in a variety of message construction forms, individual differences in performance can play a dominant role in establishing the expected accuracy. In these cases where procedural mistakes might be caused by low volume reporting from a work station or by message complexity, a clerk with primary emphasis on recording the data could be the best choice. Reporting events by groups compromises these issues and reduces the required quantity of relatively expensive data collection terminals, but increases the non-productive travel time to an input terminal."

By means of comments we may now realize some of the manyfold implications of the above problem. From what is said it looks like if ACCURACY were some composite function of MOTIVATION (for high accuracy), and VARIABILITY & FREQUENCY - say FAMILIARITY - of certain tasks.

Familiarity may be seen as referring to the performance of the original "object" task as well as its original observation and coding, but it may also refer to the task of entering the coded observation, directly or by transcription from e.g. an original form, into the system. Smith talks about both tasks as"recording" probably because in his production environment the entry was directly made by the workers-observers into the remote terminals. In his work Smith keeps anyway the distinction between the two tasks by means of classification of errors in different types; the distinction, however, cannot be considered so clear as in Root & Sadacca's study.

Concerning the choice itself between direct and indirect entry, one criterion appears to be the maximization of familiarity, but at the same time a trade-off is envisaged against motivation.

It is difficult to find support for the suggestion that direct entry is recommended when best total speed and accuracy are needed. Indirect entry, by saving the time of the observer-coder might be preferable, not so much because the time of costly specialists is expensive, but rather because of lower rates of certain kinds of errors in the performance, observation and coding of the original "object" task. The lower rates of such errors might well compensate and more than compensate for an increase of the rate of other less important transcription errors.

The above comments are concerned with allocation of data-entry and observation-coding tasks. A similar discussion could be done, but is left outside the scope of this paper, concerning the use of pre punched cards and other computer-prepared turnaround documents. In that case we would have Davidson's suggestion, as referred by EDP Analyzer (1971b, p.9), to be qualified by the empirical findings of Smith (1966, p.16,66) and Kramer (1970, p.246). These last two authors suggest that the use of pre-punched cards, badges for individual or machine identification etc. may have a negative effect on accuracy because of increased opportunities of certain procedural mistakes which are not offset by the system's detection and correction features.

What conclusions can we draw from the above comments on the statements obtained from the reviewed literature ? We do not know how to use the reported figures of "hard" research on error rates. We do not know how much confidence to place on general advices not even in those cases where they are based on experimental confirmation of common-sense guesses. We do not know what ACCURACY really is: we are rather told what it might depend on, in certain circumstances.

In order to formulate the only conclusion which appears to be safe, we are tempted to borrow the words from some of the reviewed papers and formulate the following:

"In any specific situation, the decisions for improving accuracy will have to be based on an analysis of the task and of the situation requirements, of the nature of the task cycle and flow."

And this is about the same as saying nothing, a meager result indeed, considering the scope and statistical ambitions of the reviewed papers and the ambitions of our own study! At this point we feel that it is also doubtful whether some support can be found for Shackel's statement that "more research would be desirable to enable better guidance", if one thinks of the research being done along the same lines as the one we have reviewed.

2.7 THE GENERAL SETTING OF THE EMPIRICAL QUANTITATIVE RESULTS

In order to come out of the impasse, let's go back to statement No. 16 in the earlier list of statements of the section where we asked ourselves: "what can be stated on the basis of the results (of the review of literature with empirical quantitative results) ?".

Statement No. 16 is of our own make, and it was suggested by some of the literature. It states the following.

"Consider source errors, sometimes called content, event, omission, procedural, misidentification, miscount, etc., generally more important in percent and seriousness of consequences than other entry-operator, hardware or communication-links errors."

A review of the literature indicates that errors in EDP hardware and communication links are often associated with figures of about 1:100,000 or less. Similarly, entry-operator e.g. punch-machine operator errors are about at 1:100 in order of magnitude.

(Let us for the moment forget the problem of interpreting the units of such figures. The reader is referred for this purpose to the earlier discussion in this chapter.)

However, as soon as the literature touches on the subject of what we in statement 16 called "source" errors, error rates seem to soar up to 1:10 or 1:5 without difficulties.

Figure 2.1 is an attempt to visualize the general experimental setting which in the reviewed literature conducted to the mentioned rates above.

Figure 2.1 here

Figure 2.1 shows a source with an ongoing series of activities which are observed and coded in a coding process (2). Such codes may generally be registered on an original document like a form which is subsequently used in a data entry process (3). The data entry may, as for instance in the case of keypunching of cards, be followed by a correction process (4) that in the example would be a keypunch verification (and correction). The verified inputs so obtained are then, possibly after being transmitted through a communication channel, be submitted to so-called editing, validation or diagnostic preparatory programs of the computer, (6) prior to their input and use in the normal information processing programs.

The source, which also could be visualized as a set of processes, is also designated by a number, (1) in spite of standing for more than proper information processes as the following ones.

Figure 2.1 suggests that the source might begin by contributing to the total error rate with what we call in this context "source errors". The coding process results in the information set that we label ORIGINAL INPUTS or SOURCE DOCUMENTS, possibly supplemented with check digits or control totals. This is the first existent information set in the sense of the reviewed literature (information related to the EDP system) and it will, besides the previously mentioned undefined source errors, include CODING ERRORS added in the course of the coding process.

The data-entry process transcribes the original inputs or source documents to e.g. card, tape or disc, i.e. to INPUTS IN MACHINE READABLE FORM, and it will contribute with TRANSCRIPTION ERRORS. This data-entry process may use devices with built-in programmed verification and validation (in the sense explained by e.g. EDP Analyzer, 1971a) and correction.

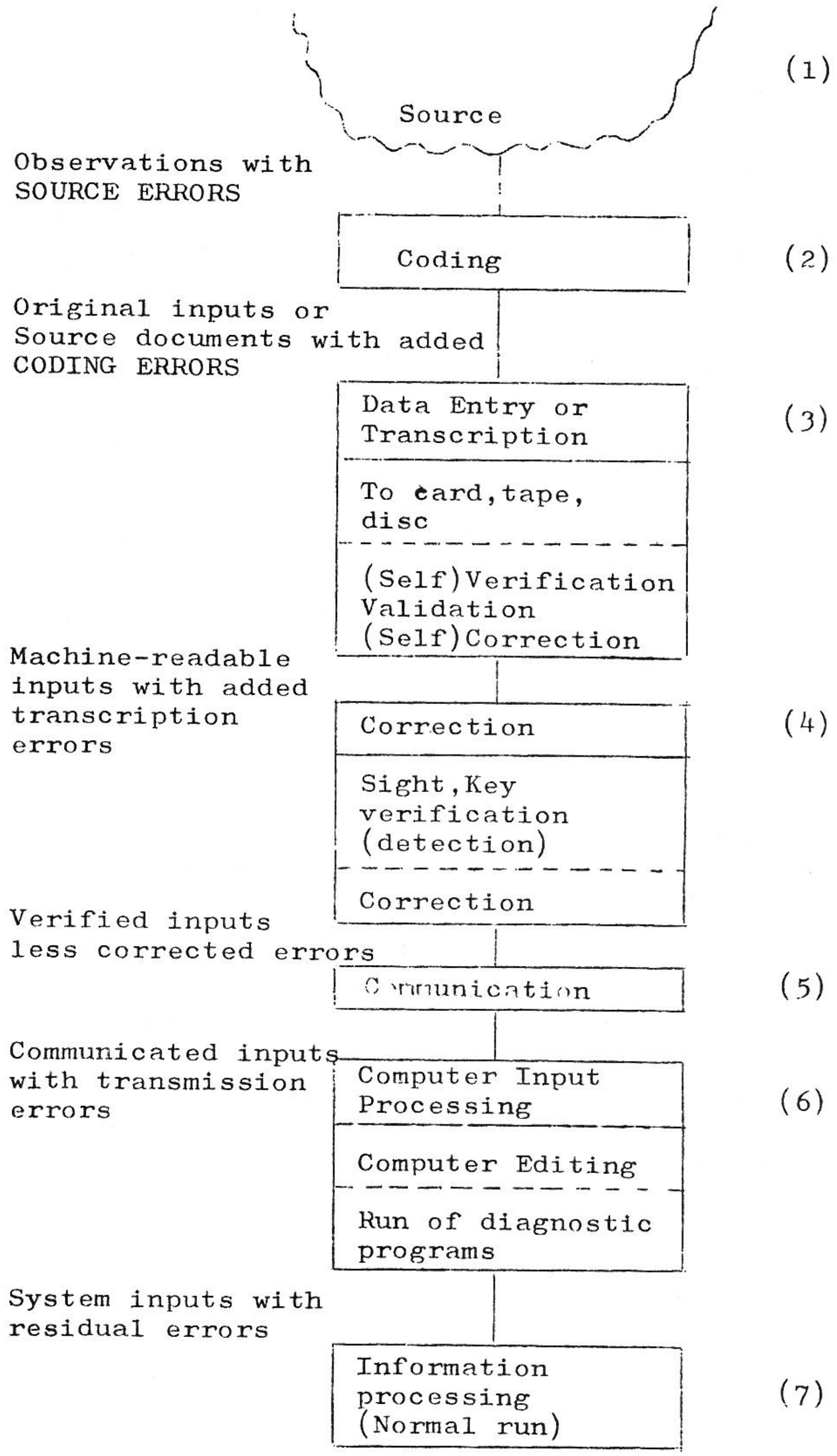


Figure 2.1

The general setting for experiments and measures leading to the reviewed empirical quantitative results.

The prefix "self" stands for the feature being incorporated to the entry device, rather than being performed by the human operator.

To the extent that verification and correction are not performed or sufficient at the data-entry process stage, they will be performed separately at the following correction stage. Correction is seen to include the detection sub-process (e.g. sight or key as in keypunch verification) and the correction itself, leading to what we labeled VERIFIED INPUTS. Verification, validation and correction in the data-entry process (3) and in the correction process (4) will delete some of the errors previously introduced in the chain, but - at least theoretically - may introduce own errors which we label CORRECTION ERRORS (e.g. correcting an input which is actually right, to become wrong - Klemmer, 1959, is one author who considers this problem).

The verified inputs may be submitted to a transmission process by a communication system resulting in what we label COMMUNICATED INPUTS which include undetected TRANSMISSION ERRORS (we delete here the detailed breakdown of the communication problem - that is considered e.g. by Norman, 1971). Such communicated inputs are finally used in the computer input process (6) leading to the final INPUTS which include what is usually labeled as RESIDUAL ERRORS.

What does this visualized experimental setting tell us ? In the first place it calls our attention on the possibility of placing emphasis on different stages of the overall process. Before going any further let us associate figure 2.1 with another similar figure that is found in the scientific literature.

2.8 THE COMMUNICATION-APPROACH TO THE ACCURACY PROBLEM

In discussing the case of a "discrete channel with noise" in the context of his mathematical theory of communication, C.E. Shannon (1949) considers the problem of a signal that is perturbed by a chance variable - called NOISE - during transmission or at one or the other of the terminals. He considers the case in which the received signal is not the same as that sent out by the transmitter, and when it does not always undergo the same change in transmission (distortion), i.e. most generally he considers the case when the RECEIVED SIGNAL IS NOT A DEFINITE FUNCTION OF THE TRANSMITTED SIGNAL.

In order to develop a theorem that gives a direct intuitive interpretation of the average uncertainty of the correctness of the received signal, Shannon considers a communication system and an observer (or auxiliary device). THE OBSERVER CAN SEE BOTH WHAT IS SENT AND WHAT IS RECOVERED (WITH ERRORS DUE TO NOISE). THIS OBSERVER NOTES THE ERRORS IN THE RECOVERED MESSAGE AND TRANSMITS DATA TO THE RECEIVING POINT OVER A "CORRECTION CHANNEL" TO ENABLE THE RECEIVER TO CORRECT THE ERRORS. The situation is indicated schematically by Shannon in the figure 2.2 below which was slightly changed by us for the purpose of clarity in the following discussion.

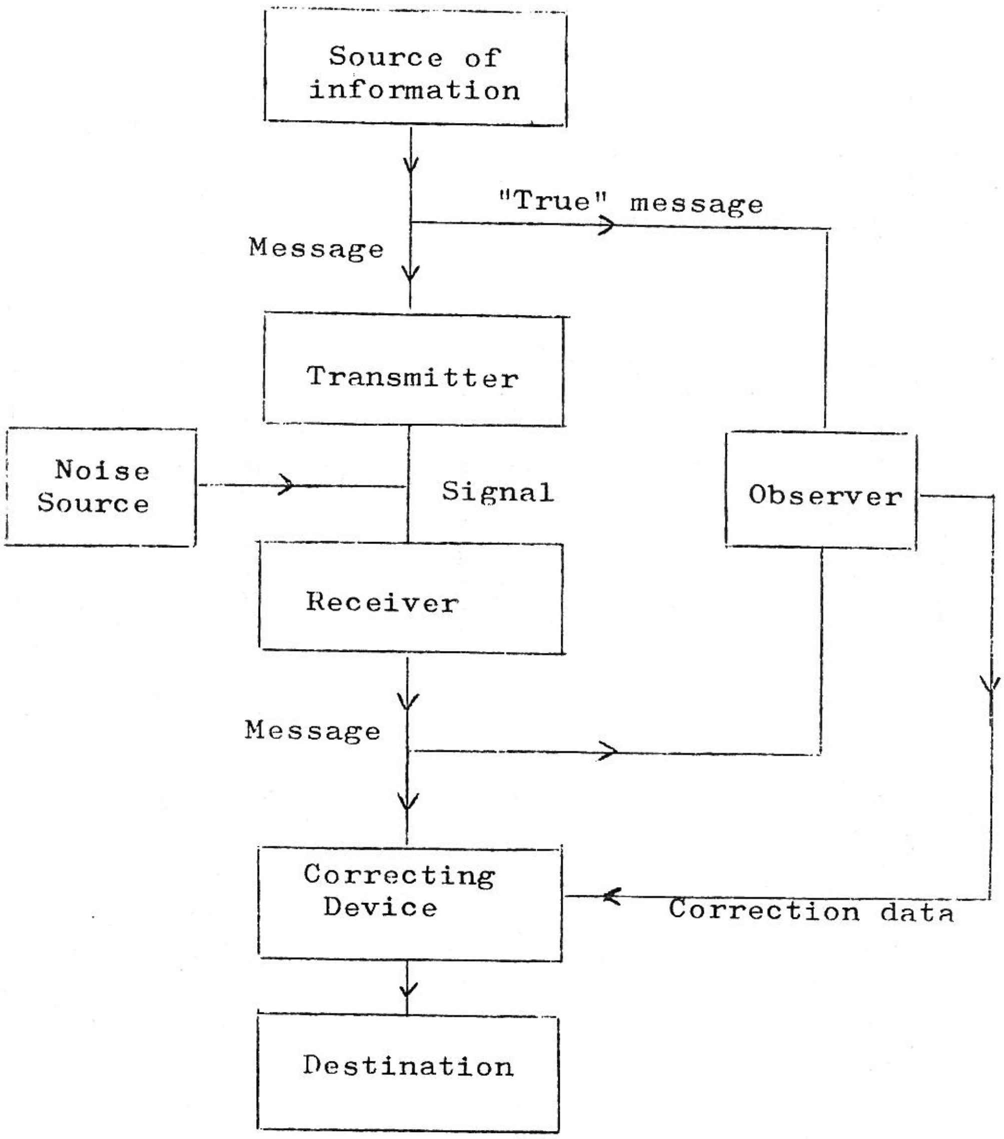


Figure 2.2

Schematic diagram of a general communication and correction system

It is now apparent that the communication approach to the accuracy problem, as illustrated in figure 2.2, can only be applied to the process steps (3), (4), (5), (6) of the earlier figure 2.1 where we visualized the general setting of the empirical quantitative results. To the extent that one is able to consider the output of an EDP program as a FUNCTION of the input information, there is a possibility to apply the communication approach also to step (7). In any case this appears to be the implicit basis for present thinking in AUDITING OF EDP SYSTEMS.

▷ The important thing to note in the context of applying the communication approach is that in all cases one assumes the existence of an "objective" OBSERVER WHO "KNOWS" THE TRUTH OR CORRECTNESS OF TWO OUT OF THE THREE ELEMENTS -INPUT, -FUNCTION, -OUTPUT and is therefore in position of"authority"for "CORRECTING" THE THIRD ONE. For example, if one knows that the customer address printed by the computer-printer on the invoice is not true (i.e. wrong), and also knows that the program updating the customer file is true (i.e. right), then one can deduce that the input to the program was not true (i.e. wrong). The "one who knows the truth" is what we labeled as the "objective" observer. In specific situations, the objective observer appears sometimes disguised under other labels such as system analyst, manager, decision maker, investigator, researcher, verifier.

▷ From the above it is apparent that it will be troublesome to apply the communication approach to those steps of figure 2.1 which include truths of doubtful observability, such as steps (1) - that is dealing with events outside the frame of the reviewed literature-, (2), and (7).

Let us consider the process (2) - coding -.
What is a RIGHT or ACCURATE input to the coding process, since such input is appearing prior to our formalization in terms of information ? Whenever the reviewed literature has touched on related problems, e.g. Owsowitz & Sweetland (1965) and Van Gigch (1970a and 1970b), it has assumed the existence of a certain set of right inputs; this is a particularly important assumption as remarked by Weaver (Shannon & Weaver, 1949), since it emphasizes that the general setting of the analytical communication studies deals with only the first level, A, out of three possible levels of communication problems:

A. How ACCURATELY can the symbols of communication be transmitted ? (The technical problem).
B. How PRECISELY do the transmitted symbols convey the desired meaning ? (The semantic problem).
C. How EFFECTIVELY does the received meaning affect conduct in the desired way ? (The effectiveness problem).

Shannon & Weaver's mathematical theory of communication then deals only with level A. It is therefore left unsaid whether the subdivision in the other two levels (semantic and effectiveness), as well as Weaver's use of the words ACCURACY versus PRECISION and EFFECTIVENESS, are in some sense scientifically justified. In our opinion, the distinction among these words as suggested by Weaver does not assist our research on the issue of quality of information.

▷ In any case it is now clear that most reviewed empirical results, as suggested by appendix A2, adopt the communication approach and as such deal with all processes of figure 2.1 except (1), (2) and (7). An analysis of the quality of information in these terms apparently disregards the most important aspects of quality relative to data banks and information systems for administrative control.

Furthermore, we do not know of any proof showing that such most important aspects are intractable in terms of other approaches, other than the communication approach. On the contrary, the physical sciences make extensive use of the concepts of accuracy and precision in situations where no "observer" is idealized who can compare a supposedly "true" input to the output etc. and where the inputs are considered to be members of a set of possible true inputs. The example of quality concepts from the physical sciences suggests alternative approaches to the problem.

2.9 THE REVIEWED LITERATURE GIVES PRACTICAL EXAMPLES OF IMPORTANT UNSOLVED QUALITY PROBLEMS

EDP Analyzer (1968), referred in appendix A1, in our opinion touches on some symptoms of the most important quality problems when listing EVENTS THAT DO NOT CONFORM TO POLICY among one of the major causes of poor data. At the same time it differentiates such cause from INCORRECT CODING OF CLASSIFICATION FIELDS, suggesting that in terms of our figure 2.1 both causes may correspond to the source and coding processes (1) and (2).

Smith (1966) classifies mistakes in FORMAT errors, CONTENT errors, and EVENT errors. Format errors are by him defined as items that can be detected and screened from system input (such as wrong message length, illegal characters or malfunction of data entry equipment). Content errors are items that have correct form, but can be detected as logically inconsistent (such as shop status contradictions, unusual quantities, wrong machine or operator designations). Event errors are those items that have correct form and are logically processable, but prove inconsistent after subsequent entries or upon use, (such as omitted entries, failure to correct detected mistakes).

Smith furthermore points out that some comparisons between error rates in the field and in the laboratory experiment must make allowance for the fact that CONTENT MISTAKES WOULD BE FEWER IN THE EXPERIMENT BECAUSE MISIDENTIFICATION AND MISCOUNTS WERE NOT INVOLVED.

Referring to the card-verification procedure used to check the accuracy of card punching operations, Smith states that such card verification procedure can only identify mechanical and copying mistakes, HAVING NO FRAME OF REFERENCE to analyze event description, misidentification or miscount, and many format inconsistencies.

What is this "frame of reference" that Smith is referring to ? We think that it has much to do with the theoretical understanding of the quality of information that we ourselves are looking for. The expression "frame of reference" unhappily belongs to the class of heavily misused words ("concept" is another such misused word) but it appears that Smith considers his classification scheme as the frame of reference appropriate for the object of his study. We cannot accept such frame of reference for our purposes since Smith does not motivate it with considerations of scientific method which assure its generality and indicate how it will be used.

For instance, why does Smith consider corrections to good entries as CONTENT mistakes, while failure to correct detected mistakes is considered as an EVENT mistake ? (See p. 5,6,39,40 of Smith, 1966)(It is difficult to conclude whether some inconsistency in the allocation of mistakes to different classes is an unintended print error.)

More important, however, we see the problem of evaluating Smith's frame of reference or classification with, for instance Root & Sadacca's (1967) classification in SPELLING, OMISSION, CONTENT and SEQUENCE. By omission,they mean any failure to enter a required item of information; by content,they mean wrong information such as wrong identification of the nature of an event or object (e.g. "tank" instead of "truck"); by sequence, they mean information items in a message not being in the proper sequence.
We are then led to believe that Root & Sadacca's omission, content and sequence all are included in Smith's event type.

Similar comparisons may be done with Kramer's PROCEDURAL and OMISSION errors; Berglund & Larson's errors due to the NATURE OF MATERIAL (source uncertainties) and OMISSIONS; EDP Analyzer (1971a) classification of data (and implicitly-errors ?) in TEXT, JARGON, and NON SENSE.

▷ This means to us that without a general theoretical understanding of the quality issue one will not be able to compare own error rates with Smith's residual rate at about 4 % of entries or Root & Sadacca's approximate rate of 2 %. And we have now seen that the difficulty to compare is caused by much more deep reasons than any ambiguity on what is meant by digit-character-symbol, or ambiguity on the nature of the message in terms of number of digits-including or not including pre-punched sections etc. (See the discussions in the earlier sections of this chapter).

▷ Finally we see that even practical, empirical approaches to the problem of quality of information raise unavoidable important theoretical questions. Such questions appear in spite of using a communication-naive setting, because this setting is being applied to some complex aspects of the information systems problem.

2.10 SOME GENERAL CONSIDERATIONS ON THE MATERIAL IN THIS CHAPTER. SUMMARY.

In the previous chapter we had met difficulties in defining and measuring the quality of information. We raised the question whether such difficulties could be by-passed, avoided by applying a so-called practical, realistic approach to the problem.

▷ An extensive review of literature containing empirical quantitative results disclosed a great number of figures on error rates which proved difficult to interprete and apply in practical situations. The same appeared as a result of analysis of statements containing advices on what to do in order to improve quality, where the statements were explicitly or implicitly obtained from the reviewed literature.

▷ The remarkably higher rate of certain types of errors reported in the literature, suggested that they referred to certain steps of a general information-processing sequence. This sequence was visualized in terms of a figure which encompassed the measurement setting of most reported figures on error rates. This setting was seen to be the same as the one used to illustrate the quality-accuracy issue in communication systems.

▷ The communication approach to the quality of information was seen to be too limited for the purposes of application to data banks and information systems. Attempts to apply this approach to such environment raise many more questions than are able to answer, but they suggest that the unanswered questions are the most important ones justifying our further study in that direction.

2.11 CONCLUSIONS FROM THIS CHAPTER

1. Most available measures of information quality in quantitative terms assume a concept of quality in terms of communication theory (theory of signal transmission).

2. The utilization of above measures in a particular information system, and the development of other necessary measures require a broader concept of quality which can be made operational.

The above two statements were formulated from the material contained in the sections of this chapter, specifically: questions that are raised by the literature, comments on the statements obtained from the reviewed literature, the communication approach to the accuracy problem, and - the reviewed literature gives practical examples of important unsolved quality problems.

Before attempting the development of a broader concept of quality we will dedicate the next chapter to illustrate two possible consequences of lacking such a broader concept. This illustration is intended as an additional support to the conclusion of the previous chapter regarding the importance of the quality issue, and it will at the same time supply a concrete feeling for the implications of the theoretical developments of the broader concept.

AGGREGATION AND CODING AND EXAMPLES OF CONSEQUENCES OF A LIMITED QUALITY CONCEPT.

3.1 AGGREGATION AND CODING: TWO CONTEXTS WHICH ARE LESS OBVIOUS

In the attempt of illustrating the implications of a narrow understanding of the information quality, it is easy to think about the waste of research and activities which are to be based on false information premises. Alternatively one may think about the damage inflicted to business and society resulting from the implementation of false conclusions derived from false premises.

Within the more limited scope of this paper we instead intend to illustrate the way in which the narrow understanding of the quality issue hides important exposures in the context of two quite familiar and supposedly non-controversial activities of the data-bank and information system environment.

3.2 AGGREGATION

Aggregation, in the context of control systems, is described by one author as being the description of a system by a lower order model, lower in the sense that the model variables in a given sense represent "averages" of the system variables. This given sense may be a mathematical function defining an "index" of the original variables.

Emery (1969) expresses the function of aggregation in the context of design and implementation of organizational planning and control systems, as being one way of obtaining DATA COMPRESSION. The purpose of data compression in an organization is said to be the reduction of the VOLUME OF AVAILABLE DATA in order not to swamp the organization with trivial information and in order not to reduce too severely their information content. The aggregation of data over unwanted CLASSIFICATION DIMENSIONS, IRRELEVANT FOR THE PURPOSE AT HAND, attains reduction of volume. For instance, sales transactions might be aggregated along the dimensions of customer, salesman, industry, and geographic region, leaving the data classified in terms of the remaining dimensions - item and time period.

What is said above has a strong intuitive appeal, it recalls obvious experiences we all have had in the context of simple EDP applications, and is clearly related to much traditional thinking in statistics where one talks about SUFFICIENT STATISTICS or contractions of observations, sufficient for the PURPOSES TO WHICH THE OBSERVATIONS MAY BE PUT, and especially providing a SIGNIFICANT SAVING IN THE MECHANICAL LABOR OF STORING AND PRESENTING DATA.

The same view on aggregation may be held in many contexts of applied research and operations analysis. A good illustration of such contexts is given for instance by Ackoff (1962, p.126) who, in the context of omitting uncontrolled variables in the building and use of models states that the aggregation of several variables does not exactly omit any of the variables, but it does reduce the number that have to be considered. Ackoff also gives some examples of aggregations from business applications.

3.2.1 AGGREGATION AND ERRORS

Up to now everything seems OK; our interest in aggregation appeared the first time because of what is said on ERRORS in the context of aggregation: this is what we will cover next with a question in our mind - "does aggregation help to attain better accuracy ?".

Emery (1969) in discussing qualitative aspects of the value of ACCURACY of information states that in the case of decision processes dealing with unaggregated data, the VALUE of information may be highly SENSITIVE TO ERRORS. When data are aggregated for high-level decisions, Emery says, THE VALUE OF GREAT ACCURACY drops off sharply. The author illustrates this point with the case of an error in a bank account balance, which may be very expensive indeed, while its possible impact on high level decisions using aggregate bank-deposits by state, is much weaker.

While Emery makes his statements in the same context as ours, i.e. data-banks and information systems, it is interesting to note that his views seem to be analog to those expressed e.g. by Ackoff (1962, p.126) in the much more constrained context of a well structured applied research. Ackoff then states that where variables are aggregated, the ERROR (in the estimate of the outcome) which is introduced is ROUGHLY PROPORTIONAL TO THE RATIO OF THE WITHIN-AGGREGATION VARIANCE TO THE BETWEEN-AGGREGATION VARIANCE. Put in another way, he says, it is desirable to make the variables aggregated as homogeneous as possible and the aggregations as heterogeneous as possible.

The above makes us believe that an interpretation of such view on aggregation and related error-accuracy problems, is that the variables refer to the components of a so-called NEARLY DECOMPOSABLE HIERARCHIC SYSTEM. Such near-decomposability implies that the short-run behavior of each of the component subsystems is APPROXIMATELY INDEPENDENT of the short-run behavior of the other components, and that in the long run, the behavior of any one of the components depends IN ONLY AN AGGREGATE WAY on the behavior of the other components. (Simon, 1969, p.100).

The striking implication of this proposal is that one knows the implications of aggregation and related errors, if the system-problem is assumed to have been already solved in the sense suggested by Simon (1969) or Langefors (1968b). One of the serious difficulties of such an assumption, however, is the common knowledge that information must be used and erros estimated in business and social contexts where obviously the assumption does not hold, since nobody claims to have designed the system or defined its goals etc. Furthermore, many data-banks will use and store information which has been generated and which will be used in unknown contexts, certainly not designed nor understood in Simon's or Langefors' system terms.

3.2.2 AGGREGATION AND ERRORS IN ECONOMICS

Applications of economic science in business and national planning makes use of an enormous quantity and variety of data or statistics which can very well be immagined to be stored in data banks. In most industrialized western countries such implementations of data-bank are to some extent already being done, and it might be only a question of time before it becomes common-place.

Applications of economics to business and national planning are much closer to our context of data-banks and information systems for administrative control, than the trivial applications to bank accounts or assumed well structured problems of applied research mentioned in the last section of this chapter.

It is therefore important what O.Morgenstern has to report from an extensive experience in the subject matter, in his book "On the Accuracy of Economic Observations" (1963). We edited the following.

> A whole economy is entirely inaccessible for computation, unless drastic simplifications are introduced. This leads to the process of aggregation, i.e. the formation of larger entities from myriads of components, which presents one of the most important but also most troublesome problems of economics. Too much aggregation mixes the unmixable and gives us models that are easy to handle but with low, if any, power of resolution. By aggregating, errors of a new kind are introduced. (p.101)
>
> It is possible that the influence of one error which drives a number in one direction is exactly offset by the influence of another errors doing the opposite, leading to a "true" figure for our observation. But we have not MADE a true observation ! The notion that errors cancel out is widespread and when not explicitly stated, it appears

> as the almost inevitable argument of investigators when they are pressed to say why their statistics should be acceptable. YET ANY STATEMENT THAT ERRORS "CANCEL", NEUTRALIZE EACH OTHER'S INFLUENCE, HAS TO BE PROVED. Such proofs are difficult and whether a "proof" is acceptable of not is not easy to decide. (p.53)
>
> The mere repeated "checking" of the transcription of figures from some source and their correct transfer to other papers is no substitute for the determination of errors of observation and their significance for deductions and inferences.
> It is also necessary that WORTHLESS STATISTICS BE COMPLETELY AND MERCILESSLY REJECTED ON THE GROUND THAT IT IS USUALLY BETTER TO SAY NOTHING THAN TO GIVE WRONG INFORMATION WHICH - QUITE APART FROM ITS PRACTICAL, POLITICAL ABUSE - in turn misleads hosts of later investigators who are not always able to check the quality of the data processed by earlier investigators. THIS IS ESPECIALLY IMPORTANT IF DATA ARE TO BE USED IN EXTENSIVE AGGREGATIONS. When elaborate calculations are needed that are difficult to set up, this misleading information may make the use of high-speed computing machines meaningless.(p.54)

How can one evaluate what Morgenstern says in the context of economics against for instance Emery's much more optimistic view of the matter ? Maybe the answer lies in the assumptions. Maybe the answer is suggested by what Morgenstern says on the success of modern physics:

> In physics errors were recognized for a very long time; but they were held to be a secondary nuisance, to be neglected and to be ignored by the THEORY. Or as Brillouin expresses it:" The assumption was that errors could be made 'as small as might be desired', by careful instrumentation, and played no essential role. Modern physics had to get rid of these unrealistic schemes, and it was indispensable to recognize the fundamental importance of errors, together with the unpleasant fact that they cannot be made 'as small as desired' and must be included in the theory." (p.61)

This implies that aggregations will not imply any difficulties when they are performed in an information system dealing with problems which are well explained by available theories, like physics.

▷ The situation will become much worse in the context of social events such as found in business and government where no established theory exists.

▷ Such insight on the problems of errors and accuracy in the context of aggregation is impossible within the much narrower frame of accuracy suggested by the literature reviewed in the earlier chapters.

3.2.3 AGGREGATION AND THE ACCURACY OF INVENTORY RECORDS: A CASE STUDY

Appendix A3 presents some details of a case study on so-called inventory differences as signs of the inaccuracies of inventory records of the stock of completed parts in a plant manufacturing electro-mechanical machines.

The results of the case study are not fully exploited in this paper, but some of them can be used to illustrate the vagueness of the implications of aggregation in a situation in which the system problem has not been solved, as well to illustrate the complexity of the quality-accuracy issue in terms of the vague SOURCE and CODING errors mentioned in the last chapter.

Plant management and auditors consider the accuracy of the inventory records to be a very important matter. Does this imply that they do not care of the differences since they will in some sense "cancel out" in aggregations over time and over items ? Certainly not, to judge from the existence itself of a rotating inventory count and from the recurring investigations on the nature of the differences found through these counts. Also, certainly not, to judge from the richness of the number of reports and variables in the follow-up statistics on inventory differences, most of them not usable for low-level decision making.

It actually appears that higher levels of management are very dependent on detailed knowledge of differences. They are not interested in the possibility that positive differences "cancel out" negative differences. They must keep negative differences down to some minimum because of e.g.

1. Danger of running in line-stop leading to delays in delivery of products and waste of idle resources.
2. Incurrence in extra costs for placement of additional emergency orders.
3. Requirement to protect stockholders.
4. Losses leading to charges on the product price.

Positive differences must be kept down to a minimum because of e.g.

1. Losses from interest on investment on too high stock.
2. Losses from not being able to take advantage of the maximum allowable write-down of stock value.
3. Protection of the public from an over-evaluation of assets

In the appendix A3 it is possible to see that no easy conclusions can be drawn on the aggregate effects of the errors listed in the summary list of errors leading to inventory differences. If anything, it is for instance possible to notice from the summary table of the first investigation (1964) that there are two kinds of causes that only contribute to negative differences and never can cancel each other.

▷ The most interesting insight, however, from the case study is that even if the differences cancel-out, the problem is to know HOW they cancel out, and to what extent the way of cancelling is acceptable in face of management's above listed seven objectives in keeping differences to a minimum: for instance, what is the amplitude and frequency of fluctuations around the "true" value, that would be considered to be acceptable by certain particular stockholders ? An evaluation of aggregation and its errors is thus seen to require an understanding of the total system.

▷ Outside of the particular subject of aggregation, the case study also shows the nature of many source, coding or observation errors, as they were labeled in the review of literature on quality. Ignoring such kinds of errors appears to be equivalent to ignoring the larger system in which the purely technical EDP system is contained. It is not surprising that, to the extent that error rates can be measured in some way, the larger contribution to such rates in a complex social system will originate outside the strictly defined technical EDP subsystem. Concentrating the quality effort on the technical aspects may thus be a grave suboptimization: it is something like avoiding the cause of difference listed under number 9 in the appendix A3, wrong punching, when the other 29 listed causes are not considered at all.

▷ The list of causes of differences also shows how many so-called "human factor" errors may be in their turn considered as caused by the inflexibility of the EDP program itself (for instance see points 13, 23, 26). Such facts should have far reaching organizational implications in future complex systems.

Finally we can very concretely notice the absence of the "objective" observer of the "true" inputs. The rotating inventory clerk is the verifier-observer of the stock clerks' activities; the three reported investigations were performed by verifiers of the verifiers, i.e. by objective observers of both the rotating inventory and stock clerks; and our own present study can be seen as a further step of verification or "objectiveness" - we are discussing the meaning of the accuracy of those who checked the accuracy of the rotating and perpetual inventory system. A discussion of the accuracy of the follow-up statistics summarized in appendix A3 would be a concrete document of the vagueness of the complex accuracy issue.

A superficial examination of the summary of the contents of follow-up statistics on inventory differences, as displayed in appendix A3, discloses the creation of a great number of "aggregation variables", out of the basic original observations of differences. These extensive statistics and tabulations relate only indirectly to the basic problems as illustrated by the list of causes of differences. This suggests to us the applicability of Ackoff's statement originated from a number of experiences in the field of operations research: "The less we understand a phenomenon, the more variables we require to explain it. Hence the manager who does not fully understand the phenomenon that he controls plays it 'safe" and wants as much information as he can get."

This suggests that the vagueness of the complex accuracy issue leads to the use of aggregations whose aim is not data-compression for preventing the need to communicate large volumes of trivial information. Aggregations may then rather be used in the attempt to remediate lack of knowledge on the nature of errors or lack of control on them, by massive data-processing of the information that happens to be available on them. Such perspective is just one alternative to the image of tomorrow's sales manager who, when confronted with an unfavorable trend of sales, sits down at an on-line terminal requesting all possible aggregations and statistical tests to be performed on past sales transactions, "searching for patterns in the data". We obviously question the belief that such a procedure will substitute the direct understanding of the original object system; the available resources might better be applied to such an understanding.

3.3 CODING

There is some evidence that the broad subject of coding in the context of information systems and data-banks is not completely understood.

In the EDP literature, coding has at its best been considered as a communication tool, and it has been evaluated in technical terms: communication-economy through a channel, economy of identification in the storage and retrieval of information etc. Codes have been developed with primary attention given to machine processes, in order to facilitate machine operations, such as the "tight" coding on many 80-column punched cards.

In more recent years, as suggested by some of the literature reviewed in the previous chapters, some people have realized the need to "design human factors into" the code structure in order to minimize for instance transcription or digit-manipulation errors by humans who are then also considered as "communication channels".

In view of coming ambitious projects for implementation of complex data-banks and information systems, we think that the time has come to enlarge the above view on the meaning of coding.

One possibility is to integrate the communication-approach into the body of modern organization theory. An organization may create CATEGORIES for classifying situations and events. Such classification schemes are the basis for the program-evoking aspects of communication: once the event has been classified, the appropriate program can be executed. (March & Simon, 1958, p.162)

The above can be illustrated as follows. As soon one knows in a manufacturing plant that a particular item is not a detail part but rather an assembly, to be bought from a local vendor to whom the plant will have to consign all of the detail parts to be assembled, - then the particular item is to be coded CQ-509 in the perpetual inventory file. This file will later be used e.g. in the requirement generation program.

Another illustration may be taken from the EDP application for updating perpetual inventory records of the manufacturing plant. If a particular item was previously requisitioned from stock in order to be quality-inspected, and it is found that it is no usable, and it cannot be reworked but it must rather be scrapped, then the transaction to the EDP application program must be coded 5119 08. The transaction will then be processed updating stock status and later it will also be used e.g. in accounting applications.

A second possibility to enlarge the view on the meaning of coding is to regard it as one method of expressing measurements: one attempts to assign e.g. objects to classes, while in others one tries to establish a specific relationship or attempts to assign numbers. A coding system will then be a language for class assignment, whose rules are the means by which a decision-maker uses the information expressed in the language. A perfectly "adequate" language of class assignments must meet all potential informational requirements, that is, must provide an exhaustive classification. (Churchman, 1961, p. 106)

The striking consequence of this enlarged view of coding is that it becomes much more than a question of economy in communications, storage, and retrieval. It becomes an information problem that reaches beyond hardware, software or human-factors considerations.

3.3.1 FORCING REALITY TO FIT THE MODEL

▷ CODING MAY THEN BE REGARDED AS THE COUPLING, INTERFACE, OR MEASUREMENT PROCESS LINKING THE REAL WORLD (OBJECT SYSTEM WHICH IS TO BE CONTROLLED) TO THE MODEL REPRESENTED BY THE INFORMATION SYSTEM OR BY THE INFORMAL HANDLING OF THE CODED INFORMATION. The importance of this insight for our inquiry in errors and quality of information derives from the possibility to regard CODING ERRORS not only as caused by the "human factor" or by non-understanding of the model by the human coder. The coding errors may also be seen as caused by NON-ADEQUATENESS OF THE MODEL itself, i.e. by MODEL ERRORS in not taking into account relevant aspects of the real world, including the social system and humans who are supposed to work with the model.

As a simple illustration, consider the research reported by Cardozo & Leopold (1963) and its extension by Van Gigch (1970a and 1970b). Their results suggest the existence of a maximum human communication load, above which human communication error rates are expected to increase steeply. Codes belonging to a code-scheme can be interpreted in terms of such communication load. If the load is too high many coding errors will be committed. Which is the conclusion ? Before we had available the referenced research, or to the extent that it is not accepted as part of "established" psychological theory, we would have claimed that the errors were OBSERVATION or CODING errors, requiring e.g. better discipline and training of the human subjects. To the extent that the research is accepted and perhaps incorporated in a theory, we would instead claim that the errors were MODEL errors: the system designer has allowed the disorganized growth of interdependent EDP programs which impose their own coding scheme without consideration to the known "facts" on human constraints. The system designer will have to improve his training and discipline.

The above could have been reached by sheer common sense. What the enlarged view of coding enables us to do is, hopefully, to integrate and evaluate many different concurrent interpretations of coding errors in a particular situation,in terms of scientific method.

As a more complex illustration of the implications of the enlarged view on coding, reconsider the case of coding of items in the perpetual inventory file of the manufacturing plant. What would happen in a case when some but not all detail parts are to be consigned to the vendor from whom the plant buys the completed assembly ? Or in the case when some of the detail parts turn out to be also assemblies in their turn ? What will the coder do, which will his "information load" be if many such sometimes unique exceptions appear every day, and which will the consequences of his coding decision be in terms of the system designer's or programmer's understanding of the coder's environment,code scheme, and program logic ?

▷ Inaccuracies may in such situations arise from the coder's attempts to FORCE REALITY TO FIT THE MODEL. In our case study on inventory differences this could be illustrated by the stock clerk reporting a stock location as being 999 whenever he has to store a certain item in a "third" stock location. He knows that in this way he will prevent errors of the type listed under number 26 of the list on causes of differences: parts not found because the EDP program allows a reporting of at most two stock locations for the same item, and deletes the record of the first upon reporting of the third. The stock clerk knows that each time he reads 999 as second stock location of an item, this means that his own manual records or to a common stock location where many such items are stapled leading perhaps to errors of the type listed under number 14: parts are not found because too many different parts are stored at the same stock location, being easy to overlook them.

How to evaluate such errors in other environments (object systems) which may be much more complex than the stockroom of a manufacturing plant, especially whenever there are no resources for adapting inflexible information systems, coding systems and EDP programs, to a changing environment ?

A striking cybernetic interpretation of the deep implications of what has been said above, for the possibilities to control organizations, is given by Beer (1966). It is reviewed here below in terms of edited abstracts. (p.310)

3.3.2 A CYBERNETIC INTERPRETATION, AND OTHER INTERPRETATIONS

On the shop floor, one can always find an example of a machine-loading arrangement which "controls the flow and allocation of material around the shop". What it actually does is to make desperate attempts to keep the job cards posted as they are returned - to provide something like an accurate reflection of what is going on. To the objective cybernetician, then, the shop floor is a control system generating variety for the purpose of controlling the planning office, and not vice versa. The reasons for this unhappy example have been formally uncovered. They are: lack of requisite variety, disobedience of the theorems of communication about channel capacity and so on, AND ABOVE ALL, A STATIC, INADEQUATE, UNADAPTIVE MODEL OF WHAT THE WORLD SITUATION USED TO BE LIKE SEVERAL YEARS AGO.

Fortunately, however, control procedures have a way of keeping themselves viable and of rectifying their mistakes: by means of "ad hoc" comparisons

> of real events with their predictors, the control subsystem struggles in a horribly inefficient way to acquire a certain adaptability. GIVEN THAT THE PROPORTION OF NEW EVENTS IS QUITE LOW (new events is namely what this kind of control is very bad at handling), and given the capability to organize the feedback information, everything usually can run fairly smoothly.
>
> The trouble, however, is that in the course of time, BECAUSE OF THE VITAL NECESSITY FOR CREATING CONTINUOUS AND DETAILED FEEDBACK, the control organization must be allowed to grow and become prohibitively expensive in terms of personnel, facilities, and equipment including large-scale electronic data processing equipment.
>
> But nobody notices that this is a fault in the state of affairs, because it is too familiar, and because the energies of all concerned are totally absorbed in arguing the merits of alternative computers. Typically, the absurdities inherent in the situation are obscured by the APPEARANCE of modernity and technical competence which all this activity betokens.

Beer's cybernetic interpretation is paralleled by Blumenthal's system-positivistic interpretation and description of troubles at higher organizational levels. (Blumenthal, 1969, p.197). Disorganized incremental growth of so-called systems where

> system is piled on system, or a continuing series of minor enhancements is made to existing systems, in an attempt to generate relevant management information as a hopefully serendipitous by-product accompanying the production of increasingly vaster quantities of irrelevant, unused, or merely historic data...
>
> As the information pile-up occurs another system modification or addition is created to produce ostensibly only that which is wanted in the situation...
>
> This process is a form of change, true; but it is only marginally and fitfully adaptable change. Ultimately the patchwork collapses. Systems become moribund, and, like dead horses, no longer respond to the whip.

Blumenthal goes on giving, in a positivistic mood, the answer to this problem: a new dynamics of adaptable systems growth. This appears to us, a new aspect and name for the ever pervading problem of model building - in this case information systems. What bothers us, however, is the implication of all what was said above for our issue of quality-accuracy of information, as well for the related "errors" made at distinct organizational levels.

It is easy to immagine that the terrible descriptions of serious problems by Beer and Blumenthal must mean also serious things happening to the errors and accuracy at different levels of the information system. We tried to illustrate this by means of the case study on inventory differences but the illustration is obviously incomplete in many respects.

The reviewed literature does not offer any example of the problem. We could guess about an example by reading"between the lines" of Orlicky's discussion of so-called integrity of an average manufacturing routing file, and its maintenance.(Orlicky,1969,p.153)

> Such file will consist of several tens of thousands of records encompassing active, inactive, semiobsolete, and obsolete parts. Each of these records carries the prescribed sequence of operations, their descriptions, the routing to the various departments and machine tools within these, job standards, and the required tooling, not to mention part master data in the record header.
>
> This file is constantly affected by so many changes in manufacturing method,standards,tooling, engineering changes, machine tool procurement, downgrading and retirement, shop reorganizations, etc., that true file maintenance becomes a nightmare. This is so BECAUSE MANY TYPES OF CHANGE LITERALLY EXPLODE THROUGHOUT THE FILE (such as in case of adoption of a new class of cutting tools, changes in departmental boundaries, or the acquisition of new productive equipment). A single such change MAY CALL FOR HUNDREDS, OR EVEN THOUSANDS, OF PARTS TO BE REROUTED, operations to be added or deleted, and methods, standards, and tooling revised accordingly.

It is possible to guess what such requirements mean in terms of impact on the ACCURACY OF CODING. Orlicky goes on stating that the key to this problem is the staffing and budget provided for file maintenance. Our broad concept of the nature of the coding process allows us to frame this statement in concert with e.g. Beer's and Blumenthal's: when things begin to look like as in Orlicky's description,a better contribution to overall accuracy might come from an improved system design (with built-in human factors considerations) rather than from increased staffing and budget for file maintenance.

We hold that the quality of information, particularly as expressed in the nature and rates of coding errors, may be an important indicator of the adequacy of system design or of the model. Up to now it has been regarded as an indicator mainly of the coding and observation process itself.

3.4 GENERAL COMMENTS ON THE CONTENTS OF THIS CHAPTER

After showing in the previous chapter that the empirical approach to quality of information assumes a narrow concept of quality, and that it does not dispense a sound theoretical understanding of the issue, we attempted in this chapter to show how a too narrow understanding of the issue misses important problems arising e.g. during use of data banks and information systems.

Two such less obvious problems are the considerations of accuracy in the context of coding and aggregation. The optimistic view on the aggregation of data assumes that the system-problem is already solved, and this was seen to be not motivated as suggested from problems in economic science and in a case study on inventory differences in a manufacturing plant. The optimistic view on coding regards it as a communication tool for efficient machine processing and misses the possibility of regarding it as a measurement process where "errors" may indicate model inadequacies.

We may eventually note that the issues of coding and aggregation appear to be closely related. When one aggregates for example sales transactions along the dimensions of customer, salesman, industry and geographic region, this corresponds to the creation of a new set of sales data where the above dimensions do not make difference and are therefore coded as belonging to one same class. The assumption is that the new code defines a class of information that will be useful for some particular decision.

3.5 CONCLUSIONS FROM THIS CHAPTER

1. Without an understanding of the information-quality issue, aggregation of data may be uncritically accepted as being error-free in the context of high-level decision making.

2. Without an understanding of the information-quality issue, it is possible to miss the evaluation of coding errors and coding difficulties as symptoms of inadequate model building or system design.

As a contribution to improved system design, we shall try in the next chapter to develop the concepts of ACCURACY and PRECISION as two aspects of the broader understanding of quality of information, to be operationalized and "built into" data-banks or information systems for administrative control.