THE LINGNAN INSTITUTE OF BUSINESS ADMINISTRATION

THE CHINESE UNIVERSITY OF HONG KONG

ANALYSIS AND RECOMMENDATION FOR CHANGES IN THE METER READING METHOD FOR AUTOMATION OF THE HONG KONG GOVERNMENT WATER BILLING SYSTEM

by

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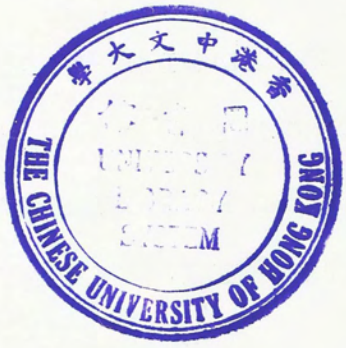

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LOWER ALBERT ROAD
HONG KONG

本署檔號 OUR REF.: (121) IN DPD 7/38/09

來函檔號 YOUR REF.:

Data Processing Division,
New Mercury House, 16th floor,
Hong Kong.

19th March, 1976.

Mr. CHEUNG Ping-yu,
The Lingnan Institute of Business Administration,
The Chinese University of Hong Kong,
Shatin,
New Territories.

Dear Mr. Cheung,

I would like to take the opportunity of thanking you for the work you did on data collection for our Waterworks accounting project. As the stage of the project is currently related to a fairly conventional data collection system, we have not yet really considered our approach to this subject. We will however be most interested in seeing your thesis as the preliminary findings you presented were of great interest, and I am sure that our project team will be able to make considerable use of the impressive thought and planning in your work.

Yours sincerely,

(L.M. Tate)
Data Processing Manager

ABSTRACT

The Hong Kong Government has decided to implement a computerized water billing system for the Waterworks Office. It is going to take full advantage of the computer for processing large volumes of data. Higher accuracy, timeliness in billing and control of the billing process should give substantial dollar benefits. This study is mainly concerned with the meter reading method, which constitutes the major input into the water billing system.

The approach begins with a survey of the present meter reading method. The main transactions and the inadequacy of the present method in meeting the future automatic system requirements are identified. A spectrum of nine different meter reading approaches are examined. Out of the suitable approaches, three most desirable alternatives evolved, which are the key-to-tape turnaround, optical character recognition (OCR) turnaround and optical mark (OM) turnaround alternatives. A cost/benefit analysis on these three alternatives indicates the OCR alternative is optimum. It consists of handwritten numeral input by an OCR reader.

The operation cost for key-to-tape alternative is about HK$511,000 for a four-month billing cycle. The cost for OCR is HK$506,000 and for OM about HK$450,000. This difference in cost is not great enough to warrant that a particular alternative is better than the other two. However OCR will have the lowest long term cost.

Because of its relative high reading speed, it can handle future increasing number of accounts without installing additional equipment. It is also the technique that the Data Processing Division will find increasing applications and will have less resentment from meter readers compared with the OM alternative. It will also creat less human/machine interfaces compared with key-to-tape alternative.

For the first phase of the conversion from the manual to automatic system, in which ten percent of the large accounts is involved, the key-to-tape alternative is recommended, chiefly because of its reliability and the lack of time to install, test and debug the OCR alternative in a few months' time.

FOREWORD

This thesis was written in partial fulfillment of the requirement for the degree of Master in Business Administration. The project was concluded for the Division of Data Processing of the Hong Kong Government, under the supervision of Dr. B.J. Bennington of the Lingnan Institute of Business Administration and Mr. Lee Tate of the Government. The project began in September 1975 and was completed in December of the same year.

ACKNOWLEDGEMENT

One of the many things I have learnt from this kind of project is how to work efficiently and effectively. My teachers and friends provided many concepts leading to the research plan and furnished me with advice and encouragements. Thanks must be extended to them, for the success and completion of the thesis and valuable learning experiences I have undergone.

Professor H. Sutu, Director of Lingnan Institute of Business Administration also provided me with critical advice and I must express special appreciation to him.

I am also grateful to Mr. Lee Tate, Manager of Data Processing Division, and other personnel at the Division of Data Processing and the Waterworks Office of the Hong Kong Government, for their cooperation and assistance, which greatly facilitates my analysis.

Last but not least, thanks must be given to Miss Caroline Cheung who prepared the typing and documentation of the thesis, especially for her tolerance of the writer's horrible handwriting.

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1.0 INTRODUCTION

1.1 Purpose of the Study

Water supply in Hong Kong is managed by a Government agency called the Waterworks Office (WWO). The Accounts Division of the WWO is responsible for billing the consumers on the basis of meter readings taken by one of its sections, the Meter Reading Section. At present the Accounts Division handles about 670,000 meter-accounts. The number of water meter installations has been increasing recently at an average rate of eight per cent annually. This in part is due to the growth in population, which has expanded from four million in 1971[1] to 4.4 million in 1974.[2] Another attribute is the Government's policy of encouraging independent meter installations as mentioned in one of the organization and management (O&M) studies of WWO.[3] A number of similar O & M reports also indicated there has been a chronic shortage of staff in some of the sections of the Accounts Division. Consequently some of these sections have been under a heavy workload.

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[1] Hong Kong Population and Housing Census 1971, (Census and Statistics Department, Hong Kong 1971) p. 3.

[2] Hong Kong, Report for the Year 1975 (Hong Kong Government Press 1975), p. 180.

[3] Lin Chiao-shih S.A.A. (S.G.G.) Facts Finding Report, Review of the Functions of Meter Reading Section (Waterworks Office files of reports, 1972), p. 17.

Essentially most of the billing procedures are repetitive jobs that demand specific low-level decisions. These large volumes of repetitive manipulations and calculations appear to be the grounds for automation of the billing system. A feasibility study made in 1974[1] by a local consulting firm indicated there was a potential annual saving of $0.6 million if the billing system was automated due to the capability to bill in a more timely manner. More recent studies have shown that may be even as great as $1.5 million. Higher accuracy, timeliness and control of the billing process should also give substantial dollar benefits and in addition a better consumer relationship with WWO can be established.

In 1975, the Hong Kong Government decided to go ahead and automate the water billing system. The Data Processing Division within the Government is responsible for all data processing activities and is in charge of implementing the automation proposed. As a pre-requisite to billing, meter readings must be put into the system. Currently meter readings are recorded in meter reading slips which cannot be input directly into an automated system. In September 1975, following exploratory efforts to determine areas of Government that the Lingnan Institute could offer research assistance, the Data Processing Division requested the Institute to study the data entry aspects of the water billing system. It provides an analysis of alternative methods suitable for including in a computer based system. The specific objectives of the study were:

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[1] Commercial Water Billing System Report, Lowe Bingham Consultant Co. Ltd., 1974.

1) to examine the current meter reading method of the Hong Kong Government Waterworks Office;
2) to recommend a modified method of reading meters suitable for providing input to electronic data processing of the water billing system, including development of a unit cost for collection;
3) to suggest a practical meter reading method recognizing the bad meter reading environment caused by such things as water flooding, dirt, and grease;
4) to present a method which can be used by the Data Processing Division of the Hong Kong Government for project decision-making by the end of the calendar year 1975.

1.2 Scope of Study

The project scope covers only the conversion of meter readings registered by water meters into a machine readable form. The meter readings constitute the primary data which will be put into the automated billing system. Report codes on meter conditions and meter reading environments are also part of the system input. There was no consideration of altering the routes taken by meter readers as this would have been a sufficiently large project in itself.

In addition to the project described in this thesis, there are a number of other projects leading to the automated water billing system -- for example, the file conversion from manual records to machine readable records, the optimal billing cycle frequency and the design of the automated billing system itself. The primary concern of the file conversion project is in the master files of the billing

system while this project is mainly concerned with the data entry to the transaction files. However discussions within this project were dependent upon system design considerations which only emerged during the course of these projects. Consequently close liasion was required with these other projects.

1.3 Methodology

The approach consisted of surveying transactions involved in the present Meter Reading Section of the Waterworks Office. The nature, volume, timeliness and accuracy of the data inflow into the water billing system were then identified from these transactions. Problem areas in reading meters and data entry were also examined. Possible future changes in data requirements due to enhancement of the billing system were studied and notes were taken in the analysis.

A spectrum of alternatives for the modified method was surveyed, each being based upon the best available assumptions concerning the whole system under development. These alternatives for the conversion of meter readings into machine-readable input of the automated water billing system were developed in some detail; and then from an economical and technical viewpoint, the three most feasible alternatives were selected. A cost/benefit analysis of these three alternatives was performed and a recommendation was then made to the Data Processing Division of the best method and considerations involved in its implementation.

The method was accomplished in six tasks over a period of three months at a level of effort of some twelve hours per week.

Task One: Capture of Reference Materials

Prior to the acceptance by the Government of the project approach, a comprehensive proposal and work plan was prepared and submitted. This consisted of work statement and project plan. The work statement, project plan and Gantt chart were reviewed with the Manager of Data Processing Division and the project supervisor of the Lingnan Institute. A schedule of interviews was then set up. System analysts of the China Light and Power Co. Ltd., a local electrical utility that had pioneered the use of computer for utility billing in Hong Kong were interviewed. Their optical character recognition (OCR) documents and work plan concepts were examined. Reference materials were also sought from the Waterworks Office so that a preliminary idea of how the Meter Reading Section operated was captured. These materials were mainly organization and management surveys of the WWO. Based on these materials, interview topical guidelines were prepared for the main interviews conducted in Task Two.

Task Two: Preliminary Survey of the Current Meter Reading Method

Through arrangements of the Data Processing Division, the Treasurer Accountant of the Waterworks Office was contacted. Organization charts and cost data were sought from the accountant. He also made arrangements with an initial interview with the Executive Officer in charge of the Meter Reading Section. The present meter reading process was examined to the level of detail such that the transactions involved were identified. Samples of input forms were captured. The overall organization, problems related to data entry and future

expansion and changes of the Meter Reading Section were discussed.

Task Three: Detailed Analysis of Current Method

The Executive Officer made arrangements for interviews with individuals in the reporting chain--from Junior Meter Readers (J.M.R.) who collect meter readings in the field via Meter Readers (M.R.) who check and supervise their juniors' jobs to the Chief Meter Reader (C.M.R.) who is in charge of the whole team. Their responsibilities, work procedures and difficulties were examined. Possible loopholes in the reporting chain was identified. Half-a-day was spent with a J.M.R. in the field collecting meter readings to get exposure to how they actually do their work. The bad meter reading environment such as the location of meters and the dirty conditions that may affect machine-readable meter readings were noted. The difficulties and time for filling in OCR turnaround and optical mark documents were assessed. The attitude of the J.M.R. to his work was also observed.

Task Four: Survey of Alternatives of Data Imput

Based on current technical journals and other reference materials of data processing, a spectrum of alternatives was listed. This covered the completely automatic on-line meter reading entry to simple transcription using a key punch or something similar which was used manually. The technical and economic limitations of the present situation were identified. Three most suitable alternatives from an economic and technical viewpoint were chosen. Unit cost estimates and other reference materials for resource and cost estimation were sought from the Operation Manager of DPD and from vendors of data entry equipment.

Task Five: Cost/Benefit Analysis of Different Alternatives

From the unit cost estimates and the resource estimates, the total recurring operating costs were found for each of the three alternatives. The one time implementation costs, such as equipment installation, were also calculated. Benefits such as timeliness, accuracy, savings from job displacement, better consumer relationship were quantified as far as possible. When benefits could not be quantified, supporting information was developed. The impact of the alternatives on WWO, DPD, and consumers was also considered. Based on the cost/benefit analysis, the most suitable method was chosen.

Task Six: Presentation of the Project

The findings of the project were presented orally to the Manager of the Data Processing Division and relevant staff with emphasis on why the three major alternatives had been chosen and why the final selection had been made. Implementation factors such as problems anticipated in the modified method and their possible solutions were also highlighted. Comments and recommendations from that review meeting were adopted and the whole project was then documented according to plan.

There were no particular problems encountered during the project, thanks to the help and cooperation of the staff of DPD and WWO. The project was finished according to time schedule. However some difficulties did arise.

At the time when the project was carried out, the future automated billing system requirements had not been developed. In

fact the design of the billing system took place parallel with this project. Consequently, many assumptionsconcerning the future billing system had to be made in the cost/benefit analysis of alternatives. These assumptions might not agree with the eventual system and the practicability of the findings and recommendations might be affected.

Staff at the Meter Reading Section generally had misunderstandings of the project. It was very time consuming to explain what the project was actually all about. Some of them thought it was yet another organization and management exercise aimed at checking their work. It was difficult to limit the scope of topics discussed solely to the activities of the Meter Reading Section. Despite this, the transactions in the present meter reading process could be clearly identified.

Further difficulty was that only one meter reading zone was surveyed and one Junior Meter Reader interviewed, because of the stringent time limitation of the project. The Junior Meter Reader and meter reading area might not be a truly representative sample of their respective populations. The Junior Meter Reader appeared to be very devoted to his work and might be among the best of the team. Nevertheless he did not seem to have any resentment to this kind of survey and showed a good understanding of the project. The meter reading area, as commented by the management[1] of the Meter Reading Section lies in the middle rank of difficulties in meter reading. It also encompassed all kinds of reading environments.

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[1] The Executive Officer and the Chief Meter Reader commented on the Wanchai zone which the writer surveyed.

2.0 CURRENT METER READING METHOD

2.1 Waterworks Authority

Waterworks Office

The 4.4 million people in Hong Kong are almost entirely dependent on rainfall as the sole source of water supply because there are no large rivers or lakes in the Colony which can provide a sufficient amount of drinkable water. Consequently water supply is an important public utility in Hong Kong and is managed by the Government itself.

The Waterworks Office (WWO) is the Government agency responsible for all aspects of water supply and distribution. It belongs to the Public Works Department. Basically it is concerned with the design and construction of reserviors, purification works together with desalination plants, the distribution and sale of fresh and sea water.

The workload of WWO is divided among eight divisions and three units, each with specific responsibilities as shown in the operation and organization chart shown in Appendix I. Consulting engineers are appointed to carry out planning, feasibility studies and construction of new works which require specialist knowledge or at times when resources of the office are fully extended.

Accounts Division

The billing of water accounts is under the responsibility of the Accounts Division. This division is in charge of all accounting

and stores functions including the preparation and issue of water accounts. It also responsible for the general and financial control of all revenue services. It deals with personnel matters and provides general administration, secretarial, transport and other services. The Accounts Division is divided into a number of sections. The organization of the division is shown in chart 2.1.

Meter Reading Section

The Meter Reading Section is the section responsible for entering meter readings into the billing system.

The meter readings recorded on a meter reading slip form the basis for billing the consumers. A fixed rate is charged per 1,000 degrees of water consumption (equivalent to one unit). The fixed rate is different among trade and domestic accounts. On top of that is a percentage charge for salt water consumption. If there is a special meter for salt meter then the meter readings of these meters will be the basis for billing. There are three kinds of consumers:

1) Domestic account - household consumers.
2) Trade account - retailers, manufacturers, companies.
3) Special account - Government, public utilities and Universities.

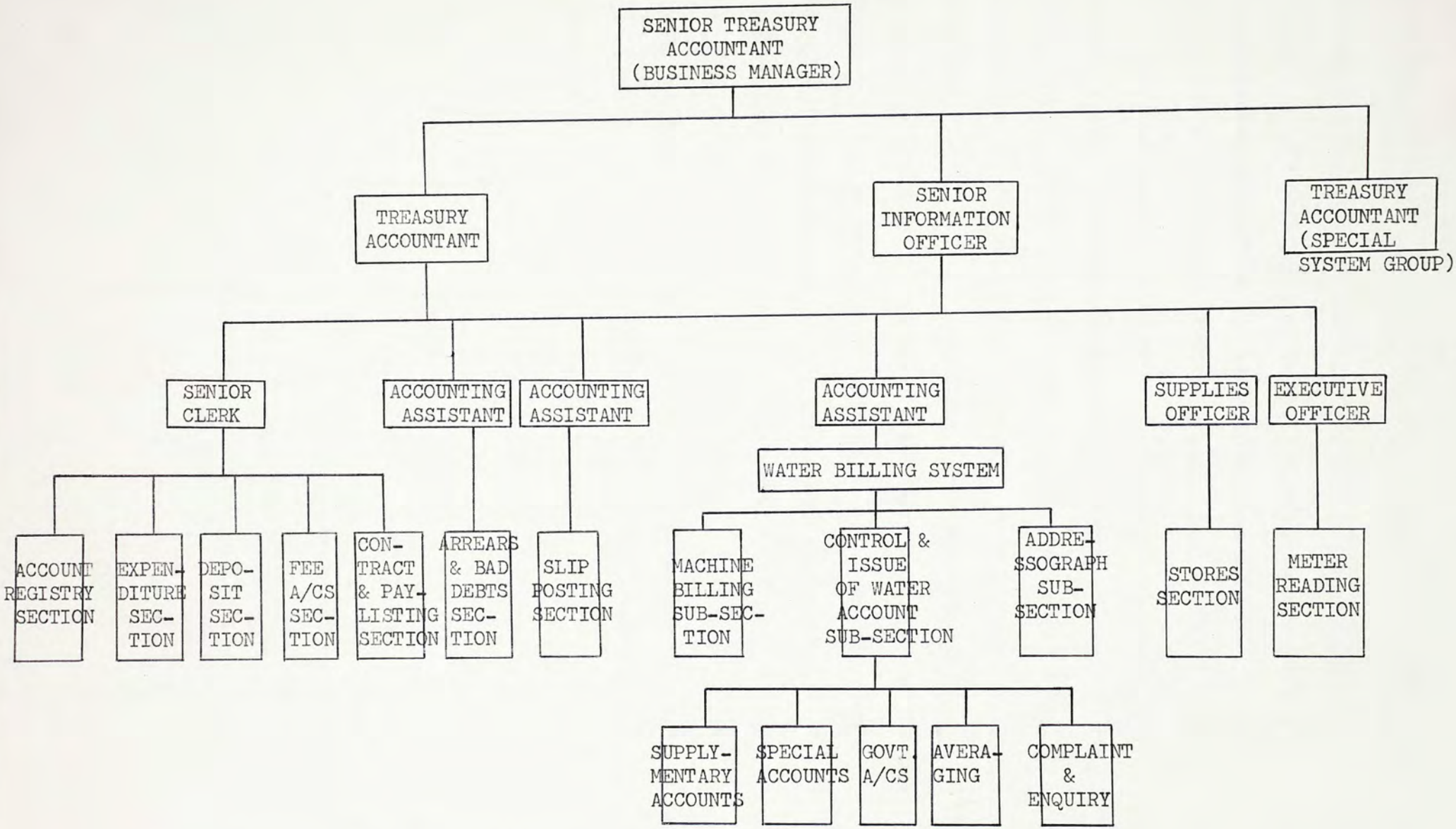
The same meter reading method applied to all categories of accounts.

Besides taking meter readings, there are a number of secondary responsibilities relating to taking meter readings. Thus the Meter Reading Section

1) reports meter defects.
2) compiles statistics and reports of meters in service.
3) allocates account numbers in walking order.

CHART 2.1

WWO ACCOUNTS DIVISION ORGANIZATION CHART



Source: WWO Accounts Office

4) makes preliminary inquires into irregular consumptions.

5) supplies data in respect of Trade, Flushing, Concessionary and Government supplies for analysis of consumptions.

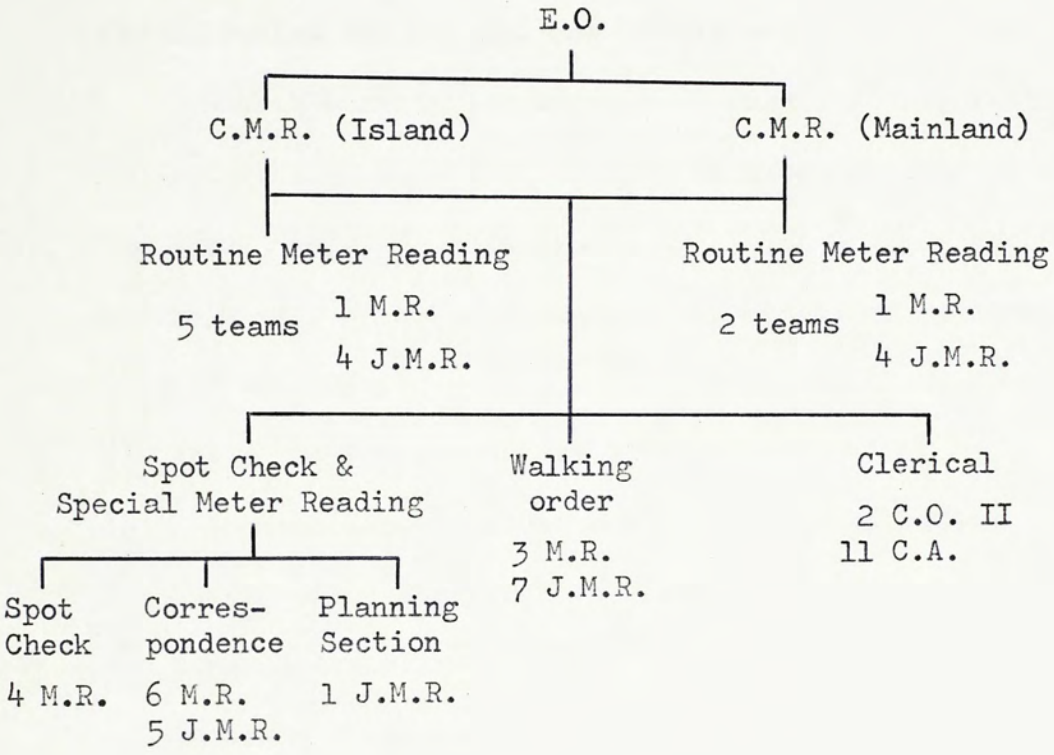
6) provides information for answering complaints.

The head office of the Meter Reading Section is situated on the first floor of Murray Building. It deals with all the responsibilities afore-mentioned and maintains all the records. A suboffice is situated at Argyle Street Depot Kowloon. It is provided for Junior Meter Readers (M.M.R.) reporting on routine meter reading duties in the mainland (i.e. Kowloon & New Territores) and for Meter Readers (M.R.) to supervise more directly of J.M.R.'s daily work by checking their handbooks and raise queries more expeditiously. The Hong Kong head-office is managed by the Executive Officer (E.O., Meter Reading). The Kowloon suboffice is headed by a Chief Meter Reader (C.M.R.) answerable directly to the Executive Officer.

The deployment of staff of the Meter Reading Section is shown in Figure 2.2.

CHART 2.2

ORGANISATION OF METER READING SECTION AS OF JUNE, 1974



C.O. = Clerical Officer
C.A. = Clerical Assistants

Source: Survey of Meter Reading Procedure, P.W.D. Report OM/DA/410.

1. The Executive Officer (E.O., Meter Reading): is in charge of the general management and is the head of the whole section.

2. The Chief Meter Reader (C.M.R.):

   a) allocates and rotates day-to-day meter reading duties.

   b) prepares monthly and annual statements of meters in service and other statistics relating to water consumption.

3. The Meter Reader (Application):

   a) processes circulation sheets in respect of applications for new supplies.

   b) check particulars on new meter slips.

   c) allocates a new account number in walking order.

   d) update meter handbooks for changes of metered premises.

   e) makes notes on meter slips for meters removed by reference to House Service Meter Removal Registers.

4. The Meter Reader (Handbook Checking):

   a) checks outine meter readings recorded by Junior Meter Readers by assessing the reasonableness of the readings.

   b) takes actions for doubtful readings and irregular consumption and for inaccessible meters.

5. The Meter Reader (Spot Check):

   a) arranges and supervises spot-checking of readings taken by Junior Meter Readers.

   b) takes special readings for billing outside normal billing cycle or in connections with some particular enquires or investigations into doubtful readings, irregular consumptions complaints etc.

6. The Meter Reader (Files & Memos):

   a) deals with points raised in files answerable by Meter Reading Section.

   b) updates meter handbooks from information contained in replies of memos from House Service Section.

7. The Junior Meter Reader (J.M.R.):

   a) takes readings of consumption registered by meters.

   b) makes preliminary enquires into irregular consumption.

   c) locates new meter position for inserting new meter slips in walking order in handbooks.

   d) reports defective meters.

   Some J.M.R. are assistants to meter readers in processing of applications for new meters, conducting spot checks etc.

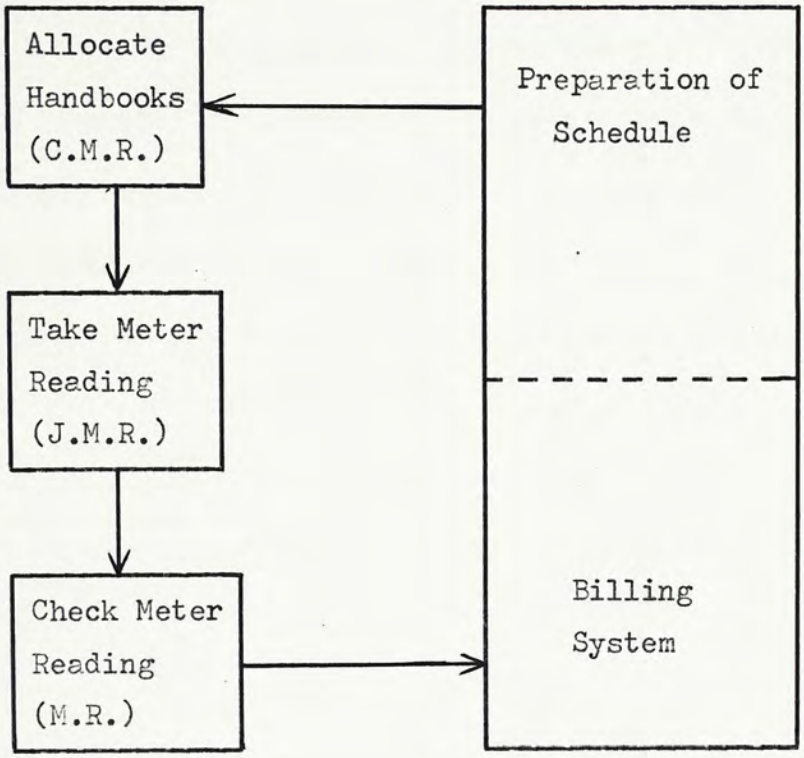
8. The Clerical Assistants (C.A.) deal with all clerical work arising from the Meter Reading Section. They are headed by the Clerical Officer (Meter Reading Registry).

2.2 Survey of the Present Method

The workflow chart of Meter Reading Section that is within of this project can be visualized as shown in Figure 2.3.

FIGURE 2.3

WORK FLOW DIAGRAM OF METER READING METHOD



A full description of the workflow at the Meter Reading Section is illustrated in Appendix II.

The meter reading job is essentially a continuous batch process. There are twelve meter reading zones. Each zone will be covered within a given period of about one-week so that the meters of whole Colony can be read within a four-month period. The consumers are billed three times a year.

The meter handbooks are allocated by the C.M.R. to the J.M.R. via the M.R. (Handbook Checking). At present one M.R. supervises three J.M.R.. The J.M.R. takes the handbook out to the current meter reading zone and enters the consumption registered by the water

meters to the respective meter reading slip of the assigned handbook. A sample of meter reading slip is shown in Figure 2.4. He also reports any meter defects into handbooks and notes down irregular consumption trends by substraction from the previous readings. If the readings are three times above or below the consumption trend that is shown in the handbook, the J.M.R. then goes to the consumers' house and makes preliminary inquires for the irregular consumptions. If no one answers the door then he tries the neighbours or the janitors. He enters the answers of his inquiries (if any) into the handbook. Any particular information that will make meter reading difficult is also entered so as to give a note to other J.M.R. who may be assigned the handbooks in future.

The J.M.R. normally can finish one handbook per day (approximately 250 accounts per handbook) and then reports back the following morning.

The next day the J.M.R. brings back the handbook to the office. He might make an oral report on some accounts that special troubles have arisen e.g. disputes that concern locking of the yards where the meters are located. He also submits reread readings accrued to him the previous day. The M.R. who supervises the J.M.R. then hands over another handbook to him. He takes the handbook out and collects meter readings.

At the office, the meter reader then goes over the handbook. He checks the consumption trend of each meter reading slip. If the consumption appears to be irregular, he refers to the remarks column to see if the accounts has changed e.g. change from a domestic

FIGURE 2.4A

A METER READING SLIP, SAMPLE, FRONTPAGE

Ref. No. _ _ _ _ _ _ _
Premises

Meter Size & No. for Flats

_ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _ _ _ _ _ _ _ _ _ _ _ _ _

Notes to J. M. R.

Reading Date	Reading	Report Code	Assessed Consumption	Date Removed	Meter Fixed	Remarks
						12
						11
						10
						9
						8
						7
						6
						5
						4
						3
						2
						1
b/f						

W. W. O. 15 (Rev.)

FIGURE 2.4B

A METER READING SLIP, SAMPLE, BACKPAGE

Ref. No. _ _ _ _ _ _ _
Premises

Meter Size & No. for Flats

_ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _ _ _ _ _ _ _ _ _ _ _ _ _

Notes to J. M. R.

Reading Date	Reading	Report Code	Assessed Consumption	Date Removed	Date Fixed	Meter Remarks
						18
						17
						16
						15
						14
						13
b/f						

Report Code Explanations:—

F Yard Flooded
L Premises Locked
O Obstruction

HC High Consumption
LM Meter Lid missing
SB Seal Broken

FW Meter facing wall
GB Glass broken
GO Glass obscured
HM Hands missing

D Letter delivered by hand
P Letter sent by post

HI Hands not in proper position
ID Index dirty
LC Low consumption
MD Meter damaged
MC Meter covered by earth
NR Not registering
PF Meter pit flooded
PJ Pit cover jammed
SR Special reason of defects not coded (Explain in Remarks)

Special Notes:—

account to a trade account, or where a new tenant has moved in. If he thinks that the readings are reasonable, then he let the readings pass. If he thinks the superficial explanation is inadequate, he would make a note of the account and order the J.M.R. to reread. He will give a list of these accounts to the J.M.R. on the next day.

In cases where the meters has been noted by J.M.R. as leaking, or the premises have been demolished or meter disconnected or anything concerning the meter defects, he will send a memo to the clerical staff who would prepare a letter to the House Service Division. In cases where the meters cannot be located he will make a memo to the Special Reading Unit which arranges special effort for finding the meters.

The handbooks will normally stay in the Meter Reading Section for one week. They are then delivered to the Averaging Section which takes averages on consumptions for inaccessible readings, low or high consumption accounts whose inquiries are still under progress.

For some large accounts, e.g. textile factories, arrangements may be made (at the discretion of the C.M.R.) to read the meters on a monthly basis so as to make sure that the readings are correct.

Special accounts such as University of Hong Kong, China Light & Power Co. Ltd. and the Hong Kong Government which are to be billed on fixed dates are entered on specially colored meter reading slip of the same handbook but then at the office are processed in

a different route in the billing procedures of the Billing Section.

Resources and Cost of the Present Method

For the purpose of making cost comparisons of a modified method with the present method of reading meters, a resource and cost analysis of the present method is presented. Only differential cost is calculated for the purpose of making such a comparison. By differential cost is meant a cost item that is likely to be changed after the modified method is introduced. If a cost item is not likely to be altered by the introduction of the modified method, then it is not taken into account.

The resources employed under the present method can be classified into three categories as follows:

a. Personnel Cost:

The annual cost formula prepared by the Colonial Secretariat was used in calculating personnel cost. This formula is as follows:

Annual salary	+	Annual per capital charge	+	37% of annual salary	=	Annual cost

The annual salary was found by multiplying the mid-point monthly salary of each rank by the twelve (months of the year). Then the total cost in each rank was found by multiplying the number of employees in each rank by the annual cost. The grand total was found for the six ranks of the Meter Reading Section, using the number of deployment at present. These data are supplied by the section. Over-time charge and traveling expenses of J.M.R. were then added to the total. The detailed calculation is shown in Appendix III. The total

cost of the current method of meter reading for a four-month billing cycle amounted to HK$814,000.

b. Equipment Cost

Only the uniform cost for J.M.R. and M.R. could be identified with individual sections in WWO. The cost for stationary and other equipment could not be identified. However it occurs this item is not likely to be altered much after a modified method is introduced. Since only differential cost was considered this item was disregarded.

c. Renting Space Cost

At present the Meter Reading Section occupies about 1,500 square feet. The current monthly rate is approximately $8 per square foot. So this amounts to $48,000 in a four-month billing cycle. But this item of expense is again not likely to change much after a modified method is introduced. So this was not considered in the cost of the present method.

Summing up the cost of the present method (differential cost for comparison purpose only) is about $814,000.

2.3 Difference in Data Requirements

In the present billing system, the primary data (meter readings) are recorded in meter reading slips in numeral symbols, understandable by the individual person in the communication channel of billing system. Secondary data such as report codes and changes in the accounts are also entered to the meter reading slips. These are written in the general English language which can be recognised and interpretated by the human elements of the communication channel. Sometimes the source data are also transmitted by oral means via

conversations.

In an automatic system, these source data have to be presented to a data processing machine instead of human beings. To input data into a data processing machine is similar in many ways to communicating with another person in written forms.[1] However the requirements will be much more rigid for data to be input into the machine because machine can only carry out specific instructions. Some of the rigid requirements are discussed as follows.

1. A Set of Input Symbols

When a data item is entered into a machine, a device called the scanning unit will make a comparision between the symbols contained in the data item, symbol by symbol, with the symbols stored in its memory system. If the right conjugate pair is matched, then the symbol will be entered into the machine. The symbol will be interpreted with the meaning of the conjugate and then will be acted upon accordingly. Now because the number of symbols that can be built into a data processing machine is much more limited relative to a human brain, the symbols used for input must lie within a set of characters that are acceptable by the machine.

Because of the fixed position of the scanning unit relative to the input documents, the data must be at a specific position on the documents to make them readable. The symbols must also be beyond a specific threshold of prominence such as darkness of lead deposits etc.

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[1] Oral input is restricted to some very sophisticated machines which will not be discussed here.

2. Conditions of input documents

Not only must specific symbols be used for input into machines, but the data must also be presented on input documents of specific dimension because the size of the opening for input is fixed. Thus the documents must be of specific lenght, width and thickness. Foldings on documents will not be acceptable because the machine may be jammed. Water stains, dirts etc. will not be acceptable if they interfere with the scanning function.

3. Schedule for Input

An effective computer system must be utilised as far as possible. The data processing center (Data Processing Division of the Government) will be providing service to a number of applications, so only a fixed scheduled time can be assigned to processing meter readings. Consequently a batch of meter readings must be collected and received by the data processing center at or before a certain time during the computer operation.

Many meter reading slips contain scribbles of meter readings which cannot be recognised by a data processing machine. Some meter reading slips are not of uniform size. Many have water stains, dirtsor are folded. Thus because of limitations imposed by machines, these meter reading slips cannot be used as direct input documents into the data processing system. A modified method of data entry must be designed to meet the change in data requirements and other system requirements of the future automatic water billing system.

2.4 Problem Areas

Labor turnover

The turnover rate of Junior Meter Readers are high. There appear to be two reasons for this. They have very limited prospects for promotion and their working environments are horrible. Consequently their motivation for work cannot be considered high especially as their jobs are dull and routine.

There is no accurate estimation for the percentage of 'false' meter readings which are made up by the J.M.R. themselves in teahouses or at homes. However, making up these readings is easy because the consumption trends for each account are shown on the meter reading slips, and especially spot checking has not been performed recently because of lack of staff. Nevertheless a very high portion of the readings are reliable.

These unreliable readings are the major source of errors in the data. The errors of copying the meter readings into the handbooks are much smaller than these 'teahouse' readings. One possible solution is not to show the trend of water consumption on the meter reading slips. Another way of checking would be a statistical check on the readings taken by a particular Junior Meter Reader. A T- test for the distribution of his readings against the sample taken from all the readings at that time and for that particular meter reading zone would be appropriate. Of course the best solution, perhaps, is to perform spot checking on samples of readings. The samples should be large enough to justify a high level of confidence that the readings are accurate.

The handbooks of meter reading slips are in constant movement. There is only a loose control on the handbooks at present. Handbooks

are put on the shelves and are accessible to anyone in the Waterworks Office. Someone may take them away for answering inquires because they are the only source documents available which contain all updated information of water consumption of an account. Someone else may take them away for billing. Some Meter Readers may take them away to enter memos. In fact, the Chief Meter Reader often has to 'chase' after the handbooks and keep them available for reading meters for a given period in the billing cycle.

Source documents

Because the handbooks are the only documents which contain updated information and serve for a number of purposes, this creates a problem as regards to their role as source documents for data entry. Now some handbooks are in very bad conditions. Pages are torn out. The books are old, and are likely to lose a page or two. So information contained in the handbooks are liable to be lost and it becomes very difficult to retrieve and establish the data again.

One of the solutions to this problem is to create a new set of source document for data entry purpose so that the handbooks may be set aside for uses in other purposes. Alternatively the idea of source document can be bypassed and meter readings can be entered directly into an automated billing system.

The consumers' account numbers are at present coded in accordance with the walking order. When a new meter is installed the first step is to find out the meter location with respect to the neighbouring meters. After the meter position has been located, then the next step is to find out the account numbers for the meters immediately preceding and after it. The new account number is then

assigned using prefix or suffix and take such forms as 1234/1 or 1/1234 or 1234A. In other words, no reserve has been made in the present set of numerals of account number for expansion.

Account numbering system

This present method of coding account number is inadequate in that it fails to provide a ready sum for meters or types of meters in service. But more important is that it fails to provide a logical sequence for data processing. Now the meter readings must be keyed with numeral account numbers in order to be processed efficiently. So the coding method must be modified in such a way that it is converted to all numerals. A suggestion is for the first two digits be used to represent the zone in which the meter is located. The second and third digits may be used to represent the types of meters while the last six digits may be used to represent the walking order. The counter in the computer register can give a ready summing of the accounts by type.

If the account number is to be stored in the master files of the automated billing system, the file structure should be designed in such a way that there would be room for expansion or deletion of the account numbers.

2.5 Future Changes

We shall consider a number of changes concerning the Meter Reading Section that will affect data entry.

Growth in meter numbers

The number of water meters installed over the past years can be summarised as shown in Table 2.1.

TABLE 2.1

GROWTH IN METER NUMBERS (1969 - 1981)

Year	No. of Meters
1969	296,481
1970	379,163
1971	424,864
1972	486,830
1973	556,872
1974	610,816
1975	654,871
* 1978	760,000
* 1981	840,000

* by linear extrapolation

Source: Survey of Meter Reading Section (P.W.D. report OM/DA/410) p.1.

Thus it is estimated by 1981, five years after the automated water billing system is implemented, the number of accounts will amount to 840,000. Assuming a four-month billing cycle, the Data Processing Division will be handling about 10,000 data entry forms per working day.

So in designing a modified meter reading method, the capacity of the data input machine must be such that expansion is possible without incurring any large amount of installation cost, to meet the future growth in account number.

Provisional standing order 514 &
822 may terminate

By these two provisional standing orders of the Public Works Department, a Junior Meter Reader is required to make preliminary inquiries for irregular consumptions that exceed three times above or below normal consumption trends of the accounts as indicated on the meter reading slips. He has to find out whether a new tenant has moved in or the number of persons consuming water has changed. The results of these inquiries are entered into the meter reading slips and are checked upon by meter readers to see if the consumptions are reasonable. Otherwise the meters will be reread or in case of abnormally high consumption, the House Service Section would be informed for checking leakages.

These kinds of inquiries impose a heavy burden on the Junior Meter Readers who may have to go up and down the buildings many times to locate the house of the account and ask for information. On the other hand these preliminary inquiries save a lot of the House Service Section effort as well as clerical work.

In case these standing orders are terminated, then it will affect data entry in two ways:

1) The previous meter readings will not be required to be printed on the meter reading slips. In this case, 'tea house' meter readings can be minimized because they have no previous meter readings to make up false entries.
2) The amount of data entries per day may increase because Junior Meter Readers can read more meters per day.

Separation of trade supplies and domestic supplies account

At present about 1,500 of the Trade Supplies accounts make up for 65% of the total water revenues of the Government. Some Domestic Supplies accounts have so little consumption that it may not be worth billing at all because the cost of preparing a bill may in fact be higher than the resultant revenue. In fact for some prominent trade accounts, their meters are read every month instead of thrice a year to make sure the meter readings are correct.

So in the consideration of a data entry method, perhaps it may be possible to design two different methods for Trade Supplies and Domestic Supplies accounts. However, the water meters of large trade accounts are not geographically separated from domestic accounts and are scattered over the Colony. So the modified method of reading large water meter accounts must take this factor into consideration.

Shortening of the billing cycle

At present, accounts are billed thrice a year. If the billing cycle is shortened to one month and the meters are read monthly, then the volume of data entry will be increased at least four times. Thus suppose the Data Processing Division is handling 10,000 accounts per day, it will have to handle 40,000 accounts a day if the billing cycle is shortened to one-month. So the capacity of the Data Processing machine must be considered to handle this four-fold increase in workload.

3.0 A SPECTRUM OF ALTERNATIVES

3.1 The Nature of the Job

Essentially whenever water is consumed, the needles of a meter will be moved mechanically in a lever system by the water flow. A change in the meter reading is indicated. The difference in the meter reading from the reading in the previous billing cycle would indicate the water consumption for that account during four months. This difference constitutes a basis of calculating the amount chargable to the account. So the meter reading is the raw data input which must be entered into a billing system.

Converting these source data into a form acceptable by an automatic machine is a major difficulty in data processing. Input is usually provided by people. People do not always behave consistently. People change their jobs and even those who stay are bound by emotions. Consequently input may be functioning well at one point in time and badly shortly afterwards, when people provide unacceptable input into the machines. So it is necessary to monitor input continuously and if the quality falls below an acceptable standard, immediate corrective action is called for. Once the standards fall, deterioration can be rapid.

However, control of the quality of input is usually difficult because source data usually originated in some line-departments (viz. WWO in this case) which data processing personnel (viz. of DPD) have no control over. Interdepartmental cooperation is necessary to upkeep

the standards of input data. In the design phase of the system, agreement should be reached in that WWO should be responsible for the quality of the data input.

Data input constitutes one of the key factors in the success of a computerized system, and very often, on top of that data preparation cost may make up as much as 50% of the total operation cost of a computer system.

There is a spectrum of alternatives associated with the data input into a computerized system -- from completely automatic direct on line data input on one end of spectrum, to the transcription of data in existing documents into machine readable forms by keypunch or similar. The automatic end of the spectrum has least human involvement and depends on machine most. The other end of spectrum requires the most human effort to keep a high quality of data input. We shall discuss the two ends of the spectrum and about their limitations. An optimum alternative for a modified method of meter reading entry will lie somewhere in between the two ends of the spectrum.

Ordinary handwritten meter readings need to be converted into a machine readable form before they can be input into an automatic water billing system. The conversion process is called transcription from the source documents. In this case, the meter reading slips on which meter reading are recorded may be considered as the source documents.

Correspondence in layout between source documents and input media is conducive to accurate conversion. Items which are in a different sequence on the source document from that in which they entered on an input medium often cause delays in conversion. Illegible

handwriting often causes errors and delays due to interpretation by the operators. Source documents, which contain data resulting from a number of transactions often complicate the conversion process and again will lead to errors and low efficiency in conversion.

Conversion from source documents is completely unproductive in the sense that nothing is added to the source documents except errors. Often it is necessary to validate the conversion process and this procedure further delays the whole processing of data. Thus the conversion process is usually not only expensive but also a rate-determining step in a data processing cycle.

Many systems require that the input documentation be used for other reasons not connected directly with computers. If such input documents can also be read by human eyes, then the input problem can be greatly simplified. Optical Character Recognition devices would be suitable. Marks or symbols are made on the OCR forms which can thus be read directly into the computer. At the cost of some training of staff the input can be entered without conversion.

On the other end of the spectrum, all source documents are eliminated. Data might be transmitted from the point of origin and input directly into the computer. The organisational problem of handling large amount of input will disappear. However relief of one set of problem lead to another set. One of the most serious limitations of this approach is the installation cost of the data capture and transmission system. The maintenance cost may also be so high that this approach may not be economically feasible. Another limitation is that this kind of data capture and transmission technology may not yet be available when the water billing system is to be

implemented. Finally an inherent difficulty of this kind of fully automatic system is in system reconstruction after it has been out of order. Before the system can be used again it is necessary to test run it to a satisfactory level of reliability because the subsequent direct human observation of the accuracy of the system will be very little.

Reference has already been made to the turnaround document concept, we shall take a look at it now.

Turnaround documents

Turnaround systems are systems in which a document originally prepared within a computerized system is distributed to an external system. Further data are added to the documents and are returned. These documents are then used as a means of direct input back to the original system. Thus data are printed out in machine readable fonts. These data are useful for people using the documents. Data are added at a later date, may be in forms of handwritten OCR sensed characters or mark-sense bars. On return to the system, the documents can be used to input raw and previously printed data together. Turnaround documents concept has been widely used in utility billing, fixed penalty for traffic offense, salesmen ordering system, input of census and survey results.

This kind of direct input eliminates the problems associated with source documents such as high cost and slow data preparation. One of the factors contributing to a successful application of OCR equipment is to have sufficient volume to keep the equipment busy at least half of the time and not having to retype the input source document. OCR is thus usually associated with turnaround documents viz.

output produced by data processing system becomes input for the system at a later stage.

High rejection rates for these kinds of turnaround documents have imposed specific rigidity for its characters. There must also be minimal stains and dirts. There must be no folding otherwise the document processing machine may be jammed. So test-run for rejection rates of these documents must be performed first before full implementation of the system.

Limitations to Changes

Introduction of a computerized water billing system will inevitably create changes. There will be changes in organisation, work procedures and management responsibilities in both the Meter Reading Section and the Data Processing Division. It may also create changes concerning the water consumers and its socio-political environment. These changes, however are subject to a number of limitations. These should be considered so that the dimension of changes will be restrained to a managable pattern. In this way implementation of the computerized system will prove beneficial, otherwise it will be diastrous.

Like the introduction of any computerized system, the billing system will cause changes in the work procedures. The normal pattern of events and expectations of staff at the Meter Reading Section, both personal and group, will be disturbed. On top of that, skills and knowledge accumulated by the staff over years of working experience may become obsolete and his position may be displaced by the computer. This will introduce insecure feelings. In fact, during the series of interviews proformed in the Meter Reading Section (the analysis phase of this project), the writer has been directly asked by some meter readers whether

their jobs will be displaced by the computer.

Insecurity will lead to opposition to the new computerized system. They may sabotage the future modified meter reading method. Not only the Meter Reading Section will be disturbed out the whole Accounts Division may be affected. The key to a successful computerized system lies in the human/machine interface. It is imperative to gain the cooperation and faith of the staff of the Meter Reading Section. In order to gain their cooperation it is necessary to communicate to them how the method will improve the efficiency and will be more convenient to them, through iterative explanations. Their participation in planning the changes should be used such as during interviews with the analysis phase. But it is most important to minimize displacement of jobs. For those whose jobs will inevitably be displaced, it is imperative that they can find a replacement of jobs either inside the Government or outside. In this year of financial difficulties and bad employment condition, it may be very difficult to find another suitable jobs for staff displaced at the Meter Reading Section because they generally do not have special skills. So a serious limitation to change is incurred: displacement of staff at the Meter Reading Section must be as low as possible.

Fast unplanned changes will inevitably lead to diasters. An employee must fully understand before he can be contented and be a more efficient employee in effecting changes. In particular, with staff at Meter Reading Section who are so used to routinized work, it may require repetitive explanations before they can understand their new procedures fully. Now for the project, the system design phase has just begun, the speed of the introduction of the modified

meter reading method has to be keyed on to the progress of the system design. So the modified method can be introduced slowly within this period.

It may also be required to test-run some turnaround documents first to decide on their practicablilty in view of the horrible meter reading environment. Summing up all these there is a limitation to changes under the present condition: to introduce the modified method of meter reading at the right point of time.

The primary purpose of the introduction of the automatic billing system is in the economy of the use of computers. Therefore to justify a modified meter reading method, a limitation is incurred: the modified method of meter reading must be as economical as possible.

Some alternatives of change may be very appealing in paper. But they may not be practical because the equipment or technology know-how is not easily available in Hong Kong. Many equipment that appear in magazines and other facilities may not be immediately available in Hong Kong. Even though they are available, it is necessary that they will be compatible with the present operation system in the Data Processing Division. So a limitation to change is incurred: new technology may be acquired first before a change in modified method can be introduced.

3.2 A Spectrum of Alternatives

1. Direct Input

The meter reading could be transformed into electrical impulses which could be fed into a minicomputer. This meter reading signal would be stored in the core memory and then might be output into a

transaction tape for further processing of the water billing system.

This approach could almost eliminate the human/machine interface entirely. Consequently the short comings associated with the interface would vanish. Thus the meter reading operation could be done with such a speed that all the meters in the Colony could be 'read' within one week. It could also minimize management problems of people such as low morale, emotion and salary inflation.

However, the implementation costs of such an alternative would also be tremendously high. All the water meters in the Colony would have to be modified. Wire connection networks would have to be established and a minicomputer and an encoder would have to be installed. Whenever a new water meter is installed, another wire would have to be connected. This totally may amount to the set up cost for a new Hong Kong Telephone Company! Moreover the operation cost may even be higher than the Telephone Company. Because the water meters are generally located in bad conditions, maintenance cost would be high. In fact the repair rate of the present water meters is about two to three times than of electrical meters. If an electrical device is installed in a damp condition, short-circuit is so common that many readings cannot be recorded. Also inherent in this direct input approach is the difficulty of directly observing the accuracy of the input data because these data are transmitted from a remote area.

This alternative would be appropriate for a well-confined area under controlled condition especially for such meters that require constant monitoring and may find applications in fully automatic institutions such as blocks of trade premises and estates.

2. Built-in Data Recording Device

This alternative would consist of installing a plastic strip to a water meter. When a meter reading is to be taken, a button is pressed and the meter reading would be punched into the strip so that the meter reading would become machine-readable. The strip is then taken out by a meter reader and replaced by another one for the meter reading of the next period. The strip also has an account number prepunched on it. The strip could then be taken back to the Data Processing Division and could be read directly into a minicomputer. A transaction tape would be the output and could be used for further processing.

This approach would eliminate 'teahouse' readings because meter readersmust reach the meters before they could take out the plastic strips. They could not make punches on the strip themselves nor would they go to the trouble of making one. In cases of defective meters, these could be reported by the meter readers. In cases when punching is defective, the meter readings would also be noted down manually and could be input as supplementary readings. So the input control as regards to defective meters would be better than the fully automatic alternative.

However the installation costs of these device might be high. Moreover these device might not be available in Hong Kong. Compared with the present method, the speed of meter reading would not improve nor the cost of reading meters could be reduced.

For meters located in bad conditions, it might be virtually impossible to pull out or replace the plastic strips. Plastic strips might also be easily damaged, truncated or distorted in such a way

that they could not be fed into input device. Furthermore they could be stolen easily if no security measure is taken.

This alternative might be used in meters that demand a high degree of accuracy in reading. It might be used in those sophisticated meters that could justify for its cost of installations. Thus it might be applied to meters of large consumers such as factories and resettlement estates where the amount of revenues-per-meter is high.

3. Portable Data-Recording Machine

This alternative would involve equipping each Junior Meter Reader with a portable data recording machine. The machine is about the size of a portable calculator and has a keyboard whereupon alphanumeric data could be punched onto a strip like a paper tape. The J.M.R. would be supplied with the list of meter numbers. He would enter the meter readings and account numbers in a sequence according to the sequence of the meter numbers on his list. The paper strip would then be collected at the Data Processing Division and could be read into a minicomputer directly for producing a transaction tape. The tape would be further processed by the billing system.

Compared with the built-in data recording device alternative, the portable machine is more flexible. They would be under better control because they are in the hands of meter readers. Thus they are less liable to damages. They could be used for other purposes in addition to reading meters. The process of reading meters would be faster than the previous alternative and minimum training for meter readers would be required.

However, like the previous alternative this machine is still not available in Hong Kong. Because the strip is sequential, an error

made at one point might cause a series of errors following it. So it would be rather troublesome to detect errors and to make corrections, and the whole strip might have to be reread.

If the price of these machines and more information could be obtained, it might be worthwhile to look deeper into this alternative. These kinds of machines have been widely used in taking inventory of goods and might have mass production in two years' time.

4. Optical Character Recognition Alternative

Optical Character Recognition (OCR) equipment has the ability to read printed or handwritten documents directly into a computer system, thus circumventing other means of data preparation such as keypunch from source documents. Basically an OCR reader consists of the following parts: a document transport unit, a scanner unit, and a recognition unit.

The document transport unit is the device required to carry the documents from the input stacker to the appropriate output stacker. In this process, the characters to be read are scanned by some kind of photo-electronic device called the scanner unit, which converts the characters on the input documents into a pattern that is analysed by the recognition unit. This unit matches the pattern against internally stored reference patterns. Those identifiable patterns are recorded on tape or directly input into a control processor unit. Those documents which cannot be identified will cause the input documents to be rejected. These data have to be entered again after corrections or amendments of the characters are made so that they become identifiable.

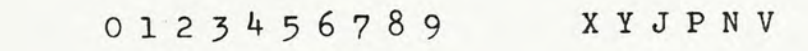
There are a number of character recognition methods, generally matrix methods are capable of reading limited numbers of characters in accordance to some printed fonts (or character repertorie) e.g. E.C.M.A. B Font Size 1 as shown in figure 3.1.

FIGURE 3.1

E.C.M.A. 'B' FONT

EXTENDED NUMERICS

(SIZE 1)



Source: Introduction to Computer Systems. International Computers Ltd., 1972

Curve tracing method are suitable for recognizing handwritten characters which can vary in size and shape within a certain limit.

OCR was firstly conceived in 1870 but it was not until 1956, when that Reader's Digest Company Ltd. bought the first OCR machine for converting typewritten input into punched cards. Since 1960, there have been slow steady growth of OCR application but not so swiftly as people expected. "In the quarter century since the first appearance of digital computers, processor speeds have increased by a factor of 10,000 and I/O speeds

have increased by a factor of 1,000."[1]

The rate-determining step of data processing appears to be in keypunch. One can only keypunch two to three characters per second. However OCR readers are capable of inputting directly 2,000-3,000 characters per second. OCR is also generally associated with turn-around document systems. These are systems which involve preprinting useful data on the documents. These data will be entered together with the raw data to be input. This useful concept also accelerates the speed of the whole data processing cycle.

However OCR has not grown as fast as people expected. "Technology in OCR is very sophisticated and expensive and is still considered leading edge by most companies that are investing money in it."[2]

"Document readers priced generally from US$100,000 to US$200,000 and rented for US$2,000 to US$6,000 a month."[3]

When there is sufficient volume of input, then OCR may be cost justified.

While the scanners and recognition units may become cheaper in future, the document transportation unit may not. Essentially, the cost of sophisticated mechanical device will not be likely to decrease in future; the document transport is a complex mechanism designed to handle paper of different sizes, weights, thickness and

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[1] Robenstein, The Status and Potential of OCR, Infotech State of the Art Report 22 (Berkshire: Infotech Information Ltd., 1975), p. 166.

[2] Ibid., p. 167.

[3] Robert J. Thierauf, Data Processing for Business Management (John Wiley & Sons Ltd., 1973) p. 322.

some in bad conditions such as foldings or dog-eared corners.

OCR generally suffers from two setbacks, viz. rejection and substitution. Rejection rate refers to the reader that does not read very well and rejected unrecognized characters and documents. Substitution rate refers to the reader that substitutes one character for another and thus incurs a reading error. Rejected characters can be 'refurnished' and entered again. Unless there is high percentage of OCR documents in bad conditions, rejection is not as serious a problem as substitution. But substituted characters are errors which are expensive to correct. The cost of correcting these errors may even be higher if not corrected in time. Audit routines capable of back tracing such as sum checks of a column of numerals or check digits will have to be built into the data processing machines to overcome these difficulties.

Generally as a machine becomes more flexible as an input device, the percent read error rate increases as well as the cost. Thus machines capable of handling handwritten documents, documents of wide range of paper weight and quality have much higher read error rate then keypunch, which is very inflexible.

OCR has been widely used in firms that have large volumes of data input. In places where trained keypunch operators are rare, OCR is an especially favored alternative because the firms can look for clerical typists to handle the data preparation. OCR has been currently used in public utilities for processing meter reading and statement stubs with payments by the firms' customers. It is also used in airline industry to process air-line tickets.

5. Optical Mark Alternative

Forms that have been marked by a standard type of lead pencils eg. HB pencils and taking the form of a bar can be read by an optical mark reader. The marks which can be read by human eyes are also easily recognizable by the mark reader. Mark reading is accomplished by a row of fixed number of photoelectric cell pairs. Each cell pair corresponds to a predetermined marking position on the documents. The documents are transported to the read drum where they are carried under the cells and read line by line. Where the marking position is empty, the corresponding photoelectric cell remains unactivated. Where the marking position is marked, the cell will become activated. So where a mark has been made, a difference in reflectance of the cell pair arises and causes an electrical signal. The electric impulse is analysed and coded into a computer language and this constitutes an input of the data. It can then be recorded on a magnetic tape.

If there are two or more marks in a given grid, the machines logic will choose only the darkest mark. The marks on the document can be made by hand or can be printed by line-printers.

This kind of equipment is to be distinguished from mark sense reader whose documents must be marked with special pencils containing soft and highly conductive lead. It operates on the electricity conductivity principle of the lead rather than on optical reflectances. Erasures can be made with mark sensing. However there is a distinct risk that sufficient lead remain deposited even when it appears to the eye that erasure is made fairly clean. This erasure problem seldom occurs in optical mark because it can only take place when the drops in reflectance at two positions of the grid are accidentially equal,

which is rare.

Optical mark equipments are less expensive than optical character recognition equipment. The rejection rate and read error rate is also lower because the bar mark can only appear in a specific position on the document and of specific size.

However the reading speed of optical mark reader is slower than OCR. Optical mark is also less flexible in the sense that only bar marks can be made and the positions of the mark have to be in such a way that correspond to the rows of photocells of the readers. This makes spacing in the design of optical mark document relatively more difficult and usually demands more spaces for entering a data item than OCR.

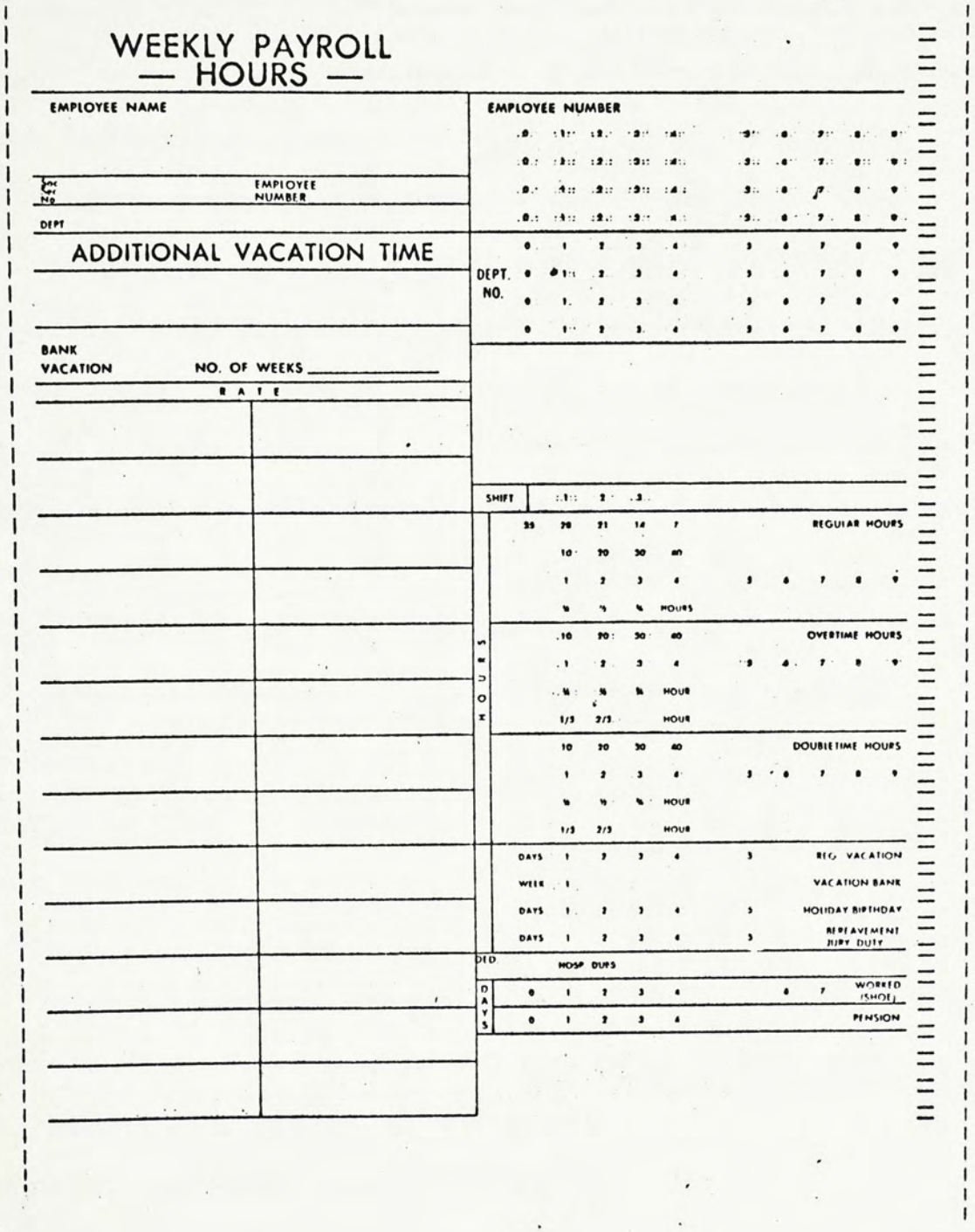
Optical Mark readers were used mainly to score test results at one time. To-day, they are used as data entry form in payroll, inventory control and off track betting. A sample mark reader form is shown in figure 3.2 on the next page. Values are printed at the mark point as in an ink which is not detectable by the optical mark reader.

Like OCR, optical mark forms are generally used as turnaround documents. Typically forms are preprinted with header information and other required user data. These forms may then be marked by the firm's personnel or send to and marked by customers or consumers.

6. Punched Cards Turnaround Document Alternative

This alternative would consist of the computer to prepunch consumer account number, meter number, location of meter and other information on a card. Then a pile of cards will be assigned to a Junior Meter Reader. He would carry a portable manual keypunch machine. The meter reading is then punched into the assigned column of the card at

FIGURE 3.2



Source: Robert J. Thierauf, Data Processing for Business and Management, (John Wiley & Sons Inc., 1973.)

the spot where the water meters are located. He can then return the cards to the Data Processing Division on the following day. The cards will then be read by a card reader and processed to output a magnetic tape, using an off-line minicomputer if the work load of the mainframe is too heavy.

Cards are read by a card unit and are punched by a punch unit. In a read unit the file of cards is placed in a read hopper. In response to a read command a card is moved past two sensing stations. The sensing stations use either wire brushes or photoelectric cells to generate electric impulses. The reasons for two stations is to compare results of the two read operations, to detect possible errors in reading. After the cards are read, they are placed in one or more output stackers. A card punch unit may punch only blank cards except in some advanced machine can additional data to be punched in the same card. Generally the card reader and punch are combined into a single unit.

The rejection rate and read error rate of a card reader are lower than optical mark reader. A read punch unit is also cheaper than the sophisticated optical device.

However the rate of reading is much slower than the optical machines. The rate of punching may even be only one-third of the rate of reading. Card reading and punching will take up a lot of time of the central processing unit. Moreover card files are bulky and are very inconvenient to carry around.[1] Individual card of a pile may be lost easily if proper security measures are not taken. The portable

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[1] However IBM system 3 has some 96-column cards that are more impact and has higher capacity to record data.

manual punch must also be handy enough and must be available locally when the water billing system is to be implemented. One such suitable machine has been mentioned in a book by E. Jerome McCarthy, Integrated Data Processing System.[1]

Punched card systems were the most common form of input medium in early computer systems. Punched card is still widely used to-day especially in smaller computer installations. This approach of turn-around documents has been used in utilities firms for reading meter readings.

7. Key-to-Tape Alternative

In a key-to-tape system, data is entered by a key-to-tape machine in Data Processing Department Office similar to a card keypunch machine. The data are recorded directly on a magnetic tape. Generally, verification can be made with punch verification or the data keyed in is stored in a buffer and is displayed on a video display unit so that the operator can see if the correct entry has been made. In cases of errors, the operator can backspaces and retypes the data into the system. When the record is completed, it is released and recorded into the magnetic tape.

When a number of key-tape systems are being used to input data, records from each of the tape can be pooled on a single tape for entry into a single tape. Some systems use a controller unit so as to direct records keyed at each of several input stations to a central tape.

The key-to-tape systems can be further enhanced by use of an off-line minicomputer in place of the controller. Data are entered

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[1] E. Jerome McCarthy, J.A. McCarthy, Duward Humes, Integrated Data Processing System (New York: John Wiley & Sons Inc. 1966), p. 105-106.

through keyboard stations, are processed by the shared minicomputer and recorded onto a magnetic disk. The minicomputer can be programmed to perform a number of editing and validation functions normally performed by the mainframe computer. After these operations, the data may be input directly to the mainframe or may be batched on a single magnetic tape for further processing.

A key-to-tape machine is faster than keypunch because recording is electronic rather than mechanical. It may be 25 to 35% faster. Key-disk systems may be even 75% faster. Key-tape system allows records sized up to several hundred characters, as compared to 80-column or 96-column cards. This again will enhance entry speed and also circumventing some record design problems. The correction of errors is more convenient. It is not necessary to repunch an entire card. The operator merely backspaces to error positions and rekeys the correct character.

For systems involving an off-line minicomputer, the work load of the mainframe can be released. It will thus improve scheduling of procedures. As soon as input arises, is logged; it can be punched and verified and can be passed back to the user, or further processed. A secondary benefit is that the minicomputer can be used to run some of the smaller mainframe jobs.

The cost of ordering, handling and storing cards is eliminated because magnetic tape can be reused. However the overall cost of the equipment installation will be higher than keypunch. Furthermore the lease of a system of key-to-disk generally involves a set of fixed number of keypunch stations, the lease will be justified only in case where there is large enough volume to utilize the whole set of stations.

Unlike the OCR and optical mark approach, the turnaround document concept cannot be used directly in that the computer produced meter reading slips which cannot be read directly by the key-to-tape machine. However, the turnaround principle can still be applied. Useful information can be printed by a computer to a meter reading slip first. Then the data content can be keyed in, including added meter readings, and using the meter reading slip as a source document.

This alternative is suitable in cases where there is a large volume of data input and there is already a heavy work load on the mainframe so than expansion is difficult. It has been used in utilities firms and has been widely used locally in the Data Processing Division of the Government.

8. Magnetic Ink Character Recognition Alternative

The American Bankers Association has adopted a national standard code for the banking industry called Magnetic Ink Character Recognition (MICR). It consists of numerals and symbols of a distinctive type. There are fourteen different characters.

The idea is to inscribe meter readings and account number from the source documents viz. the meter reading slips of handbooks in this case. Inscribing is accomplished by a key-operated machine that prints on an input document in magnetic ink containing particles of iron oxide. The documents could then be read by a MICR equipment. The sensing process is accomplished by transmitting electronic signals to a character matrix. Data could then be recorded on magnetic tape for further processing.

The speed of reading is as slow as in punched card and more costly. The chief advantage is that the characters are easily recog-

nizable with human eyes. It is commonly used in banking industry as an alternative to the keypunched method to handle large volumes of checks.

9. Punched Paper Tape Alternative

This alternative would consist of recording data from the source documents viz. meter reading slips of handbooks on paper tape. Recording on paper tape is performed by some machines that punch data on it by a direct connection to a typewriter or a keypunch. Data stored on paper tape are recorded in patterns of round punched holes, located in parallel channels along the length of the tape. A character is represented by a combination of punches across the width of the tape. Like the punched card method, the tape could be read in a computer system either by wire brush or photoelectric cells. A transaction magnetic tape might then be produced for further processing.

Punched paper tape allows easy and compact storage. It is lighter and less spacious than a pile of punched card. It is also cheaper than the punched card approach because of lower cost of tape and their lower transportation cost. Data is also not confined to 80-columns.

Compared with more advanced media, punched paper tape has just the same problems as with punched cards. Furthermore the read/punch speed is lower. It is harder to correct an error because of the sequential nature of the record, especially it is more likely to break during processing. It cannot be split apart for sorting, collating and other manipulations like punched cards. Above all, the punched holes could not be interpreted by human eyes and could not be used as turnaround documents.

Paper tape is seldom used as an input medium. It is most often used in system where data is received over communication circuits such

as Telex and in scientific applications involving limited input and output.

3.3 Selections of Feasible Alternatives

We have studied a spectrum of nine alternatives for a modified method of meter reading, as an input into a computerized water billing system. On the fully automatic end of the spectrum, the alternative does not appear to be desirable on the ground that the total amount of investment required to build up such a network for tapping meter readings. Moreover whether it is possible to build such meters in bad meter reading environment is questionable. The time required to build up this network will not meet the implementation date of the water billing system. Furthermore, all the jobs of the meter readers will be displaced, which will be against one of the important limitations to changes.

For the other end of the spectrum viz. the punched paper tape system, the rate in data processing will be so slow that it would be impossible to meet the requirements of processing 10,000 accounts per day unless a very large number of machines are used. The Data Processing Division may not find other uses for these outdated read/punch tape machines. Above all it is an inferior alternative in almost all aspects to keypunch card. This alternative will be more expensive than manual method and are also prone to errors which are hard to correct. Thus it is seldom or ever used for this kind of applications.

The Magnetic Ink Character Recognition Alternative is just as slow as punched tape. It is also more expensive than punched tape. Thus it is not a feasible alternative.

The Built-in Data Recording Strip Alternative suffers from the fact that such a device may not be available in Hong Kong. The installation and maintenance cost of this device can be assumed to be pretty high. Above all there is a security problem that these strips can be easily stolen or damaged.

The Portable Data-Recording device appears to be a rather promising approach. Unfortunately information on their features, prices, and compatibility with the operation system of the Data Processing Division are not available for analysis at present. It appears that such a device may be found among device used for the point-of-sale terminals. These are designed to capture sales data at the point of sale.

Eliminating these five alternatives leaves us with four desirable alternatives, namely Optical Character Recognization, Optical Mark, Punched card Turnaround Documents, and Key-to-tape.

The card punch turnaround alternative appears to be a feasible alternative. However considering the amount of information required to be prepunched onto the card, this alternative will appear to be too costly. The total amount of information will occupy about sixty columns of the card. So when a meter reading and report code is punched manually it will take up a whole card. For some manual punch card system, every other column is skipped on this type of card, which provides only forty columns because this reduces potential confusion and errors. In other words, the card could only be used once. The punching of information will take up a lot of computer time and will be very costly. It can be estimated to be two to three times higher than the key-to-tape alternative in data preparation. Rate of punching is very slow. This will create a heavy load on the mainframe or may require two or more

minicomputers to do the data preparation.

An IBM device Port-A-Punch is very handy and is designed with the prescored card placed in a specially designed plastic container. This device seems to be rather suitable for the application. But unfortunately it is not yet readily available in Hong Kong at present.

Moreover the keypunch operation will inevitably reduce the speed of reading meters. Thus it may be necessary to hire more J.M.R. This will further add to the cost of the alternative.

Summing up all these it is very likely that the alternative will cost more than the manual system. Because of the economic limitation to changes, the punched card turnaround alternative will not be considered.

For OCR and OM turnaround documents alternatives it is possible to send the documents to the consumers. The consumers will then read their meters themselves and record their meter readings into the documents and send it back for processing. This alternative has some advantages. The meter reading jobs of J.M.R. can be eliminated to a large extent and this saves a lot of expenditure. The consumers will become more conscious of their water consumption and may make an effort to save water. However this approach is not practical in the sense that it will require legislation to enforce consumers to send back the documents before a certain date. Whether such legislation can be passed within the next two years before the water billing system is fully implemented will be a matter of doubt. Furthermore intensive education program will be necessary to instruct the consumers how to find the meters and to record readings into the documents. Another high-powered program will be required to teach the consumers not to

fold the documents or stain it and keep it in perfect condition. Yet a third program will be necessary to teach them how to record OCR or OM acceptable characters. Summing up the cost of these programs may be tremendous.

Moreover, it is still necessary to retain a number of meter readers to check meter readings on a sample basis. Legislation for the prosecution of dishonesty in meter readings will also be required. It will be very difficult to tell whether incorrect meter readings are recorded faultily or not. If the legislation is not enforceable, then a great percentage of the documents will be ignored.

Thus to conclude, turnaround documents involving consumers recording their consumption do not seem to be feasible under the present condition.

This leaves us with three alternatives for further exploration. They are OCR turnaround, Optical Mark turnaround and Key-to-tape turnaround without consumer involvement. We shall focus on their work flow processes and the cost/benefit considerations of these three alternatives.

4.0 COST/BENEFIT ANALYSIS OF THREE PRINCIPAL ALTERNATIVES

4.1 Introduction

In the previous chapter, we have discussed the limitations to changes from the manual to automatic water billing system. We have also discussed a spectrum of alternatives starting from a fully automatic approach to keypunch paper tape manually of the other end of the spectrum. The limitations to changes were minimum job displacements, economy, available technology and introduction of the automatic system at the right time. Based on these limitations, three principal alternatives were chosen from the spectrum of nine alternatives. These were optical character recognition (OCR), optical mark (OM) and key-to-tape turnaround approach. We shall discuss a detailed workflow process of each alternative in this chapter, followed by the resource requirements and cost estimations of each.

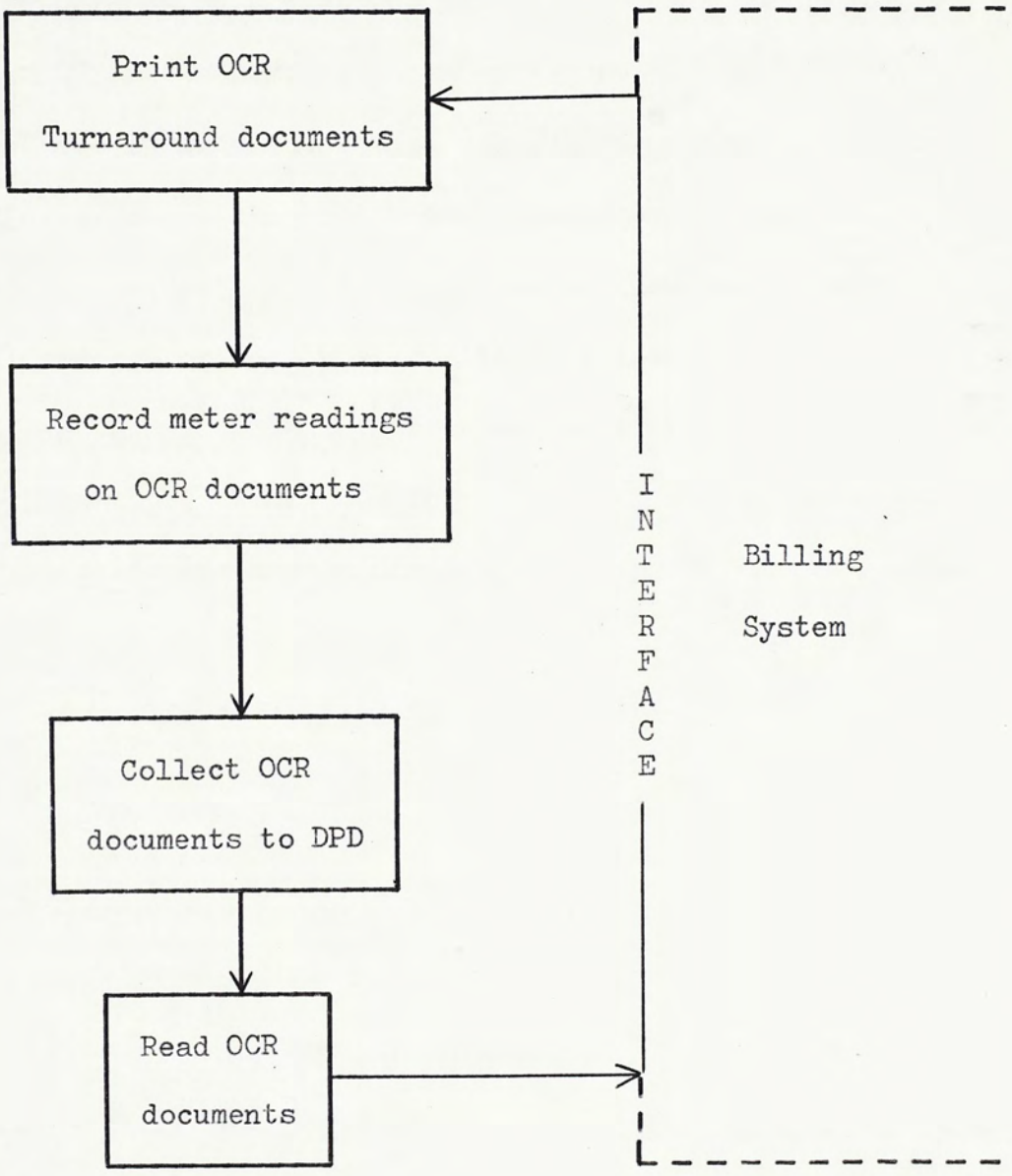
4.2 Description of Three Principal Alternatives

Optical Character Recognition (OCR)

The work flow diagram of the OCR alternative is shown in Figure 4.1 on the next page.

FIGURE 4.1

WORK FLOW DIAGRAM OF OCR ALTERNATIVE



Process

I. Print OCR Turnaround Documents

Imformation will be retrieved from the master files of the billing system according to a billing schedule. These information are printed on the appropriate positions of a specially designed OCR documents, as shown in Figure 4.2 on the next page. These include account address, meter number, previous readings, expected range of consumption (may be omitted), meter reader's notes, date and J.M.R.'s number, and the document control codes. Account number will be printed by the line-printer in OCR readable form because these are the key of the transaction tape. These OCR forms will be sent to the Meter Reading Section one day before the scheduled meter reading day. The forms will then be distributed to the J.M.R. who go out to read meters. The assignment of the meters to J.M.R. is on a rotation basis and can be done by a core-program of the billing system which prints out a list of meters assigned to the J.M.R. for that particular errand.

II. Record Meter Readings to OCR Documents

The J.M.R. will bring the OCR documents to the field and find the locations of the meters in the usual manner. They will enter meter readings in the assigned spaces. They will be specially trained to make OCR recognizable hand-written numerals using an HB pencils, paying attention not to make pig tailed 'zero', broken top 'five', high waisted 'six' etc. Each of them will be supplied with a list for report codes on meter defects, locked

FIGURE 4.2

OCR METER READING SLIP, SAMPLE

****

Meter Reading Slip

Address	Normal Consumption	Meter No.
178, 10/E	10 units	579630

Last Meter Reading: 00389.108

Present Meter Reading Report Code

_____

_____

Account No. M.R. Note:

2345678 Roof

****

****

Street	Page No.	M.R. No.
Sugar Moon, West Point.	_____ _____	07 Date: 9/7/76

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yards, fierceful dogs etc. They will also enter the report codes if any, in the assigned space. The list of report codes can be found in Appendix IV. These will be written in Chinese and English in prominent types because it was observed by the writer that most of the J.M.R. do not make use of these report codes to make comments in the present operation. The J.M.R. will be reminded not to fold the OCR documents (which they often do so with the meter reading slips at present) and to keep the paper as clean as possible.

III. Collect OCR Documents to DPD

The OCR documents will be collected by a person in charge of the documents at the Meter Reading Section in the following morning. The number of sheets returned will be checked against a control sheet. Any possible unnecognizable readings will have their numerals modified to make them readable. Damaged sheets, dirty sheets, dog-eared sheets etc. are noted down. The documents will then be carried by a messager to the DPD.

IV. Read OCR Documents

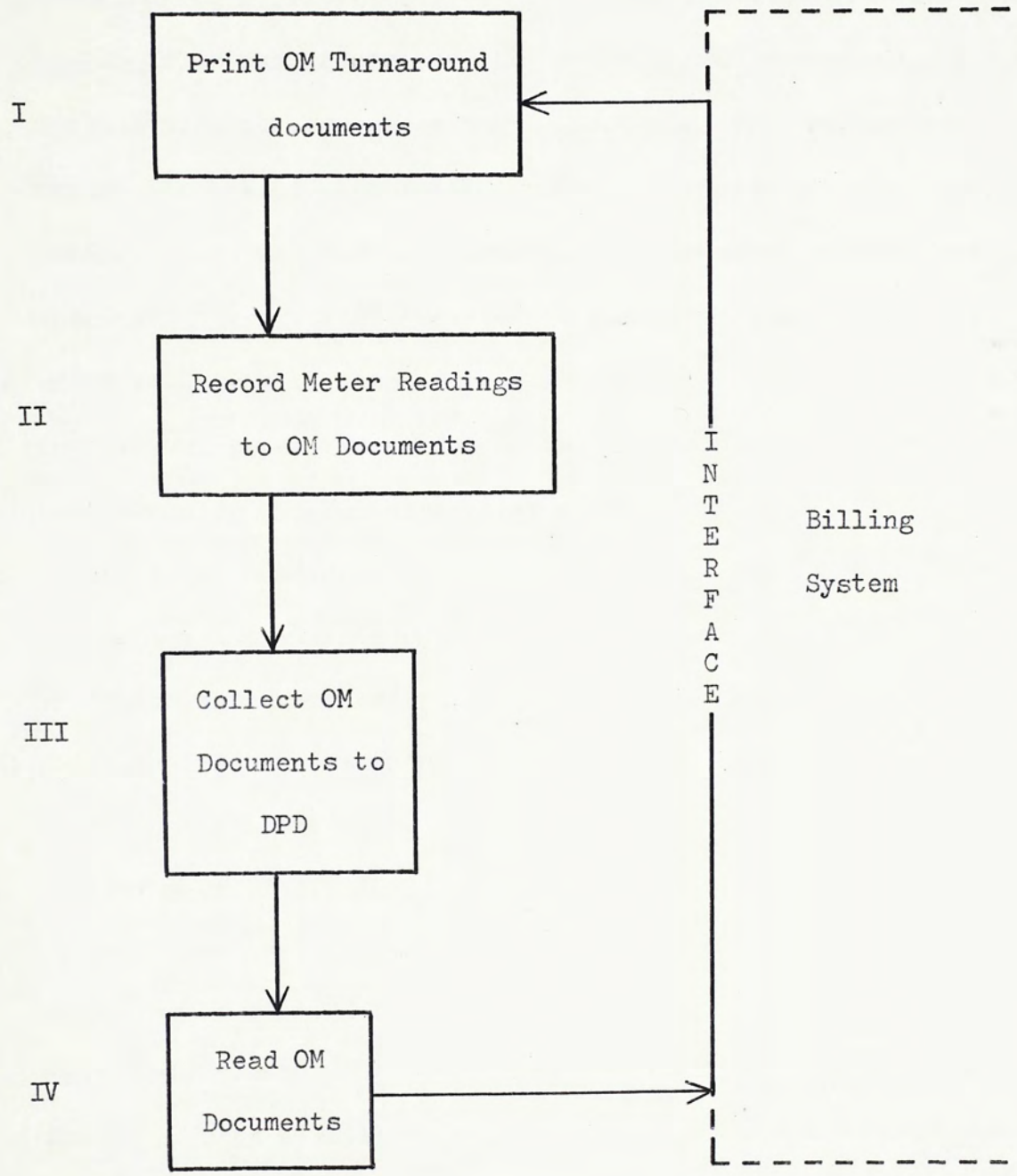
The OCR documents will be fed into the OCR reader, and data will be recorded on a magnetic tape. This transaction tape can be entered into the computer for further processing. Any irregular entry such as due to damages in OCR documents, inreadable meters etc. will be entered through supplementory entry sheets.

Optical Mark (OM) Turnaround Documents Alternative

The work flow diagram of the OM approach is shown in Figure 4.3.

FIGURE 4.3

WORK FLOW DIAGRAM OF OM ALTERNATIVE



Process

The approach is basically similar to the OCR alternative.

I. Print OM Turnaround Documents

According to a billing schedule, information will be drawn from master files and printed on the OM turnaround documents. These include account address, meter number, previous readings, expected range of consumption (may be omitted), notes to meter readers, date and J.M.R.'s number, and documents control codes. Account numbers will be printed in machine readable form. A meter reading slip which may be suitable is shown in Figure 4.4 on the next page. These documents will be distributed to corresponding J.M.R. before they go out.

II. Record Meter Readings to OM Documents

J.M.R. bring documents out to field and enter meter readings in the assigned spaces.

III. Collect OM Documents to DPD

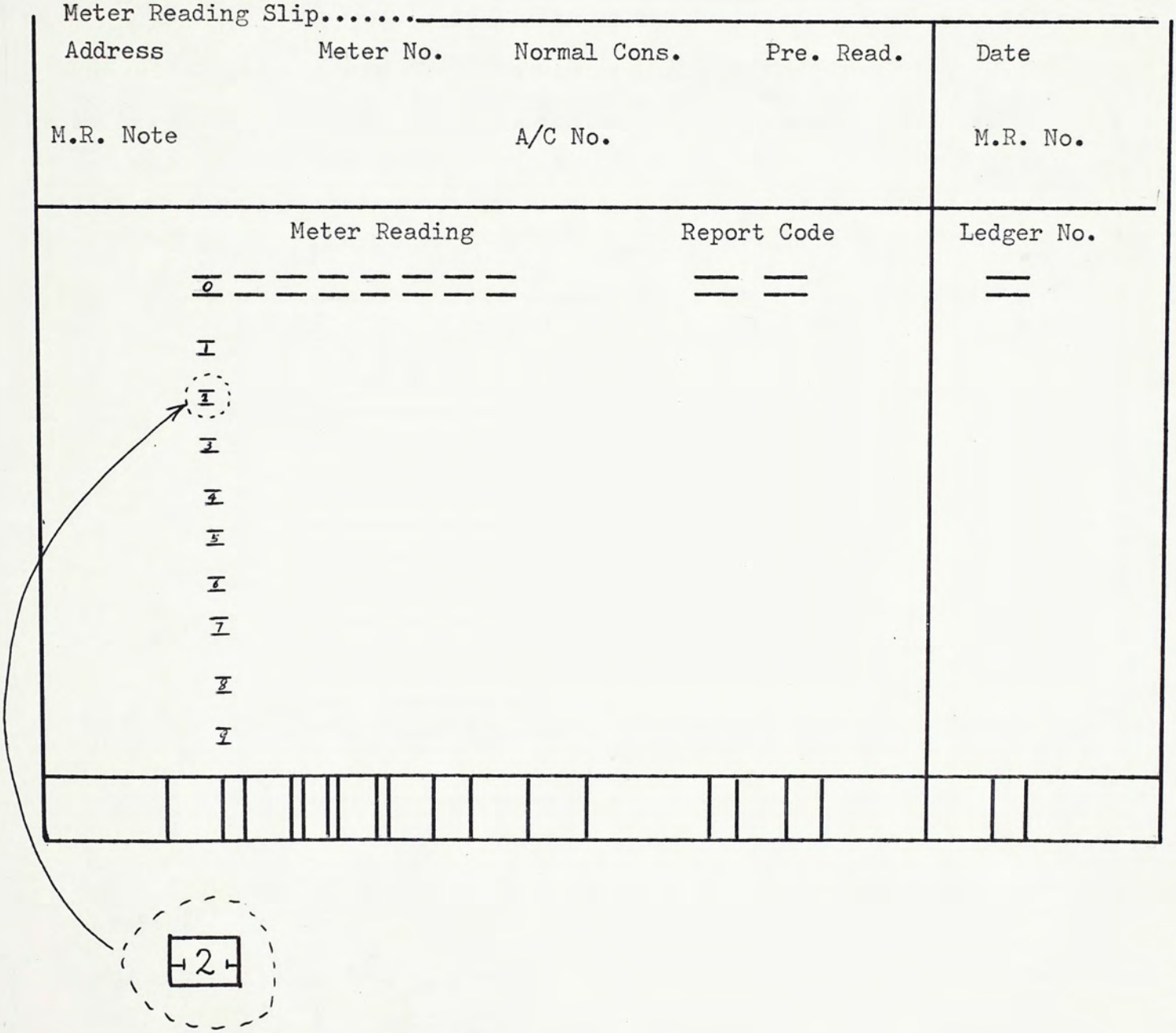
The OM documents will be collected in Waterworks Office in the following morning. The documents will be checked against a control sheet and for unrecognizable entries. These sheets will then be carried to DPD.

IV. Read OM Documents

The OM Documents will be fed into the Universal Document Transport (UDT) and read by an OM reader. The data will enter the transaction file and are ready for processing. Any irregular entry will be made through supplementary OM documents.

FIGURE 4.4

OM METER READING SLIP, SAMPLE

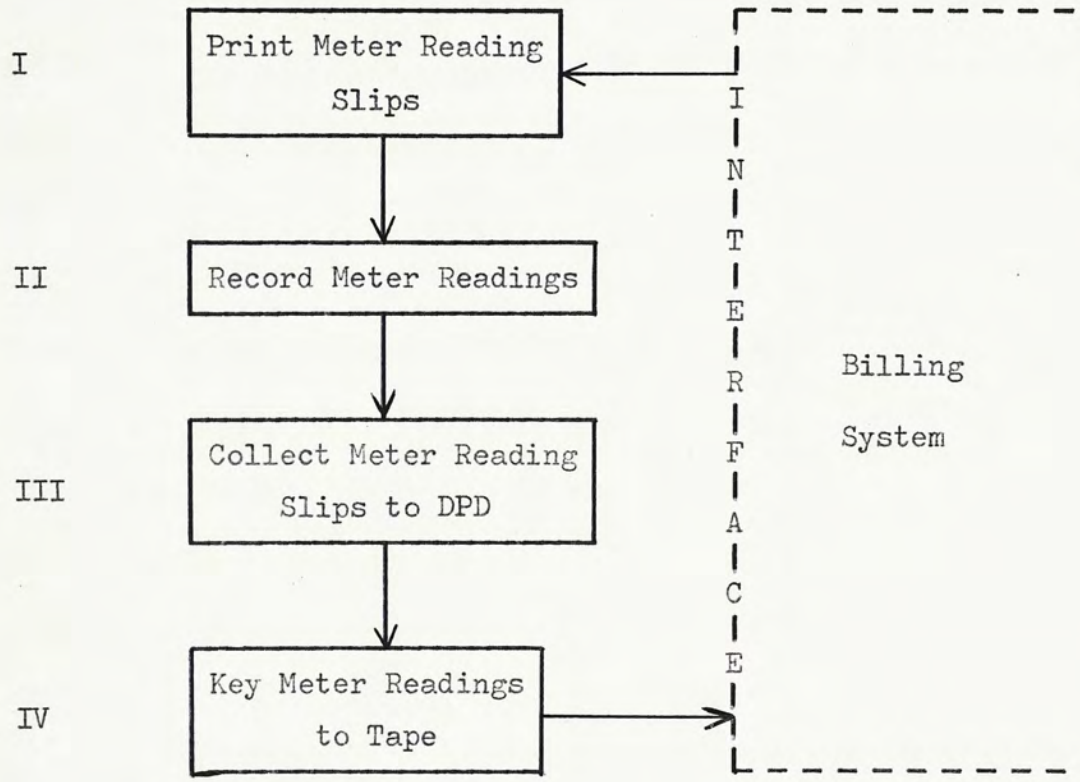


Key-to-tape Alternative

The work flow diagram of the key-to-tape turnaround approach is shown in Figure 4.5.

FIGURE 4.5

WORK FLOW DIAGRAM OF KEY-TO-TAPE TURNAROUND ALTERNATIVE



Process

I. Print Meter Reading Slips

According to a billing schedule, information will be drawn from the master files of the billing system and printed in the meter reading slips. These meter reading slips are essentially similar to the OCR documents except it is not necessary to set

aside spacing on the sheet to suit the scanning unit of an OCR reader in reading the handwritten data. Like the OCR documents, the information to be printed include account address, meter number, previous reading, expected range of consumption (may be omitted), notes to meter readers, date and J.M.R. number, and document control codes and account numbers which need not to be printed in machine readable form because these will be keyed in latter together with the added meter readings. These meter reading slips will be distributed to the J.M.R. similar to the case in the OCR alternative.

II. Record Meter Readings to Meter Reading Slip.

The J.M.R. will go out and find the meters in the usual ways. They will enter the meter readings to the meter reading slips in the usual manner. But for the report codes, they will be instructed to enter numerals in according to the list given to him instead of short phrases. (please refer to the list in the OCR alternative.)

III. Collect Meter Reading Slip to Data Processing Division.

The meter reading slips will be collected in the following morning by the document control unit. They will be checked against the control list and will be carried to DPD from the Meter Reading Section.

IV. Key Meter Readings to Tape

An off-line minicomputer will be used. A team of keypunch operators will key the meter readings and report codes into the key-to-tape system from the meter reading slips entry.

The keypunch will be verified simultaneously. The data will then be recorded onto a disc and can then be input directly into the mainframe or stored into a magnetic tape. The transaction tape can be further processed.

4.3 Resources and Cost Requirements of Feasible Alternatives

The following analysis are based on a four-month billing cycle. The resources requirements for each task are broken down into equipment, personnel, stationary and subcontract, and computer time. A detailed calculation is shown in the Appendix V to Appendix VII.

1. OCR Alternative

Assume 700,000 accounts will be considered. For printing the address (only the street number) meter number, normal consumption, previous reading and M.R. note onto the meter reading slip will mean about 700,000 lines will be printed. In addition 70,000 lines will be required for the name of streets and district, the ledger control code, the meter reader number and date. So totally 770,000 lines will have to be printed by the line printer.

The transaction tape will be keyed by the account numbers. They need to be OCR-readable because they will be input together with the meter readings (and report codes). So they must be printed by 'barrel' line printer in OCR-recognizable fonts. The ordinary 'chain' line printer can be changed over to a 'barrel' printed by replacing of 'chain' by 'barrel' at the printing head.

The OCR documents will be made through subcontracting a document printing company. A conservative estimate indicated

that a 8"x15" OCR document can be divided into fifteen meter reading slips. The thickness of the documents are such that they will not easily be foldable nor damaged. They are also designed in such way that it is convenient for the meter readers to record the meter readings (and report code) into the specified space of the sheet. The OCR reader will have specification for the assigned spaces for reading in typewritten or printed characters on the documents. The OCR reader can be leased from any local vendor as long as they are cheap and compatible with the present operation system at DPD.

There would not be much difference between the modified method and the present method in the operation speed for Junior Meter Reader in reading meters. In the OCR method they can record meter reading in handwritten numerals just as fast as writing into meter reading slips of handbook. Since at present fifty-four J.M.R. are deployed, a total of fifty-five J.M.R. will be required to read 700,000 meters in four month's period in coming years.

Two clerical assistants will be required to control and distribute the OCR documents to the meter readers before they go out. They will also check against control sheet for the returned documents. In addition they will make modifications for likely unrecognizable typewritten entries to render them readable. One operator will be required to operate the OCR equipment and to make supplementary entries for rejected documents. He will also take part in 'refurnishing' unrecognizable handwritten characters if necessary.

A programmer will have be required to write an application program. It is used to direct the printing of information by the on-line lineprinter.

A messenger will be required to bring the document back and fro from DPD to WWO.

A summary of the resource requirement is shown on Table 4.1

TABLE 4.1

RESOURCE ESTIMATES OF OCR ALTERNATIVE
(FOUR-MONTH PERIOD)

Resources / Steps	Equipment	Personnel	Stationary & Subcontract	Computer Time
I	1 line Printer	1 x Programmer	52,000 Data Sheets	32.5 Hours
II		55 J.M.R.		
III		2 x C.A. 1 x Messenger		
IV	1 OCR Reader	1 Operator		

Based on unit cost data obtained from DPD and Meter Reading Section, the total cost estimates of the OCR alternative is shown on Table 4.2. The detailed cost calculation is shown in Appendix V.

TABLE 4.2

COST ESTIMATES OF OCR ALTERNATIVE
(FOUR-MONTH PERIOD)

Resources / Steps	Equipment	Personnel	Stationary & Subcontract	Computer Time	Total
I			$5,200	$10,000	$16,200
II		$385,000			$385,000
III		$10,400 4,400			$14,800
IV	$80,000*	$10,400			$14,400
Total	$80,000	$410,200	$5,200	$10,000	Grand Total $506,400

* Assume full allocation of the rental of OCR Reader to this application.

2. Optical Mark Alternative

Like the OCR alternative 770,000 lines will have to be printed out by the computer. In addition 700,000 account number must be printed out in optical mark readable bars by the printer in the prescribed position.

The optical mark document will be made through subcontracting a document printing company. A 8" x 15" OM document can be divided into four meter reading slips. Like the OCR documents, the documents will be of specific thickness and dimension. The design of the OM document will also have to allow for the clock track and the number of photo cells available

in the OM reader.

There should not be much difference in speed for entering meter readings into OM documents and into handbook. So like the OCR alternative fifty-five J.M.R. will be required to handle 700,000 accounts in a four-month period.

Like the OCR alternative, two clerical assistants will be required to control the documents. One messenger will be responsible for transportation and one OM reader operator required to operate the system.

The resource estimates is summarized in Table 4.3 while the cost estimates is shown in Table 4.4.

TABLE 4.3

RESOURCE ESTIMATES OF OM ALTERNATIVE
(FOUR-MONTH PERIOD)

Resource / Steps	Equipment	Personnel	Stationaries & Subcontract	Computer Time
I	1 x Line Printer	1 x Operator	201250 x OM Documents	34 hours
II		55 x J.M.R.		
III		2 x C.A. 1 x Messenger		
IV	1 x OM Reader	1 x Operator 2 x C.A.		

TABLE 4.4

COST ESTIMATES OF OM ALTERNATIVE
(FOUR-MONTH PERIOD)

	Resources / Steps	Equipment	Personnel	Stationaries & Subcontract	Computer Time	Total
I	Print OM Turnaround Documents			$20,000	$10,000	$30,000
II	Enter Meter Readings to OM Documents		$385,000			385,000
III	Collect OM Documents to DPD		10,400 4,400			14,800
IV	Read OM Documents	$2,500	10,400			30,400
	Total	$2,500	$410,200	$20,000	$10,000	Grand Total $442,700

The detailed cost calculation is shown in Appendix VI.

3. Key-to-tape Alternative

700,000 accounts will be considered. For printing the address (only the street number) meter number, normal consumption range, previous reading and M.R. note and account number will mean about 700,000 lines will be printed. In addition 70,000 lines will be required for the name of streets, district etc. so as to complete the address of the accounts. So 770,000 lines will have to be printed by the line-printer on the meter reading slips.

The meter reading slips are essentially similar to the OCR documents. They will be prepared by a subcontractor. A conservative estimate indicatedthat a 8" x 15" sheet can be divided into fifteen meter reading slips. The dimension and quality of these sheets are not as stringent as in the case of the OCR alternative.

There would not be much difference between the modified method and the present method in recording meter readings and report codes into the meter reading slips. So a total of fifty-five J.M.R. will be required to read 700,000 meters in a four-month billing cycle.

Two clerical assistants will be required to control the meter reading slips. They will distribute the slips to J.M.R. before they go out and then will check against control sheets against the returned documents.

A programmer will be required to write a program to direct the printing of the information by the on-line printer to the meter reading slips.

A messenger will be required to bring the slips to and from DPD to WWO and serve as link between the two offices in general.

About twenty characters will have to be keyed to tape, including account numbers, meter readings and report codes. Assuming a keying speed of 9,000 strokes per hour, then a set of six keypunch stations and a minicomputer will be required, including verification of the characters. The team of six keypunch operators (KVO) will be under the supervision of a keypunch

supervisor.

About fifteen magnetic tapes will be required to hold the transaction file for one week, allowing for contingency.

The summary of the resource requirements of the key-to-tape turnaround alternative is shown in Table 4.5.

TABLE 4.5

RESOURCE ESTIMATES OF KEY-TO-TAPE TURNAROUND ALTERNATIVE (FOUR-MONTH PERIOD)

Resources / Steps	Equipment	Personnel	Stationaries & Subcontract	Computer Time
I & II		55 x J.M.R.	52,000 meter reading slips	17.6 hours
III		2 x C.A. 1 x Messenger		
IV	1 x Minicomputer 6 x Keypunch-Verifing Machines - 15 Magnetic Tapes	6 x KVO 1 x KVO Supervisor		

The summary of cost estimations is shown in Table 4.6.

TABLE 4.6

COST ESTIMATES OF KEY-TO-TAPE TURNAROUND ALTERNATIVE
(FOUR-MONTH PERIOD)

Tapes \ Resource	Equipment	Personnel	Stationaries & Subcontract	Computer Time	Total
I & II Enter Meter Readings to H.B.		$385,000	$5,200	6,000	$396,200
II Collect H.B. to D.P.D.		10,400 4,400			14,800
IV Keypunch Readings	$29,700	70,400			100,100
Total	$29,700	$470,200	$5,200	6,000	Grand Total $511,100

The detailed cost calculation is shown in Appendix VII.

4.4 Benefits Comparisions

One alternative may have an advantage over the other two, but it may be at a disadvantageous position in other aspects. A comparison of the relative benefits of the three alternatives is summarised in Table 4.7. The factors under considerations are listed in descending order of importance to the successful implementation of an automatic water billing system. This order of importance is shown in the priority column.

TABLE 4.7

BENEFIT COMPARISONS OF PRINCIPAL ALTERNATIVES

Factors	Priority	Key-to-tape	OCR	OM
Speed of operation	1	Low	high	Medium
Read error rate	2	Low	high	Medium
Error rate in reading by J.M.R.	3	no change	lower than present	higher than present
Impact on DPD	4	some	more	some
Impact on J.M.R.	5	no change	insignifi-cantly affect	a little affected
Maintenance and backup	6	adequate	not clear	adequate
Other intangible factors:				
Keypunch Operator Requirement		Yes	No	No
Program Requirement		high-level language	high-level language	low-level language
Space Requirement		high	limited	limited
Installation time Require-ment		short	uncertain	available now

Speed of Operation

The practical speed of keypunching is about 9,000 strokes per hour.[1] Assuming one stroke is equivalent to the recording of one character, this will give a practical speed of about two to three characters per second.

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[1] DPD Performance Standards supplied by Mr. MacDonnald, Operation Manager of DPD.

For OCR equipment, input speeds vary from 400 characters per second to about 1,500.[1] Some sophisticated equipment such as Input-80 Optical Character Recognition System, manufactured by Recognition Equipment Inc., is capable of reading many different fonts and can code up to 3,600 characters per second.[2]

OM equipment can read small or large documents. Autolector by ICL can process small forms (four to six inches wide and five to six inches long) at 400/minute and large forms (7½ to 8½ inches wide and nine to sixteen inches long) at 270/minute. The Mark Reading Station (OM Reader 8301/1) by ICL allow maximum 60 rows of 23 marking positions of a 13 inch document.[3] This is equivalent ot 120 characters per large sheet. Thus the effective reading speed will be 540 character per second.

The reading speed of the OCR and OM equipments are very high because they are electronic device. The rate-determining step is the mechanical document transport mechanism. Although the processing speed is high for the machines, allowance must be made for documents jams inside the machine and rejection rate. The later will be discussed under the read error rate factor. An allowance of five percent jamming rate is assumed.

Thus we can compare input speeds for key-to-tape, OCR and OM reader in terms of characters per second and allowing for paper jam

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[1] P.A. Losty, The Effective Use of Computers in Business (London: Trinity Press, 1970), p. 44.

[2] Robert F. Thierauf, Data Processing of Computer in Business, (New York: John Wiley & Sons Inc., 1973), p. 319.

[3] P.A. Losty, The Effective Use of Computer in Business (London: Trinity Press, 1970), p. 42.

rate. The number of key-to-tape equivalents for the three alternatives can also be summarised in table 4.8.

TABLE 4.8

A COMPARISON OF INPUT SPEED OF THE PRINCIPAL ALTERNATIVES

	Key-to-tape	OCR	OM
Input Speed (maximum no. of characters/sec.)	3	3,400	510
Key-to-tape equivalents	1	1,000	170

Read Error Rate: There are two types of read errors involved in the OCR and OM readers. The characters may be rejected because they are unacceptable. One characters may be substituted and misrepresented as another character by the reader. These two errors together give the read error rates. For the key-to-tape alternative, the read errors include the errors in keypunch and the error in recording the characters to magnetic tape.

For most OCR equipments, the rejection rate is below ten percent.[1] However the exact rejection rate for the meter reading application cannot be assessed until a controlled experiment is performed. However the read error rate for OM equipment should be lower than OCR equipments. The error rate for keypunch should be the lowest.

From the Infotech State of the Art Report 22,[2] a plot of flexibility

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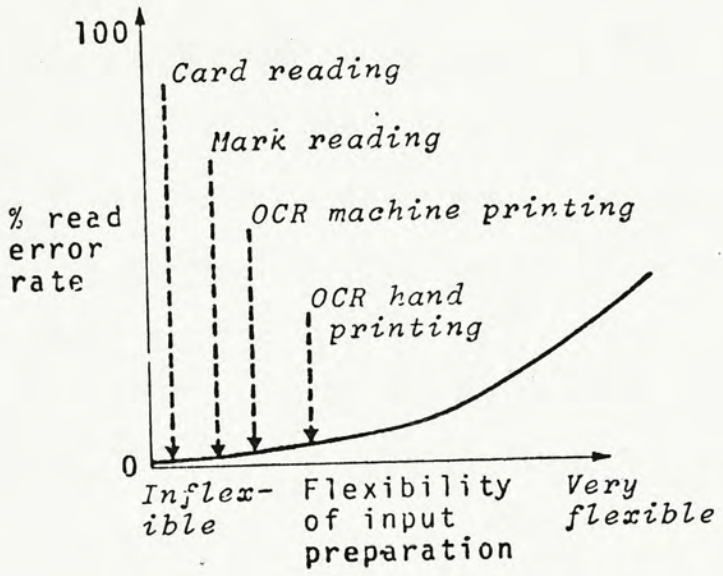
[1] Gordan Davis, Introduction to Electronic Computer. (Tokyo: McGraw-Hill Kogakuska Ltd., 1971) p. 237.

[2] Rubenstein, The Status & Potential of OCR, Infotech State of the Art Report 22. (Berkshire: Infotech Information Ltd. 1975) p. 165.

of input against record error rate as shown in figure 4.6 supports this assertion.

FIGURE 4.6

A PLOT OF FLEXIBILITY V ERROR RATE IN INPUT MEDIA



Source: Infotech State of the Art Report 22 Input/Output Berkshire: Infotech Information Ltd., 1975.

The read error rate can be quantified by assuming the cost in correcting the errors. Thus for the OCR equipment, the cost in re-entry for rejected document can be quantified in dollar terms. Unfortunately because the error rate is not available now, it is impossible to quantify this factor further.

Error rate in recording by J.M.R.

The error rate associated with J.M.R. making meter reading entry has been found to be pretty low. A sample of 100 meter readings showed not a single meter reading had been recorded erroneously into handbooks.

The error rate associated with entries to OCR documents can thus to be expected more or less the same as present. Perhaps the error rate may be even lower because the J.M.R. are expected to make more careful handwritten entry so that they can be OCR readable.

The error rate associated with input of OM documents may be higher especially if the documents are not designed properly. It may be easy to make a wrong entry to the box of next column or row. But the error rate will still be insignificantly low. However if this factor is to require further quantification, a sample test of the entry to OCR, and OM meter reading slips can be performed to find out the relative error rate for the three alternatives.

Impact on DPD

At present the Data Processing Division has a twin system for on-line input. It is made up of two card readers and a universal document reader which is capable of handling optical mark documents. There are also five off-line key-to-tape sites. Each site is made up of a minicomputer and a number of key-to-tape stations. There is no optical character recognition reader. The hardware configuration of the input equipment and their application areas is shown in Appendix VIII.

If the OCR alternative is to be implemented then a new OCR reader has to be installed, tested and debugged. Some disturbances in the operation schedule of DPD will be invitable and it will take some time before the equipment can be run efficiently and effectively.

If the OM alternative is to be implemented then in the short run probably an additional OM reader is not required. However

as the number of water accounts increases over the year, an additional reader may be required since the equipment is already involved in a number of applications at present. Some problems in scheduling may be involved but will be less than in the OCR alternative because the DPD personnel already have some working experience with the OM equipment .

If the key-to-tape alternative is to be implemented, then another site of key-to-tape stations may have to be procured. However because the equipment is off-line, the impact on scheduling will be least compared with the other two alternatives.

Thus in the short term the key-to-tape alternative will incur least undersirable impact on DPD, followed by OM alternative and the OCR alternative. However this factor is hard to quantify.

Impact on J.M.R.

For the key-to-tape alternative, the procedures for J.M.R. will remain unchanged. The OCR alternative will require the J.M.R. to make careful handwritten entry. However the document will be more convenient to handle than the bulky handbooks, especially if the documents are designed to fit hand-size and have a supporting writing board. The OM alternative will require the J.M.R. to make bar mark entries. It may cause some difficulties because the box are relatively small and the rows and columns of boxes are also close together. Some J.M.R. seem to resent to this entries by commenting that this approach is too 'tedious'.

Measurements on the time to record meter readings to the three different documents showed that they are insignificantly different from one another. In particular, the time spent in recording meter

readings is only a relative small portion (less than 10%) of the total time in taking meter readings. The major portion of the time is spent in travelling, finding meters and making inquiries of irregular consumptions.

Thus the key-to-tape alternative will have least undesirable impact on J.M.R., follow by OCR and OM alternative. It will be very difficult to quantify this impact. Apparently it does not seem to justify to make an effort to quantify this factor because it is not as significant as such.

Maintenance and Backup of Equipment

The keypunch verifying and OM equipments can be considered to have adequate vendor's support in maintenance and backup at present. For the OCR equipment details of the vendor's support is still not available. But it can be assumed to be adequate. There are a number of users of OCR equipments in the Colony. During the interview with the personnel of China Light and Power Ltd., they did not report to have problems with the maintenance of their OCR equipments. In general, maintenance and backup from vendors are adequate for leased equipments.

Other factors

The key-to-tape alternative will require a number of key-punch operators. While the supply of keypunch operators in the job market can be considered adequate at present, whether this condition will prevail in future is doubtful, especially when more keypunch operators will be required as the number of accounts grow. The OCR and OM equipment will demand less skilful personnel to operate. The supply of this group of human resource can be considered to be

plentiful among the various Government departments or from outside.

The OM alternative will require a machine-language program to direct the readers and printing of information on OM documents. The supply of this kind of programmer in the Colony is very limited. Besides, DPD policy is to discourage the use of low level language programs.

The key-to-tape machines will require more space in the DPD office. The space requirements of OCR and OM machines are limited. Space may become a scarce resource in the future at DPD when it expands from the present size of operation. It presents no problem at present, because there are some vacant spaces. However the monthly rent of the office space is pretty high (about four to six dollars per square feet) and equipment that requires less space will be preferred.

The time requires to install the OCR equipment is not clear at present. Probably the equipment may have to be ordered from abroad. It may take one to two years before the equipment can be delivered, installed, tested and readied for full-scale operation. The time for installing key-to-punch machines may be shorter but no data is available at present. However this factor may not be very significant if full-scale implementation of the billing system is to take place two years from now.

5.0 CONCLUSIONS

5.1 Conclusions and Recommendations

The operation cost for implementing the key-to-tape alternative is about HK$511,000 for a four-month billing cycle. The cost for the OCR alternative is HK$506,000 if the full rental cost of the OCR machine is charged to the application. The cost for the OM alternative is about HK$450,000. If the rental of the OCR machine is charged on a utilization time basis (like in OM alternative), the total cost will only amount to $430,000.

About 70 percent of the cost of each of the three alternatives is due to the salary of the J.M.R. So the actual difference in cost between the alternatives is only HK$30,000 to HK$40,000 in a four months' period. This difference in cost of the three alternatives is not great enough to warrant that a particular alternative is better than the other two. Because this is a first system in a relatively unskilled environment, a reliable method is more important than cost consideration since the cost difference is small.

In the initial phase of the change, the first ten percent of the accounts (the large accounts) will be involved.[1] This will take place about three months from now (in July, 1976). Because of the limitation of time, it will be impossible to install and test the OCR equipment in such a short period of time. If the task is done hurriedly, the total errors involved in the change will be undesirably high. The same applies to the OM alternative. The OM documents have

[1] According to the recommendations of the system design group.

to be tested first to make sure that the rejection rate and substitution rate is not so high that the method is unuseable. So in the initial phase of the change, the key-to-tape alternative is recommended. This will be the most reliable method in this short period of six months because DPD has extensive experience with the equipment.

After the initial phase is completed, the second phase will begin immediately. This phase will involve the remaining 90 percent of the accounts, which totals to about 600,000. By the time this second phase commences, which is about two years from now (that is, in January 1978), the OCR equipment should have been properly debugged and tested for the rejection rate of inreadable documents. The file conversion project which involves the conversion of the manual records in account cards to magnetic files of a computerised waterbilling system will also begin, about one year before the start of the second phase. This file conversion project will probably require OCR equipment for data input because of the large volume of data to be entered into the files within a relatively short period. This large volume of data will probably require 100 keypunch operators if they are to be keypunched, which is not feasible. The Data Processing Division will probably find a lot of suitable applications for the OCR equipment. Because of the increasing uses of the OCR equipment at DPD, the cost of the equipment allocated to this application will decrease proportionately. This factor will make the OCR turnaround approach relatively attractive in the second phase. Furthermore DPD will accumulate experience with the OCR equipment and this will open up a new alternative of data entry which DPD will most welcome.

Let us look at some other factors in which the OCR alternative are superior over the other two alternatives.

The optical mark alternative suffers from the resentment of the J.M.R. who found it very tedious to enter a small mark to a specific position of the OM documents, especially in bad meter reading environments. This kind of resentment will be fatal to the success of implementing a new water billing system, if it is not probably managed. In addition, because of the difficulty in recording the meter readings to the OM documents, the error rate in recording meter readings will be higher than in the OCR documents. Whether this error rate is significant or not will depend on the design of the documents and the training given to the J.M.R.

At present, the OM equipment is engaged heavily with other applications at DPD. When the number of water accounts grows in the coming year or when the frequency of reading meters is increased because of the shortening of the billing cycle, probably another OM equipment will have to be installed. Then the organisational problems and additional cost will make the OM alternative less favorable than the OCR alternative.

We have seen that the operating speed of the key-to-tape machine is about 100 times slower than the OCR reader. As the work-load increases in the coming year, another set of key-to-tape equipment must be procured. This will lead to a big step increase of cost plus all the organisational problems of introduction of another set of equipment. The key-to-tape equipment will also require more space than the OCR equipment. Space may become a scarce resource at DPD by the time when the additional set of equipment is required.

The key-to-tape alternative will require a team of keypunch operators whereas the OCR alternative will only require only one OCR reader operator. It will be more difficult to manage a team of operators than one OCR reader operator. The efficiency of the whole operation will depend much more on the efficiency of the human elements which tend to fluctate over time. In situations when the supply of skilful operators is acute, there is a problem of recruitment of operators and the whole situation worsens. In suming up all these disadvantages, OCR is the better alternative than the key-to-tape alternative in the second phase.

No data are yet available for the rejection rates of the OCR and OM documents. Nor is the read error rate of substitution available. A controlled experiment has to be performed to find out the read error rate. Improvement on the documents or the J.M.R. procedures will need to be designed to minimize the error rate.

In conclusion, the OCR alternative is recommended to be the optimal method for input meter readings in the second phase of the implementation. The main advantages of this approach are: its ability to handle large volume of data, most welcome by J.M.R.; least space requirement; and the ability to meet further demands in application. It will also bring new experience to DPD in OCR equipment; and if increasing applications are found, it will be the cheapest approach. However the read error rate has to be tested carefully to make sure that it can be minimized before full implementation.

5.2 Implementation Considerations

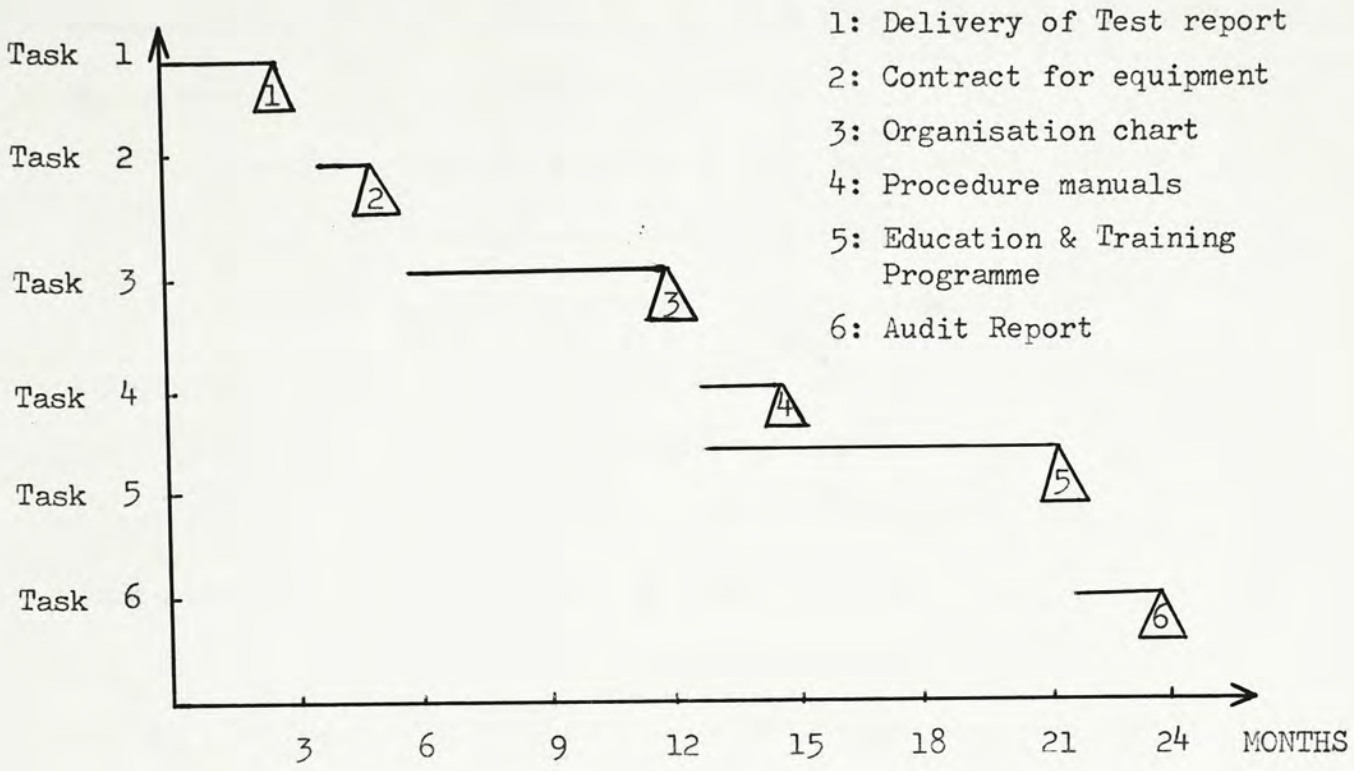
A number of tasks have to be performed before the operation phase of a modified method of meter reading will begin. These tasks of implementation include:

1. Testing the modified method
2. Procurement of Equipment
3. Plan for Organisational changes
4. Development of Procedures
5. Training and education of Personnel
6. Post implementation audit against design criteria

These six tasks are scheduled by the Gantt Chart as shown in Figure 5.1. The operation phase is expected to commence two years from now, around January, 1978. So the implementation tasks can be spread within these two years. If necessary, the schedule can be shortened to meet the operation date.

FIGURE 5.1

GANTT CHART FOR IMPLEMENTATION CONSIDERATIONS



Task one: Testing the Modified Method

Some of the meter reading conditions are pretty bad. It may be very difficult for a meter reader to keep the OCR documents free from water stains, dirts or dogeared corners. Further the conditions may be such that properly OCR-acceptable handwritten numerals may not be possible. So it may be necessary to test-run some of the OCR documents to find out the rejection and read error rate for a particular OCR equipment.

Samples of meter readings from most meter reading areas can be used. There is a special reading team going out to take meter readings covering all areas. This assignment may therefore be put on the team. Junior Meter Readers may be selected randomly from the team. They will be trained to make OCR entry. About 5,000 meter readings (in about

twenty samples of two hundred and fifty) can be collected. This will use up about twenty working days. The test can be run with the proposed vendor's OCR equipment. The rejection rate will be recorded. The read error rate can also be found out.

Improvement on the quality of the paper may be made if the rejection rate due to dog-eared corners or foldings is high. Similarly plastic cover may be used to minimize water strains and dirts. The number of clerical assistants required to 'refurnish' the meter readings to make them OCR-acceptable can also be worked out. If it is found that it is uneconomical to correct the high rejection rate, then this method may be substituted by other alternatives.

This module-testing should be scheduled to couple with the system test which will commence after the system design phase is completed. So it will be used to provide data for the system test run.

Task Two: Procurement of Equipment

A buy or lease decision has to be made regarding the OCR equipment. A technical specification has to be drawn firstly, covering such details as the flexibility of the optical font, the reading speed, and paper specification. Proposals from vendors will be studied, paying particular attention to the compatibility of the machine with the present equipment at DPD and the maintenance terms. Maintenance will be important because the machine will be required to operate daily to deal with the batch of meter readings and delayed downtime will cause much troubles.

The OCR equipment should be tested with some of the OCR documents. Finally a contract for the lease or purchase will be formed.

Task three: Plan for Organisational Change

The organisational structure of the Meter Reading Section will be affected by the introduction of the computerized billing system. Apparently most part of the Meter Reader's job in checking meter reading will become redundant. Many of the clerical duties such as typing memos and letters can also be taken up by a computer program. So these groups of human resources may be used in other sections or departments. The spot check team may also be expanded with these excess personnels, because at present little or nothing is done with spot checks of meter readings. A document control unit has to be set up. This unit is responsible for the quality of the OCR documents and handwritten entries of meter readings. This unit also serves as a link between DPD and the Meter Reading Section.

The proposed organisational chart and the responsibilities manuals will have to be documented as soon after the test run is found successful. They should be presented to the Colonial Secretariat for justification, which may take some time before the final approval.

Task four: Development of Procedures

A complete set of instructions for preparing input to the system will be formulated by the joint efforts of the system designers and the system analysts. The users procedures should include both narrative and graphic materials. Understanding the procedure is facilitated if the narrative portion is supported by flowcharts.

In addition to the user procedures, data processing procedures has to be developed for the operation of the OCR equipment. A set of data control procedures has also to be formulated. This is used to

assure complete, correct data are input. This control procedures will apply to the document control unit of the Meter Reading Section.

All these procedures will be documented in a procedure manual.

Task five: Education and training of Personnel

As stressed earlier, it is vital that everyone in the Waterworks Office who may even be remotely affected by the planned introduction of a computerized billing system be fully communicated clearly of what the advent of the computer will mean to him and the Office. Unless they are fully informed, there still remains a mystique about a computer and these inherent fears and anxieties must be quelled. Personnel cooperation is the key to the success of the introduction of a computerized system. So not only do they need to be educated on the use of the computer but they should be invited to take part in preparing the changes.

After all procedures have been completed, training of the personnel can begin. Most often this training includes both formal and informal training sessions. The entire user group is brought together to explain the OCR input procedures for the system as a whole. Then the detailed operation procedures are discussed with individual positions.

If this task is done thoroughly, it can serve as the final 'debugging' activity prior to the publication of procedure manuals.

Task six: Post Implementation Audit

Within three months of cutover to the modified method an audit is performed. The performance is compared to the original objectives to insure the system is accomplishing what it was conceived to produce.

The audit will be done by an independent audit group because it is a violation of the concept of control to have a group auditing itself.

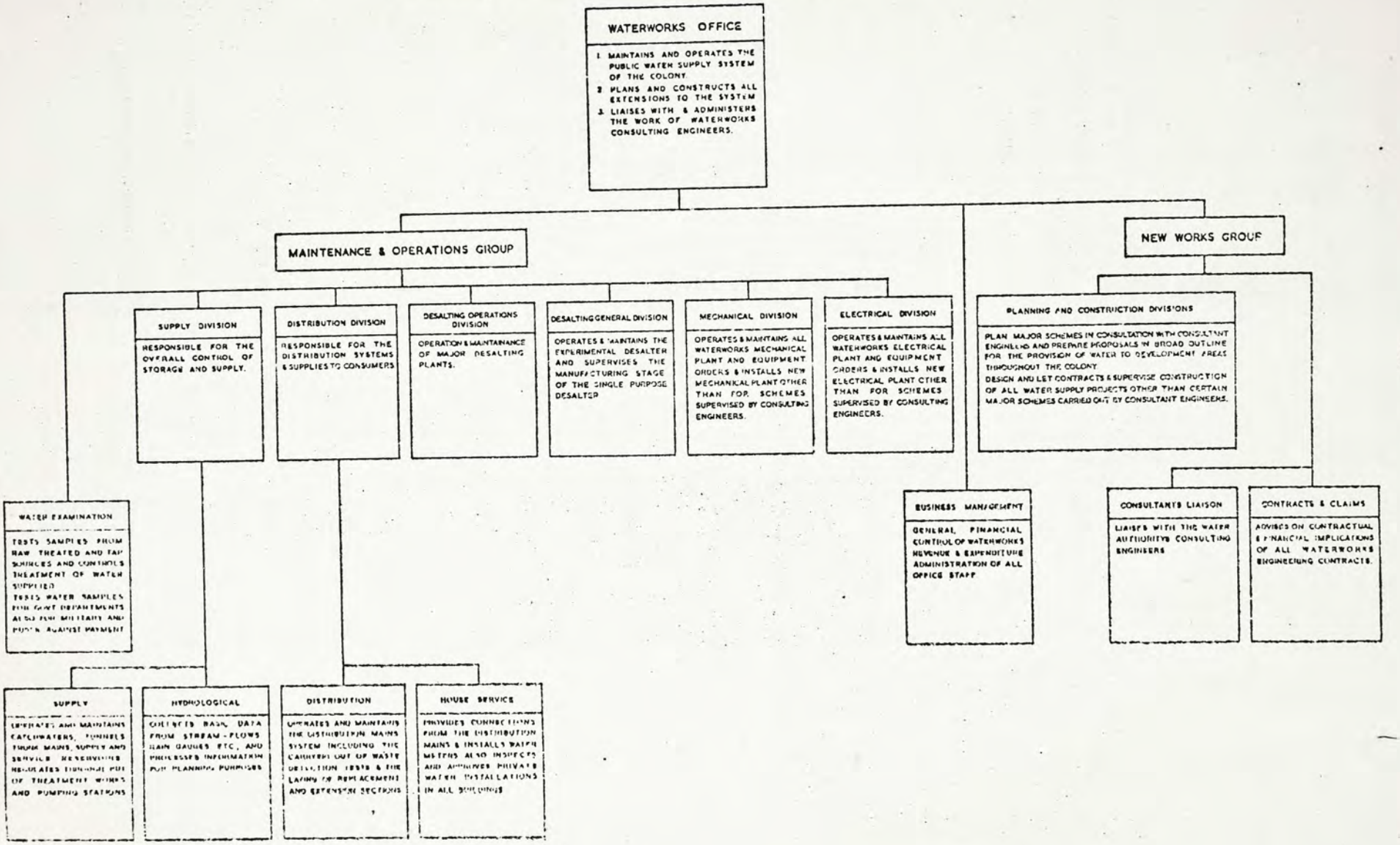
5.3 A final word

After the implementation tasks are completed in a period about two years from now, the operation phase of the project is due to begin. Then the whole system development cycle will start again when the system is to be enhanced viz. feasibility study, design, implementation, operation. Five years from the time the method is introduced, perhaps another modified method will be required to meet the user's demand and the explosive advancement of computer technology.

APPENDIX

WATERWORKS OFFICE

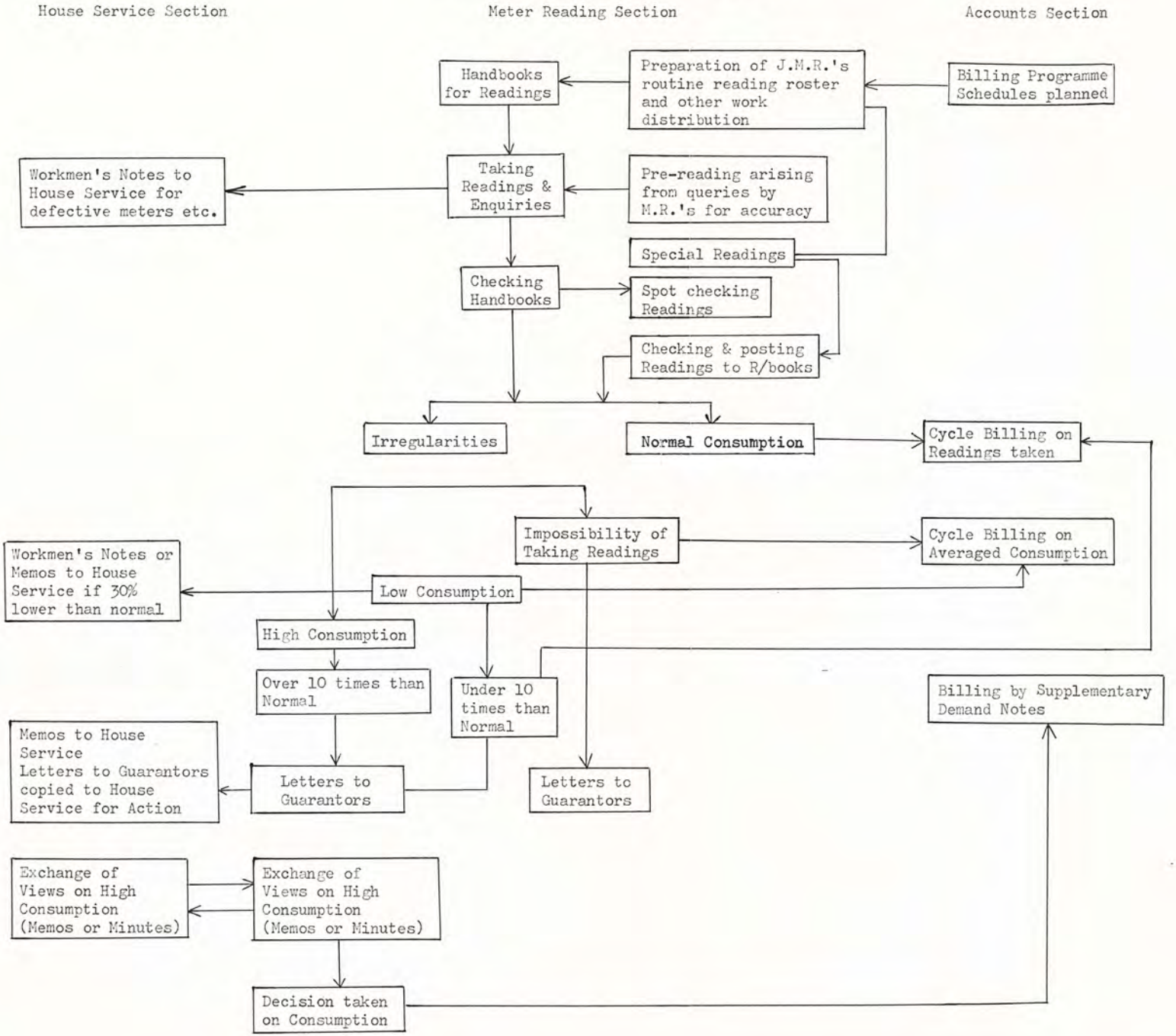
OPERATION AND ORGANIZATION CHART



Source: P.W.D. Department Report, 1973-74.

APPENDIX II

WORK FLOW CHART OF METER READING SECTION



Source: Lin Chine-shih, Facts Finding Report, Review of the Functions of Meter Reading Section, P.W.D. Report (1972).

APPENDIX III

COST ESTIMATES OF THE PRESENT METER READING METHOD ESTABLISHMENT

	1975/76
Chief Meter Reader, C.M.R.	3
Meter Reader, M.R.	23
Junior Meter Reader, J.M.R.	54
Clerical Officer, CO.II	2
Clerical Assistant, C.A.	16

Mid-point salary/month

C.M.R.	$2,040
M.R.	1,540
J.M.R.	1,070
C.O.II	1,240
C.A.	875

Annual per capital charge = $1,170

Overhead rate = 37%

Formula for calculating annual cost per person

$$\$ \left[(\text{mid-point salary} \times 12)1.37 + 1170\right]$$

∴ Cost per billing cycle (4 months)

$$= \$ \left[(\text{mid-point salary} \times 12)1.37 + 1170\right] \frac{4}{12} \times \text{No. of persons of the grade}$$

1. Personnel Cost

For four months,

C.M.R. Salary and Overhead

$$\$ \left[(2040 \times 12)1.37 + 1170\right] \frac{4}{12} \times 3 = \$34,710$$

M.R. Salary and Overhead

$$\$ \left[(1540 \times 12)1.37 + 1170\right] \frac{4}{12} \times 23 = \$203,070$$

J.M.R. Salary and Overhead

$$\$ \left[(1070 \times 12)1.37 + 1170\right] \frac{4}{12} \times 54 = \$337,690$$

C.O. II Salary and Overhead

$$\$ \left[(1240 \times 12)1.37 + 1170\right] \frac{4}{12} \times 2 = \$14,370$$

C.A. Salary and Overhead

$$\$ \left[(875 \times 12)1.37 + 1170\right] \frac{4}{12} \times 16 = \$82,960$$

This totally sums to $672,800

The Executive Officer's Salary has not been considered. Also the conveyance allowance, non-pensionable allowance, uniform cost, traffic expense re-inbursement are excluded because these expenses are assumed to be more or less the same after the modified method is introduced. (These sum to $110,530.) There is an overtime charge of $141,200 for the Meter Reading Section (including the coding exercise) during the year 1975-1976. This overtime charge can be assumed to be eliminated if computer is introduced. Thus the total personnel cost of the present meter reading method = $(672,800 + 141,200)

= $\underline{\underline{\$814,000}}$

APPENDIX IV

REPORT CODES

01	Yard flooded 天井水浸
02	Premises locked 鎖閉(不能內進)
03	Obstruction of meters 錶位受阻(不能讀錶)
04	High consumption 用水量過高
05	Low consumption 用水量過低
06	Change in number of consumers 用水人數改變
07	Change to trade account 轉為商戶
08	Change to domestic account 轉為家戶
09	Inquiry unsuccessful 調查不果
10	Suspected leakage 懷疑漏水
11	Not registering 水錶失靈
12	Meter lid missing 錶蓋失落
13	Seal broken 錶號失落
14	Glass broken 玻璃打破
15	Glass obscured 玻璃模糊
16	Meter facing wall 水錶向牆(讀錶困難)
17	Hands damaged 壞錶針
18	Other meter defects 壞錶(其他項目)
19	Beware of dog 提防惡犬
20	Other reasons 其他特別事故

APPENDIX V

COST ESTIMATES OF OCR ALTERNATIVE

1) Assume line printers has a practical speed of 800 lines/min.

No. of lines to be printed = 770,000

∴ CPU lapsed time = $\frac{770,000}{800 \times 60}$ hours

Allow 10% contingency = 16 hours

So adjusted CPU lapsed time = 17.6 hours

The account numbers are to be printed by 'barrel' printer.

No. of lines to be printed = 700,000

∴ CPU lapsed time = $\frac{700,000}{800 \times 60}$

= 15 hours

Allow 10% contingency including time for replacing 'chain' with 'barrel' printer head.

So adjusted CPU lapsed time = 16.5 hours

∴ Total CPU lapsed time = 34.1 hours

The standard cost at DPD for on-line printer and operator are allocated on the basis of CPU lapsed time at $300 per hour.

A programmer has to be hired to write a program to direct the printing.

The monthly salary of a programmer is \$4,000. Assume it takes one month for the programmer to write, compile, debug, test-run etc., then the programmer cost = \$4,000. Allow \$2,000 for CPU lapsed time, fringe benefits of programmer and other contingency. Assume the economic life of the operation will be five years and are the implementation cost will be amortized during this period, leaving no salvage value.

Then the 'cost' for a four month cycle

$$= \$6,000 \times \frac{1}{5 \times 3}$$

$$= \$400.$$

∴ Total cost of printing information on OCR documents by on-line line printer = \$34.1 x 300 + 400

= \$10,630

or rounding off = \$11,000

2) The OCR documents will be prepared by a subcontractor. Assume each OCR document will cost \$0.1.

A 8" x 15" documents can be divided into fifteen meter reader slips.

So number of sheets required $= \frac{700,000}{15}$

$= 42,000$

Allow a 10% contingency for rejection, lost, & damages.

Adjusted number of sheets required = 52,000

So total cost of OCR documents = \$5,200.

3) Rental of OCR reader = $20,000/month

Rental cost for four months = $80,000

Because the equipment is procured for this application, full rental charge will be given.

Presumably, the rental will include installation and maintenance cost.

4) Assume 55 J.M.R. will be required to read 700,000 meters during four month's period.

Mid-point salary for J.M.R. = $1070/month

Uniform cost (J.M.R.) = $ 850/year

Conveyance allowance (J.M.R.) = $ 20/month

Non pensionable allowance (J.M.R.) = $75/month

Annual per capita charge = $1170

Overhead rate = 37% of annual salary

Total cost of one J.M.R. for four month

$$= \$(1070 \times 12 \times 1.37 + 850 + 20 \times 12 + 75 \times 12 + 1170) \times \frac{4}{12}$$

$$= \$7,000$$

Grand total for 55 J.M.R. = $385,000

5) Mid-point salary for clerical assistants = $875

Annual per capita charge = $1170

Total cost for one C.A. for 4 month

$$= \$(875 \times 12 \times 1.37 + 1170) \times \frac{4}{12}$$

$$= \$5,200$$

Total cost for C.A. = $5,200 x 2 = $10,400

Assume the salary scale for operator and assistants are similar to clerical assistants.

Total cost for operator and assistants = $10,400.

6) Mid-point salary for messenger = 755

Annual per capita charge = $820

Total cost for one messenger for four month

$$= \$(755 \times 12 \times 1.37 + 120) \times \frac{4}{12}$$

$$= \$4,400$$

Summing up items one through six, the total cost

$$= \$(11,000 + 5,200 + 80,000 + 385,000 + 10,400 + 4,400)$$

$$= \$506,400$$

APPENDIX VI

COST ESTIMATES OF OPTICAL MARK ALTERNATIVE

1) The cost of printing information on Optical Mark documents by computers (including programmer cost) can be assumed to be similar to that of printing on OCR documents.

   So the cost = $11,000

2) The OM documents will be prepared by a subcontractor at a cost of $0.1 each

   Assume each document can be divided into four meter reading slips.

   So number of sheets required = $\frac{700,000}{4}$

   $= 175,000$

   Allow a 10% contingency for rejection, lost and damages:

   Adjusted number of sheets required = 192,500

   $\doteqdot$ 200,000

   Total cost of OM documents = $20,000

3) Rental of OM reader = 7,400 per month.

   This can be assumed to include installation and maintenance cost. The rental can be allocated on the basis of the time utilization of the machine.

   No. of OM documents processed each day = $\frac{200,000}{80}$

   $= 2,500$

The reading speed of an average OM reader = 250 documents/min.

$\therefore$ Lapsed time with OM reader = $\frac{2500}{250}$

= 10 min.

But the rate determining step is again the document transport mechanism. It can be assumed it takes thirty minutes to process the documents.

Thus rental of OM reader allocated to this application

$$= 7400 \times 4 \times \frac{61}{6 \times 2}$$

$$= 2,500$$

4) The total cost for 55 J.M.R. is similar to the OCR alternative which amounts to $385,000.

5) Similarly the total cost for the clerical assistants, operator and assistants, and messenger are same as OCR. The grand total of the cost of the items

$$= \$(11,000 + 20,000 + 2,500 + 385,000 + 10,400 + 10,400 + 4,400)$$

$$= \underline{\underline{\$442,700}}$$

APPENDIX VII

COST ESTIMATES OF KEY-TO-TAPE TURNAROUND ALTERNATIVE

Assume line-printer has a practical speed of 800 lines/minute.

No. of lines to be printed = 770,000

$$\text{CPU lapsed time} = \frac{770{,}000}{800 \times 60} \text{ hours}$$

$$= 16 \text{ hours}$$

Allows ten percent contingency,

Adjusted CPU lapsed time = 17.6 hours

The standard cost at Data Processing Division for on-line printer and operator are allocated on the basis on CPU lapsed time at H.K.$300 per hour

The programmer cost is similar to the OCR alternative (=$400)

Total cost of printing information on the meter reading slips

$$= \$17.6 \times 300 + \$400$$

$$= \$5{,}280 + \$400$$

$$\doteq \$6{,}000$$

The cost of preparing the meter reading slips by a subcontractor can be assumed to be similar to the OCR alternative. The cost of preparing the slips

$$= \$5{,}200.$$

Twenty characters will have to be keypunched covering account number, meter readings and control codes.

Depression rate of keypunch verifying operators (KVO)

= 9,000 per hour.

A KVO works 6.5 hours a day and 22 days in a month

∴ No. of keypunch verifying stations required

$$= \frac{700{,}000 \times 20 \times 2}{4 \times 6.5 \times 22 \times 9000} \doteqdot 6$$

A team of six KVO will need one supervisor. A set of keypunch stations with a minicomputer installation will also be required.

Rental of six keypunch-verifying machines = \$1758/month

Rental of one minicomputer = \$4994/month

∴ Total rental of equipment for four months = \$6752 x 4

= \$27,000

Fifteen tapes will be required. But the cost of these tapes will be neglected especially they are reusable.

Mid-point monthly salary of KVO = \$875

Staff cost (annual) of KVO = \$15,030

Cost for six KVO for four months

$$= \$(875 \times 4 \times 6 + 15{,}030 \times \frac{4}{12} \times 6)$$

$$= \$(21{,}000 + 30{,}000)$$

$$= \$51{,}000$$

Mid-point salary of KVO supervisor = \$1,340

Staff cost (annual) of KVO supervisor = \$22,396

Cost of one KVO supervisor for four months

$$= \$(1{,}340 \times 4 + 22{,}396 \times \frac{4}{12})$$

$$= \$(5{,}360 + 7{,}465)$$

$$\doteqdot 13{,}000$$

$\therefore$ Total cost for KVO personnel = \$64,000

Total cost for data preparation = \$(27,000 + 64,000)

= \$91,000

Allows 10% for contingency,

Adjusted total cost for data preparation = \$100,100.

Total cost for fifty five J.M.R. = \$385,000

Total cost for two C.A. = \$10,400

Total cost for one messenger = \$4,400

Summing up the grand total cost is

$$\$(6{,}000 + 5{,}200 + 100{,}100 + 385{,}000 + 10{,}400 + 4{,}400)$$

$$= \underline{\underline{\$511{,}100}}$$

APPENDIX VIII

INPUT EQUIPMENT AT DPD

I. Mainframe: ICL 1904S, 192,000 words of core storage.

II. On-line twin system:

Configuration A 128K	Configuration B 128K
Communication processor	Hardware scanner connected
1 x card reader (ICL 1903T)	to Communication processor
1 x line printer	1 x card reader
8 x magnetic tape units	1 x line printer
10 x EDS (60) transport	8 x magnetic tape units
1 x Universal Document reader	5 x EDS (60) transport

III. Off-line:

5 x CMC(5) key-to-tape sites

Terminals with VDUs.

IV. Main Application Areas:

- Census*
- Trade
- Labor accidents, Labor employment
- Immigration
- Birth, Death, Marriage Registration
- Metrological Survey

- Architectual Office, Building Record
- Government Supply (Stock and Inventory)
- Inland Revenue Department Salary Tax Return*
- School Certificate Exam., Secondary School Entrance Exam., GCE Exam.*
- Family planning
- Hospital patients
- Hong Kong Police Mosaie System
- Prisoner Statistics
- Driving Licence, Provisional Driving Licence
- Vehicle Registration
- Traffic Fixed Penalty*

* Universal document reader is used in the applications (to some extent at least).

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香港水務局現行抄錶方法之分析與水費帳單系統電腦化後其改進之建議

由於香港人口膨脹及政府鼓勵用戶安裝分層水錶的影響，水務局處理水費賬單的工作，便日益繁重。為了解決這個問題，政府當局便於一九七五年決定用電腦處理水費賬單。電腦的準確及快捷地處理繁複的資料，故最適合處理繁複的水費賬單。同時因為節省人手及減少錯誤的閱像電腦化後可望每年約節省一百五十萬元。而且，因為電腦處理資料的準確性及翻查效率之提高，用戶及水務局間的閱像亦可望改善。此篇論文的重點，乃研究如何將抄表資料輸

入電腦及處理的最佳方法，以供政府电腦部參考。

水費賬單系統的主要資料輸入，就是水錶的度數。全港大概有七十萬個水錶，分佈於十二個指定的閱錶區。在四個月內，抄錶員按照一定的時間表到各区進行記錄水用水度數。他们須將那些水數及有関資料記入水數单內，並單返水費部，由高級抄錶員再行核對。他们將一季內用水數過高或過低的水數單抽出，嗚咐抄錶員重讀或致函用戶查詢。那些核对過的水數单，便隨即送到計算組計算水費及寄發給用戶。平均而言，水費單部一日內要處理一萬張水數單。

記錄在水數單的資料，如不經過處理，是不能輸入電腦机。最普通的處理方法乃用按鍵机把水數、用戶號碼等有關資料打孔入電腦咭，再由閱咭机輸入。由於按鍵員的人數及工作速率有限，所以不能在一天內處理太多的用戶。另一方面，最快速的方法是將所有水牀改為電動化，將度數自動轉入控制中心，然後再轉入電腦。然而此系統的費用昂貴，而且根本沒有可說在兩年內安裝妥當。

幸好這兩个方法都行不通，但有三個比較適合的方法，即 OPTICAL CHARACTER RECOGNITION (OCR)，OPTICAL MARK (OMR) 及 KEY-TO-TAPE (KTT)。這三個方法有其共同特點，那就是都採

用資料運轉的概念(TURNAROUND CONCEPT)。首先由電腦將有關資料(如用戶手續等)打於打錶表格上，再由打錶員將用水度數填寫在指定的方格裡，再經特製的閱讀机便可將資料輸入。

由于它有接連的工作程序及由電腦机快捷地打出有關資料，因此等候時間及準確性上都較勝一籌。

OCR 方法是利用 OCR 閱讀机輸入資料，其主要部分是將輸入的數字與其記憶系統裡的數字比較。較相近的數字返接入，如上述數字的意義即輸到總机去。若不相近的，即將表格排斥出來。OCR 閱讀机的特點，是能閱讀打錶員寫下的數字，只要字體端正，且不超越指定的範圍。

OCR 方法大同小異，主要的差別是 OCR 机只能閱讀由鉛筆填滿的格子，而不能閱讀打號員寫下的數字。其原理是利用光應的反射，如格子是用鉛筆填滿，其反射則特強，因而該數字便被輸入。所以抄號員只要把代表數字的格子填滿，那份表格的有関資料便可輸入。

方法是先由電腦把主要資料打出，方便抄錶員記錄水數及其他有関資料，然後將一切有関的資料用 OCR-70-型 MACHINE 輸入小型電腦，記在磁帶上。此法必按鍵机相似，主要不同點在於不用打時而直接輸入磁帶，以及改錯方便，同時，所要时间亦比打時節省百分之廿至卅。

如以四個月一個水季計算，此三個方法各需要五十五個打孔員及三數個助理員。其餘的高級抄錄員及文員的工作，可以電腦代替。若以OCR方法計算，先要添置OCR閱讀機，然後準備約五萬張OCR表格及需要三十二個電腦小時。因為這一部OCR機是持為水費賬單系統而添置，所以它要承擔全部的租金。倘若電腦部門的應用此機於其他用途時，水費賬單系統所負責的租金，將會相應的下降。應用OCR方法，則需要準備廿萬張OCR表格，三十多個電腦小時，及一個OCR閱讀機，然其租金可與其他用途分担。若以KEY-TO-TAPE STATIONS，方法則需要五萬多份普通表格及六個KEY-TO-TAPE STATIONS，

以及一個小型電腦。並且需要六個操鍵員及一個管理員以來處理資料。此外小型電腦亦可應付十八個KEY-TO-TAPE STATIONS。

比較之下，OCR及KTT方法每種需要二十萬港元，而OM方法只需四十二萬元，其中百分之七十左右的開支是用於折舊及的租金。以四個月份攤，三個方法的費用相差甚少。由於費用相差不大，因此，要比較這三個方法的孰優孰劣，從着相重其對比數計、包括外、及用戶服務的影響。

OCR方法是最快捷的方法，其輸入速度大概高於OM方法七至八倍，更高於KTT方法一千倍以上。OCR方法比

較新穎，電腦可因而可藉此機會而展開其他用途。他日用戶陸續增加，一部OCR機即附庸於該機。另一個優點就是抄錶員可直接寫下記錄水數，這對他們的工作程序及水數計算都起少影響。但它的最大缺點，和OCR方法一樣，就是它的表格排斥率可能很高。這主要是由于水錶安裝的環境太差，因而表格容易受污水染污。若為抄錶員附加以小心填寫，相信排斥率亦不至於過高。

OCR方法對於抄錶員而言，可算是沉重的負擔。因為在惡劣的抄錶環境下，「填格子」是非常困難的。如果抄錶員不合格，將會產生很多錯誤。同時，電腦程序表及表格的

設計，也是一个困难的问题。

KTT方法一方面需要较多人手，另一方面速率亦较慢，而且佔用较多地方。然而，此法较为可靠，因为电脑印较有经验。但長遠来看，当用户日益增多時，势须安装更多的KTT STATIONS。這樣，对於電腦部的操作程序，又将有一定的影响了。

根據系统設计组的建议，水费賬單电脑化之作将分两期進行。首先是將那些大用户（约佔全部用户十分之一）的电腦處理，继而處理数約六十萬的较小用户。第一期将於一九七六年七月间实施，第二期则於兩年後始進行。由於时

间的限制，OCR方法将不能用于第一期。KTT方法将较适合，因其可靠性较高。到第二期时，OCR机定的安装及试验妥当，故应加以适当应用。