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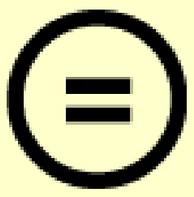

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AN ERGONOMICS STUDY OF THE CHECK-OUT SYSTEM FOR SELF-SERVICE SHOPS IN SWEDEN

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SUMMARY

This thesis is concerned with the design and evaluation of a check-out system in self-service shops in Sweden. The aims were (a) to study the ergonomics of the development of a new check-out system which is to be part of a new automatic data handling system in retailing, and (b) to evaluate certain ergonomics methods used in a system development programme.

The thesis falls into five parts. The first deals with a system analysis of check-out systems in self-service shops. The second consists of a literaturereview of the ergonomics of keyboards relevant to cash register design. The third describes an experimental evaluation of two keyboards suitable for use with cash registers. The fourth describes surveys, involving interviews, cuestionnaires and observational studies, on customers and cashiers using and working in self-service shops. In the fifth and final part experimental and survey results are discussed and interpreted.

The principal results obtained can be summarised as follows.

(a) For ten button keyboards speed and accuracy of performance is better with the keys 123 on the top row and the keys 789 on the bottom row, than conversely. Cashiers generally prefer the 123 to the 789 keyboard.

(b) A new cash desk (into which the 123 keyboard may be placed) incorporating two moving conveyor belts, which has recently been introduced into self-service shops has improved working conditions for cashiers. Suggestions are made on how the cash desk may be further improved from the point of view of both cashiers and customers.

(c) Important relationships between results obtained from interviews involving the reporting of critical incidents, questionnaires and observational studies are reported and the methodological implication of these relations reviewed.

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AN ERGONOMICS STUDY OF THE CHECK-OUT SYSTEM FOR SELF-SERVICE SHOPS IN SWEDEN

PART 1

DESCRIPTION OF THE RESEARCH AREA OF THE THESIS AND A FUNCTIONAL ANALYSIS OF THE CHECK-OUT SYSTEM

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1.0 INTRODUCTION

The possibility of using automation in the context of retailing has been discussed in the literature for some time. In 1964 J. S. Ewing discussed the impact of automation on ~~or~~ retailing in a paper presented at the 13th International Conference of the Green Meadow Foundation. Ewing and other authors (e. g. Unger, 1970 and French, 1971) state that there should be an increase in productivity in retailing. They express the view that automation has to be considered by supermarket chains and that such chains must try out new retailing techniques in the coming decade if they are to avert financial disaster. The profit margin in retailing has dropped in the last few years. In the United States, between 1960 and 1970, the average profit margin dropped from 2. 5 % to 1. 2 % and return on investments from 15 % to 10. 7 %. At the same time salary rates rose by an average of 5. 8 % a year. As the salary costs are a very large percentage of the total expenditure of supermarkets, there is naturally a very large demand for increase in labour productivity.

In the 1970's it seems likely that there will be substantial technologica developments in new systems for retailing. These new automatic and mechanized systems will probably be introduced in the 1980's.

1.1 Automation in retailing

The spread of the credit system in the United States is probably the major reason for a more rapid introduction of automatic systems in retailing in that country compared with Europe.

Automation in retailing can conveniently be discussed under two headings. The first involves the use of keyboards and associated automatic data processing (ADP) systems for automatic handling of information in retailing. The second type of automation involves the automatic handling of goods within and into shops. This thesis deals mainly with problems of information and goods handling at the point-of-sales.

Several automatic systems which affect primarily information and secondarily goods-handling at the point-of-sales will be marketed in the near future. The new systems, to be offered by several manufacturers, are very similar. Basically they involve a clerk or cashier at the point of sale, (e.g. the check-out point in the supermarket), inputting information about goods sold, (e.g. type, quantity and price) into a computer. Information input is achieved by means of a keyboard. The aim of the systems seems to be (a) to provide better sales statistics, so that trends over time can be rapidly obtained to keep control over the whole credit situation, (b) to introduce automatic ordering or recording of goods, (c) to keep track automatically of how many of each type of goods are in stock, so that an instant inventory of goods is available. These last two factors make it possible to order more accurately goods needed to replace those already sold. By this means the quantity of goods in store, and hence the required storage area, in super-markets and other retail outlets can be decreased.

Other advantages of the new electronic systems are that the clerk cannot make inadvertent or purposeful errors, (d) as such errors will be immediately recognised by the computer, (e) that the customer cannot cheat the firm by altering codings (if present) on goods which are inputted into the computer. (f) that the sales clerk or cashier is not subject to lapses of memory concerning prices, taxes, etc., as code numbers are available on all goods.

Power (1971) describes three basic systems: "Stand-alone", "store-and-forward" and "on-line". Stand-alone defines a system which can operate even if the electronic point-of-sales terminal communication wires are cut from the computer. This would mean that the point-of-sales terminal can be used for printing out of receipts. In this situation all sophisticated communication with the computer is lost so that all data have to be subsequently punched from receipt print outs. Store-and-forward defines a system consisting of an electronic machine, at the point-of-sale, which is not connected with a central computer. It is envisaged that the machine provides computation and printing facilities, and also storage of information on magnetic tape or similar devices. According to Power's formulation, separate tapes can be connected directly to each point-of-sale or a central magnetic tape may be provided and connected to several points-of-sales. These magnetic tapes are sent to a computer for processing at a later stage.

In the third kind of system (on-line) the electronic machine at the point-of-sale consists primarily of a keyboard or some other kind of data information or recording device from which information is sent on-line to a computer which has all standard features for computation data storage and presentation.

For most of the point-of-sales devices on the market today is claimed the capability of reading printed or punched tickets attached to goods and identifying them. More recent innovations include the development of so-called "vanned" methods of reading, (optically or magnetically) coded merchandise identification tickets. This method involves making a stroking movement with a special optically or magnetically sensitive head over the ticket which does not require to be removed from the product.

It will, however, be some time before these automatic reading devices are widely available in supermarkets at points-of-sale. In the meantime the probabilities are that keyboards for inputting data into tape or computer will be the next generation of cash register at the point-of-sale. In any case it is conceivable that keyboard and automatic reading devices may produce compatible outputs to feed into the same data storage and computation machines.

1.2 Motives for automation

French (1971) suggests that new automatic point-of-sale devices are expected to:

" 1. Decrease present sales audit and sales-person staff payroll.

2. Decrease present merchandise ticket control staff.

3. Decrease credit authorization staff; provide direct credit authorization facility to reduce bad debts and frauds.

4. Increase customer service by faster transaction recording by providing automatic discount calculation, providing automatic tax calculation, providing automatic price-quantity extensions, and physically producing sales checks.

5. Provide faster (more accurate) reporting capability measured within hours of actual sales.

6. Allow better personnel scheduling for sales-persons and receiving work forces. "

Boutet (1967) gives twelve advantages and four disadvantages associated with the use of automatic ordering for the supermarket through an electronic point-of-sale system. One of the disadvantages is that all goods have to be price and/or code marked. Another is that the cost of this kind of equipment is quite considerable. It has not been possible to find in the literature reports of objective evaluations of this kind of system in terms of the implications for man appearing in the role of supervisor, cashier, labourer or customer. When the advantages and disadvantages of this kind of system are discussed, the discussion is mainly centred upon theoretical calculations. Furthermore, it is mainly

the retailers' or wholesalers' points of view which are considered. Thus, a better assurance that goods will not be stolen by customers or personnel is often claimed to be a great advantage of this new system (Unger, 1970, Boutet, 1967). Petersen (1971), for example, in discussing an electronic point-of-sale system called 'Trader' describes how, through the Trader System, a woman who had an overdrawn credit was discovered. "The woman ran as fast as her legs would carry her for the nearest exit".

Ewin (1964) discussed in general terms the possible social impact of these kinds of new systems for retailing and distribution. He points out that the need for personnel in the supermarkets of the future will decrease and that the kind of personnel needed will be persons with a higher degree of skill than is necessary today. This means that technological development in retailing will create the same kind of situation as industry where there seems to be permanent unemployment for increasingly large groups of people. Ancilliary to this, Ewin asserts that the retailer has to consider, as a cause for selfish concern, men and women who become unemployed as a result of this new technological development. Because they are unemployed they lose value as customers.

"The completely automated central market with no workers directly involved in the selling process which is technologically possible may well be built and put into operation. But the owner of such a technologically marvellous shop may find himself without customers to take advantage of this technology because the machines have cost them their jobs and they have been unable to find others". (Ewin, 1964).

1.3 The KF system

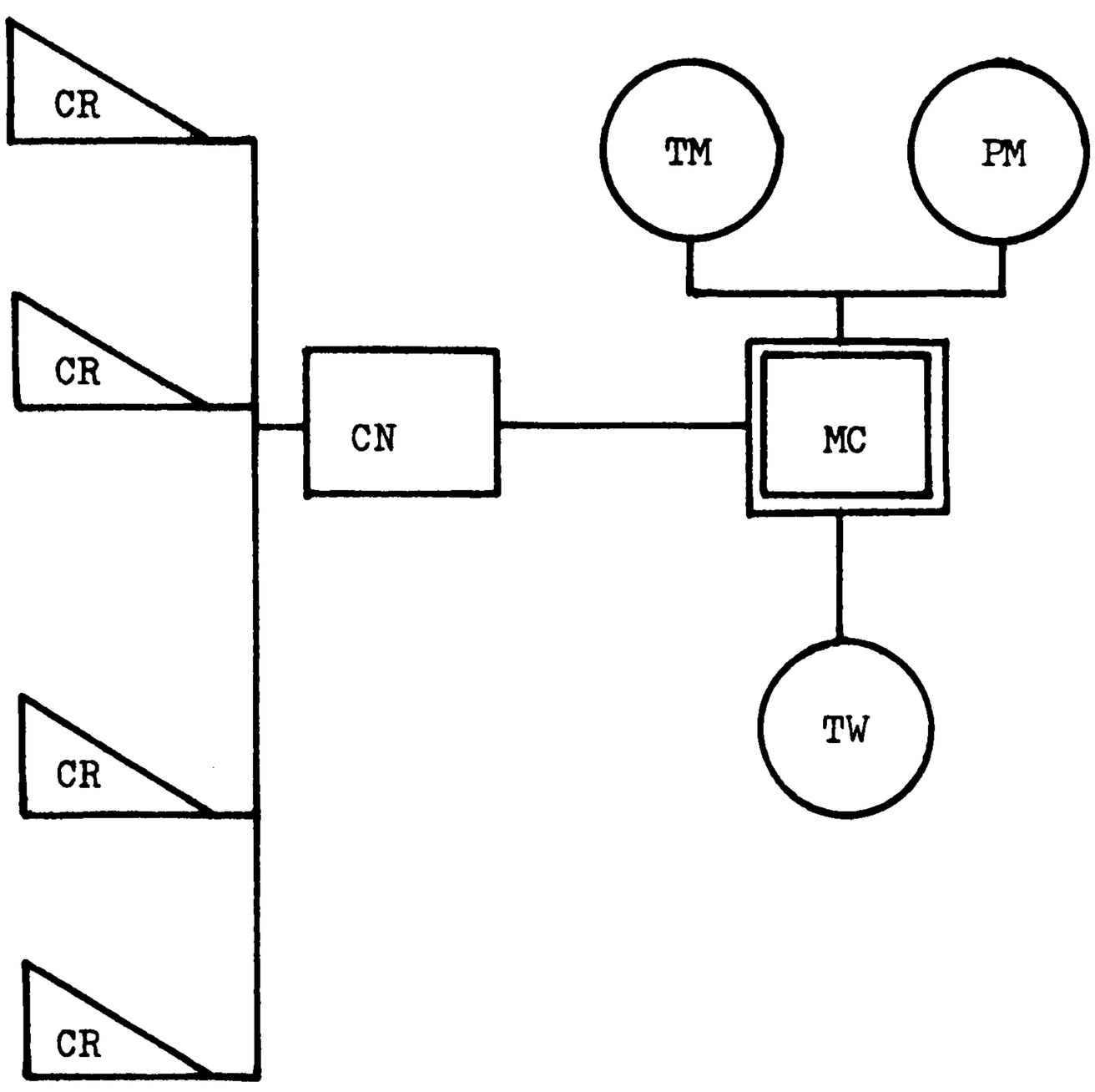
Kooperativa Forbundet (KF), the Swedish Cooperative Union and Wholesale Society is a very large organisation consisting not only of many manufacturing units but also of a large number of retail outlets, including many supermarkets and department stores.

It is planned that in the supermarkets and department stores of KF that a new point-of-sale system will be introduced for registering and controlling sales and associated data, similar to those already discussed.

The main features of the new system, which will be manufactured by KF at its cash register factory, (Hugin Ltd), are outlined in Figure 1.1. In each of the supermarkets and department stores, it is planned that there will be more than fifty electronic cash registers (CR). The CR's will be connected via an electronic communication network (CN) to a special mini-computer (MC). A price memory (PM) will be connected to the computer. It is intended that when a product code is registered on the keyboard of the CR, a price corresponding to this code will be collected by the computer from the price memory and sent back to the CR. Prices and codes will be recorded on a tape recorder memory (TM). If the prices of some goods need to be changed in the PM, this will be performed on the typewriter (TW). The price and the code will be shown on a special electronic display board available to the cashier and the customer. The price and code will also be printed in special printing equipment so that the customer has a receipt for his transaction. All the equipment shown in Figure 1.1 will be located in each department store or supermarket.

FIGURE 1.1

THE MAIN FEATURE OF THE NEW PLANNED SYSTEM FOR THE SWEDISH COOPERATIVE SHOPS



CR = Cash registers

CN = Communication network

MC = Mini-computer

PM = Price memory

TM = Magnetic tape memory

TW = Typewriter

The aim of this KF system is by the board of KF stated to be:

1. to collect money (or its surrogate, e.g. cheques, credit) to the value of goods provided for the customer
2. to perform automatic ordering of new goods from the warehouse
3. to collect information for sales statistics and to make computations on these sales statistics.

1.4 This research project

This research project is essentially limited to the interface between the customer and the supermarket or department store personnel and equipment at the point-of-sale, and is especially concerned with cash transaction procedures. There are complex inter-men and men-machine interactions at the point-of-sale. The men (the cashier and the customer) have information tasks. These include the transfer of prices and of ware code numbers from the goods to the cash register, and the provision of general information about the shop, the quality of goods, etc. The personnel in the system, both cashiers and customers also have power tasks to perform such as the transport and packing of wares. To some extent certain tasks involve a combination of power utilisation and information transfer, i.g. in inputting information into the keyboard.*

In Europe the check-out systems are not at present very well developed technically. Thus the machine parts (the desk and cash register) have only a limited number of functions to fulfill, e.g. storage of goods (the desk), summation of prices and printing of receipts (the cash register). However, recently a great deal of technical development work has started in Sweden both on problems associated with the cash desk and register. To guarantee rational technological development, integrated man-machine-system design methods have to be applied. This means that ergonomics has to play a central part in the design process.

---

*However, as the aim of the task is the transfer of information, the task ought to be considered as an information task.

The description of the present ergonomics research concerned with the customer/cashier/equipment interface at the check-out point has been divided into five different parts. Part 1 is a description and analysis of the check-out system. Part 2 is a literature survey relating to the design of keyboards (especially keyboards used for inputting data into computer systems). Part 3 is an experimental evaluation of two prototypes of a new keyboard. Part 4 is devoted to a series of different studies of ergonomic and social problems found with two currently available check-out systems. The problems are considered from both the cashiers and the customers points of view. Part 5 brings together the findings reported in Parts 1 - 4 inclusive. A discussion of all results given in Parts 1 - 4 is provided together with recommendations for the design of a new check-out system.

In parallel with this project, other studies are being performed. These include the development of (a) a new electronic cash register and new mechanical cash desks, (b) new training and selection schemes for cashiers, (c) new computer programme systems for sales statistics, (d) a new electronic mini-computer to be connected on-line with the cash registers. The whole of this new planned system goes under the name of "The cash-computer system". All of the research work is being conducted under the auspices of KF.

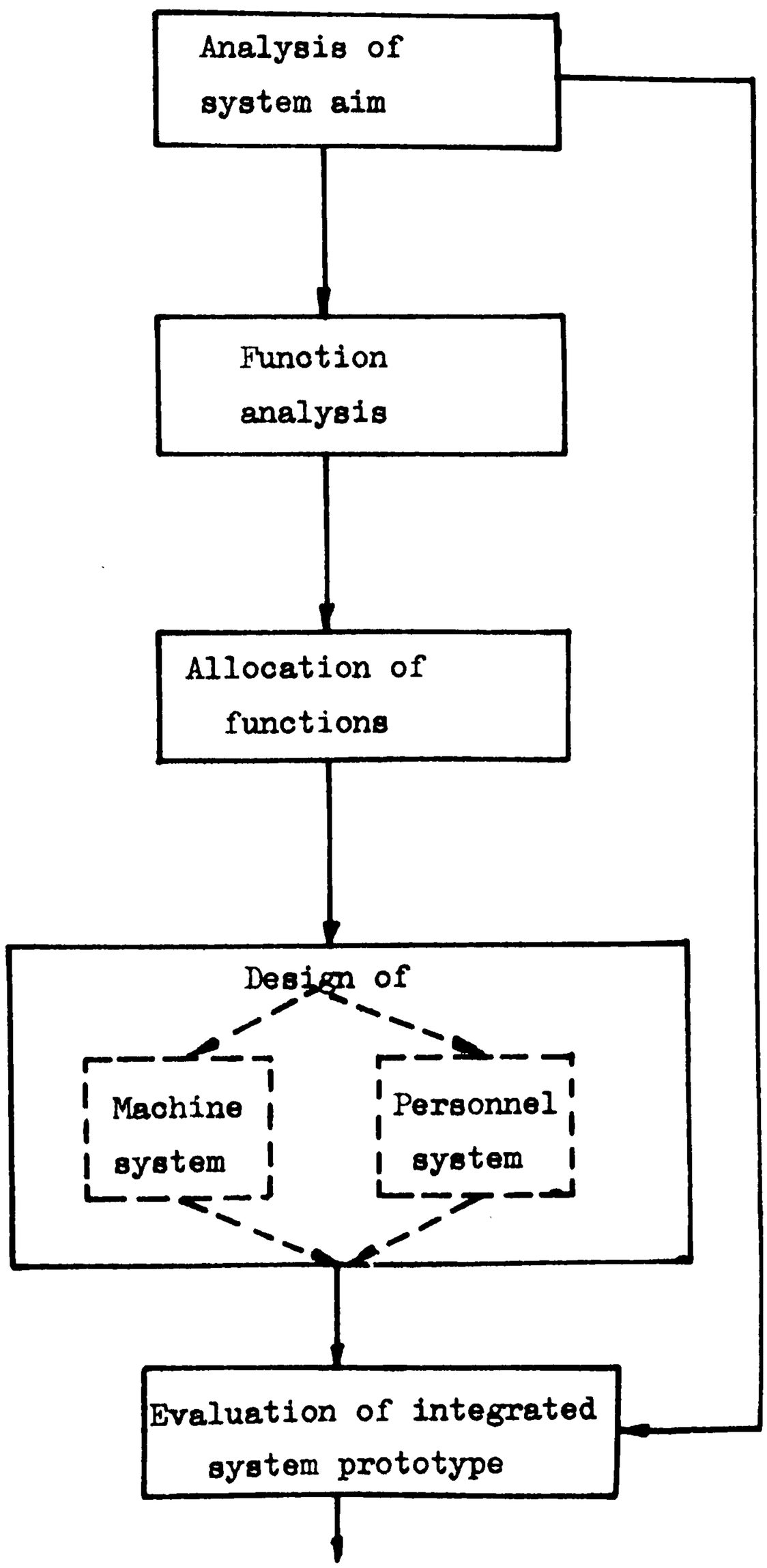
2.0 A FUNCTIONAL ANALYSIS OF A CHECK-OUT SYSTEM

The analytic method used for the study of the check-out point in a self-service shop which is given in this section is based upon techniques described in Archer (1965), Gagne (1962), Ivergård (1969), Jones (1967) and Singleton (1967). Before proceeding to the functional analysis of the check out point, a brief description is given below of the place of functional analysis in an ideal design process as conceived by the above authors, particularly Singleton (1967). A diagrammatic representation of the design process, including the place of functional analysis in it, is given in Figure 1.2.

Design work should start with a definition of the aim of the system. The designer is then supposed to define what kinds of functions are needed to fulfill the system goal. This should ideally be done without too many preassumptions about technological or human means of actually fulfilling the system's aim. After the analysis of the functions an allocation of the functions to man or machine, or both, is made. In the allocation of different functions, certain criteria relating to human needs, (safety, health, well being and comfort), system performance (speed and accuracy), and economics have to be met. After this allocation of function, the actual design work begins and involves both hardware and software components. Included in the latter are different kinds of personnel programmes. When the design of different parts of the system is completed and prototypes manufactured, the system components can be integrated to form the complete system. After that the performance of the system can be evaluated against criteria stated in the aim of the system.

FIGURE 1.2

A SYSTEMATIC METHOD FOR DESIGN



In the following functional analysis of the check-out system, the work will be described and briefly discussed under the following headings which directly relate to the design process as conceived by system analysists.

(1) the system hierarchy

(2) the system goal

  (i) mission

  (ii) criteria

  (iii) limitations

  (iv) relative values

(3) the system function

  (i) how to define functions

  (ii) main functions and function diagram

(4) the system allocation

  (i) different methods of allocation

  (ii) discussion of allocation

(5) the design and system evaluation

  (i) design of system components

  (ii) design of production process for physical system components

2.1 The system hierarchy

When a system is to be studied it is important that it is clear under what conditions it will function. A system seldom functions alone. It usually exists as a component of a greater system. The latter is called the parent system. The system itself is in turn made up of different sub-systems.

The parent system puts restrictions upon the system under study and provides inputs to and accepts outputs from it.

The parent system in the present case is that concerned with the transfer of wares from the producer to the customer. It is assumed that the parent system is a rather traditional self-service shop. This means that the customer himself chooses and collects different products in the shop. There is no automatic handling of goods in the shop nor are staff available for collecting goods for the customer. The inputs to the check-out system from other parts of the parent system are the different kinds of goods collected by the customer. Of relevance for the system are both physical and informational aspects of the goods. Included under the former aspects are the shape and weight of the goods: under the latter, the kind and amount of goods and their price. The outputs of the system are again both of a physical and informational kind and are similar in nature to the inputs. In order to translate the different kinds of inputs into outputs, the system has to consist of a series of sub-systems concerned with, for example, the transportation of goods, storage of goods, information collection, information storage, and so on. The different sub-systems of the check-out system under study will be defined below in the functional analysis (2.3).

2.2 The system goal

Analysis of the aim of a system can conveniently discussed under the following headings:-

(i) mission

(ii) limitations

(iii) criteria

(iv) relative values

(i) The system mission:

In general the main objective of a check-out system, in a supermarket, including the new one planned by KF, is to transfer the ownership of the goods from the shop to the customer. However, in the particular case of the new KF system, the check-out point is furthermore expected to be a part of an automatic shop organisation for ordering goods from the warehouse. This check-out system will also involve the collection of information for sales statistics, inventory checks and so on.

(ii) The system limitation

There are different constraints and limitations for a system. Some of them are provided by the parent, as the latter defines the inputs to the system. The parent defines, for example, what kind of information is put into the system. In the present case it was decided by KF that only 75% of the goods need to be code marked. For 15% it was felt that there should be both a price and code

marking of the goods, (where the price varies from item to item, e.g., due to different weights of the item. This is mainly the case with meat and other kinds of fresh food). For 10% of the goods there is to be a number and a code to be sent into the system. This procedure is to be used when several items of the same goods are purchased. Another limitation is that the goods will be received into the system via the customer. As yet there are no cost limitations defined for the system.

(iii) Criteria for the fulfilment of the mission

In this context only those criteria which are of direct relevance for the situation at the point-of-sales will be considered and not other criteria which have to be met but which are mainly relevant to the other kinds of information systems of which the cash-out system is only a part. This means that there will be no consideration of the kinds of criteria which are important from the point of view of an automatic goods ordering system.

Two important criteria are the service and queueing times for the customer in the system. The former is of course closely related to the latter. The queueing length can be calculated from a knowledge of the service time and the distribution of the arrivals to the system, (Lindblad and Blomquist, 1955).

Mean waiting time for customers at check-out points during the top selling time in KF shops is calculated (KFO, 1965) to be not more than two minutes if the mean number of goods

is assumed to be nine per customer. It has been posited that the queueing time in the new system is not allowed to increase above that in the old. Thus the service time in the new system has to be less than two minutes. If possible the service time for goods ought to be decreased as the mean number of goods per customer is increasing over 9, the current value.

A third criterion is that errors shall be as few as possible. However, this criterion is not important in the new kind of check-out system envisaged by KF as a combination of codes and prices is used for identification purposes in the system. This will mean that total information in the code is redundant and that the computer can be programmed to identify most of the errors which occur in the system. The computer will compare the prices and codes to check if the combinations entered into it are the correct ones. Thus, if the goods have a certain code number the computer will check by means of special programmes if the price recorded together with the code number really is the price of the actual goods.

Using these computer programmes it will be possible to ascertain the type and number of errors made. Instantaneous or very rapid feedback of this data to cashiers at the check-out point should, of course, result in an improved performance with respect to errors.

A fourth criterion is that the system shall be as safe, easy and comfortable to use as possible both for the customer and the supermarket or department store personnel.

As well as easy and comfortable to use the system, it ought to be attractive for the customer.

It is very difficult to predict what kind of attitude customers will take to this new system relative to other systems. It is, therefore, also very difficult to suggest what kind of features the system ought to have to attract the customer.

The customer will probably get a positive attitude towards the system from such features as the provision of receipts on which the names of different goods purchased are written in a highly legible form. However, the customer may react negatively to the fact that not all goods are price marked and the fact that the system makes it easier to control and check if the customer tries to cheat the shop. Of course the handling of goods in the check-out system should be as easy and comfortable as possible for the customer. It is also important that the design of the system is such that the customer immediately understands how to perform in it.

(iv) Relative values

Finally, we have to define the value of the system. The question has to be posed. Is it really most appropriate and important to start the study at the point-of-sales in the KF shops and supermarkets or are there other problems which ought to have a higher priority? It is, for example, more important to study the transport of goods within the parent system (the supermarket) or

is it more important to study possible ways of collecting goods in the shop? This, of course, is a very difficult question to answer in an objective way.

However, the priority problem has been presented to the Board of KF, and it has decided that new systems for collecting sales statistics, sales information and new processes for merchandising ought to be studied and developed. This decision seems to be in agreement with arguments presented in the literature for example by Unger (1970) who says that if new systems of this kind are not developed, it will be very difficult for the supermarket to survive without very many problems. A similar argument is also presented by Petersen (1971). On the other hand Ewing (1967) seems to be doubtful about the need for new electronic automatic systems in retailing.

From experiments which have been carried out to investigate the effects of different kinds of technological developments in retailing (Petersen, 1971), it seems quite clear that automation and electronification of the check-out system seems to be the most profitable innovation today, both from an economic and human point of view. It is, however, more difficult to say much of significance about the value of this kind of system in the long term. It is also very difficult to predict what kind of impact this kind of system will have on the culture and social-geographical situation in Sweden.

At the moment the cost of automated or electronic check-out systems is quite considerable. This will inevitably mean that the introduction of this kind of system will promote the development of larger retailing units, i.e., bigger supermarkets and department stores.

This in turn will increase the distance between the shopping place and living areas. Thus as a result, people may travel much more. As things are today, travel will be effected to a great extent in private vehicles with increases of air pollution and traffic accidents, etc. However, if the development of this new kind of system is carefully controlled, the consequences may in the long run be different from those given above. Of course the provision of better ways of transferring information, (e.g. electronically on a telephone network) may make it possible to locate sales terminals in very small shopping areas. It may also be possible to combine this kind of electronic system with new display systems, so that the customer can order in a sort of "electronic mail order" activation.

Small shops can only carry a very limited number of items in stock. However, by means of this very advanced display set-up, the number of items available, from an information point of view, could be increased considerably. This would mean that the goods which are not physically available in the shop could be studied by the customer through the new electronic point-of-sales system. However,

this possibility is only a vague speculation and such a system is not a reality today. But systematic studies in this area could establish what social effects new automatic retailing system will have.

2.3 The functions of the system

Functional analysis is also a very important part of the design method. The end product of function analysis is some kind of functional diagram. It is very important that, in the definition of different functions, few preassumptions are made. It is important, in particular, that in this part of the work functions are not assigned to either physical or human agencies. The different functions should not be defined in a physical sense until later in the design process. At that stage allocation of function to man or machine or both should be made in the light of systems criteria.

An abstract function analysis correctly performed can be a good aid in order to find the new and better solutions in that it divorces the designers mind from conventional thinking and the limitations that imposes on the creative process.

i. How to define functions

It is difficult to think of the system functions in an abstract way divorced from possible solution. Man is conditioned to associate certain objects with certain functions due to the fact that in the world around him objects and functions co-exist together in given combinations. To simplify our thinking we often try to make concrete the abstraction. This leads us to think of objects and functions in familiar ways. When we talk about the check-out system in department stores and supermarkets, the cashier, cash register, cash desk and a customer immediately come to mind in their conventional forms. But it is by no means certain that these components are necessary to the proper functioning of a new check-out system. Even if they remain, in part their function may be

changed. Singleton (1967) discusses the difference between physical and functional diagrams and the problems which arise in connection with them.

It is also very difficult to determine at what level the different functions shall be defined. If the functions are defined in too broad and too general terms the allocation process becomes meaningless as these general and broad functions very often s imultaneously require both human and technological components. This kind of division of functions does not assist in the design of the different technical components. Nor does it give any help in the analysis of what kind of work the man has to do in the system, on the basis of which the design of training programmes, selection schemes, work aids, etc., may be carried out.

Conversely it is probably not so dangerous to go into great detail in the divisions of functions. It is, of course, useless to define the functions in such small units that it is inevitably true that if one function is assigned to man a whole series of other functions is necessarily assigned. Ideally the level of analysis should be such that the associated functions fall under one heading. Thus, when a functional analysis which Is conducted is operator oriented, knowledge about the operator's skill can be used as a clue to how detailed the function division need be. Gagne (1962) gives some general conditions which have to be fulfilled in the allocation of functions to man and these conditions can in fact give some clues about a suitable level of defining functions.

ii. Main functions and function diagram

Table 1.1 gives the different functions in a check-out system with the limitations which are given by the parent system, i.e. the new supermarket and ordering system for KF. In Figure 1.3 all these different functions are put together in a diagram. The lines and arrows between the different functions indicate the time-cause relationship between them and thus also describe the functional flow between the inputs and outputs. Table 1.1 and Figure 1.3 largely speak for themselves, but in the interests of clarity a summary of the functional analysis is given below.

The starting point of the system is that different kinds of goods enter it, (function no. 1). The goods are then stored (no. 2) while they are waiting to be transported (no. 3). The first part of the transportation is to a point where the goods can be identified (no. 4) and allowing this transportation the function flow divides into two: one function line is concerned with the transfer of information and the other with further physical transportation of the goods, (no. 51).

These function lines are considered in turn, the transfer of information line first. The initial step on this line is the identification of the goods according to the coding system, if any, adopted. If no identification is available on the goods, a series of functions follows in order to find the correct code number and/or price.

If the goods are properly marked it has to be decided if they are marked with either a code or a code and price or a code and weight. Three different kinds of action have to be carried out consequential upon code, weight and price

TABLE 1.1

LIST OF FUNCTIONS IN A CHECK-OUT SYSTEM

Notes

i. The numbers refer to the boxes in Figure 1.3

ii. The physical agent; man, machine or manfunction normally carrying out the function in present existing systems are indicated in the parenthesis below.

1 - Entering of goods into system (man)

2 - Storage (machine or man)

3 - Turning and transport (man and machine)

4 - Identify goods (man)

5 - Decide if or if not marked (man)

6 - Decide if marked code or code + price + weight (man)

7 - Decide if or if not the code + price are in the price and code storage (man)

8 - Recall price and code (man or machine)

9 - Price and code storage (machine)

10 - Different kinds of action (man)

11 - Read price (man)

12 - Select and decide registrations action - what keys to be depressed if the keyboard is used - (man)

13 - Perform registration of price (man and machine)

14 - Perform registration of the key to defining that the previous information was a price (man and machine)

15 - Read code (man)

16 - Select and decide code registration action (man)

17 - Perform registration of code (man and machine)

18 - Perform registration of the key defining that the previous information was a price (man and machine)

TABLE 1.1 (continued)

LIST OF FUNCTIONS IN A CHECK-OUT SYSTEM

19 - Read weight (man)

20 - Select and decide registration action of weight on figure keys (man)

21 - Perform registration of weight on figure keys (man and machine)

22 - Perform registration on weight key (man and machine)

23 - Read code (man)

24 - Perform registration of code on figure keys (man and machine)

26 - Perform registration on code key (no-key) (man and machine)

27 - Read code (man)

28 - Select and decide code registration action (man)

29 - Perform registration of code on figure keys (man and machine)

31 - Select and collect price from price storage (man)

32 - Price storage (machine)

33 - Perform registration of price on the cash-register print-out (man and machine)

34 - Decide if or if not the last parcel is handled (man)

35 - Compute the sum, discounts, etc. (machine)

36 - Store prices and codes (machine)

37 - Inform the customer about the price to pay (man)

38 - Take up means of payment (man)

39 - Find kind and amount of payment (man)

40 - Transport the payment (man)

41 - Receive payment (man)

42 - Read off the payment (man)

43 - Record the received payment (man)

44 - Decide if it is the correct amount of payment (man)

45 - Compute the change (man and machine)

TABLE 1.1 (continued)

LIST OF FUNCTIONS IN A CHECK-OUT SYSTEM

46 - Transport the change (man)

47 - Store the change (man)

48 - Store the payment (machine)

49 - Make a receipt (machine)

50 - Transport the receipt (man)

51 - Transport goods (man or machine)

52 - Store goods (man or machine)

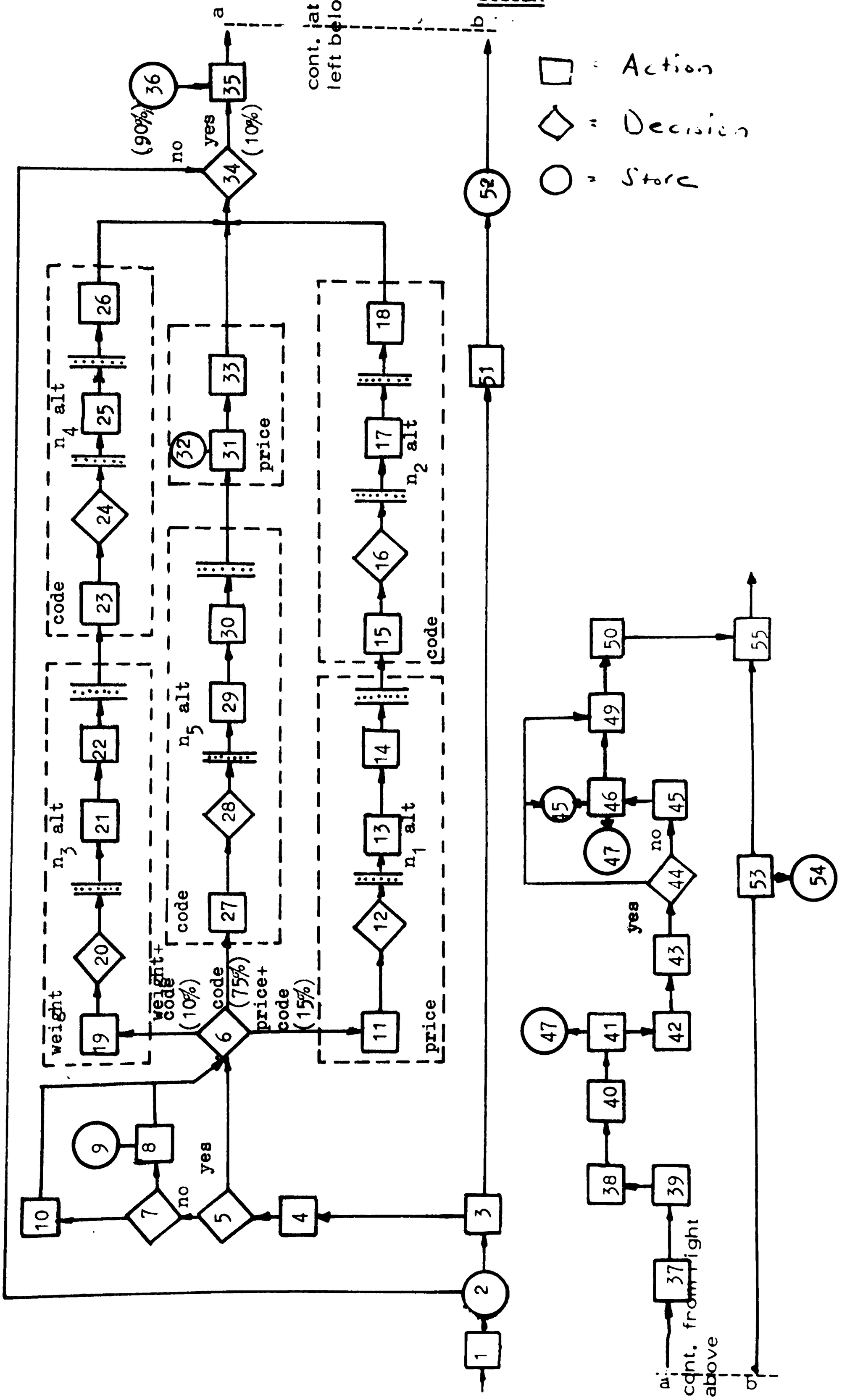
53 - Pack the goods (man)

54 - Store wrapping and bags (machine)

55 - Removal (man)

FIGURE 1.3

FUNCTION FLOW DIAGRAM OF A CHECK-OUT SYSTEM



information availability. For example, if the goods are price and code marked then first the price has to be read. The selection of appropriate registration action in relation to price has to be effected. Thereafter comes the actual registration of the price and also an action which indicates that the previous registration was one of a price and not a code. An analogous procedure is followed for the code.

It has to be decided if the good being dealt with is the last one to be handled. If not, the procedure is repeated again from function number two for new goods. If the good in question is the last, we go on to compute the sum, discounts, etc., and this information is also stored, (function 36). The customer has to be informed about the price he has to pay for the goods. He has to find the appropriate means of payment. The payment has to be introduced into the system and then checked and recorded. If the correct payment has not been given, the change has to be computed and transported to a storage place from where the customer can take it.

The amount payable for the goods has to be stored and a receipt has to be made which also has to be transported away.

Parallel to these informational processes the goods are transported through the system, (no. 51) to a storage location. The goods have to be packed and the packing material is taken from a storage of wrappings and bags. Finally the goods have to be removed from the system together with the receipt.

2.4 The allocation

It is at the allocation stage of the design process when it is appropriate to decide which functions are to be carried out by technical means and which by man, (in the form of the customer or the cashier). For example the entry of goods into the system can either be performed by technical equipment or by the customer or by the cashier. One can conceive an automatic device which picks up the goods from the carrier in which they have been collected and places them on the cash desk. This could also be done by the cashier or the customer. In the same way the transport of goods through the system could be done by means of human hands (the cashier's or the customer's) or by a mechanical conveyor belt of some kind. The identification of the goods and the reading of the code and the price could also be effected by some kind of automatic device or by the cashier or perhaps the customer. The codes and prices of the goods could be stored in a computer or in the cashier's head. The packing of the goods could be carried out by a technical device or by man. Which of these different alternatives is finally adopted should be decided in the light of the previously given criteria, (i.e. speed, accuracy, comfort and so on).

i. Different methods of allocation

When system analyses are used for military applications, the main criteria involve consideration of system performance. System performance is, of course dependent on man and machine performance. A number of listings comparing the performance of man and machine has been published. The most well known is the Fitts List and a modification of this list is published in Gagne (1962). But in civilian

applications other criteria also have to be considered. Economic criteria for example are important. This is especially true for the retailing business. Finally, and perhaps most important is the way the system interacts with man. Will man be injured or worn out, or will he feel uncomfortable and tired by the use of the system? If possible one should also consider whether or not the system is creating meaningful jobs for its employees and if the system is attractive to the user.

This allocation procedure can partly be aided by the use of ergonomic check lists (e.g. the International Ergonomics Check List 1964). From this kind of check list and lists of the type similar to that of Fitts', one can consider man performance relative to the performance of different kinds of technical devices. The check list also gives information from which judgments can be made about comfort, ease of use and to a certain extent, risks to health. Sometimes it is possible to get information about different kinds of socio-psychological questions such as the meaningfulness of the job. To a certain extent all this information can be used for economic calculations. For example information about man's performance can sometimes be translated into economic terms. However, it is much more difficult to translate the meaningfulness of the job, the risks to health, etc. to economic values.

The ideal would probably be that the ergonomist defines what kind of problems, for man, are associated with different system alternatives. These alternatives can then be subject to collaboration between the employers and employees. Who must answer the question: How much are we prepared to pay for the better working conditions? Of course the presentation has to be in such a

language that both the employers and employees fully can understand the consequences of the different alternatives and from the collaboration arrive at a common decision about a suitable alternative.

However, the state of the art has not yet reached the point where the ergonomist in general can make this kind of judgement just from a theoretical function analysis. There are still many situations where the ergonomist is not able to predict what the practical result for man will be for a certain system solution, (i.e. which kind of cash desk is best from a comfort and performance point of view). In this kind of situation the only rational, where feasible, thing to do is to carry out an experiment in which different alternative design situations are tested. In the following section there is a brief general discussion about allocation of different functions. In subsequent parts of this thesis (Parts 3 and 4) some more detailed studies are described which contribute to a more understanding, realistic allocation of functions. A further discussion of allocation of functions is, therefore, given in the last part (Part 5) of this study.

ii. Discussion of allocation

To perform different kinds of physical activities such as the transporting and lifting of goods, the machine is often the best alternative. This is especially true when very simple manipulative operations have to be done and when they involve monotonous and repetitive functions. This is true both from the point of view of performance and from the point of view of different kinds of human criteria. For more complicated manipulations as turning the goods to read the price the technological alternatives are probably too

expensive and therefore man is probably the best from an economical point of view. The loading of the system is probably therefore best done by man.

The transport of the goods through the system is, for the reason given above, most naturally done by a machine. The identification of prices, codes, etc., can also quite easily be done by electronic and mechanical devices available today. However, these kinds of devices are very expensive. It is doubtful to decide if the increased performance really will even out this great investment cost. The economic transaction functions, (collection of money, etc), is, however, most probably experienced by the cashiers as an interesting part, and an automation of this part of the work has, therefore, to be done very carefully so that the motivation in the work is not decreased. The keying work of the cash register is a fairly tiring job especially on a full keyboard. There is also a lot of errors in the keying of full keyboards. A simplification of this part of the job ought to be of value for the cashier and the retailer. The technical alternative for the packing of the goods is probably preferred as well from the economical as from the human aspect. The reason for this is that this function slows down the speed of the system and this work probably is experienced as negative by the customer. Unfortunately most of the technical solutions, which have been suggested for this purpose, do not give a performance of a sufficiently high quality as perishable goods most probably will be damaged by a technical packing process.

Work and time studies carried out by KF Work-Study Department indicate that the functions which slow down the service-time in the present systems are loading, paying and packing. Further studies

of these functions ought, therefore, to be carried out. It is said (I have not been able to confirm this information) that development is taking place in the U.S.A. of goods carriages which incorporate a conveyor belt. When the carriage is pressed against the cash desk the conveyor belt of the carriage links together with the conveyor belt of the cash desk and the goods are automatically transported up onto the cashier's desk. For the paying function, perhaps the use of credit cards and accounts will provide a partial solution. The best method for packing may be the use of special staff for this task.

A new regulation embodied in the Swedish Factory Act require that the work place should be so designed that the cashier is able to sit during work, (KAS, 1967) and is not required to pack and transport the goods. This regulation has increased the cost of the new cash desk. It has been questioned by KF whether these changes really have improved working conditions for cashiers and if there are not more important problems which should first be solved for the cashiers. These questions are examined in Part 4 of this thesis.

In the assessment of different allocation alternatives it is most important that not only the function and behaviour of the completed system is considered. One has also to consider in what way different allocation alternatives affect the production environment, (i.e. the environment within and outside the factory) which will be needed to construct and build the new system. It is also most important to consider in what way a third party will be affected by the use of the completed system or in the process of completing the system. For example in the production of the system for transporting

people in air (e.g. in an aeroplane) one must not only consider the problems in the manufacturing of the system or the problems for the user of the systems.

One has also to consider that people not using the system may be affected by it, e.g. by noise and other pollutants. It is, however, sometimes very difficult to anticipate and evaluate these kinds of effects in the very early stages of design. This kind of evaluation can, however, come in at the stage of evaluation and design of system prototypes. How this would be done is discussed in more detail below. Some general comments could, however also be done in the system allocation stage.

Craig Sinclair (1970), suggests a method by means of which the effects of risk could be assessed in economic terms for the system user, the system producer and the third party. For the design of the check-out system it has not been possible to obtain sufficient detailed information from the manufacturers of the cash desk and cash register concerned to make the analysis suggested by Sinclair.

2.5 The design and system evaluation

For more complicated systems the actual design itself becomes a process which needs its own design system. The previous broad allocation of functions to man and machine has to be followed up on the technical side by an allocation to different technological professions and disciplines (i.e. should a particular function allocated to a machine be effected by a mechanical system, an electronic system, a chemical system, etc). For KF's new check-out system the design of the electronic computer, (see page 9) has been farmed out to a computer manufacturer. The design of other electronic ~~department~~ components of the ~~system~~ such as the keyboard has been a task for a new electronic department of the KF cash register factory. The design of the mechanical parts has been given as a task to the traditional mechanical department of the factory. Finally the design of the cash desk has been effected by a special working group with representatives from retailers, architects and the cash register manufacturers. An ergonomist has been acting as a consultant to these different parties.

i. Design of system components

In the design process the engineer concerned with producing hard-ware components is dependent upon ergonomic guidelines of different kinds. These guidelines can either be in the form of specifications produced by the ergonomist from different kinds of human criteria of the kind previously specified, (2.4). The specifications can either be in a more general form stating what kind of requirements should be fulfilled for man and the environment (e.g. maximum noise level, suitable comfort level, lighting and glare level, etc), or the specification could directly tell what kind of technological solutions

are most appropriate. The later kind of specification will though, contain details about, e.g. suitable insulating material, suitable light fittings, suitable configuration of keys on a keyboard and force in the springs for the keys, etc.

But as said before, the ergonomist is not always capable of producing this kind of specification. In such circumstances a prototype has to be designed and made up so that a proper test can be performed to find out which kind of design solution meets the criteria given in 2.4. In this present study Part 2 is an example of a specification for one critical part of the system. Part 3 is an example where not enough information was available to be given directly in the ergonomic specification and, therefore, an experiment had to be performed. Part 4 is an example of another method where detailed studies are done of the function of present systems and the effect of recent technological changes are analysed. From these kinds of detailed studies, one hopes to be able to draw conclusions about what kind of technical changes in the system will improve the systems function.

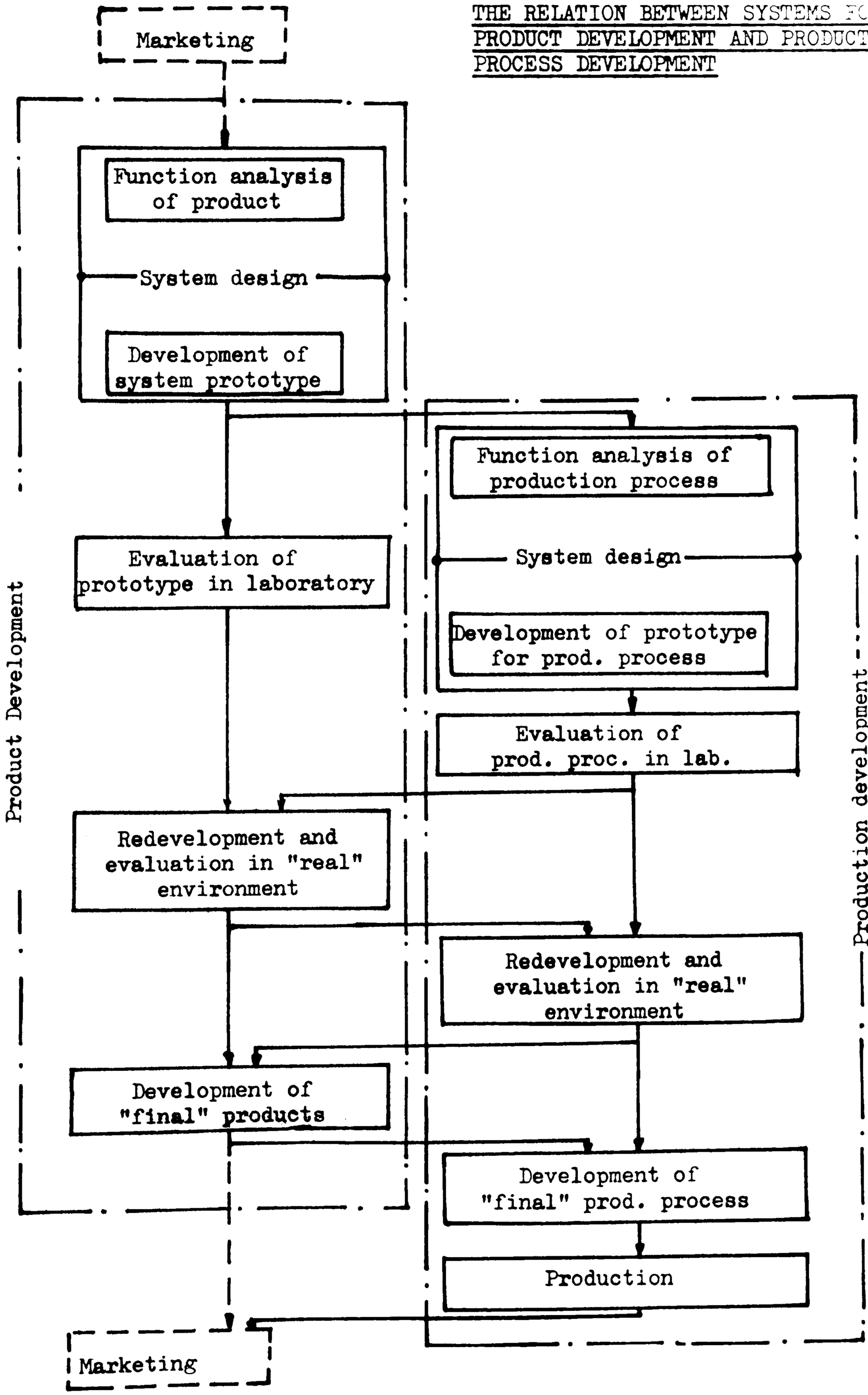
In the design stage there has also to be a design of the different personnel systems e.g. the training programmes and selection programmes and perhaps also to define different kinds of instructions for the customer. This work is not included in the present research study but some valuable material for such work will probably be obtained from some parts of the studies performed for Parts 3 and 4, where the performance in and attitude to the new check-out system will be studied.

ii. Design of production process for physical system components

In the design and development of a new system it is not only the system itself which has to be designed. Parallel to the design and development of the system, one has also to design a process whereby the system can be manufactured - a production process, (see page 14). The design of the manufacturing line ought to figure as early as possible in the design of the system. Some general work on this problem can start when the main system allocation process stage for the system is carried out. However, the main work on the design of the production line has largely to be done when the first system prototypes have been made up. The development of the production line in functional terms follows very much the same kind of design routine as for the system itself (see Figure 1.4). The analysis of the production process will, however, not be included in this Ph. D. project. For the sake of completeness, the principles for the design of the production system in relation to the design of the product have been presented.

FIGURE 1.4

THE RELATION BETWEEN SYSTEMS FOR PRODUCT DEVELOPMENT AND PRODUCTION PROCESS DEVELOPMENT



2.6 Conclusions

In this chapter, an analysis and a description of a new planned check-out system for self-service shops has been performed in functional terms. The analysis has been done in such a way that as few assumptions as possible have been made which could limit the freedom for selection of technical and personnel solutions for the design work. The objectives of the system have been defined in as realistic and concrete terms as possible. Furthermore, the system has been broken down in functions and the way about how to allocate these functions to man or machine has been discussed.

The description of the system objectives will be of value in the general design work and constitutes the criterion for a final evaluation of the whole completed system. But it will also be of value for different kinds of sub evaluations, which will be performed for selection between different kinds of prototypes. Part 3 of this research project is an example of this kind of evaluation.

One can see from this study that there are great difficulties in performing the allocation of functions properly if one only has to rely on what is known about these kinds of systems in accordance with previous research reported in the open literature. This means that this study also indicates what areas should be studied in more detail. One can, for example, see that one critical point in the planned system is the loading of goods into the system. A questionnaire study of what the customer thinks about this kind of work could give some indication about these difficulties. A questionnaire study directed towards the customer is included in Part 4.

Value of mechanical transportation of the goods within the system has been questioned by KF. Some study of this kind has been performed (Carlsöö, 1967). However, more information could perhaps be obtained by interviews and questionnare studies directed towards the cashiers and to some extent by interviews with the customer. Also these kind of studies are included in Part 4.

An important part is the function which deals with the identification of the price and identity of goods. This is interesting, because the system as it is designed today (i.e. keying prices into a cash register) means a lot of errors, which increases the loss for the shop. By Carlsöö (1967) and others this keying work on cash registers is claimed to create an unsuitable work posture for the cashiers. It is also interesting from the point of view that in this new planned system, not only the price of the goods, but also the identity of the goods, (the code number) should be sent into the system. In this first stage it is judged by KF as unwise to go the full step out in the technological development and choose an automatic reading device. One works instead under a transitional period relying on some form of keyboard. Part 2 of this research project gives a review of the use of keyboards for inputting information to the computer. It also gives a specification of a design of keyboard to be used in the new KF check-out system. Part 3 is an experimental evaluation of two alternative keyboard prototypes specified in Part 2.

Another very interesting point according to the allocation process is the paying function where one could discuss several alternative solutions, both human and technological. However, in this case

it is at present of no interest as KF at the moment are not prepared to make any changes in relation to what is being used today. The cash system is a part of the idea behind the Co-operative movement. Another interesting function is the packing of goods. Here to one hopes to obtain further information from the interviews and questionnaire study of Part 4.

AN ERGONOMICS STUDY OF THE CHECK-OUT SYSTEM FOR SELF-SERVICE SHOPS IN SWEDEN

PART 2

LITERATURE REVIEW OF THE ERGONOMICS OF KEYBOARD AND A DESIGN SPECIFICATION FOR CASH REGISTER KEYBOARDS

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3.0 INTRODUCTION TO PART 2

The second chapter (in Part 1) indicates different problem areas which have to be studied in more detail. In the second chapter also, different objectives for this new planned system are given.

As one can see from the allocation procedure there are some problems to select proper means for fulfilling the functions in the check out system dealing with identification of different kinds and types of goods. It is doubtful what technical means are the most appropriate in terms of human comfort, well-being and in speed and accuracy of work. The KF cash register factory in this first stage of development is primarily interested in some kind of keyboard solution. In a second stage automatic devices for the reading and inputting information, prices and codes of the goods to the computer system of the shops will be considered.

The aim of this second part of the research project is to produce a background knowledge of previous research about the interface between the operator and the keyboard and to produce a specification for a design of two keyboard prototypes which could fulfil the system objectives. A subsequent experimental study (Part 3) will then be performed in order to select the best of these two prototypes and also in order to describe the performance of work on these two kinds of keyboards.

4.0 LITERATURE REVIEW

Ergonomics design work starts with a definite aim (Ivergård 1969). The aim in the system under consideration is to make it possible to feed into a central computer, by means of key-boards, the kinds and amounts of goods bought in a shop or supermarket. The criterion of the system is that it should allow the best possible performance: accuracy is vitally important, and the number of errors should be minimized. Speed, however, can be regarded as less important. The keyboard which is a sub-system to this system should be designed in such a way that nobody will be damaged by working at it for a long time. It should also be designed so that it feels natural and comfortable in use.

The following topics are discussed in succeeding sections; the keyboard surface, location of the keys on the keyboard, design of the individual keys, marking of the keys, selection and training of keyboard operators and inputting information to a computer other than by a keyboard.

4.1 The keyboard surface

To avoid the operator becoming damaged in the long term or tired in the short term, the keyboard should be so designed that the angle between the upper arm and the forearm is at least 90^{o}, perferably slightly more, though no upper angular limit is specified (Carlsöö 1967, Langdon 1965, Yllö 1962). During a longer period of work performance can possibly also be improved, if the keyboard is positioned at the correct height and angle (Yllö 1962).

According to Creamer and Trumbo (1960) and Kroemer (1963), the speed capacity can be increased if the keyboard (for the right hand) is turned anti-clockwise in the horizontal plane through at least 30^{o}. Kroemer says that this location of the keyboard also leads to a physiologically more desirable position for the shoulder, arm and hand. This probably only applies if the keyboard is placed in line with the operator's sagittal section.

Chapanis et al (1965) showed that the operator felt that an inclination (inclination upwards seen from the operator) of the keyboard of 10^{o} was more comfortable. However, the speed of performance was not affected by the inclination of the keyboard. Dreyfuss (1959) is also of the opinion that an angle of about 11^{o} is optimal for the keyboard surface. The individual keys, however, ought to move vertically regardless of the inclination of the keyboard.

Carlsöö (1967) maintains, from an anthropometric point of view, that a keyboard operated by the right hand should be designed with an angle of $20 - 40^{o}$ inclination downwards from left to right to minimize strain.

The thumb preferably should not work in the same plane as the other fingers. If possible, the working plane of the thumb ought to be at an angle of 65 - 90° to that of the other fingers. (Stave, Personal Communication to Kinkead, 1967). This is probably applicable if great mobility of the thumb is required.

Within limits the size of the total surface of a keyboard does not affect the speed of work to any extent. The very large surfaces of full keyboards or of similar kind of keyboards may, however, decrease speed owing to the large movements that must be executed. Lower speeds of performance with full keyboards, however, chiefly arise from other causes. These are discussed in the next section.

4.2 Location of the keys on the keyboard

Several studies (Bertelson and De Cae 1961, KFO 1966, Minor and Ravesman 1962) show that so-called full keyboards are inferior to ten-button keyboards as regards speed and accuracy as well as fatigue. Furthermore, the full keyboards are often so big that they are very difficult to position in an ergonomically correct way at the place of work. It is also very difficult, (Seibel 1969) but possible (Swan 1969), to learn the touch-method on a full keyboard.

Several studies, described in detail below, have been made concerning the design of the ten-button keyboard. Work has mainly been done using two approaches. Firstly, studies have been made of where people expect to find the digits in a particular configuration of keys or in given sets of key configurations. Secondly, performance in terms of speed and accuracy has been studied. Two models for location of the keys have chiefly been evaluated: the arrangement where one starts in the upper row, from left to right, with the keys 1, 2, 3 and so on - this keyboard is henceforth referred to as "the 123-arrangement". This configuration is to be found on the new press button telephones and on most punch-tape and similar machines. The other arrangement has the figures 7, 8, 9, in the upper row, and the figures 1, 2, 3, in the lower row. This will subsequently be referred to as "the 789-arrangement" and is most common on adding machines.

Chapanis and Lutz (1965) show that people expect the 123-arrangement to a considerably greater extent than the 789-arrangement.

In a study, where 18 different kinds of key allocations were compared (Deininger 1960 a) similar results were obtained and it was also found that the 789-arrangement was the least frequently expected of the 18 arrangements. Chapanis and Lutz (1965) found that their subjects expected to find 0 after 9 and not before 1. Studies of speed and accuracy show that the arrangement 123 is consistently the best, and sometimes considerably better than the arrangement 789. A representative study is that of Conrad and Hull (1968); in it the number of errors with the 789-arrangement was twice as great as with the 123-arrangement. No paper has been found reporting how speed and accuracy are affected by the location of the zero key.

No special investigations have been found suggesting key positions for inputting information which is not numerical. However, there are some general ergonomics rules to consider (Ivergård 1969, Murrell 1965). There should be as few keys as possible, as the risk of incorrect strokes and the reaction time, i.e., registration speed, is affected in proportion to the number of keys. For a summary, see Ivergård (1968). The information transferred per key also affects reaction time and accuracy. High information per key increases the reaction time and the error frequency. The total number of strokes is decreased, however, by co-ordination of several keys to one key (i.e., increase of the amount of information per key). This means that the risk of incorrect strokes and the reaction time for the individual key increased, but, as the total number of keys decreases, the complete work is often faster, and the total error frequency less for all the keys (Conrad and Longman 1965, Seibel 1962, 1963, 1964).

Further, the keys should be allocated in such a way that keys used in sequences of frequent occurrence are placed near each other and in the correct order. A movement of the finger from one key to another decreases the speed compared with using another finger for the other key (Hällje 1957, Webb and Coburn 1959). This means that one ought to have the "start position" on keys that are used frequently, and the keys used in sequences ought to load different fingers. This is particularly the case if one wants to obtain the highest possible speed. Incorrect strokes are most frequently obtained on keys placed above, below or immediately to the side of the key that should have been pressed. Studies, for example, by Conrad (1967), show this. Other studies, for example by Flynn (1959), show on a typewriter that errors have a slightly higher tendency to occur on the same line. Diagonal errors, however, are considerably less frequent. This means that keys that must not be confused should be placed diagonally in the first place, and secondly above each other, if they cannot be placed at a distance from each other. If it is of little consequence that the keys are confused, they can be placed beside each other. Westhoff (1962) obtains the same results as Flynn using a 10-keyboard. Conrad also points out that errors are dependent to a great extent upon memory and not only the location of the keys.

Fundamental to the ergonomically satisfactory design of a keyboard is that account should be taken of the expectations of the operator. For example, keys systematically used first should be placed furthest to the left, and preferably above keys that come later. Of particular importance is the order from left to right. Keys

that belong together should also, for reasons of expectation, be grouped together in some way. This grouping can be stressed by marking keys that belong together with the same colour. All colour markings should be sufficiently light or dark to give adequate contrast against information that may be written on the keys.

Carlsöö (1967) recommends a curved configuration of the key rows on a full keyboard. It is doubtful what the value of this kind of arrangement might be. The fan-shaped keyboard used by Webb and Coburn (1959) is possibly only of any value when the fingers do not have to move, as in their own experiment.

According to Kinkead (1967) the precision of movement of the thumb is less than that of the other fingers. The converse is true for muscular capacity. Of the other fingers, the index finger is the strongest and has the greatest precision, and the little finger is the weakest.

4.3 Design of the individual keys

According to standard specified by manufacturers (Kinkead 1967) the ideal distance between key centres should be 19 mm, and certainly not less that 16 mm. The force needed to press down a key should be between 100 and 300 grams (Dreyfuss 1959). The optimum depression distance is found to be 4.75 mm. In studies by Deininger (1960 b) andGallo and Levine (1966) no significant effects on speed have been found by changing the force and the depression distance. The surface of the key should be horizontal and the direction of depression vertical if possible. The best size of the key is 12 - 13 mm diameter.

Studies show that the feed-back to the operator concerning key depressing need not be visual or auditory to allow optimal performance. The removal of auditory feed-back has been studied by Diehl and Seibel (1962). It did not affect performance. Devoe (1967) shows, however, that visual feed-back does affect unskilled performance. The best and most important forms of feed-back are the kinaesthetic, proprioceptive and tactile which the operator receives by actually performing the movement and pressing the keys (Kinkead 1967). When learning the work at the keyboard, however, visual feed-back is important in keeping the number of errors small.

A general ergonomics recommendation is that the tactile, kinaesthetic and proprioceptive feed-back can be improved by increasing the resistance of the key at the beginning of the depression, then suddenly decreasing and finally suddenly increasing the resistance very strongly, i.e., the key goes to

the bottom (Morgan et al 1963). Unfortunately, there are no studies showing whether this form of pressure-dip on the key affects performance in any way. No definite result was obtained in a study by Deininger (1969b). Bowen (1964) is of the opinion that pressure-dips on typewriters and similar instruments are not desirable. Neither are there any studies showing how the very easily moved electric typewriter keys which only require a force of 55 - 58 grams, affect performance. Studies by Floyd and Edwards (1963) and Carlsöö (1968) show that the muscular effort (measured by EMG) is less on electric typewriters than on mechanical typewriters.

In the Computer International there is a report on research by Hale (1971) who claims: "there may be no point in operator pressing one key within 30 msec of pressing another". In a study Minor (1964) shows that a keyboard which allows maximal work-speed of 8 CPS (characters per second) compared with another keyboard, with an interlocking system, which limits the work speed to 13 CPS, gives a faster performance and more corrected errors and less uncorrected errors. This result seems to indicate that an interlocking system which limits the maximum workspeed could be of value.

4.4 Marking of the keys

Very few studies have been found showing how keys should be marked to indicate the information they transmit.

Morgan et al (1963) give, however, a number of recommendations, which could be of some value in solving this problem. If letters and numbers have sharp outlines, high contrast, and are well lighted, they can be indentified accurately if they are greater than 10 min. of visual angle. Capital letters are visible at a greater distance than lower-case. Labels should be as brief as possible, and should only consist of abbreviated words if the abbreviated form is familiar to all users. The best label indicates what is done and not the name of the device, as in the following: R PM not Tachometer use SPEED and not Speedometer, etc. A list of suitable surface colours is also given by Morgan et al (1963).

Some letters and numbers are easily confused with others because of their shapes (McArthur 1965). Recommended specifications for the design of letters and numbers are given in US, National Bureau of Standards: Legibility of Alphanumeric Characters and Other Symbols (1967).

4.5 The skill in the operation of numeric keyboards

The keyboard operation consists of the following main functions:

i Input of information for operator (reading, hearing etc)

ii Memorizing and decoding information and decision

iii Input of information to keyboard

The skill on keyboard operation is therefore dependent upon the skill in these different functions. As the conditions determining the skill of these different functions normally are not the same for experiments by different research workers, it is very difficult to give any quantative data about the performance on keyboards. Some indications are however, given below.

The speed of performance on full keyboards seems to be in the range 50 to 100 strokes per minute according to Minor and Ravesman (1962). This is to be compared with the speed on a ten keyboard which could be fast as 250 keyings/min. (calculated from Wärnberg's 1971, measurements of interdigital times) for very skilled subjects if the relation between the interdigital time and the time on the key is set to 1/2.7 (Ganitta, 1967). Other authors (Devoe 1967) have reported the speed of performance to be in the range of 135 to 200 strokes per minute for professional key punching operators and about 55 - 76 keyings per minute for adding machines. The reports of the number of errors on numerical keyboard operations varies very much, from 0.1% to 10% dependent upon the general conditions for the study.

In the literature there is a substantial body of data on how the performance of an operator-keyboard system can be considerably improved by proper selection and training of operators. At the

Co-Operative Union there is a system for the selection of self-service cashiers. The general opinion in KF is that it is very valuable. The present system does not, however, incorporate application of interesting developments in the area of short term memory (Broadbent 1965, Deininger 1960 a), and serial reaction time (Leonard and Carpenter 1964), which may have implications in the present context and for selection and training. Personality factors could also be of relevance for the selection procedure (Eysenck 1965).

Kinkead (1967) reports that touch operation of a ten-keyboard can be learnt in about two days of practice. No significant improvement in performance was found by Devoe (1967) after three days of practice. No data on full keyboard training have been found. The training officers of KF report, however, considerable increase in speed of performance after five days systematic training. A recent study (Hanson 1971), indicates that the cashiers only to a very limited extent are using the 'touch' keying method.

According to Klemmer and Lockhead (1960) performance on data entry task shows improvements with practice over periods of at least two years. The kind of skills which are being used in keying are changed after long time of practice, (Leonards and Newman 1964). This will mean that predictions for selection test cannot be the same for low levels of skill as for higher levels. Fleishman (1960) gives a review of different factors of importance in prediction of the keying skill.

4.6 Inputting information to a computer other than by a keyboard

Feeding data into a computer can be achieved in several different ways, other than by means of a keyboard. Man's quickest and most accurate channel is his voice. In the future one can expect that there will be relatively simple and cheap methods for automatic registration of the human voice, whereby information can be spoken directly into computers. There are already technical methods by means of which communication performance can be considerably improved. One can today, unfortunately, only obtain technical solutions for very limited aims (Cornog and Cornog 1969).

Other forms of more advanced technical solutions for communication between man and computers are touch displays. Even methods for automatic reading by means of photocells, magnetic touch arrangements and the like will, in the near future, be of such high technical standard that they can compete with man's capacity on the keyboard (Cornog and Cornog 1969). Today, however, most kinds of such instruments cannot, in view of their limitations, compete with the human operator. The automatic reading arrangements are so sensitive to correct adjustment of position, location and time, that the manipulating time often becomes as long as the time required to perform a single keyboard input. On the other hand automatic reading can lead to less errors than keyboard input (Hirsch et al 1960). The cost of automatic reading is still also very high.

Recently, Power (1971) discussed these different kinds of methods used in retailing in inputting instrumentation other than by a keyboard. The most common method is the so-called print-punch

ticket. These tickets, which are used as the price-marking medium, contain perforated machine-readable coding. More recent innovations are the use of the methods of optically or magnetically encoded identification tickets. This identification is done through a stroking action over the ticket at the time of sale. No performance data of the operators is, however, given by Power.

In Shackel and Shipley (1970) is given a review of ergonomics research on different devices other than keyboards for inputting information to computers. They do, for example, a comparison between alternate input devices. But none of the devices or methods seem to be applicable for the check-out system in supermarkets.

5.0 DESIGN SPECIFICATION

5.1 Description of sequences and frequencies of keying

In order to provide a rational starting point for the design specification of a keyboard for a new cash computer system, a special analysis has been made. In it have been recorded the different types, frequencies and sequences of occurrence of the various kinds of information, which are needed, to describe the purchases of the customer, and which are to be fed into the computer via the keyboard. The material given below is based upon data kindly provided by Gunnar Lenning, of the Hugin Cash-Register Manufacturing Company and Bertil Karlsson, of the Retailing Department of KF.

The general features of the new cash computer system are given in the first report. The following information on an item purchased by a customer can be recorded by the cash-register operator:-

(I) its code number

(II) the quantity of the item purchased

(III) the price of the item

It is intended that special keys will be depressed to tell the computer if it is a code, quantity or price, which is to be registered subsequently on digit keys. It will also be possible to ask questions about the prices of different goods and to make corrections from the keyboard by depression of the appropriate keys.

In Figure 2.1 the following definitions have been adopted:

1. Keying = depression of keys
2. Transaction argument = that part of the transaction that defines the type of transaction (depression of price key, code number key, etc)
3. Transaction = depressions of the necessary digit keys (for a price, code number etc) and its corresponding transaction argument)
4. Transaction sequence = all necessary key depressions for one product or item (all transactions)

Items (10 bottles of milk are 10 items but only one product) purchased per customer per visit for 1972 can be estimated to number approximately 10. The comparable figure for 1969 is about 8.51. The present (1970) KF shop-planning allows for each customer purchasing 9.56 items. There is evidence that the number of items per customer is increasing.

16 % of items sold are perishables, excluding bread. It is possible that perishables should not only be code marked but also price marked.

The average number of items processed per day on each cash-register amounts to about 5000.

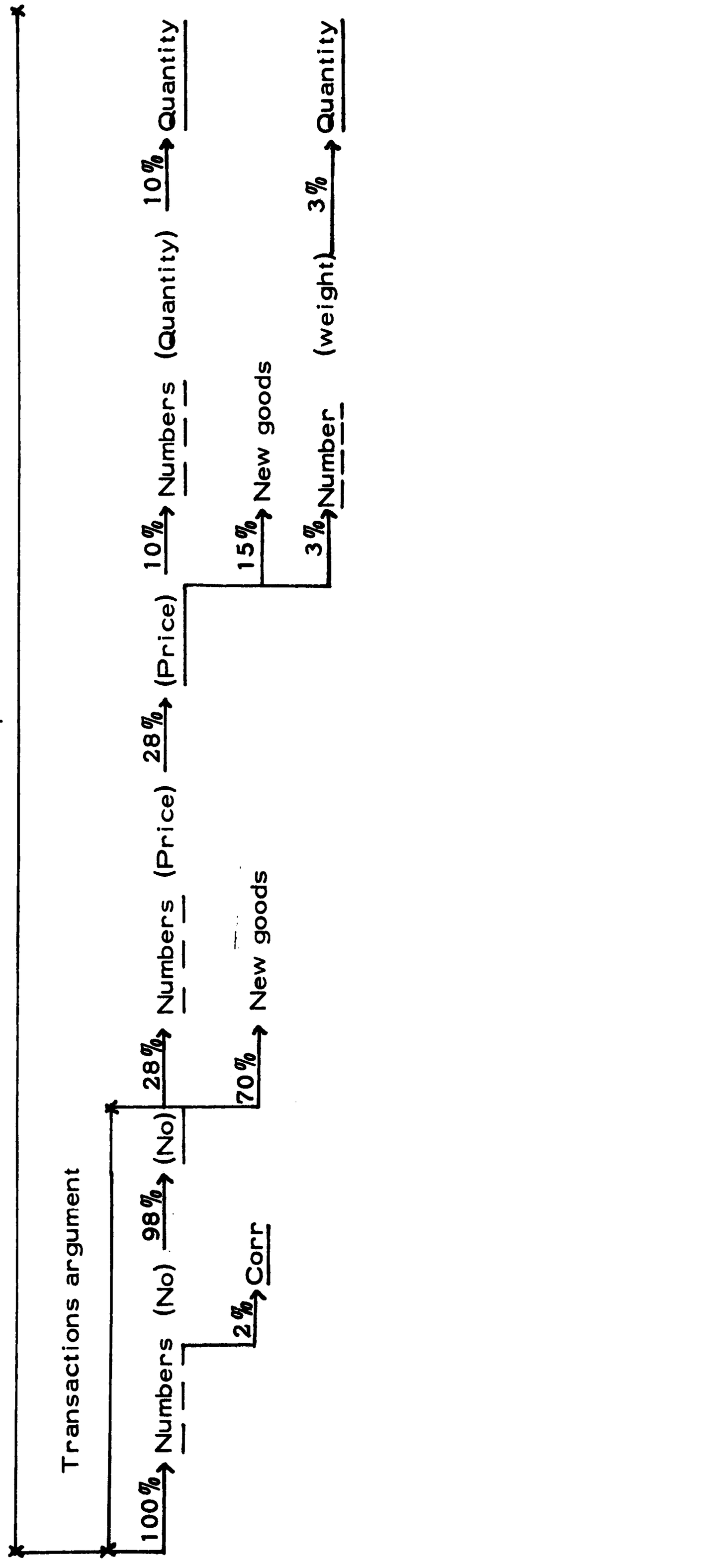
The most common transaction sequences will be clear from Figure 2.1.

The following conditions have been found to obtain:

- The price contains about 3 digits; the price occurs in 28 % of all transaction sequences

FIGURE 2.1

THE MOST COMMON TRANSACTION SEQUENCES



- The code contains about 3 digits; the code is found in 98 % of all transaction sequences

- Quantity is of two kinds; number of identical items and weight of an item. Number of identical items has been estimated to contain 1 digit on average and occurs in 10 % of the transaction sequences. Weight has been estimated to contain 3 digits and to have an occurrence of about 3 %

- The keying of correction contains about 2 digits and occurs in 2 % of all transaction sequences

The mean number of key depressions for digits alone per 100 transaction sequences will thus be:

$3 \times 28 + 3 \times 98 + 1 \times 10 + 3 \times 3 + 2 \times 2 = 400$, i.e. about 40 depressions per digit key.

The following assumptions have also been made;

- 1 price question per 10 customers
- 2 - 3 cashiers per cash-register per day

This gives the following frequencies of use for the keys of a cash-register:

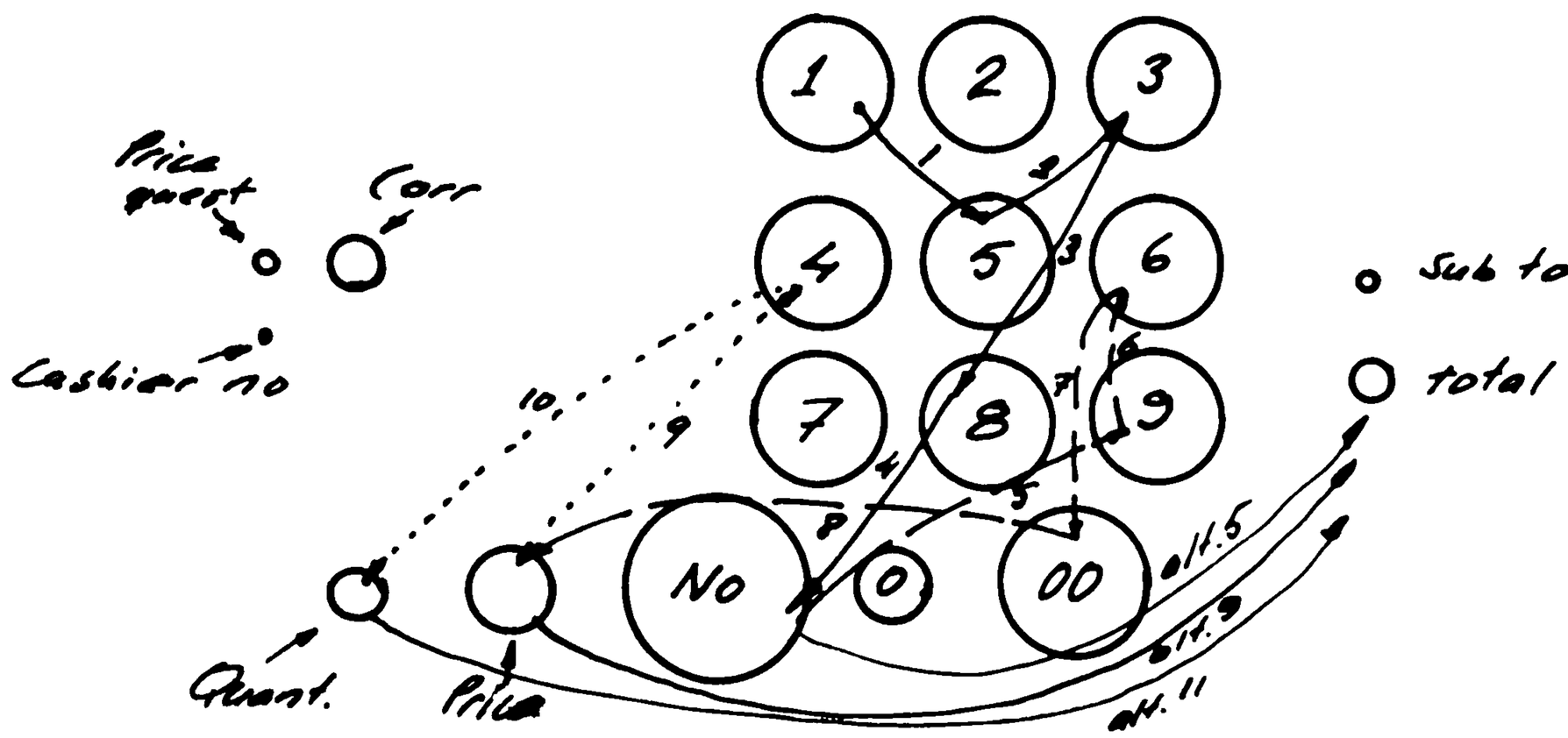
Digit keys (1, 2, 3, 4, 5, 6, 7, 8, 9, 0)	= 40 depressions per key per 100 transaction sequences
Code key (No)	= 98 do.
Price key (P)	= 28 do.
Quantity/weight key (W)	= 13 do.
Correction key (C)	= 2 do.

Total key (T)	= 10 depressions per key per 100 transaction sequences
Price-question key (Q)	= 1 do.
Number of the cashier key (CN)	= 1.05 do.

Figure 2.2 demonstrates a keyboard, whose key surfaces have their areas in proportion to their frequency of use. Sequential dependencies between keys are also shown in the figure.

FIGURE 2.2

A KEYBOARD, WHOSE KEY SURFACE HAS AREAS IN PROPORTION TO THEIR FREQUENCE OF USE SEQUENTIAL DEPENENCIES BETWEEN KEYS ARE ALSO SHOWN IN THE FIGURE



5.2 The keyboard surface

From the literature it is clearly shown that the keyboard surface should be placed on such a level that the surface of the keyboard is lower than the elbow. The keyboard should also be turned slightly anti-clockwise. To make the keyboard suitable for different applications the keyboard should be as small as possible so that it can be located without reducing other working space. The keyboard should also be as thin as possible so that the keyboard surface will not be too much higher than the working surface when placed on the desk.

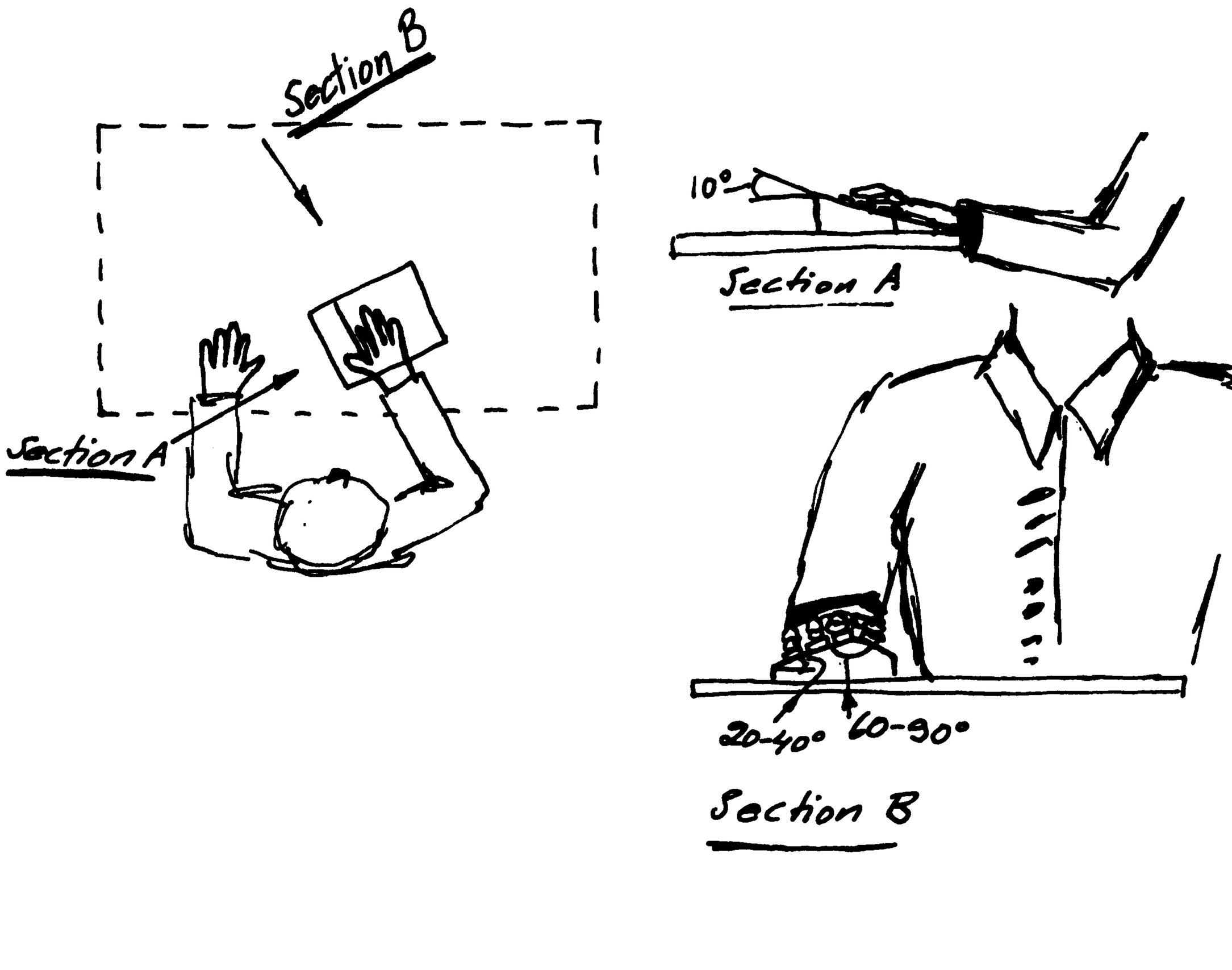
The keyboard surface should be designed with an inclination upwards of 10^{o} seen from the operator (It is doubtful if this is necessary when the keyboard surface is placed lower than the elbow). If possible the keyboard (for the right hand) surface should also be designed with an angle of 20 - 40^{o} inclination downwards from left to right. The keys operated by the thumb should be placed in a plane, which forms an angle of 60 - 90^{o} to the plane of the other keys.

To allow a good positioning of the keyboard at a frequently used exit cash-register it should be designed in such a way that an individual adjustment of the level and inclination of the keyboard is possible. As regards the possibility of sloping the keyboard it is primarily the inclination sideways that ought to be observed, but it should preferably also be possible to slope the near side of the keyboards forwards. In this context it should also be observed that the upper arm should have a slight angle forward in respect to the frontal section of the body.

The keyboard surface should also be supplied with some kind of extension to serve as a support for the wrist. An ideal keyboard is given in Figure 2.3.

FIGURE 2.3

AN IDEAL KEYBOARD ACCORDING TO LITERATURE



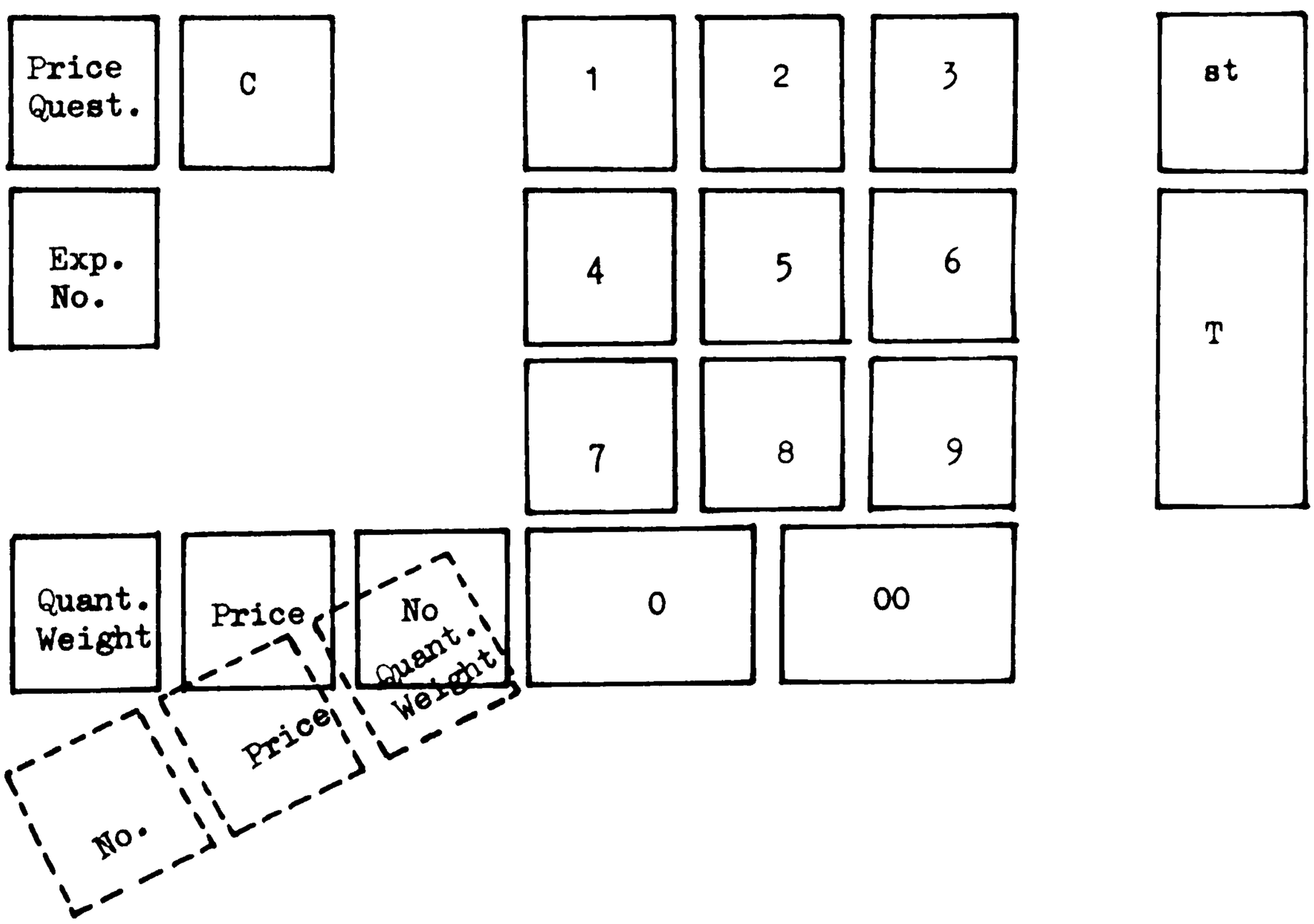
5.3 The location of keys

One condition of being able to use the touch-method after only a short period of learning (a few hours instead of several days of training) is that there are as few keys as possible. As soon as the number of keys becomes great it is very difficult to guide the fingers without also using the eyes. With visual guidance, there is a drastic decrease of working out-put and a considerable increase in the number of errors. Further, it has been considered that the precision of the thumb is a little less than that of the other fingers. The muscular capacity of the thumb is, on the contrary, greater than that of the other fingers. Of the rest of the fingers the index finger is the strongest and the little finger the weakest. The index finger has the greatest capacity of precision. It is a production demand that the keyboard should be operated by the right hand.

On these bases the configuration of the keyboard shown in Figure 2.4 appears to be the most logical. As an alternative, one should consider an exchange of the code key and the quantity/weight key to obtain a more natural working direction. The normal frequency of use of the three transaction argument keys in order is; code, price and quantity. This temporal order ought to recur as a natural (i.e. left to right) spatial order of the keyboard. Against this is the fact that the code key is used considerably more frequently than the price and quantity/weight keys and should, therefore, be placed nearer the digit keys. The position of the quantity/weight key in Figure 2.4 is less suitable from the anatomical point of view. On an ideal cash-register the transaction argument keys should be placed according to the dashed-line squares in Figure 2.4.

FIGURE 2.4

MOST LOGICAL LOCATION OF KEYS ON KEYBOARD



The deviation from the temporal order when using the transaction keys (quantity/weight, price and code keys) will probably not be of any importance to the well trained cashier. There is a risk, however, for the inexperienced. This risk should, however, be compared with the trouble that might occur for the operator's thumb, if the key for the thumb was placed in an anatomically less suitable position.

It is convenient to distinguish between keys which can be operated quickly, automatically, and with little thought by the cashier, and those which cannot, because circumstances leading to their activation are relatively unusual. On the present keyboard the digit keys, quantity/weight, price and code keys, and the total key are constantly in operation and the cashier can be expected to use the touch-method on them. The keys of question, correction and cashier number are much less frequently used and visual guidance of the fingers to these keys is necessary. As the index finger is specially suitable for operations where guidance by eye is required, it is advisable that this finger operates on these infrequently used keys: the index finger should also operate on the 0-key. The 00-keys can be operated by either the middle finger or the ring-finger. As is clear from Figure 2.2 the load on the different finger will be relatively similar with the exception of the little finger, which will be considerably less loaded than the middle finger and the ring finger.

With regard to the overwhelming amount of advantages that, according to the literature, are obtained with the arrangement 123, this system for allocating the digit keys is suggested, rather than the system 789. It is also clear from the literature

that this layout of the keyboard is also suitable for persons who alternatively use adding machines (the 789-arrangement) and keyboards with the arrangement 123. The new push-button telephones will have this allocation of the keys, which means that this keyboard will be the most commonly used in Sweden. One can expect that this arrangement will be the most common even for other applications of keyboards (for example in banks), as the ergonomic literature so clearly speaks in favour of it. The effect of negative transfer from the 789 to the 123-arrangement has not, however, been studied in very much detail. The transfer effect between the full keyboard and the different arrangement of 10-keyboards does not seem to have been studied at all.

5.4 The design of the individual keys

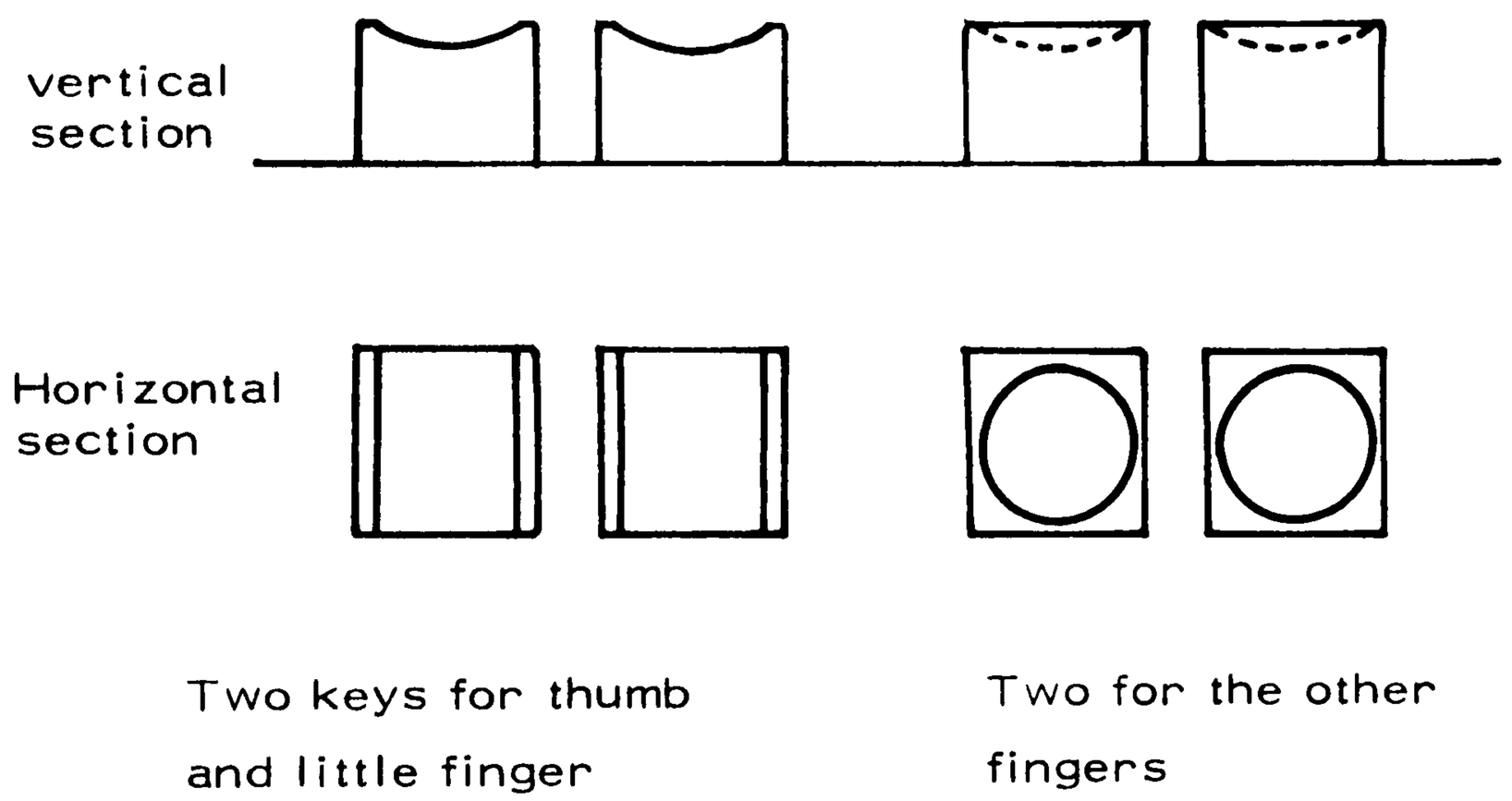
The surface of the individual keys should be horizontal and their moving direction vertical if possible. The keys should be located with a distance between the centres of 19 mm. The depression force of a key should preferably be about 80 grams, and the depression distance should be up to about 4.5 mm. The keys should be supplied with pressure dips, if possible.

Keys that will be used by all fingers except the little finger and the thumb ought to be bowl-shaped and have a matt surface. Keys that will be used by the thumb and possibly those that will be used by the little finger should have a matt surface too, but the surface should be concave to give a suitable position of approach for the horizontal finger. (See 2.5).

The keyboard ought to be provided with an interlocking system which does not allow a higher work speed than 10 keyings per second.

FIGURE 2.5

HORIZONTAL CONCAVE KEY FOR THUMB AND LITTLE FINGER



5.5 The marking of keys

The keys ought to be colour-marked in groups. The digit keys should have one colour; the constantly used transaction argument keys (quantity/weight, code, and price, total and sub-total) another colour and the unfrequently used keys (price-question, cashier-number) yet another. The correction key, which is used neither very frequently or infrequently, and moreover, has a special purpose, should have still another colour. The colours should be quite light or dark. The reason for this is that it is desirable to obtain a high contrast against the text that will be written on the keys.

To determine how the keys should be marked, further studies are needed. A questionnaire might be used for this purpose. By this technique it could be established what the cashier in the shops feel is the most natural in regard to different systems of marking, price, quantity, code, etc.

5.6 Selection and training of keyboard operators

The comprehensive working analysis and relatively detailed literature studies, which have been performed in Part 4 of this project, can form a basis for improving and creating methods of selection, teaching and training.

As regards selection it is, for example, very important to consider factors such as serial reaction time and short term memory. As regards teaching and training one has, for example, to consider for which types of feed-back the keyboard is most suited. The problem of selection and training will, therefore, be a separate study of its own, which will be reported separately within this project.

AN ERGONOMICS STUDY OF THE CHECK-OUT SYSTEM FOR SELF-SERVICE SHOPS IN SWEDEN

PART 3

AN EXPERIMENTAL EVALUATION OF TWO KEY-BOARDS

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6.0 THE AIM OF PART 3

The cashier's performance is of very great importance for the efficiency of a self-service shop. About 50% of the work time for the cashier consists of keying (KFO, 1967). A critical part of the cashier's performance involves the keying of prices and codes on the keyboard. Keying efficiency involves accuracy and speed of performance. Both of the latter affect in their turn customer service time and queue length. Information regarding keying error rates varies from different investigations. However, in most of the reported studies it seems as if the errors mainly consist of prices which are too low being keyed into the keyboards. This of course incurs a financial loss for the shop. According to an American investigation, (Hawell, 1967) the error rate could be as large as 2%. According to Swedish investigations, (Nilsson 1968) the error rate is just about one percent with a loss for the shop.

The cashier's ability to perform rapid and accurate work can be affected in several ways. Work performance may be improved by means of systematic training or selection. However, the most important thing is to obtain the correct working conditions. From the literature survey (Part 2) it would be inferred that a ten-button keyboard is superior to a full keyboard. The literature also seems to indicate that a top row with keys 1, 2, 3 is superior to a ten-button keyboard with a top row of keys 7, 8, 9. There is, however, some doubt about the conditions in which these conclusions hold true.

In particular, in development work of the new check-out system under consideration, the management of KF have questioned whether these results will apply. Within KF there are personnel who work on, and are used to either full-keyboards or ordinary desk calculators with the 789 ten-button keyboard system. No KF personnel have experience with the 123 ten-button keyboard. An experiment was therefore devised, the aim of which was to provide answers to the following questions:

1. which ten-button keyboard gives the best performance in terms of speed and accuracy for people with experience of either full keyboards or the ten-button keyboard with the key configuration 7, 8, 9 on the top row?

2. What are the operators subjective reactions to the two different kinds of keyboard, i.e. full, 1, 2, 3 and 7, 8, 9?

This experiment is discussed under the following headings:-

- Preliminaries of the experiment (Chapter 7) includes a discussion of the subjects used for the experiment and two different methods for selection and matching of the subjects.
- The planning of the experiment (Chapter 8).
- The results of the experiment (Chapter 9).

The last two chapters are both divided into two sections. The first section discusses the performance experiment and the second the performance testing, (i.e. the operators' subjective reactions).

7.0 PRELIMINARIES

Using the specification described in Part 2, two ten-button keyboards were manufactured for use in this experimental study. The keyboards were identical except that one was of 789 design, the other of 123 design.

The experimental comparison of two such keyboards involves many problems of experimental design. One of these, and it is discussed first, relates to the manner in which, and the basis on which, subjects are allocated to experimental conditions. In order to maximize sensitivity of performance measurement, it is usually recommended that either subjects act as their own controls and undergo all experimental conditions, or matched groups of subjects are assigned to the different experimental conditions. Something like the latter procedure was adopted in the present study. The principal reason for this was that the alternative, i.e. using subjects as their own controls, might have given rise to interference effects between experimental conditions which were difficult to interpret.

7.1 Introduction and type of subjects

One of the principal aims of this study is to demonstrate how performance differs on two kinds of keyboards for two special groups of subjects:- those with experience on full keyboards and those with experience on keyboards with a 7, 8, 9 button configuration.

Within KF two kinds of subjects with this experience were available for the study. One group consisted of young women undergoing training in KF as desk calculator operators. These women had experience on ordinary desk calculators with a 7, 8, 9 configuration keyboard. They did not have any experience on full-keyboards, or on the 1, 2, 3 keyboard.

Fifteen of the young women, who are henceforward called the "office girls" were available for the experiment.

The other group of subjects consisted of cashiers from two large KF supermarkets near Stockholm. These cashiers only had experience on the full-keyboard. Altogether thirty-two cashiers were available for the experiment. Henceforward this group will be known as the "cashiers".

Having obtained subjects relevant to the principal objectives of the experiment, it was then necessary within each group, (i.e. office girls and cashiers), to allocate subjects on a matched basis to each experimental condition. For reasons which will be apparent in later discussion, it seemed appropriate to match subjects in terms of their performance on two types of task, one involving reactions to serial stimuli, the other involving the use of short term memory.

7.2 Serial reaction time (SRT)

Leonard and Carpenter (1964) demonstrated that there is a relationship between performance on a serial reaction time task and performance at normal keyboard work. Equipment similar to that used by Leonard and Carpenter was constructed especially for this experiment (see Figure 3.1).

The equipment worked in the following way: fifty signals were generated at random. The signals were presented as figures 1, 2, 3, 4 or 5, one at a time, on a display tube. The subject had to react to the signal by pressing a corresponding key on a five button keyboard. As soon as the subject reacted to a given signal, a new signal was presented. This continued until 50 signals had been presented. The number of incorrect responses were recorded automatically and displayed on the back of an associated display unit. The total time from the presentation of the first signal to the response to the last were measured on a digital timing unit.

From this total reaction time and error count, an information capacity in bits of information per second was calculated for each subject in accordance with the following procedure.

FIGURE 3.1

EQUIPMENT SIMILAR TO THE ONE USED BY LEONARD & CARPENTER (1964) IN MEASURING OF SERIAL REACTION TIME. TO THE LEFT IS THE DIGIT DISPLAY AND DIGIT GENERATOR UNIT. TO THE RIGHT BEHIND THE KEYBOARD IS THE TIMING UNIT.

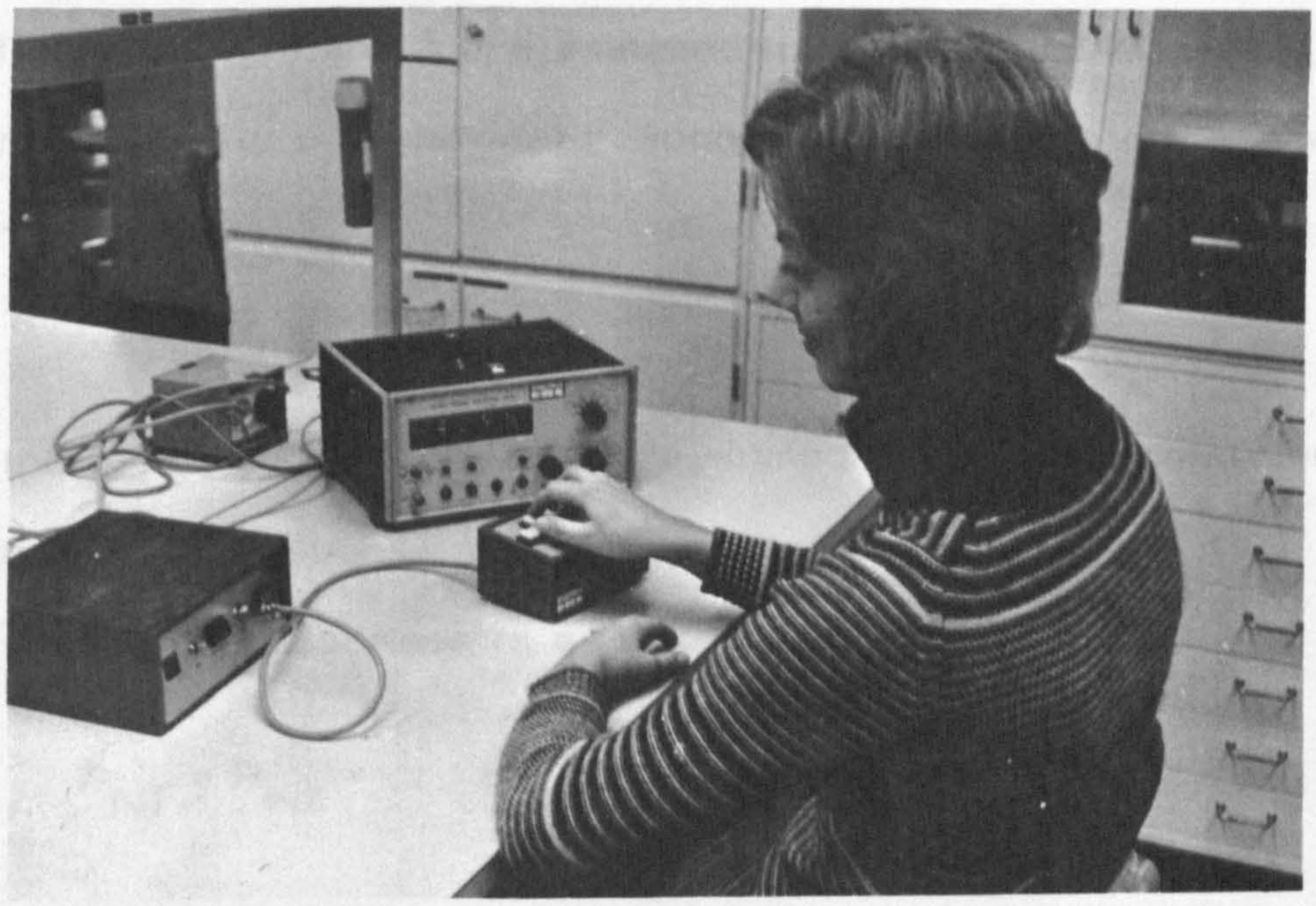


TABLE 3.1

CORRESPONDING VALUES BETWEEN INFORMATION TRANSMISSION (T_N) AND NUMBER OF INCORRECT RESPONSES (N)

T_N bits	2.32	2.24	2.00	1.87	1.76	1.67	1.46	1.37	1.28	1.20
N errors	1	2	3	4	5	6	7	8	9	10

Let N equal the number of reactions that are incorrect. Let it be assumed that these incorrect reactions are evenly distributed in the signal response matrix, (Figure 3.2). There are n or (50 - N) correct responses (the diagonal in the matrix). The digits 1, 2, 3, 4 and 5 are assumed to be equally frequent signals. The probability of a correct response (P_n) to signals 1 to 5 will then be:

$$P_{n1} = P_{n2} = P_{n3} = P_{n4} = P_{n5} = \frac{1}{5}\,(50-N)/50$$

As the incorrect responses are assumed to be evenly distributed in the signal-response matrix, the probability (P_N) for each of the incorrect responses is as follows:

$$P_{N1} = P_{N2} = \cdots P_{N20} = \frac{N}{20} \times \frac{1}{50}$$

The response and signal uncertainty (H_R & H_S) is calculated as:

$$H_R = H_S = \sum_{1}^{5} P \log_2 \frac{1}{P_n} = 5 \times \frac{1}{5} \log_2 5$$

The uncertainty for the whole matrix with N incorrect reactions will be:

$$H_N = \sum_{1}^{5} P_n \log_2 \frac{1}{P_n} + \sum_{1}^{20} P_N \log_2 \frac{1}{P_N} =$$

$$5\,\frac{(50-N)}{5 \times 50} \log_2 \frac{50 \times 5}{50 - N} + \frac{20 \times N}{20 \times 50} \log_2 \frac{20 \times 50}{N}$$

The information transmission (T_N) with N incorrect responses will hence be:

FIGURE 3.2

SIGNAL RESPONSE MATRIX FOR SERIAL REACTION TIME (SRT) TEST

Response Keying on keyboard		Signal Digits on Display				
		1	2	3	4	5
	$P_{r/s}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$
1	$\frac{1}{5}$	n_1	N_5	N_9	N_{10}	N_{17}
2	$\frac{1}{5}$	N_1	n_2	N_{10}	N_{14}	N_{18}
3	$\frac{1}{5}$	N_2	N_6	n_3	N_{15}	N_{19}
4	$\frac{1}{5}$	N_3	N_7	N_{11}	n_4	N_{20}
5	$\frac{1}{5}$	N_4	N_8	N_{12}	N_{16}	n_5

50 = the total number presented signals

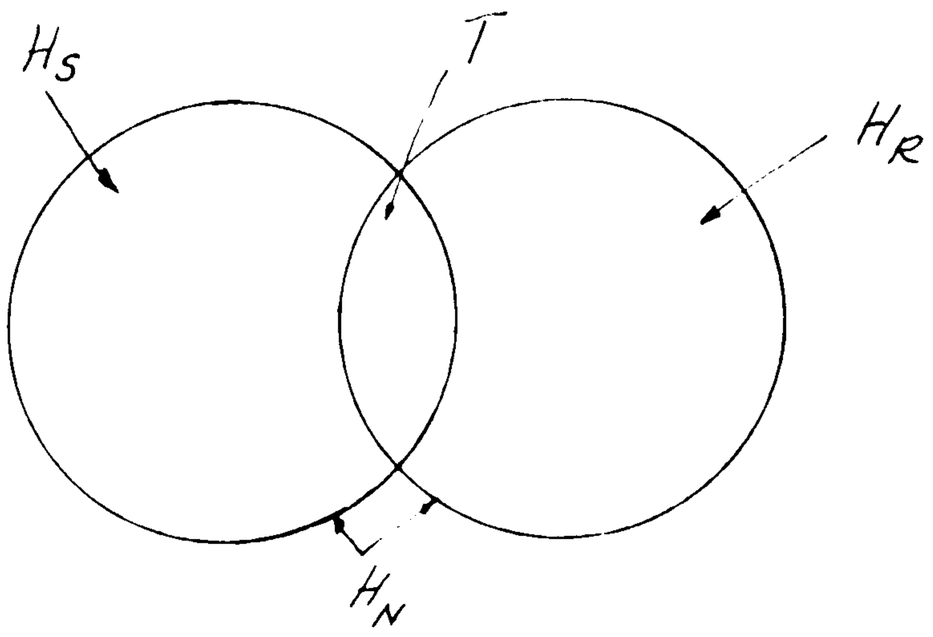
n = the total number of correct responses ($n_1 + n_2 + n_3 + n_4 + n_5$)

N = the total number of incorrect responses ($= N_1 + N_2 + \ldots + N_{20}$)

$n_1 = n_2 = n_3 = n_4 = n_5$

$= \frac{50 - N}{5}$

$N_1 = N_2 = \ldots + N_{20} = \frac{N}{20}$



$$T_N = H_S + H_R - H_N =$$

$$2 \log_2 5 - \left(\frac{50 - N}{50} \log_2 \frac{250}{50 - N} + \frac{N}{50} \log_2 \frac{1000}{N} \right)$$

In accordance with this formula for information transmission the relation between N and T_N is given and the corresponding values are calculated in Table 3.1.

The mean response time for one subject over 50 responses is $t_{tot}/50$. (where t_{tot} equals the time from the onset of the first signal to the response on the last). Hence T_N per time unit:

$$\dot{T}_N = T_N \times \frac{50}{t_{tot}} .$$

Each subject was asked to make two training runs on the equipment. After each run the subject was given information about her performance in terms of speed and errors. Following the two training runs each subject was asked to complete two test trials, and the mean value of T_N for these two tests was calculated. This procedure was carried out for all subjects.

The results from the SRT study appear in Tables 3.2 and 3.3. The first table includes the results for the cashiers and the second for office girls. The first column in each table identifies subjects by a number. The second and third columns in each table give the serial reaction time in seconds and the number of errors for each subject for each test trial. The mean serial reaction time in bits per second is given in a fourth column in Tables 3.2 and 3.3.

TABLE 3.2

SRT (SERIAL REACTION TIME) AND STM (SHORT TERM MEMORY) FOR THE CASHIERS

Cashiers

Subjects	1st trial Total time/ in secs	2nd trial Total time/ in secs	SRT Bits/sec N_T	STM No.
1	39.98/2	38.36/8	2.145	27
2	45.31/0	46.14/1	2.443	22
3	42.27/1	38.44/1	2.661	17
4	38.91/1	38.95/2	2.662	24
5	38.38/4	34.61/1	2.696	38
6	37.87/3	33.41/1	2.841	37
7	36.08/3	33.41/1	2.904	15
8	35.90/1	37.91/1	2.906	17
9	35.11/0	39.99/0	3.106	21
10	29.80/0	30.43/3	3.491	18
11	35.62/1	32.16/1	3.169	16
12	38.36/1	33.28/0	3.142	22
13	34.84/0	34.58/2	3.115	17
14	32.19/2	32.42/2	3.099	22
15	30.20/2	34.12/3	3.033	19
16	32.59/2	30.98/4	2.958	35
17	39.05/1	36.96/0	2.944	13
18	36.06/2	35.75/2	2.792	32
19	34.96/3	38.39/1	2.738	31
20	40.22/3	37.85/2	2.489	18

continued....

TABLE 3.2 (continued)

SRT (SERIAL REACTION TIME) AND STM (SHORT TERM MEMORY) FOR THE CASHIERS

Cashiers

Subjects	1st trial Total time/ in secs	2nd trial Total time/ in secs	SRT Bits/sec N_T	STM No
21*	29.22/0	27.85/0	4.073	28
22*	30.64/1	31.85/0	3.572	31
23*	34 33/0	32.31/0	3.489	34
24*	33.60/0	33.00/0	3.489	30
25*	34.03/0	33.57/1	3.303	58
26*	33.55/9	35.38/9	1.865	15
27*	27.99/0	28.34/0	4.124	36
28*	35.37/1	33.93/2	2.990	58
29*	50.98/10	53.70/3	1.609	37
30*	36.02/10	36.37/10	1.600	29
31*	45.54/1	40.25/1	1.508	54
32*	29.08/1	26.33/3	3.625	51

TABLE 3.3

SRT (SERIAL REACTION TIME) AND STM (SHORT TERM MEMORY) FOR THE OFFICE GIRLS

Office girls

Subjects	1st trial Total time/ in secs	2nd trial Total time/ in secs	SRT Bits/sec N_T	STM No.
1	29.75/2	31.45/3	3.175	27
2	33.48/2	34.56/1	3.045	38
3	37.55/0	39.53/0	3.016	27
4	37.26/0	38.98/1	2.933	17
5	36.76/1	36.33/1	2.931	33
6	36.20/3	35.60/2	2.703	42
7	40.85/2	38.28/1	2.625	13
8	39.08/3	38.03/1	2.610	30
9	34.19/2	36.99/5	2.609	30
10	41.68/2	40.29/1	2.531	15
11*	35.29/2	33.05/0	3.075	52
12*	30.70/0	32.06/0	3.703	26
13*	40.19/3	39.54/4	2.282	51
14*	36.09/4	36.78/8	2.152	47
15*	47.51/4	40.30/3	2.114	19

7.3 Short term memory (STM)

There is evidence, (Deininger, 1960a, Conrad, 1960 and Heron, 1962), which indicates that there ought to be a relation between keying performance and short term memory. This is especially true when the keyed number is relatively long in relation to the short term memory span. Subjects were also given a test of short term memory included in the selection which was used to assist the matching procedure. The test used was one described by Broadbent (1963 and 1965), and is auditory in nature.

The whole test was recorded on tape. It was presented by means of a tape recorder through earphones to two subjects at a time. The following test instructions were also given through the tape recorder:

"You are now present at a small memory test. I will give six figures in rapid succession and immediately thereafter, A, B, C,... You should then say, A, B, C, at the same time as me, and after that you write down the series of figures which were presented. If you do not remember all the figures, you are allowed to guess, hence:

Before each series of figures I will say, "Be ready", thereafter follow six figures and finally we say together, "A, B, C". Thereafter you write down as much as you remember of the figures and guess the rest of the figures. We will first do five trial runs".

Following the instructions, five trial items, i.e. five groups of digits were given. Then ten items followed constituting the test proper. In total seven minutes were spent for the whole test procedure. Between each item there was a fifteen second pause. The general relationship between the different parts in one item is:

(Be ready — one second), (pause — two seconds), (six figures — five seconds), (A, B, C — three seconds).

The following ten items were given in addition to the trial items

Item 1:	173694 ABC
Item 2:	793810 ABC
Item 3:	269715 ABC
Item 4:	536187 ABC
Item 5:	671052 ABC
Item 6:	806971 ABC
Item 7:	936512 ABC
Item 8:	347961 ABC
Item 9:	406825 ABC
Item 10:	253086 ABC

After the subjects had completed the test, their performance was evaluated on the final ten items presented to them. The number of digits correctly recalled in the proper location was recorded for each subject. The maximum score possible for each subject was 60.

The last columns in Tables 3.2 and 3.3 give the number of digits correctly recalled on the short term memory test administered to the cashiers and office girls respectively. It will be noticed that there are a good number of office girls who obtained high scores on this test. Some of the subjects who achieved very low scores on the memory test may have had difficulty possibly due to the fact that their native language was not Swedish, but Finnish. This is for example the case with subjects 26, 17 and 7 among the cashiers and number 7 among the office girls.

7.4 Matching and selection of subjects

Potentially there are several ways of selecting and/or matching subjects in relation to the results of the tests on SRT and STM., so that within both the office girls group and the cashiers group women of comparable ability are allocated to the two keyboards under test.

For example, considering SRT alone the individuals may be ordered in terms of information transmitted per unit time and successive pairs of individuals listed, one individual from each pair going to each experimental condition.

Similarly the same procedure could be adopted for the STM results alone.

Unfortunately a difficulty arises because the allocation procedure based on one test may conflict with the allocation procedure for the other when the results of the two tests do not correlate, as is the case here. As it was not possible to determine from the literature which test was likely to correlate best with keying speed and accuracy so that due precedence could be given to one test rather than another, a different approach was adopted. A scattergram was drawn (Figure 3.3) on which, for all subjects, STM was plotted against SRT, (it will be noted in passing that on visual inspection there is no correlation between the tests). For both SRT and STM severely out lying subjects were rejected in an effort to form a group of subjects, as large as possible, but as homogeneous as possible, in respect of reaction time and memory performance.

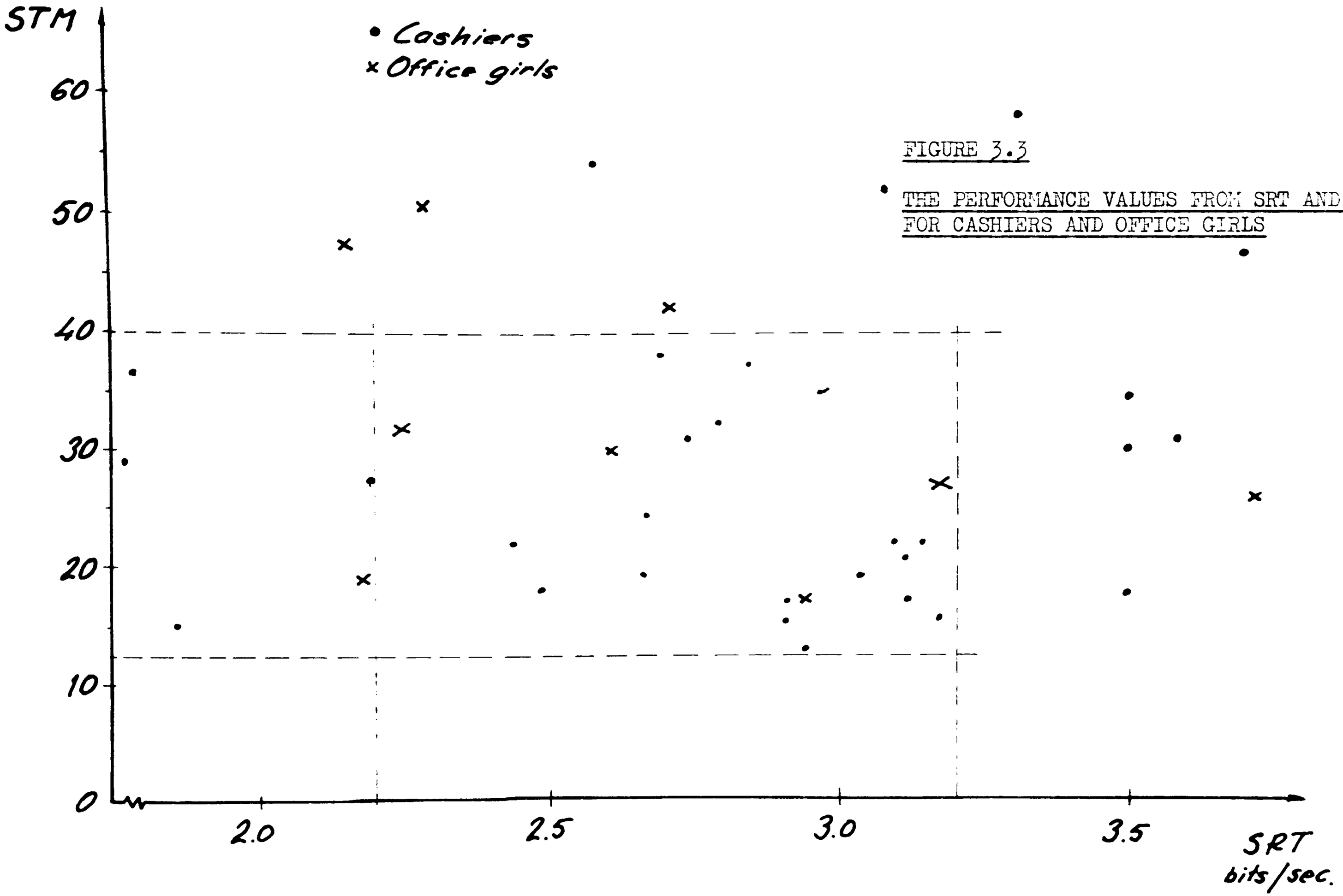


FIGURE 3.3

THE PERFORMANCE VALUES FROM SRT AND STM FOR CASHIERS AND OFFICE GIRLS

The subjects excluded because of their markedly deviant scores are marked with an asterisk in Tables 3.2 and 3.3.

On the assumption that the subjects remaining were more or less homogenous, within each of the cashiers and office girls, group subjects were allocated at random to the two experimental conditions. Thus, of the original 15 office girls, 10 were used for the experimental test described subsequently. Five were allocated to the 123 condition and 5 to the 789 condition. Of the original 32 cashiers available, 18 were used for the evaluation of the keyboard. Nine were allocated to the 123 condition and an identical number to the 789 condition.

Though this procedure is somewhat arbitrary, (particularly in respect of the selection of cut-off points to exclude subjects with markedly deviant SRT and STM scores), it is possible to check statistically for both SRT and STM scores (for cashiers and office girls) that the means (and variances) are comparable for subjects in the 123 and 789 groups.

There remains the possibility, of course, that in this particular keying task experiment the SRT and STM scores are not good predictors of keying speed and accuracy. This is an hypothesis which is examined later.

8.0 THE PLANNING

In this chapter there is first a discussion of the performance experiment, whose main aim is to evaluate two different key-board prototypes, one with the 123-keyboard and the other with the 789-keyboard. The second section of this chapter deals with the operators' subjective preferences.

8.1 The performance testing

First in this section follows a part dealing with the experimental variables and hypotheses. Parts following thereafter discuss the equipment and the procedures used.

Experimental variables and hypotheses

Independent variables:

i) keyboards

1. push-button telephone-type (1, 2, 3 keyboard)
2. desk calculator-type (7, 8, 9 keyboard)

ii) previous experience of subjects

1. some desk calculator experience (office girls)
2. cash register experience but no experience on desk calculators (cashiers)

iii) amount of practice at keyboard

1. day 1
2. day 2
3. day 3
4. day 4
5. day 5

Dependent variables:

i) speed of performance (number of keyings performed per time unit)

ii) accuracy of performance (number of errors per 100 key strokes)

Hypothesis:

Several studies (see Part 2) have shown that performance is normally better on a ten button keyboard than on a full keyboard. They also demonstrate that in certain conditions the keyboard 1, 2, 3 is better than the keyboard 7, 8, 9.

The null hypothesis is that there is no difference in performance measured in terms of accuracy or speed between the two types of keyboards either for the subjects with calculator experience (office girls) or subjects with cash register experience (cashiers).

The motives for this selection of variables and hypothesis are as follows: the formulation of the hypothesis is due to the aim of the study which is to find out what kind of keyboard configuration is most suitable in the check-out system in a supermarket. The two most common kinds of keyboard configurations have been chosen.

The full keyboard has been excluded on the grounds that all general experimental evidence seems to indicate that it is not so good from a performance point of view. However, the main reason for excluding this type of keyboard is the fact that it is claimed that this type of keyboard is uncomfortable and perhaps also damaging (KAS, 1967) for its operators due to the posture it forces them to adopt.

The factors which determine speed and accuracy of keying are the reaction time for each keying, the movement time involved and the translation process. According to information theory reaction time ought to be less on the ten button keyboard than the full keyboard as the uncertainty of the ten button keyboard is much less than that of the full keyboard. The movement time is, of course, less on the ten button keyboard than on the full keyboard.

The translation process of written or printed figures to the keyboard is effected through immediate memory, (i.e. STM). According to Broadbent, (1957), the numerals are stored and rehearsed in time sequences; this means that there are no special advantages in the spatial coding implicit in the use of the full keyboards as compared with the sequential coding implicit in the use of the ten button keyboard.

From a performance point of view the only potential advantage of the full keyboard is that the number of key strokes which are needed is less than on the ten button keyboard. This follows from the fact that it is not necessary to key the zero's on the full keyboard. If the percentage of zero's to be keyed is very large, performance might be expected to be equivalent or marginally better on a full keyboard than on a ten button keyboard. In the present application in KF where a large amount of the work in the check-out system will involve keying of codes, the number of zero's will be very small.

The people who will ultimately be asked to work on the new kind of keyboard for cash registers in the new check-out system will mainly have previous experience from either an ordinary cash register with a full keyboard or a desk calculator with a 7, 8, 9 type keyboard. This was the reason for the selection of the two groups of subjects. In this experiment it was possible to study possible transfer effects between the keyboard 7, 8, 9 and the keyboard 1, 2, 3 or between the full keyboard and the two types of ten button keyboards.

The design of the experiments in respect of transfer effects was probably not a very good one in formal design terms. However,

the approach was very practical, aimed at demonstrating the effects of previous experience on the work at these type of keyboards. Also the demonstration was required on realistically appropriate subjects.

Figure 3.4 indicates the experimental design chosen for this study. In contrast, Figure 3.5 shows a more "ideal" kind of experimental design. The main argument in favour of the present study compared with the design in Figure 3.5 is that of the subjects involved and secondly the long experimental time necessary to get valid results.

In order to estimate better the performance of operators with different backgrounds, it was felt that performance should be measured on a number of occasions. It would have been ideal to be able to continue measuring performance for each subject until evidence of stabilisation in performance was conclusively shown. This was not possible within the manpower and time and equipment resources. A literature search (see Part 2) revealed, however, that subjects working for about half an hour per day for five days reached a point in performance terms on the 4th and 5th days where further improvements were marginal. Accordingly subjects' performance was measured for half an hour per day on five consecutive days.

As said before, the speed of performance was deemed to be important for the keying work as the keying could constitute as much as 50% of the work in a check-out system.
Errors made in keying inevitably seem to mean a loss for the shop.

FIGURE 3.4

EXPERIMENTAL DESIGN FOR THIS EXPERIMENT

1. subjects experienced in use of 789-keyboard ⟶ training on 789-keyboard ⟶ on days 1 2 3 4 5

2. subjects experienced in use of 789-keyboard ⟶ training on 123-keyboard ⟶ on days 1 2 3 4 5

3. subjects experienced in use of full-keyboard ⟶ training on 789-keyboard ⟶ on days 1 2 3 4 5

4. subjects experienced in use of full-keyboard ⟶ training on 123-keyboard ⟶ on days 1 2 3 4 5

FIGURE 3.5

"IDEAL" EXPERIMENTAL DESIGN

1. naive subjects ⟶ training on 123-keyboard ⟶ test

2. naive subjects ⟶ test ⟶ training on 123-keyboard ⟶ test

And the same for the full keyboard

The equipment

The equipment consisted of the following components:-

1. Printed material from which the subjects read information to be keyed.
2. One ten button keyboard prototype manufactured by Hugin to a specification produced by the author and given in Part 2. The tops of the buttons were of such a design that it was very easy to change the keyboard from the 1, 2, 3 to the 7, 8, 9 configuration.
3. A Facit (4070) paper - tape punch to record the key-ings.
4. The necessary electronic equipment to connect the keyboard with the tape punch.
5. A timing device which rang a bell when the time for the work was completed, (similar to an alarm clock).

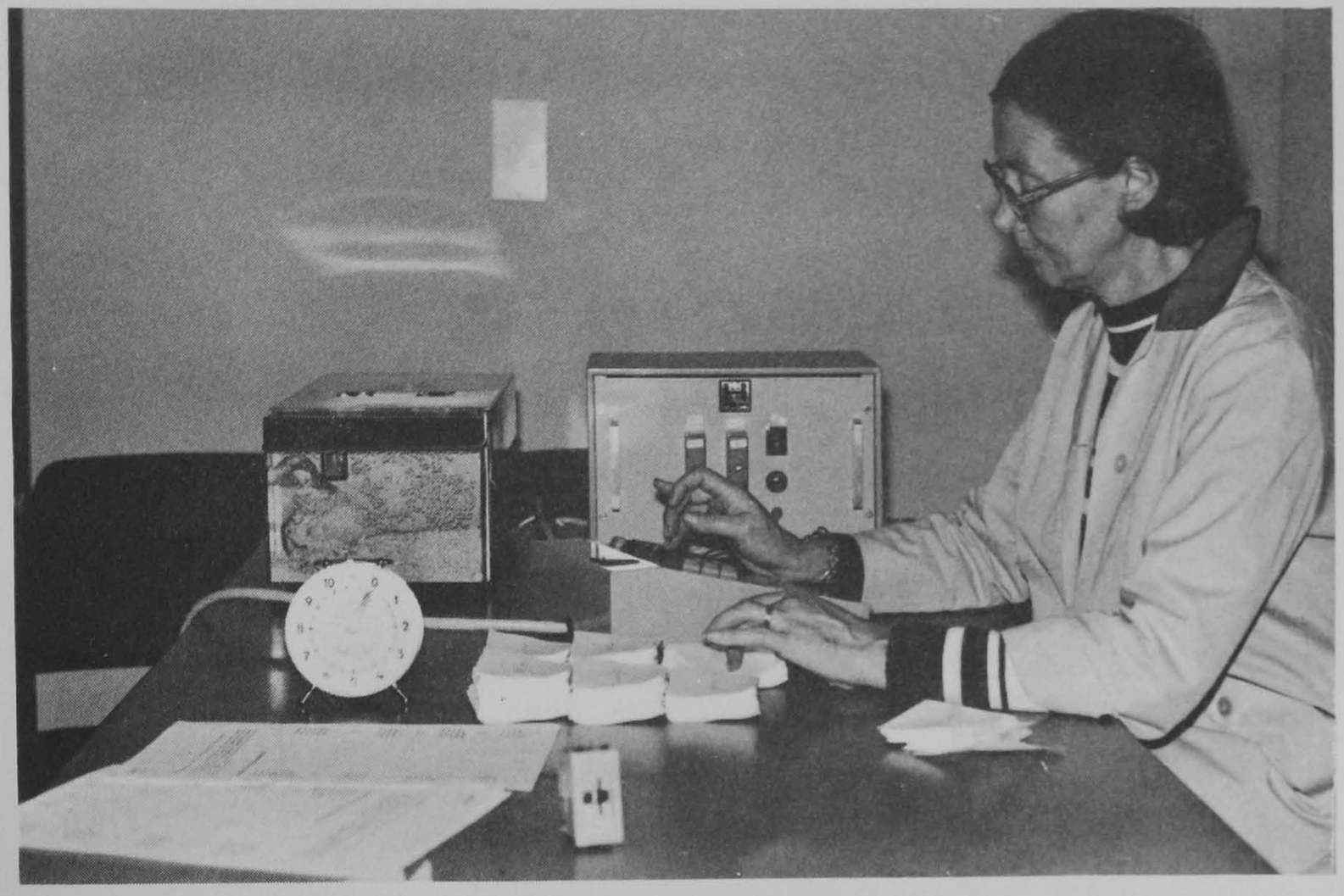
The full experimental setting is seen in Figure 3.6a. In Figures 3.6b and c, details of the keyboard can be seen. From Figure 3.6a, one can see that the equipment was placed on a desk and that the subjects were sitting beside the desk.

The materials from which the subjects did the keying were tickets with prices and codes printed on them. The tickets were produced in the following manner.

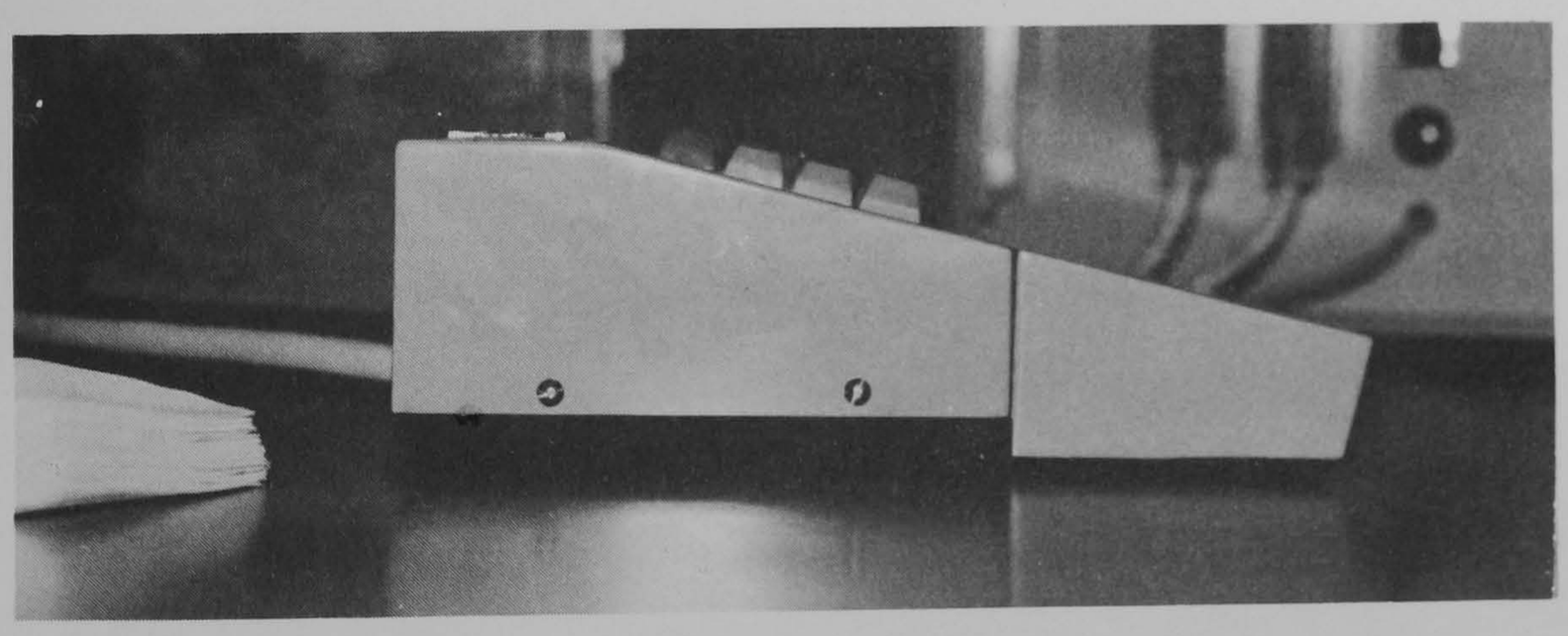
A 'master' containing information about code numbers for goods was stored on computer tape. The master was made up of a large number of randomly selected codes and prices. Ninty-percent of the codes contained only two digits and ten percent contained three digits. About eighty-percent of the prices consisted of

FIGURE 3.6

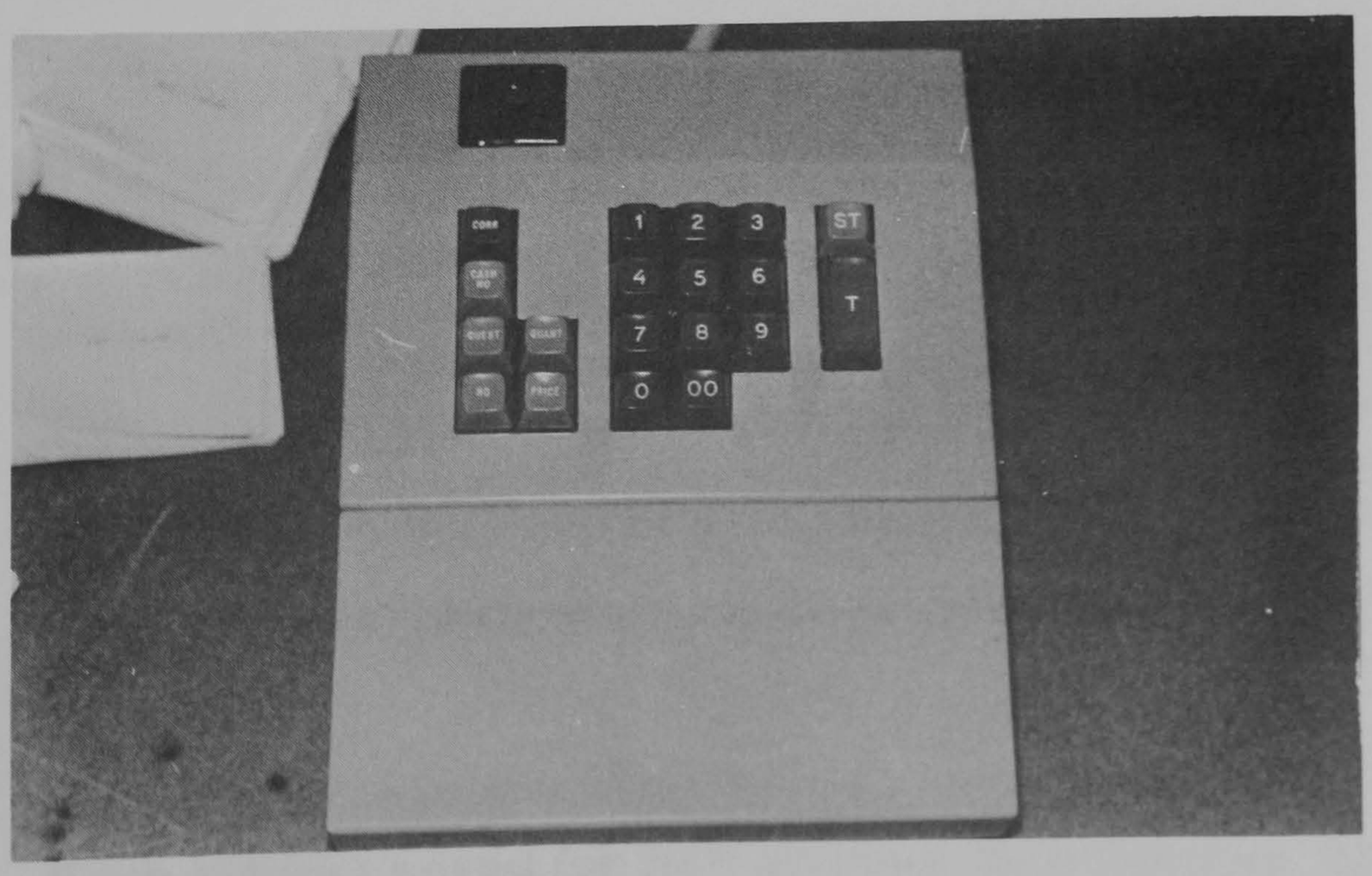
THE FULL EXPERIMENTAL SETTING.
FROM LEFT TO RIGHT AND UP AND DOWN:
FACIT PUNCH TAPE, ELECTRONIC CONNECTION
EQUIPMENT, ALARM CLOCK, KEYBOARD,
PRINTED CODE AND PRICE TICKETS.



(a)



(b)



(c)

three digits and twenty-percent of the prices of four digits. From this master a computer master-file was produced. In total, the master contained three hundred different codes and corresponding prices. The codes were each unique but the prices were not, in the sense that the same price might be associated with different codes. From the computer master-file the computer printed the 300 codes and associated prices in the form of a list. This list of codes with corresponding prices was then cut into pieces and each code with its price stuck onto a ticket. Twenty duplicate copies were produced of the computer generated list so that ultimately there were twenty sets of two tickets for use as input material to the subjects.

As all combinations of prices and codes are unique, the master file was used to identify errors which were keyed onto the punch tape through the keyboard. A special computer programme was designed to count the number of tickets punched per day, per subject and also to identify the number and type of errors made. This computer programme is given in summary in Appendix 3.1.

The procedure

The experiment examining the keying performance of the subjects took place in three locations. The office girls remained at KF headquarters in the middle of Stockholm. The performance of cashiers was studied at two large department stores just outside Stockholm.

Each subject keyed for half an hour daily for five consecutive days. Colquhoun et al (1968) have shown that performance in

a keying task varies with body temperature and time of the day. As far as possible, each subject had her test at the same time of the day on all five days.

The keying was done from tickets containing codes and corresponding prices. The procedure for the experiment may be understood from the following instructions which were given to the subjects before the experiment started:

> "The Hugin Cash Register factory and KF together are constructing a new cash register and would now be very pleased to receive your help in this work.
>
> You have already gone through two small tests. In one of the tests, the task was to remember figures and in the other test, you had to demonstrate finger dexterity. Now we ask your help in a third test where you will be asked to remember figures and at the same time, be rapid on finger dexterity. The test will be done as follows:
>
> For thirty minutes a day for five days, you will be trying out a newly designed cash register keyboard. You have to imagine that the goods in the supermarket are marked with a code number and a price, e.g. 173 19.75. For this string of numbers you should first depress the key labelled "NO" on your keyboard, followed by the keys "173" You should then depress the key labelled "PRICE" followed by the keys "1975". The code number should be keyed immediately after the "NO" key and the price immediately after the "PRICE" key. You will get a large batch of tickets

(containing code number and price information) which you shall key in turn. Imagine that there is a queue of ten persons at your cash desk and that it takes three minutes to serve each customer.

Each third minute a bell will ring to tell that the next customer should be dealt with and that the previous one is finished. When the bell rings finish the price and the code ticket you are working with. Then press the key labelled "T" to give the total. Then continue as before but imagine that you are serving a new customer. If you notice that you are mis-keying from any of the tickets, you should press the key labelled "CORR" but not before you are completely finished with the ticket. Then take the next ticket and continue as before.

You will be allowed to practice for about 15 minutes before beginning your first half hour session. Before practicing you will also receive proper instructions about how to sit at your work and how to hold your fingers and hand in relation to the keyboard. Finally let us go through the tests in summary.

A bunch of price tickets has to be registered by you. Press in turn "NO", the code, "PRICE" and the price, (and if you have done something incorrectly, press the "CORR" key). Key as rapidly and accurately as possible, when a bell rings, this means that you should press the "T" key as soon as you have finished the

ticket on which you are working and are ready to take the next ticket. The whole test will take thirty minutes each time and be performed once a day for five consecutive days".

8.2 The subjective preference study

Answers to two fundamental questions were sought:-

i. Is the full cash register keyboard preferred to the ten button keyboard, or is the converse true?

ii. What is the preferred horizontal position of the keyboard when operators are free to move their machine?

As the first question was only of relevance for people with experience on the full keyboard of the cash register, only the cashiers were included in this study. The second question applies equally well to both cashiers and office girls and so was studied for both groups.

The keyboard preferences

In order to get some indication of the subjects' keyboard preference, they were asked to fill in a form in which comparisons could be made between the experimental keyboard and their ordinary cash register keyboard. This form was handed out after the first session of training on the experimental keyboard and on the final day's session on the experimental keyboard.

A copy of the form which was handed out is given in Appendix 3.2. On this form the subjects were asked to judge both their ordinary cash register keyboard and then to judge the experimental keyboard. There were four different questions for each of the keyboards and the questions were the same for both key-

boards. The first question asked what the subjects thought in general about the two types of keyboards. The second question dealt with comfort. The third and fourth questions dealt with accuracy and speed respectively of work performed on the two keyboards. The subjects had to judge each of the two key-boards one at a time on a six-point scale.

The following hypotheses were tested for each of the four questions:-

- There is no difference between the full keyboard and ten button keyboard; (results averaged from days 1 and 5).
- There is no difference between the full keyboard and the ten button keyboard; (results only from day 1).
- There is no difference between the full keyboard and the ten button keyboards; (results only from day 5).
- There is no difference on how the subjects judged the keyboards on day 1 compared with the judgement of the keyboards on day 5.
- There is no difference between the full keyboard and the 1, 2, 3 keyboard; (results averaged from days 1 and 5).
- There is no difference between the full keyboard and the 7, 8, 9 keyboard; (results averaged from days 1 and 5).

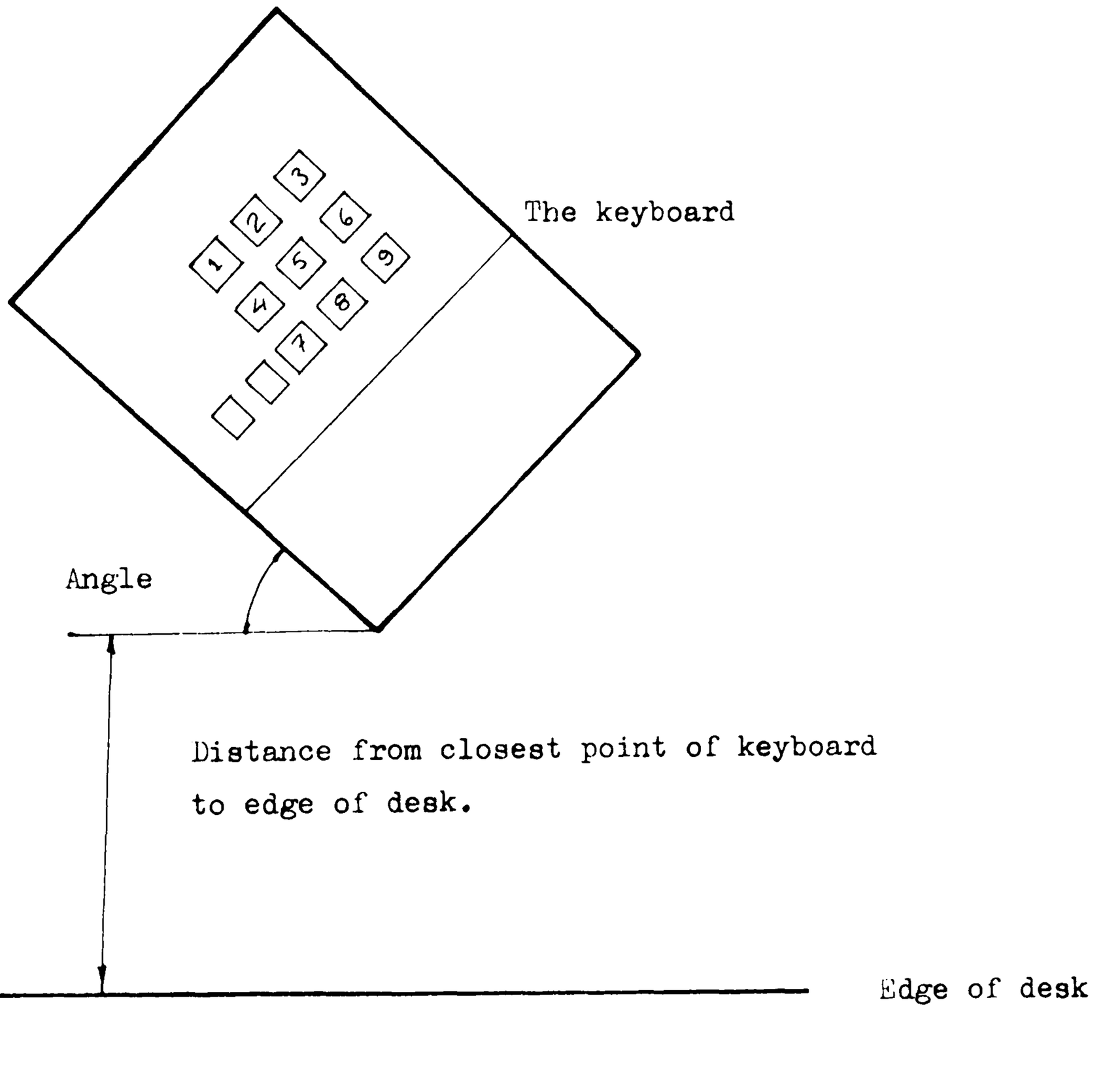
The preference for horizontal position of keyboard

Several studies have been carried out in an attempt to determine the most suitable kind of positioning of the keyboard in the horizontal plane. These studies are reviewed in part 2. As can be seen, there is some disagreement amongst them. A small study of preferred kind of positioning was, therefore, carried out in this investigation.

The keyboard was on the first and the final day deliberately positioned in a completely unusable position when the subjects arrived for testing. Before the test, the subjects, both office girls and cashiers, were asked to put the keyboard in a suitable and comfortable position. The positions were then recorded after the first day's training and after the final day's experimental session. The measurements taken were the distance between the nearest point on keyboard and the edge of the desk on which the keyboard was placed. The second measurement taken was the angle of the keyboard. The way in which these measurements were taken is more precisely illustrated in Figure 3.7.

FIGURE 3.7

MEASUREMENTS RECORDED ON THE PREFERENCE OF THE POSITIONING OF THE KEYBOARD



9.0 THE RESULTS

The presentation of the results is divided into two sections. The first section deals with the subjects' performance and the second section deals with the subjective preference study.

9.1 The subjects' performance

The data for both speed and accuracy are of such a form that it may be justifiably assumed that it is legitimate to use parametric methods in the statistical analysis. The data for both speed and accuracy are on ratio scales. Furthermore, Figure 3.9a shows that the speed scores for office girls and cashiers, though not precisely normal, are not of such a markedly deviant form as to abrogate the assumptions of the analysis of variance. A similar statement may be made for accuracy scores which are illustrated in Figure 3.9b.

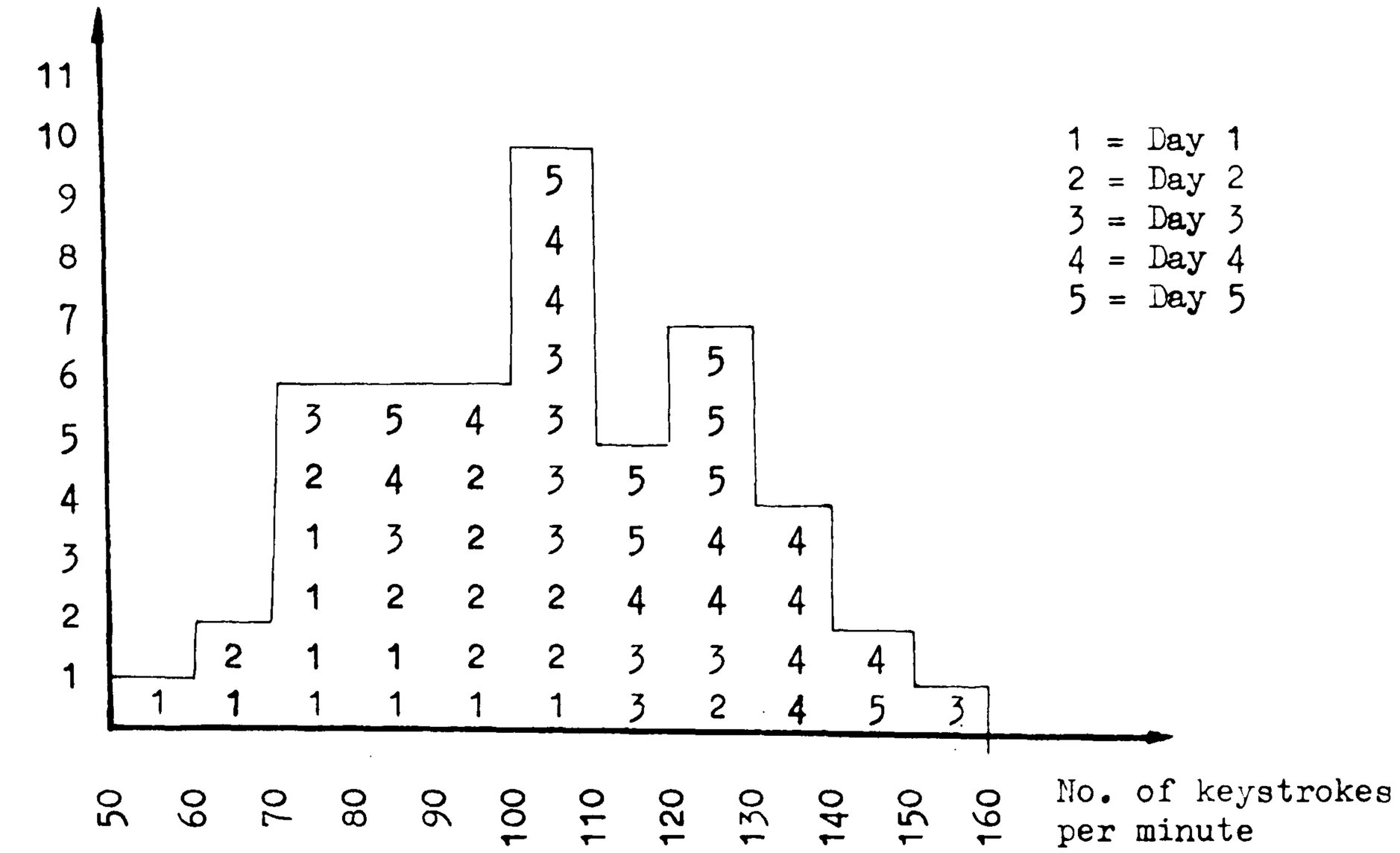
To clarify and simplify the statistical analyses the data have been divided into two main groups:- those data relating to office girls and those to cashiers. Within each of these groups separate analyses have been carried out on speed and accuracy of performance.

For each of the four sub-sets of data so formed five different tests have been applied as follows:-

(a) a split-plot analysis of variance. This technique was used because data involved in the comparisons between the two keyboards (the plots) are uncorrelated, whereas data involving comparisons between the days (i.e. repeated measured on the same subjects) are correlated. This design of experiment (and its analysis) is particularly apt in the present case as it is extremely sensitive to interactions between the keyboard and days. Therefore, differential performance levels associated with time, if present, will show

FIGURE 3.9a

SPEED OF PERFORMANCE FOR OFFICE GIRLS



SPEED OF PERFORMANCE FOR CASHIERS

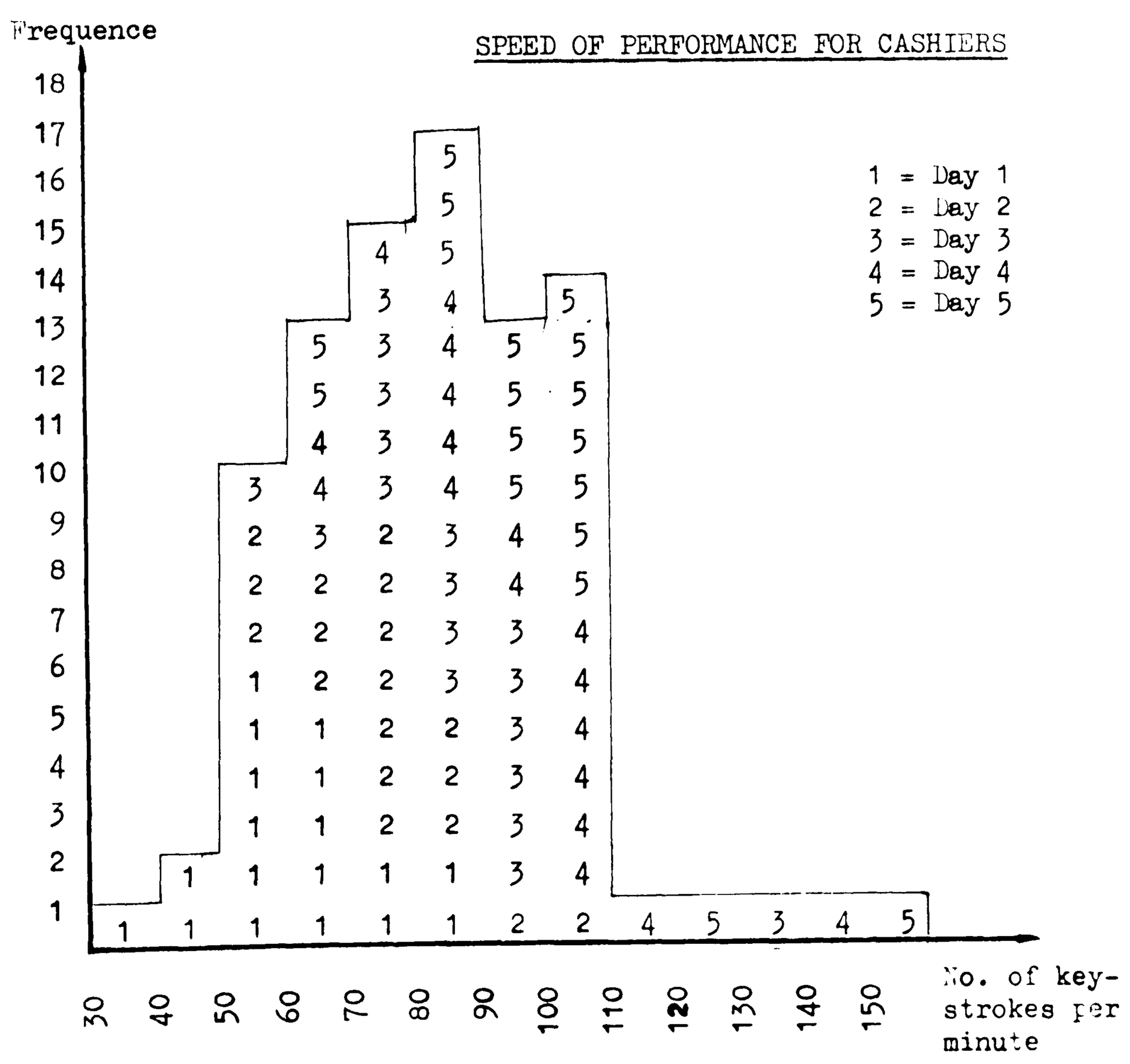
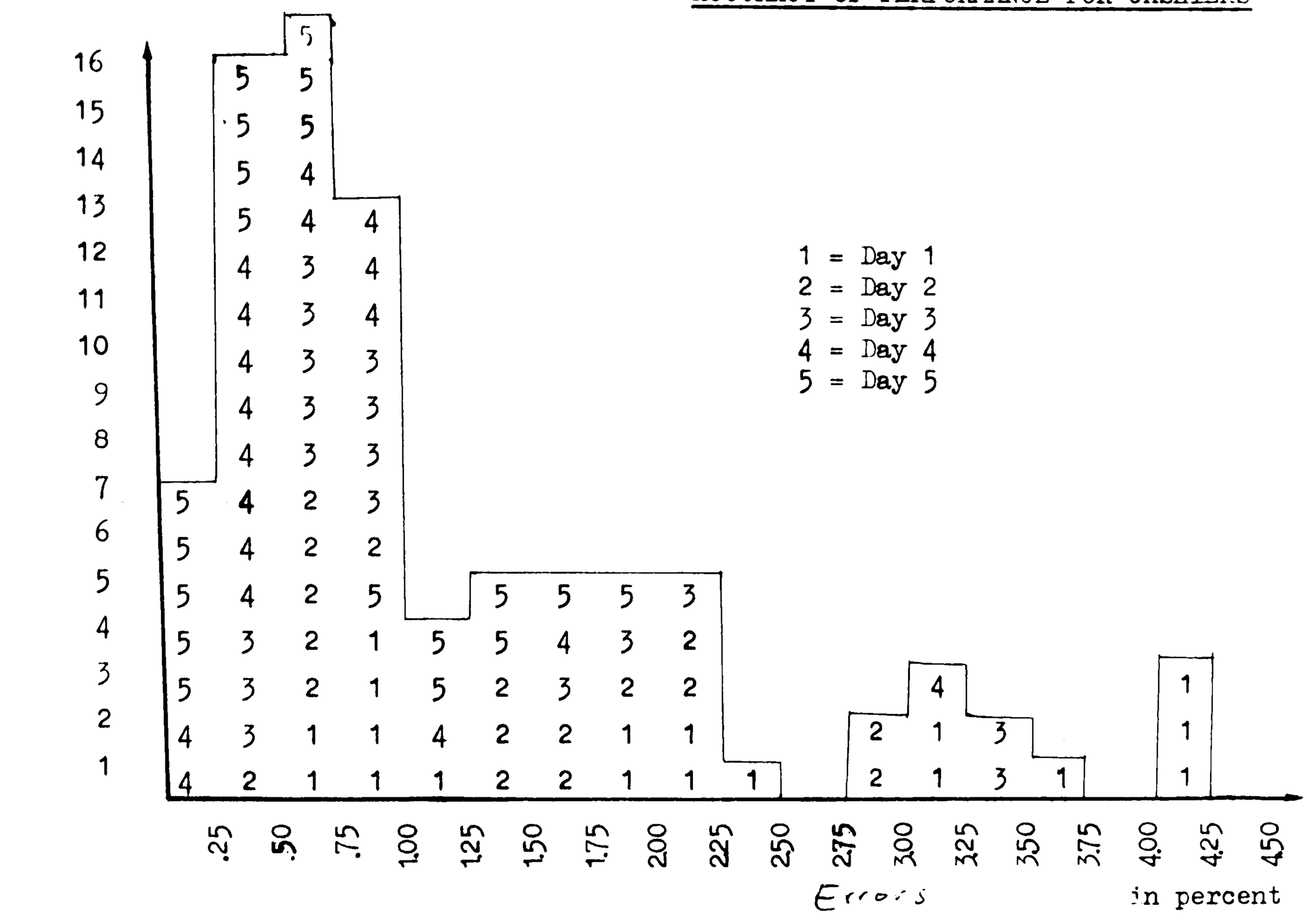


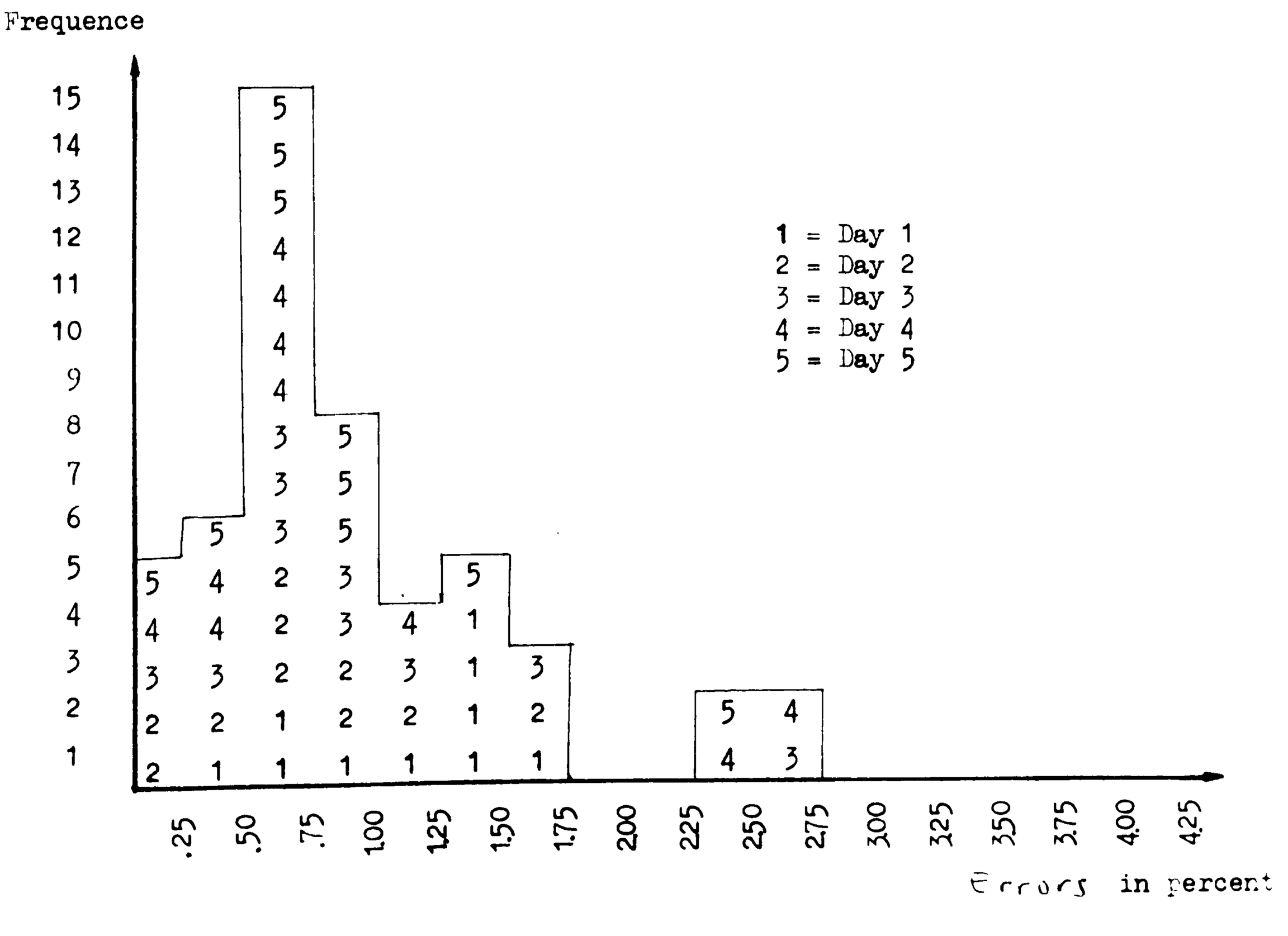
FIGURE 3.9b

ACCURACY OF PERFORMANCE FOR CASHIERS



1 = Day 1
2 = Day 2
3 = Day 3
4 = Day 4
5 = Day 5

ACCURACY OF PERFORMANCE FOR OFFICE GIRLS



1 = Day 1
2 = Day 2
3 = Day 3
4 = Day 4
5 = Day 5

themselves clearly. In Appendix 3.3 is given a fully worked example of the computations involved in a split plot analysis of variance. The example is in fact an analysis of the data relating to office girls' accuracy of performance. The methods of computation are taken from Li (1964) and Winer (1970).

(b) The confidence limits were calculated for means and differences between means where appropriate for the four sets of data. Special attention was paid to mean performance associated with each of the keyboard designs.

(c) Multiple comparison tests were performed. There are two well-known and frequently-used types of multiple comparison tests available; the Tukey Test which is described by Li (1964) and Newman and Keuls Method described by Winer (1970). As the Tukey Test is a little more conservative in significance testing (Winer, 1970), it was chosen for this study. Multiple comparison tests were applied to all four sub-groups of data to evaluate mean differences in performance between days. This factor was always significant in the split-plot analysis of variance.

(d) Tests of trends were made for all four sets of data to determine the form of the relation between performance and days. The linear and quadratic components for trend were calculated in all cases. If the linear and quadratic components were not significant the cubic component was also calculated. It was not necessary to perform

computations to establish higher order trends. The analysis of trend is discussed by Winer, (1970).

(e) Analyses of co-variance were carried out for the four sets of data, thus extending the original split-plot analysis of variance. In the subject selection and allocation procedures, inherent inter-subject variability which contributes to the error variance was reduced. This error variance may be further reduced to sensitize comparisons between the keyboards by the use of co-variance techniques on the assumption that the co-variate, in this case either SRT or STM scores, correlates with the criterion score, (speed and accuracy of performance). The analysis of covariance used for the four sets of data is based upon the appropriate split plot model described in Winer, (1970).

The raw data for the office girls and cashiers on speed and accuracy of performance is given in Appendix 3.4 and 3.5. It will be realised that these data have already been plotted and are shown in Figures 3.9a and 3.9b.

The speed of performance

In Figure 3.10 the results for the cashiers and office girls are plotted in terms of mean speed of performance (keyings per minute) against days. From the Figure it can be seen that performance increases quite rapidly over the first three days but that the increase is not maintained for the last two days. It can also be seen that the 123-keyboard has higher keying speeds

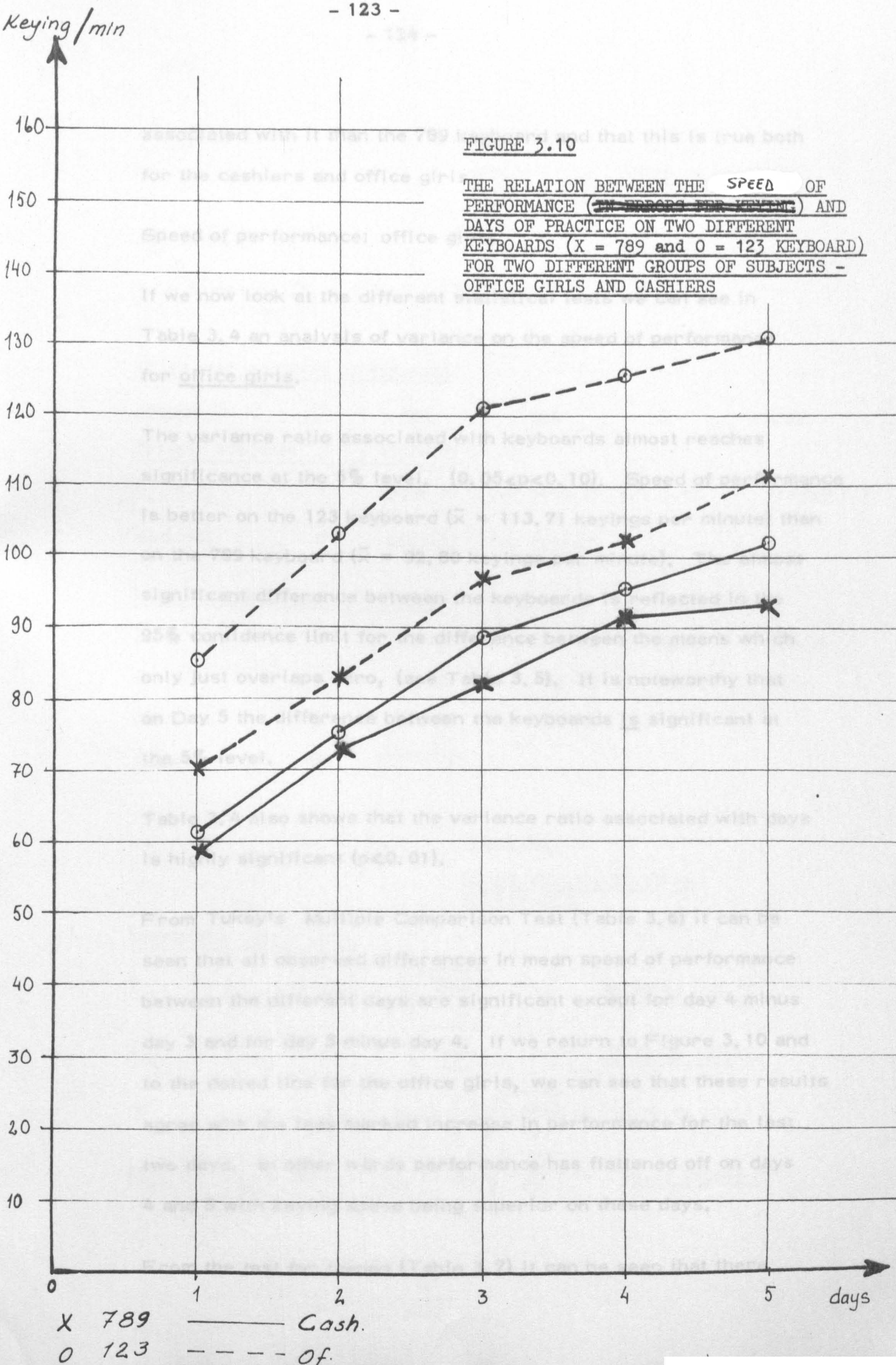


FIGURE 3.10

THE RELATION BETWEEN THE SPEED OF PERFORMANCE (~~IN ERRORS PER KEYING~~) AND DAYS OF PRACTICE ON TWO DIFFERENT KEYBOARDS (X = 789 and O = 123 KEYBOARD) FOR TWO DIFFERENT GROUPS OF SUBJECTS - OFFICE GIRLS AND CASHIERS

associated with it than the 789 keyboard and that this is true both for the cashiers and office girls.

Speed of performance: office girls

If we now look at the different statistical tests we can see in Table 3.4 an analysis of variance on the speed of performance for office girls.

The variance ratio associated with keyboards almost reaches significance at the 5% level. ($0.05 < p < 0.10$). Speed of performance is better on the 123 keyboard ($\bar{x}$ = 113.71 keyings per minute) than on the 789 keyboard ($\bar{x}$ = 92.80 keyings per minute). The almost significant difference between the keyboards is reflected in the 95% confidence limit for the difference between the means which only just overlaps zero, (see Table 3.5). It is noteworthy that on Day 5 the difference between the keyboards is significant at the 5% level.

Table 3.4 also shows that the variance ratio associated with days is highly significant ($p < 0.01$).

From Tukey's Multiple Comparison Test (Table 3.6) it can be seen that all observed differences in mean speed of performance between the different days are significant except for day 4 minus day 3 and for day 5 minus day 4. If we return to Figure 3.10 and to the dotted line for the office girls, we can see that these results agree with the less marked increase in performance for the last two days. In other words performance has flattened off on days 4 and 5 with keying speed being superior on these days.

From the test for trends (Table 3.7) it can be seen that there

TABLE 3.4

OFFICE GIRLS - SPEED (KEYINGS/MIN)

D_n = Days (1 - 5)

K = Keyboards (K_1 = 123, K_2 = 789)

SPLIT PLOT ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign
Between subjects	9	13920.37			
K_1 vs K_2	1	5466.39	(a) 5466.39	a/b 5.17	0.05<p<0.10
Residual	8	8453.39	(b) 1956.75		
Within subjects	40	13845.27			
Days	4	11956.98	(c) 2989.24	c/e 54.97	p<0,01
D x K	4	148.22	(d) 37.06	d/e 0.68	N.S.
Residual	32	1740.09	(e) 54.38		
Total	49	277765.64			

TABLE 3.5

OFFICE GIRLS - SPEED OF PERFORMANCE

CONFIDENCE LIMITS (95%)

$$\bar{X}_{K1} \pm \left[t_{.05} \ (8 \text{ df})\right] \times \sqrt{\frac{msqb}{25}} = 98.69 \text{ to } 128.73$$

$$\bar{X}_{K2} \pm \left[t_{.05} \ (8 \text{ df})\right] \times \sqrt{\frac{msqb}{25}} = 77.78 \text{ to } 107.82$$

$$(\bar{X}_{K1} - \bar{X}_{K2}) \pm \left[t_{.05} \ (8 \text{ df})\right] \times \sqrt{\frac{2\ msqb}{25}} = -0.32 \text{ to } 42.14$$

$$(\bar{X}_{K1} - \bar{X}_{K2}) \text{ day } 5 \pm \left[t_{.05} \ (8 \text{ df})\right] \sqrt{\frac{2\ msqb}{25}} = +0.43 \text{ to } +42.89$$

TABLE 3.6

OFFICE GIRLS - SPEED OF PERFORMANCE

MULTIPLE COMPARISON TEST (TUKEY TEST)

	Day 1 78.03	Day 2 94.09	Day 3 108.59	Day 4 114.22	Day 5 121.33
1. 78.03	0.00	16.06	30.56	36.19	43.30
2. 94.09		0.00	14.50	20.13	27.24
3. 108.59			0.00	5.63	12.74
4. 114.22				0.00	7.11
5. 121.30					0.00

All observed differences are significant at 5% risk level, except day 3 minus day 4 and day 4 minus day 5.

TABLE 3.7

OFFICE GIRLS - SPEED OF PERFORMANCE

TEST OF TRENDS

ANALYSIS OF LINEAR TREND

Source of variation	df	ssq	msq	F	sign
Within subjects	10	12386.92			
Days	1	11391.29	11391.29	96.6	$p<0.01$
Days x keyboard	1	52.27	52.27	-	
Days x within subjects	8	943.36	117.92		

Per cent of variation due to linear trend: $\frac{11391.29}{11956.98} \times 100 = \underline{95.26}$ %

ANALYSIS OF QUADRATIC TREND

Source of variation	df	ssq	msq	F	sign
Within subjects	10	989.14			
Days	1	511.88	511.88	10.34	$0.01<p<0.05$
Days x keyboards	1	81.32	81.32	1.64	-
Days x within subjects	8	395.94	49.49		

Per cent of variation due to quadratic trend: $\frac{511.88}{11956.98} \times 100 = \underline{4.28}$ %

is a significant ($p<0.01$) linear trend over the days. There is also a quadratic trend over the days which is significant at a level between 1% and 5%. However, the linear trend contributes 95.26% of the variation and the quadratic only 4.28%. There are no significant interactions associated with the trends. This means effectively that the experimental evidence does not reject the hypothesis that the curves are parallel. (i.e. there is no difference in the form of the curves for the two keyboards).

This result is in good agreement with that found in the analysis of variance shown in Table 3.4 where the days x keyboard interaction is not significant at the 5% level.

In Table 3.8 the analysis of co-variance for office girls is given for speed of performance when the short term memory (STM) is used as a covariate. The null hypothesis that the two keyboards are equal from the point of view of speed of performance is rejected with a risk level of between 1% to 5%. In other words, when the speed performance of the two groups of office girls who operated on the two keyboards is corrected so that the two groups of girls are equivalent in terms of STM a significant difference is found between the keyboards. Mean speed of keying is superior on the 123 keyboard. The within class correlation is computed to -0.400 between the covariate (STM) and the variate in this case speed of performance.

In Table 3.9 a similar analysis is carried out for speed of performance for office girls when serial reaction time (SRT) is used as a co-variate. The null hypothesis that the two keyboards are equal is not rejected. The within class correlation is +0.169.

TABLE 3.8

OFFICE GIRLS - SPEED/STM

ANALYSIS OF COVARIANCE

	X^2	XY	Y^2	$(Y^1)^2$
K_1 v. K_2	200.00	1045.60	5466.39	6404.01
(P)Subj. w.K	3998.00	-2280.52	7999.26	6698.42

ADJUSTED ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign.
K_1 v. K_2	1	6404.01	6404.01	6.69	0.05>p>0.01
Subj. w.K	7	6698.42	956.92		

r = -0.40

TABLE 3.9

OFFICE GIRLS - SPEED/SRT

ANALYSIS OF COVARIANCE

	X^2	XY	Y^2	$(Y^1)^2$
K_1 v. K_2	89.52	699.51	5466.39	2332.72
(P)Subj. w.K	142.50	185.38	8453.98	8212.82

ADJUSTED ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign.
K_1 v. K_2	1	2332.72	2332.72	1.99	N.S.
Subj. w.K	7	8212.82	1173.26		

r = 0.169

Speed of performance: cashiers

A split-plot analysis of variance for the cashiers' speed of performance is given in Table 3.10. The difference between the keyboards is non-significant. From Table 3.11 it may be seen that mean speed of performance for the 123 keyboard is 85.21. The corresponding figure for the 789 keyboard is 79.68. From the same Table it will be seen that on the 5th day mean performance is effectively the same for the two keyboards.

Table 3.10 also shows that the difference between days is significant ($p<0.01$). Tukey's Multi-Comparison Test has been applied to these differences (Table 3.12). All observed differences are significant with a 5% risk level except for the difference between days 4 and 5. This is in agreement with the unbroken line in Figure 3.9where it will be seen that the improvement in performance only falls off on the last day.

In the test for trends (Table 3.13) there are significant effects over days both for linear and quadratic trends. The percent of variation due to linear trend is 95.87% and that due to quadratic only 3.98%. The missing percent of variation is due to trends of higher order. There are no significant interactions associated with the trends. The result agrees with the lack of interaction for keyboards x days shown in Table 3.10. In Table 3.14 an analysis of covariance for the cashiers' speed of performance with short term memory as covariate shows that there is no difference between the keyboards. Even for the adjusted analysis of variance the null hypothesis cannot be rejected. The within correlation is -0.275. Table 3.15 gives the analysis of co-variance

TABLE 3.10

CASHIERS - SPEED OF PERFORMANCE

$n = 9 + 9 = 18$

D_n = Days (1 - 5)

K = Keyboards (K_1 = 123, K_2 = 789)

SPLIT PLOT ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign.
Between subjects	17	22804.90			
K_1 vs K_2	1	686.69	(a) 686.69	a/b 0.49	N.S.
Residual	16	22118.21	(b)1382.38		
Within subjects	72	19200.49			
Days	4	17257.67	(c)4314.42	c/e152.61	p<0.01
Days x K	4	133.31	(d) 33.33	d/e 1.18	N.S.
Residual	64	1809.51	(e) 28.27		
Total	89	42005.39			

TABLE 3.11

CASHIERS - SPEED OF PERFORMANCE

CONFIDENCE LIMITS (95%)

$$\bar{X}_{K1} \pm \left[t_{.05} \quad (16 \text{ df})\right] \times \sqrt{\frac{msq(b)}{45}} = 73.66 \text{ to } 96.76$$

$$\bar{X}_{K2} \pm \left[t_{.05} \quad (16 \text{ df})\right] \times \sqrt{\frac{msq(b)}{45}} = 68.13 \text{ to } 91.23$$

$$(\bar{X}_{K1} - \bar{X}_{K2}) \pm \left[t_{.05} \ (16 \text{ df})\right] \times \sqrt{\frac{2\ msq(b)}{45}} = -11.09 \text{ to } 22.15$$

$$(\bar{X}_{K1} - \bar{X}_{K2}) \text{ day 5} \pm \left[t_{.05} \ (16 \text{ df})\right] \times \sqrt{\frac{2\ msq(b)}{45}} = -7.22 \text{ to } +26.02$$

TABLE 3.12

CASHIERS - SPEED OF PERFORMANCE

MULTIPLE COMPARISON TEST (TUKEY TEST)

		Day 1 59.70	Day 2 75.29	Day 3 85.01	Day 4 93.91	Day 5 98.33
1.	59.70	0	15.59 a)	25.31 a)	34.21 a)	38.63 a)
2.	75.29		0	9.72 a)	18.62 a)	23.04 a)
3.	85.01			0	8.90 a)	13.32 a)
4.	93.91				0	4.42
5.	98.33					0

All observed differences marked a) are significant at 5% level.

TABLE 3.13

CASHIERS - SPEED OF PERFORMANCE

TRENDS - LINEAR AND QUADRATIC

ANALYSIS OF LINEAR TREND

Source of variation	df	ssq	msq	F	sign
Within subjects	18	17930.93			
Days	1	16546.58	16546.88	207.58	$p < 0.01$
Days x keyboards	1	108.88	108.88	1.36	-
Days x within subjects	16	1275.45	79.71		

Per cent of variation due to linear trend = $\frac{16546.58}{17257.67} \times 100 = 95.87\ \%$

ANALYSIS OF QUADRATIC TREND

(1') $\frac{416.4^2}{18 \times 14} = 688.05$

(2') $1/14\ (4.00^2 + \ldots\ 26.20^2) = 920.48$

(3') $\frac{196.5^2 + 219.90^2}{9 \times 14} = 690.22$

Source of variation	df	ssq	msq	F	sign
Within subjects	18	920.48			
Days	1	688.05	688.05	47.81	$p < 0.01$
Days x keyboards	1	2.17	2.17	-	
Days x within subjects	16	230.26	14.39		

Per cent of variation due to quadratic trend = $\frac{688.05}{17257.67} \times 100 = 3.98\ \%$

TABLE 3.14

CASHIERS - SPEED/STK

ANALYSIS OF COVARIANCE

	X^2	XY	Y^2	$(Y^1)^2$
K_1 v. K_2	100.28	- 262.41	686.68	370.23
(P)Subj. w.K	3732.22	-2499.52	22118.21	20444.16

ADJUSTED ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign.
K_1 v. K_2	1	370.23	370.23	0.27	N.S.
Subj. w.K	15	20444.16	1362.94		

r = 0.275

TABLE 3.15

CASHIERS - SPEED/SRT

ANALYSIS OF COVARIANCE

	X_2 X^2	XY	Y^2	$(Y^1)^2$
K_1 v. K_2	3.70	-50.71	686.69	853.49
(P)Subj. w.K	823.30	1316.13	22118.21	20014.08

ADJUSTED ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign.
K_1 v. K_2	1	853.49	853.49	6.39	0.05>p>0.01
Subj. w.K	15	2001.08	133.40		

r = 0.31

with the co-varia serial reaction time. Here the adjusted analysis of variance makes the effect from the keyboards significant with a risk between 5 to 1%. In other words where the speed of performance of the two groups of cashiers who operated on the two keyboards is corrected so that the two groups of girls are equivalent in terms of SRT a significant difference is found between the keyboards. Mean speed of keying is superior on the 123 keyboard. The within class correlation between SRT and keying speed is 0.31.

The accuracy of performance

Figure 3.11 gives the accuracy of performance for the cashiers and office girls. Both for the office girls and the cashiers, the performance on the 123-keyboard is better than on the 789-keyboard. The performance improves very markedly throughout two days and then flattens off.

Accuracy of performance: office girls

For the office girls the number of errors per 100 keystrokes were tested with a split-plot analysis of variance shown in Table 3.16. The difference between the two keyboards is not significant. The mean error rate for the 123-keyboard is 0.73, the corresponding figure for the 789-keyboard is 1.12. These results are shown in Table 3.17. It will be noted from this Table that on the last day, 5, there was evidence of a significant difference in performance. More errors were made on the 789-keyboard that on the 123-keyboard.

FIGURE 3.11

THE ACCURACY OF PERFORMANCE FOR CASHIERS AND OFFICE GIRLS

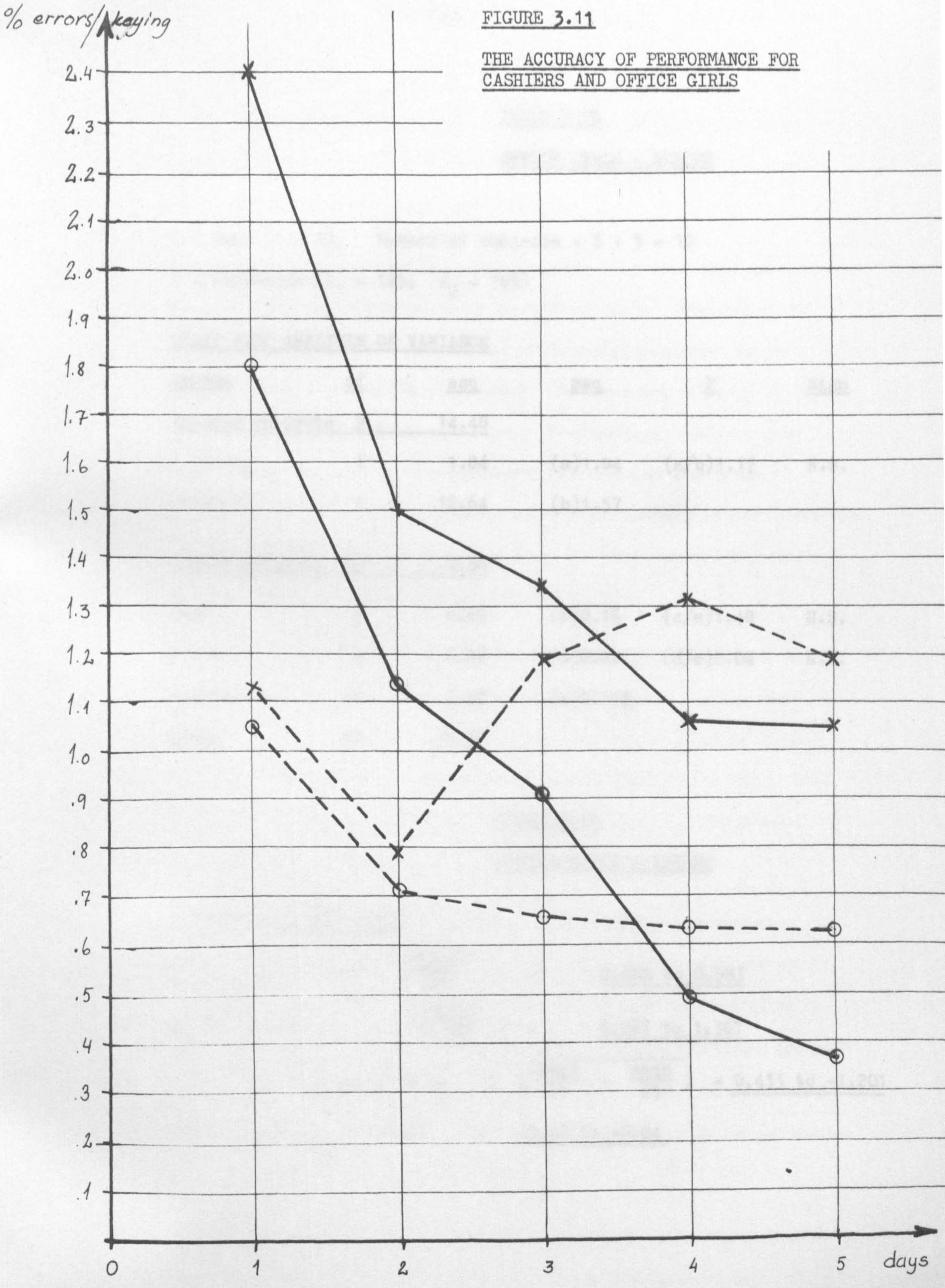


TABLE 3.16

OFFICE GIRLS - ERRORS

D = Days (1 - 5). Number of subjects = 5 + 5 = 10

K = Keyboards (K_1 = 123, K_2 = 789)

SPLIT PLOT ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign
Between subjects	9	14.48			
K_1 vs K_2	1	1.84	(a)1.84	(a/b)1.17	N.S.
Residual	8	12.64	(b)1.57		
Within subjects	40	4.98			
Days	4	0.65	(c)0.16	(c/e)1.48	N.S.
D x K	4	0.86	(d)0.22	(d/e)2.04	N.S.
Residual	32	3.47	(e)0.108		
Total	49	19.46			

TABLE 3.17

OFFICE GIRLS - ERRORS

CONFIDENCE LIMITS (95%)

$$\bar{Y}_{K1} \pm \left[t_{.05}\ (8\ df)\right] \times \sqrt{\frac{msqb}{25}} = 0.483 \text{ to } 0.983$$

$$\bar{Y}_{K2} \pm (2.31) \times \left(\sqrt{\frac{msqb}{25}}\right) = 0.867 \text{ to } 1.367$$

$$(\bar{Y}_{K2} - \bar{Y}_{K1}) \pm \left[t_{.05}\ (8\ df)\right] \times \left(\sqrt{\frac{msqb}{25} + \frac{msqb}{25}}\right) = 0.433 \text{ to } +1.201$$

$$(\bar{Y}_{K2} - \bar{Y}_{K1})_{\text{day } 5} \pm 0.28 = +0.28 \text{ to } +0.84$$

Table 3.16 shows that the variance ratio associated with days is non-significant. This implies that the mean error rate per day is effectively the same for all days.

Nevertheless, Tukey's Multi-Comparison Test was applied to the accuracy of performance of the office girls. The result is given in Table 3.18. None of the differences between means are significant at the 5% risk level. In summary errors diminished over the first two days. Thereafter, the improvement is very low. For the keyboard 123 one can see from Figure 3.11 that there is a continuous improvement in performance but for the keyboard 789 there is only an improvement the first days. There is then an increased error rate.

In the test of trends, (Table 3.19) it can be seen that there is no evidence of a significant linear or quadratic trend for the office girls. The hypothesis that there is no cubic trend would, however, be rejected with a risk level between 5% to 10%. The cubic trend contributes 65.2% of the variation, the quadratic trend 18.92%, and the linear trend only 3,78%.

In Table 3.20 an analysis of co-variance for the office girls performance in terms of accuracy has been tested with the short term memory (STM) as a co-variant. Even here the effect of the two keyboards was not significant. The within class correlation is very low indeed (0.01). This means that little is being gained by carrying out the adjusted analysis of variance compared with the standard analysis of variance.

In Table 3.21 another analysis of co-variance is performed where the co-variate against error rate is serial reaction time.

TABLE 3.18

OFFICE GIRLS - ERRORS

MULTIPLE COMPARISON TEST (TUKEY TEST)

	Day 1 1.091	Day 2 0.742	Day 3 0.925	Day 4 0.971	Day 5 0.898
1. 1.091	0	- 0.349	-0.166	-0.120	-0.193
2. 0.742		0	+ 0.183	+ 0.229	+ 0.156
3. 0.925			0	+ 0.046	- 0.027
4. 0.971				0	- 0.073
5. 0.898					0

None of the observed differences are significant at 5% level.

TABLE 3.19

OFFICE GIRLS - ERRORS

TEST OF TRENDS

ANALYSIS OF LINEAR TREND

Source of variance	df	ssq	msq	F	Sign
Within subjects	10(2')	2.3590			
Days	1(1')	0.0246	0.0246	-	-
Days x keyboards	1(3'-1')	0.6320	0.6320	2.97	-
Days x within subjects	8(2'-3')	0.2128			

Percent of variation due to linear trend: $\frac{0.0246}{0.65} \times 100 = 3.78\%$

ANALYSIS OF QUADRATIC TREND

Source of variation	df	ssq	msq	F	Sign
Within subjects	10(2')	0.9130			
Days	1(1')	0.1230	0.1230	1.33	-
Days x keyboards	1(3'-1')	0.0548	0.0548	-	-
Days x within keyboards	8(2'-3')	0.7352	0.0919	-	-

Percent of variation due to quadratic trend: $\frac{0.1230}{0.65} \times 100 = 18.92\%$

ANALYSIS OF CUBIC TREND

Source of variation	df	ssq	msq	F	Sign
Within subjects	10(2')	1.3439			
Days	1(1')	0.4238	0.4238	4.4376	0.10 p 0.05
Days x keyboards	1(3'-1')	0.1560	0.1560	1.6335	-
Days x within subjects	8(2'-3')	0.7641	0.0955		

Percent of variation due to cubic trend: $\frac{0.4238}{0.65} \times 100 = 65.20\%$

TABLE 3.20

OFFICE GIRLS ERRORS/STM

ANALYSIS OF COVARIANCE

	X^2	XY	Y^2	$(Y^1)^2$
K_1 v K_2	200.00	-19.18	1.84	1.83
(P) Subj. w.K	3998.00	1.14	12.67	12.64

ADJUSTED ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign.
K_1 v K_2	1	1.83	1.83	1.02	N.S.
Subj. w.K	7	12.64	1.80		

r = 0.016

TABLE 3.21

OFFICE GIRLS - ERRORS/SRT

ANALYSIS OF COVARIANCE

	X^2	XY	Y^2	$(Y^1)^2$
K_1 v K_2	89.52	-12.83	1.84	4.01
(P)Subj. w.K	142.50	+17.64	12.64	10.46

ADJUSTED ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign.
K_1 v K_2	1	4.01	4.01	2.69	N.S.
Subj. w. K	7	10.46	1.49		

r = -0.421

The within class correlation is quite strong (-0.42). The F value for the difference between the keyboards is greater in the adjusted analysis of variance than in the ordinary analysis of variance, (Table 3,16). The risk level is, however, greater for a rejection of the null hypothesis.

Accuracy of performance: cashiers

The accuracy of performance for the cashiers has been tested on a split-plot analysis of variance (Table 3.22). There is a non-significant effect from the keyboards. Mean error rate per 100 keystrokes for the 123-keyboard is 0.97. The corresponding figure for the 789-keyboard is 1.46. The difference between the means of performance in terms of accuracy for the two keyboards over all days include the zero, so the difference is not significant. The difference for the last day just fails to be significant on 95% level (-0.01 to 1.37). The effect over the days is, however, significant.

Table 3.22 shows that the probability of obtaining an F ratio as great as that associated with days is less than 0.01. Table 3.24 gives the results of the multi-comparison test between days for the accuracy of performance for the cashiers. It is largely between days 1 and 2 that significant improvements in error rates have been observed.

In the test for trends (see Table 3.25) there are significant effects over days both for linear and quadratic trends. The linear trend contributes 86.55% of the variation, whilst the quadratic, even though significant, only 10.75%. No interaction effects with key-

TABLE 3.22

CASHIERS - ERRORS

D_n = Days (1 - 5)

K 6 Keyboards (K_1 = 123, K_2 = 789)

SPLIT PLOT ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign.
Between subjects	17	46.61			
K_1 vs K_2	1	5.49	(a) 5.49	(a/b) 2.14	N.S.
Residual	16	41.12	(b) 2.57		
Within subjects	72	43.88			
Days	4	24.92	(c) 6.23	(c/e)21.48	$p<0.01$
Days x K	4	0.28	(d) 0.07	7	N.S.
Residual	64	18.68	(e) 0.29		
Total	89	90.49			

TABLE 3.23

CASHIERS - ERRORS

CONFIDENCE LIMITS (95%)

$$\bar{X}_{K123} \pm \left[t_{.05}\ (16\ df)\right] \times \sqrt{\frac{msqb}{45}} = 0.47 \text{ to } 1.47$$

$$\bar{X}_{K789} \pm \left[t_{.05}\ (16\ df)\right] \times \sqrt{\frac{msqb}{45}} = 0.96 \text{ to } 1.96$$

$$(\bar{X}_{K123} - \bar{X}_{K789}) \pm \left[t_{.05}\ (16\ df)\right] \times \sqrt{\frac{2\ msqb}{45}} = -0.20 \text{ to } +1.18$$

$$(\bar{X}_{K123} - \bar{X}_{K789})\ \text{day 5} \pm \left[t_{.05}\ (16\ df)\right] \times \sqrt{\frac{2msqb}{45}} = -0.01 \text{ to } +1.37$$

TABLE 3.24

CASHIERS - ERRORS

MULTIPLE COMPARISON TEST (TUKEY TEST)

	Day 1 2.176	Day 2 1.316	Day 3 1.121	Day 4 0.776	Day 5 0.714
1. 2.176	0	-0.860 a)	-1.055 a)	-1.400 a)	-1.462 a)
2. 1.316		0	-0.195	-0.540 a)	-0.602 a)
3. 1.121			0	- 0.345	-0.407
4. 0.776				0	-0.062
5. 0.714					0

All observed differences marked a) are significant at 5% level.

TABLE 3.25

CASHIERS - ERRORS

TEST OF TRENDS

ANALYSIS OF LINEAR TREND)

(1') $\frac{62.31^2}{18 \times 10} = \underline{21.5696}$

(2') $1/10\ (0.64^2 + ... + 6.49^2) = \underline{32.5064}$

(3') $\frac{34.13^2 + 28.18^2}{9 \times 10} = \underline{21.7663}$

Source of variation	df	ssq	msq	F	sign
Within subjects	18	32.5064			
Days	1	21.5696	21.5696	32.13	$p < 0.01$
Days x keyboards	1	0.1967	0.1967	-	N.S.
Days x within subjects	16	10.7401	0.6712		

Per cent of variation due to linear trend: $\frac{21.5696}{24.92} \times 100 = \underline{86.55\ \%}$

ANALYSIS OF QUADRATIC TREND

Source of variation	df	ssq	msq	F	sign
Within subjects	18	7.1589			
Days	1	2.6804	2.6804	9.7398	$p < 0.01$
Days x keyboards	1	0.0744	0.0744	-	N.S.
Days x within subjects	16	4.4041	0.2752		

Per cent of variation due to quadratic trend: $\frac{2.6804}{24.92} \times 100 = \underline{10.75\ \%}$

boards are exhibited for the trends. This confirms the result of no evidence of interaction between keyboards and days shown in Table 3.22.

Table 3.26 gives the same analysis when STM is used as the covariate. The adjusted analysis of covariance does not reject the null hypothesis that accuracy of performance on the two keyboards is equal. The within class correlation is also very low (+0.092).

In the analysis of covariance with SRT as the covariate, (Table 3.27), the adjusted analysis of variance gives about the same F ratio for the keyboards as was obtained in the ordinary analysis of variance (Table 3.22) i.e. non-significant. The within class correlation is -0.49.

TABLE 3.26

CASHIERS - ERRORS/STM

ANALYSIS OF COVARIANCE

	X^2	XY	Y^2	$(Y^1)^2$
K_1 v. K_2	100.28	+23.45	5.49	4.91
(I)Subj. w.K	3732.22	+36.33	41.12	40.72

ADJUSTED ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign
K_1 v. K_2	1	4.91	4.91	1.81	N.S
Subj. w.K	15	40.77	2.71		

r = 0.092

TABLE 3.27

CASHIERS - ERRORS/SRT

ANALYSIS OF COVARIANCE

	X^2	XY	Y^2	$(Y^1)^2$
K_1 v. K_2	3.70	4.50	5.40	4.52
(P)Subj. w.K	823.30	-91.05	41.12	31.05

ADJUSTED ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign
K_1 v. K_2	1	4.52	4.52	2.18	N.S.
Subj. w.K	15	31.05	2.07		

9.2 The subjective preference

In this section the results from the keyboard preference study and the study about preference for horizontal position of the keyboard are discussed.

The keyboard preference

The raw data comprising cashiers subjective responses to

(a) the full keyboard and the 789-keyboard

and (b) the full keyboard and the 123-keyboard

are given in Appendices 3.6 and 3.7 respectively. It will be recalled that office girls had no experience on the full keyboard and so no subjective responses were available from these subjects.

As the form of the data given in Appendices 3.6 and 3.7 is such that it is not possible to apply standard parametric tests the hypotheses specified in section 8.2 were examined by means of the Wilcoxon matched pairs signed ranks test (described in Siegel, 1956). The results are summarized in Table 3.28.

The only instances in which statistically significant differences were found between the keyboards in relation to the two questions posed were as follows:-

Q1:- difference between full keyboard and 123-keyboard (results averaged from days 1 and 5).

Q3:- difference between full keyboard and 123-keyboard (results averaged from day 1 and 5).

Question	All days: full/ ten-keyboard			Day 1: full/ ten-keyboard			Day 5: full/ ten-keyboard			All subjects: Day 1/ Day 5			All days: full/ 123-keyboard			All days: full/ 789-keyboard		
	T	N	Sig.%	T	N	Sig.%	T	N	Sig.%	T	N	Sig.%	T	N	Sig.%	T	N	Sig.%
1	-112	25	-	-21	11	-	-31.5	14	-	-153.5	25	-	-16.5	14	<5	-29	11	-
2	+114.5	26	-	-15	12	6.4	-40.0	14	-	-162.5	24	-	-37.0	15	-	-23	11	-
3	+73.0	20	-	+16.5	12	9.2	-22.5	10	-	-126.5	23	-	+7	10	<5	+30	12	-
4	+124.5	22	-	-18	11	-	-27.0	12	-	-83.5	22	-	+30	15	-	+21	9	-

TABLE 3.28

RESULTS FROM A WILCOXON MATCHED PAIRS SIGNED RANKS TEST OF THE SUBJECTIVE PREFERENCES TO THE FULL KEYBOARD vs. THE 123-KEYBOARD AND 789-KEYBOARD

Q1: General opinion

Q2: Comfort

Q3: Accuracy of performance

Q4: Speed of performance

N is the number of signed differences

T is the smallest sum of the equal signed ranks

The direction of the difference is not the same for the two questions. In relation to question 1 cashiers thought that the 123-keyboard was better in general than the full keyboard. In respect of question 3 the cashiers were of the opinion that the 123-keyboard was worse that the full keyboard in the sense that they thought more errors would be made on the former than on the latter.

One other result is close to significance the risk level being 6.4% which is very close to 5%. This occurs for the comfort question in which the full button keyboard is compared with the ten-button keyboard on day 1. The latter keyboard was judged to be more comfortable than the former.

Another result is just below 10% (9.2%). The full keyboard was judged as more accurate than the ten keyboard.

In general the cashiers judged the full keyboard as more accurate but less good in general and less comfortable.

The preference for horizontal position of keyboard

The raw measurements for the preferred keyboard position are given in Appendices 3.6 and 3.7 and in Table 3.29. It will be seen that measurements were not obtained on day 5 for ten of the cashiers and gives mean values, standard deviations and ranges for angles and distances for both the 123 and 789 keyboard. In Figure3.12 the mean values are represented in graphic form. From these results it is very difficult to track any form of systematic change in preferred keyboard position. It might, for example, have been expected that the range or the standard deviation would have

TABLE 3.29

RESULTS FROM THE MEASUREMENTS FROM THE PREFERRED KEYBOARD POSITION

		Day 1, all	Day 5, all	Day 1 & 5, all
Degrees of angle				
123T	$\bar{X}$	76.7	71.3	74.5
	S	6.4	7.1	7.2
	range	68 - 91 n =15	58 - 80 n=10	58 - 91 n =25
789T	$\bar{X}$	71.7	73.6	72.3
	S	9.4	6.6	8.5
	range	59 - 87 n =15	65 - 87 n =8	59 - 87 n =23
Distance (cm)				
123T	$\bar{X}$	9.0	12.2	10.3
	S	2.4	6.2	4.7
	range	5.5 - 14.3 n =15	3.2 - 21.5 n =10	3.2 - 21.5 n =25
789T	$\bar{X}$	9.6	6.8	8.6
	S	3.4	3.7	3.6
	range	4.8 - 14.8 n=15	1.9 - 10.7 n=8	1.9 - 14.8 n =23

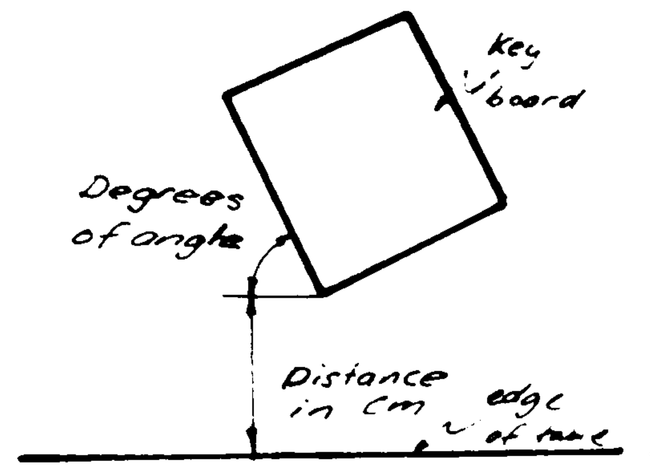
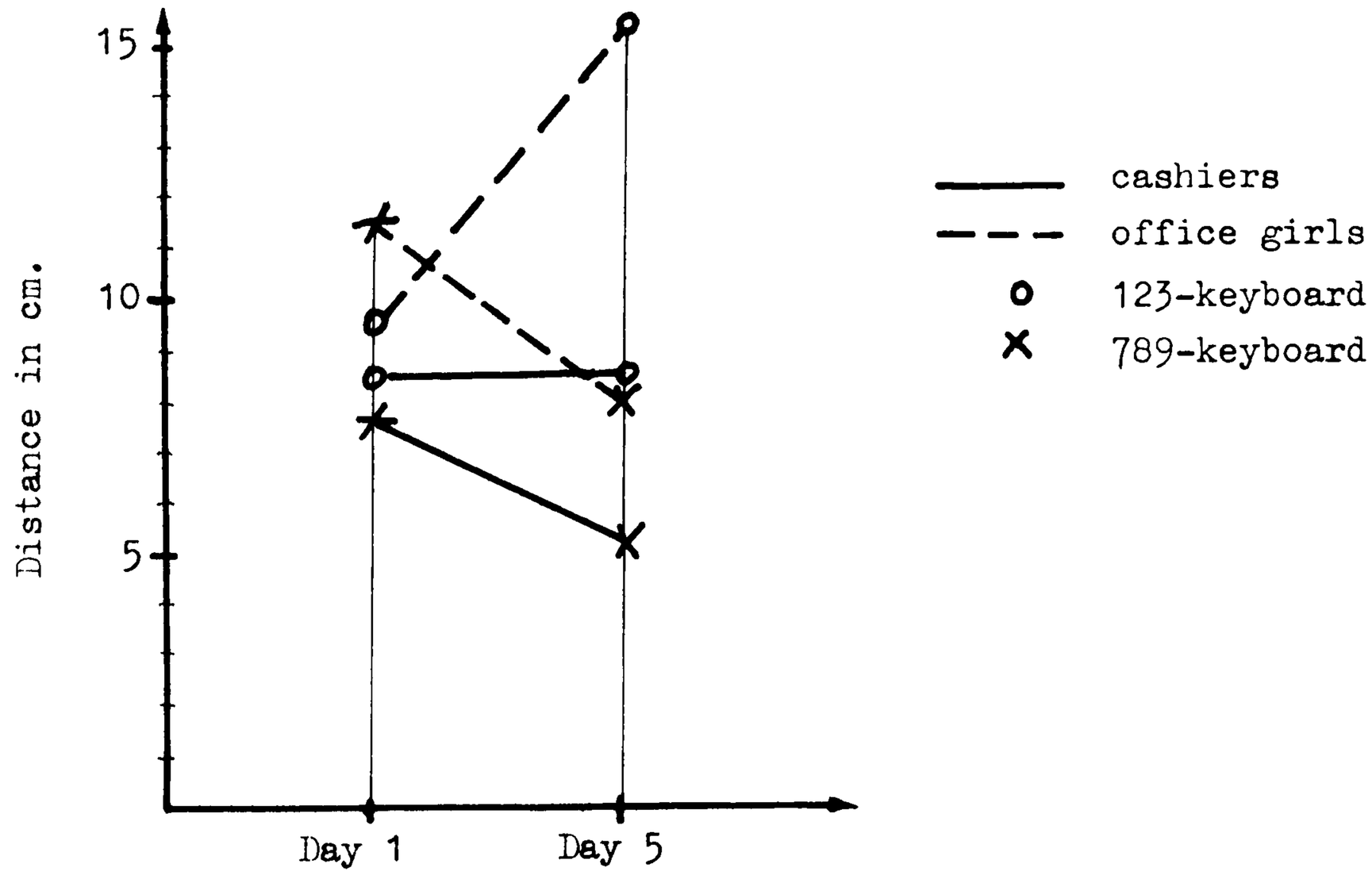


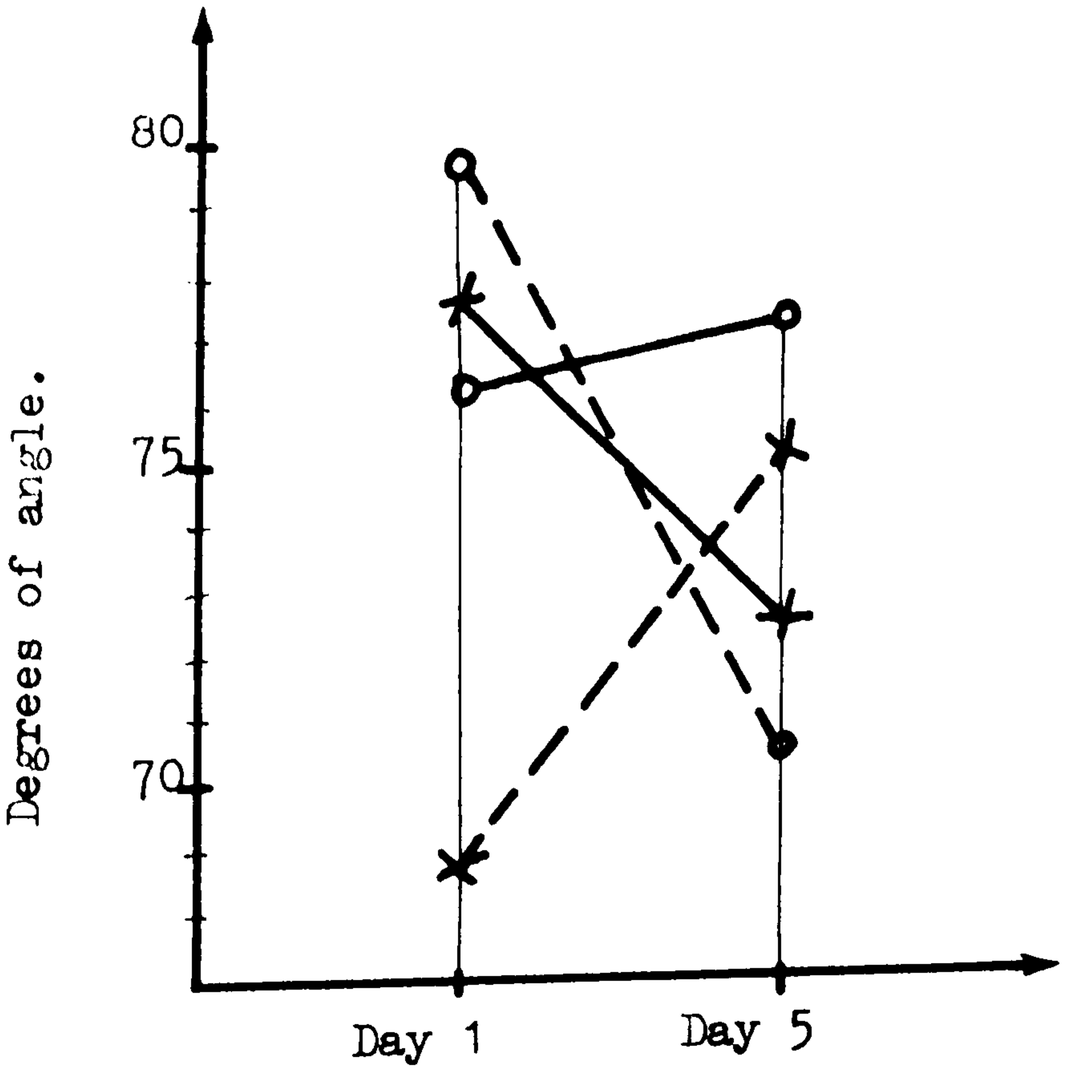
FIGURE 3.12

A GRAPHIC REPRESENTATION OF THE MEAN VALUES OF THE PREFERRED POSITION OF THE KEYBOARD

Distance to the edge of the table



Degrees of angle of the keyboard



decreased on the final day as the subjects became more used to the keyboard. This expectation would have been realistic if there is any specific "best" angle or distance. However, if the best positioning of the keyboard is different for each individual, one could not have this kind of expectation. However, the material and the differences in this case are too small to draw any final conclusions. A hypothesis that there are no differences between the angles or the distances for different days and keyboards cannot be rejected on this material.

10.0 SUMMARY OF RESULTS AND CONCLUSIONS

The performance in a keyboard task can be predicted by the performance on a serial reaction time test according to studies made by Leonard, et al (1966). Another important factor for the performance on a keyboard task, especially in relation to accuracy of performance, is short term memory. Broadbent, (1963), has constructed a test by means of which short term memory could be measured. The importance of short term memory is especially important for the new keyboard tasks for the cashiers in the new KF check-out system, where a code number is introduced in series with the keying of prices. The cashiers at the check-out desk will then be required to remember a number of digits which are likely to be near their memory span.

In the present experimental evaluation of two different kinds of ten button keyboards, it was desired to have subjects as homogeneous as as possible from a performance point of view. Therefore, the subjects were tested for serial reaction time and short term memory, and those who scored more extreme values were excluded from the experiment.

The experimental evaluation lists of performance ran for five days. Some subjects (cashiers) had previous experience on an ordinary cash register with a full keyboard and others (office girls) had previous experience on the 789 ten-button keyboard. Both groups of subjects tested both versions of the prototype keyboard, i.e. the 123 and the 789.

There was an improvement in performance over the five day testing period for both types of subjects and for both types of keyboards,

(Tables 3.30 and 3.31 and Figures 3.10 and 3.11). However, the improvement was not maintained over the final two days when performance was measured in terms of speed (number of keyings per minute). Both the office girls and cashiers worked faster on the 123-keyboard than on the 789-keyboard. The difference was, however, not statistically significant for the cashiers, (Table 3.30).

When a co-variate was introduced as a device to partial out individual differences between the groups of subjects who worked on the two different kinds of keyboards, the differences between the keyboards was more marked, (see Tables 3.30 and 3.32), when there was a significant within group correlation between the co-variate and the variate. Keyboard 123 was again found to produce superior speed of performance compared with keyboard 789. In general the correlations between the co-variates (the serial reaction time and the short term memory) on the one hand and speed of performance on the other were quite low. But of course this is natural as the more extreme subjects on the short term memory test and the serial reaction time test had been excluded from the study.

The speed performance curves of Figure 3.10 are mainly linear in nature but have a certain tendency to be quadratic (see Table 3.34). The training on the keyboards lasted half-an-hour a day for five days. The results indicate that there probably would have been an improvement in speed performance for more days of practice, but that the rate of improvement would not have been dramatic. The difference between speed of performance for the two keyboards seems to increase with time. On the last day, the difference between the keyboards is significant for the office girls, (Table 3.32).

* 0.1>p>0.05

** 0.05>p>0.01

*** 0.01≥p

TABLE 3.30

SUMMARY OF RESULTS (F-VALUES) FROM THE ANALYSIS OF VARIANCE AND THE ADJUSTED ANALYSIS OF COVARIANCE

Condition	Keyboard	SRT-adj. Keyboard	STM-adj. Keyboard	Days
Office girls - speed	5.17*	1.99	6.69*	54.97***
Cashiers - speed	0.49	6.39**	0.27	152.61***
Office girls - accuracy	1.17	2.69	1.02	1.48
Cashiers - accuracy	2.14	2.18	1.81	21.48***

TABLE 3.31

CONFIDENCE LIMITS (95%) FOR THE FOR DIFFERENCE BETWEEN THE KEYBOARDS THE LAST DAY AND FOR ALL DAYS COMBINED

Condition	Confidence limits last day	all days
Office girls - speed	+0.43 to +42.89	-0.32 to +42.14
Cashiers - speed	-7.22 to +26.02	-11.09 to +22.15
Office girls - accuracy	+0.28 to +0.84	+0.43 to +1.20
Cashiers - accuracy	-0.01 to +1.37	-0.20 to +1.18

TABLE 3.32

WITHIN CLASS CORRELATIONS

	SRT	STM
Office girls - speed	0.169	-0.400*
Cashiers - speed	0.310*	-0.275
Office girls - accuracy	-0.421	0.010
Cashiers - accuracy	-0.491	0.092

* In the adjusted analysis of variance, a significant effect from the keyboards was obtained.

For accuracy of performance, keyboard 123 was better than the 789 keyboard, both for cashiers and office girls, (Figure 3.11). For the cashiers there was an improvement in accuracy over the first three days and then a marked flattening off, followed by a small improvement in performance for the last day. For the office girls a similar, but not so marked, pattern occurred for the 123 keyboard. But for the 789-keyboard there was no significant improvement in accuracy of performance over all days. This is of course to be expected as these subjects had previous experience on this kind of keyboard. However, there was a marked improvement from the first day to the second and then a marked fall back towards the end of the testing period. It is difficult to find any convincing explanation for this result.

For accuracy of performance (Table 3.33) the quadratic trend was more marked than was the case for speed of performance. For office girls there was also a significant contribution from the cubic trend component in the curve. This tendency mainly originates from the girls working on the 789-keyboard. On the final day the difference between the accuracy of performance for the two keyboards is significant, (Table 3,31).

The performance for the office girls is better than performance for the cashiers, both in terms of speed and accuracy, (see Table 3.34).

The preference study also confirmed the results in the literature that an angle of the keyboard of about 15 degrees or more is the best. However, results also indicate that the subjects probably prefer to place the keyboard in a position which suits them

TABLE 3.33

TEST OF TRENDS OVER DAYS

	Linear trend	Quadratic trend	Cubic trend
Office girls - speed	95.26%	7.28%	< 0.46%
Cashiers - speed	95.87%	3.98%	< 0.15%
Office girls - accuracy	3.78%	18.92%	65.20%
Cashiers - accuracy	86.55%	10.75%	< 2.70%

TABLE 3.34

CONFIDENCE LIMITS (95%) FOR DIFFERENCES BETWEEN OFFICE GIRLS AND CASHIERS

		$\bar{X}$
I	Office girls - speed	103.25
II	Cashiers - speed	82.25
III	Office girls - accuracy	0.925
IV	Cashiers - accuracy	1.221

$$\bar{X}_I - \bar{X}_{II} \pm 2.12 \sqrt{\frac{27765.64}{49x50} + \frac{42005.39}{89x90}} = \underline{20.90 \pm 8.62}$$

$$\bar{X}_{III} - \bar{X}_{IV} \pm 2.12 \sqrt{\frac{19.46}{49x50} + \frac{90.49}{89x90}} = \underline{0.296 \pm 0.293}$$

individually, which could vary between ten and twenty degrees.

One can conclude from the subjective study that:-

1. 123-keyboard is subjectively preferred to the full keyboard.
2. The full keyboard is subjectively thought to give a more accurate performance.

From the experimental study one can conclude both for subjects with previous experience of full keyboard and those with previous experience of 789-keyboard, that:-

1. 123-keyboards produce about 60% less errors than the 789-keyboard.
2. 123-keyboard produces about 5-10% higher speed of performance than 789-keyboard.

AN ERGONOMICS STUDY OF THE CHECH-OUT SYSTEM FOR SELF-SERVICE SHOPS IN SWEDEN

PART 4

TECHNOLOGICAL AND PSYCHOLOGICAL PROBLEMS IN THE CHECK-OUT SYSTEM IN SUPERMARKETS

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11.0 INTRODUCTION TO PART 4

11.1 The aim of the study

The labour protection board in Sweden has recently introduced regulations (Anvisning angående utgångskassor, 1967) relating to the design of new desks for check-out systems. The aim of these regulations is to make the cashiers' work easier and less tiring and wearing. The bases on which the regulations rest are largely taken from general experience, except where it has been possible to use data from a few very small studies relating to problems of cashiers at work. An example is contained in Carlsöö, (1967). Carlsöö studied suitable ways of moving the goods on the desk surface. However, the cashiers job is of such a kind that many of the problems associated with her work are quite well known in the ergonomics literature. This means that it could reasonably be expected that good new regulations could be formulated without many more detailed ergonomics studies, and this seems to have been achieved.

The regulations specify cash desk height. They also specify a suitable form for the cash register and its location on the desk. The regulations also state that the moving of the goods should mainly be accomplished by conveyor belts and that neither the packing nor unpacking of the goods should be done by the cashier. They also state that the cashier shall be able to sit at her work.

These new regulations will create the need for a much more mechanized kind of cash desk. Within KF, the Hugin cash register factory, the architectural and retailing departments have introduced two slightly different versions of a new cash desk which fulfills the requirements of this new regulation. (Details of this new cash desk are given in the next section).

Two very interesting questions arise in relation to these new KF cash desks which fulfil the requirements of the new regulations.

1. Are they experienced by the cashier as being better than the old cash desks?
2. What are the implications of the new cash desk design for overall check-out system function?

The first question needs little elaboration. The second question involves establishing in what way this more mechanized cash desk and ancillary facilities affects the general performance of the check out system. Will, for example, the customer be more disturbed by this new system than by the old, what kind of accidents or malfunctions could occur in this new system? The two main questions posed above are examined in this part of the thesis.

The general working conditions for personnel in retailing have been studied in Sweden by Gardell, (1963) and more recently by Kilbom (1971). These studies have not dealt with the special problems of the cashiers. The study of Gardell dealt mainly with socio-psychological problems and Kilbom's study with physiological problems. In order to get further information on working conditions of the cashiers from the social and psychological point of view, this study will also incorporate a small investigation concerning these problems.

In summary, the aim of this study is then to:

1. study the function of the new cash desks

and 2. study the working conditions for the cashiers

11.2 A general background

In the old check-out systems there were a number of different types of cash desks. One quite common system was the so-called carriage-to-carriage system. In it the cashier had one carriage empty beside herself. The customer came up to the check-out point with her carriage filled with goods and placed it beside the empty carriage. The cashier took goods from the customer's carriage, looked at the price, inserted the value in the cash register and put the goods into the empty carriage. The cashier continued in this way until she had emptied the customer's carriage. The customer then paid for the goods and took the newly filled carriage away to a special location. The goods were taken from the carriage and packed in the customer's shopping basket. The carriage which had been used by the customer, and which was now empty was then used by other customers. In this system the transfer of goods from carriage to carriage by the cashier involved carrying with the body, and particularly the back, with twisted posture.

Another system which was also commonly used involved the following. The customer brought the goods in a carriage or basket in front of the cashier. The cashier removed the goods, looked at the price, keyed in the price, and then placed the goods on a sloped cash desk. The goods slid down to the bottom of this slope. At that point the customer had to do the packing while the cashier continued picking up the goods and keying in the price into the cash register. The difficulty with this system was that the slope down which the goods travelled had to be steep enough to remove them from the cashiers' location. As a result of the design of desk used, the point at which the customer packed her goods was too low for comfort.

The two old systems described above are still in extensive use. They will soon have to be replaced in the light of the new regulations for cash desks.

The new KF cash desk which fulfills the requirements of the new regulations is called the two conveyor belt cash desk.

There are two different versions of it, one recent (A), the other older (B). Both are used within KF and are included in this study. In Figure 4.1 and Figure 4.2 the two versions are drawn. The main difference between them is the positioning of the money drawer. In the older version it was placed under the cash register (Figure 4.1, item 13) on the right-hand-side of the cashier. On the new version the drawer is not a drawer, but a box (Figure 4.2, item 13) between the two moving conveyor belts. When not used the box is covered by a lid.

1. Conveyor belt from customer to cashier.
2. Conveyor belt from cashier to box.
3. Bar for changing of box.
4. Box for goods.
5. Box for bags.
6. Place for packing goods in bag.
7. Box for small bags.
8. Extra box for bags.
9. Box for special bags.
10. Waste paper basket.
11. Chair storage.
12. Safe box.
13. Cash drawer or box.
14. Cash register.
15. Place for coins.
16. Coin returner.

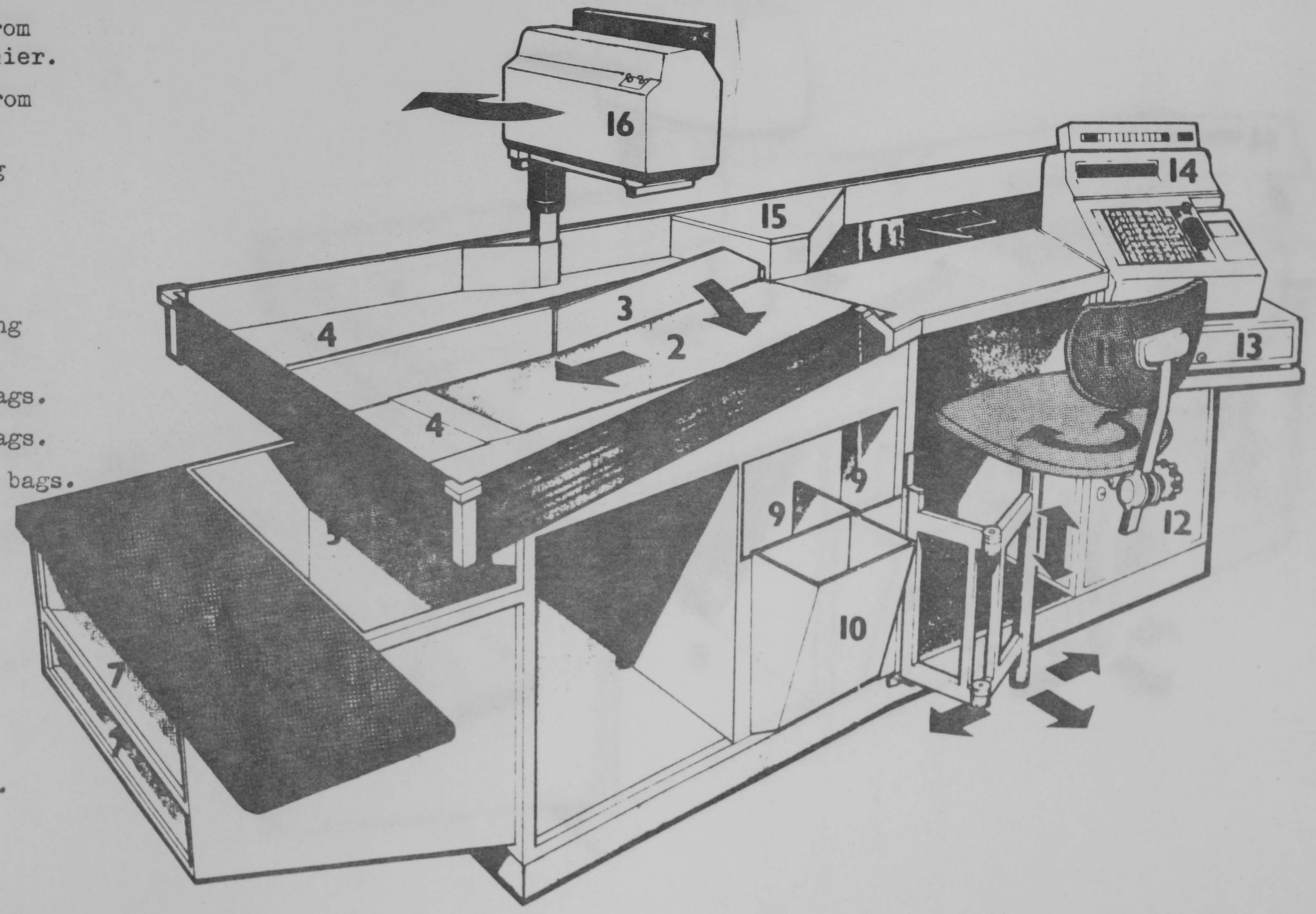

FIGURE 4.1 THE OLD VERSION OF THE NEW TWO CONVEYOR BELT CASH DESK.

1. Conveyor belt from customer to cashier.
2. Conveyor belt from cashier to box.
3. Bar for changing of box.
4. Box for goods.
5. Box for bags.
6. Place for packing goods in bag.
7. Box for small bags.
8. Extra box for bags.
9. Box for special bags.
10. Waste paper basket.
11. Chair storage.
12. Safe box.
13. Cash drawer or box.
14. Cash register.
15. Place for coins.
16. Coin returner.

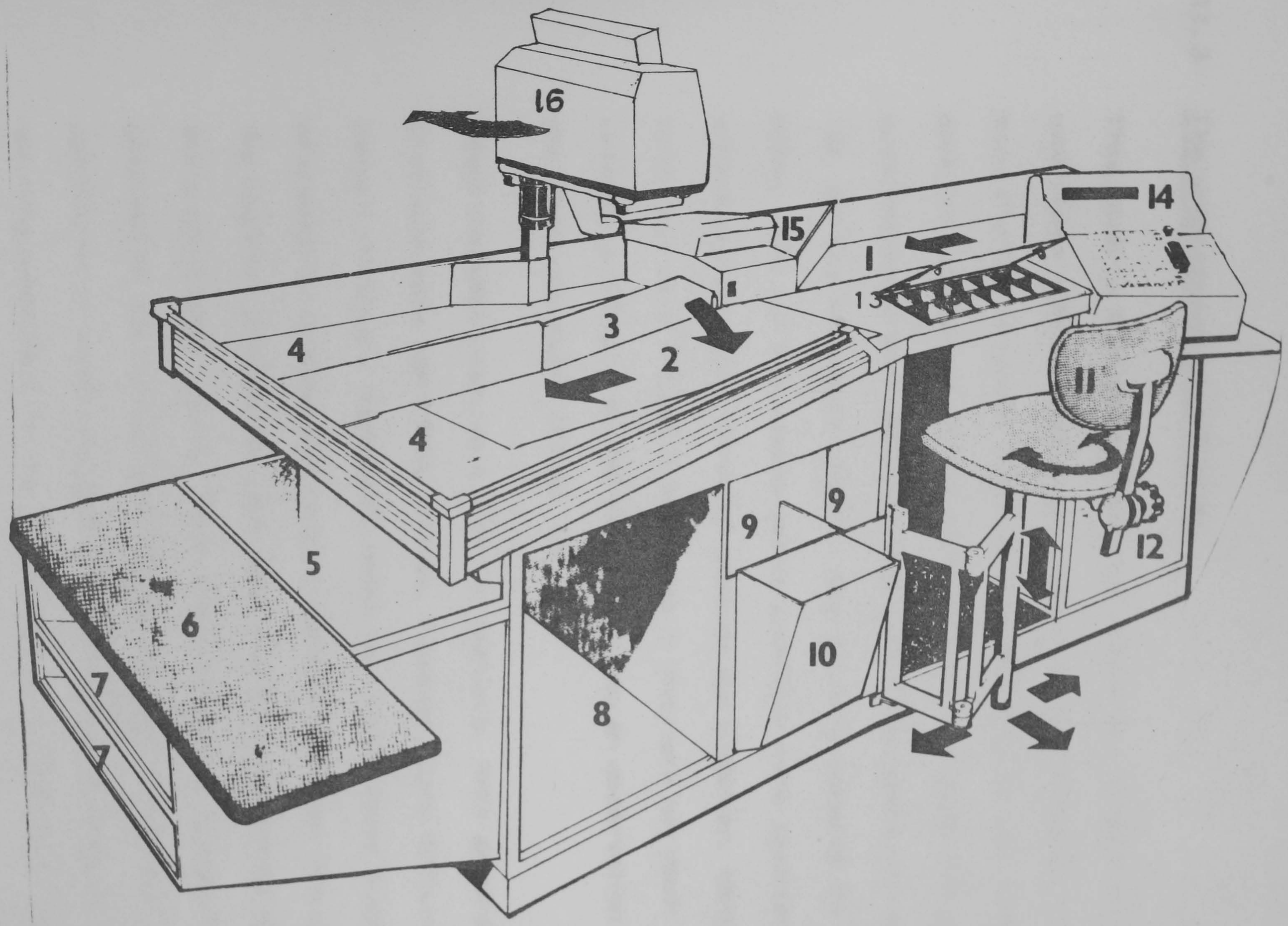

FIGURE 4.2 THE NEW VERSION OF THE NEW TWO CONVEYOR BELT CASH DESK.

11.3 The organization of this study

This study is divided into four. (a) There was a study in which open interviews with cashiers were used in order to find out what the main critical problems might be in relation to the use of the new cash desk (of both forms). From the results of this study two sets of questionnaires were designed and used in the check-out system. (Chap. 12). (b) The main questionnaire was directed towards the cashiers. (Chap. 13). (c) The second set of questions were used for a small structured interview directed towards the customer. However, this study was very limited in order not to interfere too much with the customers (Chap. 14). (d) There was also an observation study at the check-out point. (Chap. 15).

From the open interviews with the cashiers, their general problems were identified. It was, however, very difficult from these preliminary interviews which could only cover a small number of cashiers to draw any general conclusions about how difficult the cashiers thought the cash desk was to use,and what malfunctions were associated with it. This quantitative kind of data was instead obtained by the cashier questionnaire study. From this cashier questionnaire study was also obtained information about the general working conditions for the cashiers. In the customer study it was desired to get some indication of the attitudes and experience of the customer to the check-out system. In the observation study some further quantitative data were obtained about how often the different kind of incidents and malfunctions occurred in the system.

12.0 CASHIER INTERVIEWS

Introduction

The main aim of this study was to find what properties of the check-out system directly or indirectly assisted or inhibited its operation. The intention was not to get out quantitative data on the cashiers attitudes to events or malfunctions, but to find out what kind of properties and features relating to the efficiency of the check-out system it would be valuable to study in more detail. The study also sought to establish what properties of the check-out system affected the comfort and health of the cashier and the customer.

12.1 The method

Any deviation from the procedure required to operate or maintain equipment (in this case the equipment in the check-out system) in relation to its main aim, is defined as an error. It is important to notice that all errors are not alike in terms of causes or the effects on the system. Meister (1971) distinguishes between three different causes of errors:- the system-induced error, design-induced error, and operator-induced error.

The first type of error is that which results from inadequate design of the total system. This means a lack of adapting and combining the different system parts in the full system funtion. Design-induced errors result from inadequacies in the design of the individual equipment. Operator-induced error is due to individual factors, e.g. personality factors, intelligence, training, skill, fatigue.

In the check-out system there are two different "operators", the cashier and the customer. This study dealt mainly with design and system errors but to a certain extent also with operator errors. Design and system errors for future systems could be avoided by re-design of systems or equipment. Operator errors in respect of the cashier could also to a certain extent be avoided by new training, instruction and selection schemes. The behaviour of the customer could only be modified to a very limited extent. Here the system has to be as fool-proof as possible to avoid errors arising from this source.

Analogous arguments to those presented above in respect of errors could be made in relation to questions about comfort and discomfort in the system. In fact, discomfort could be defined as a deviation from a desired subjective state required to operate and maintain

the equipment and the system. In other words, discomfort caused an error according to the previously given definition.

When it is desired to find out what kind of errors are present in a system and their causes, several kinds of approaches are possible. One can, for example, use one or another of standard observation techniques. These include direct observation, memofilm techniques, ultra-rapid filming, ordinary filming, light tracing studies, and so on. For certain kinds of studies these methods are very valuable, especially when details on how work is performed, facts about work cycles, and so on are required. However, when one wants to detect infrequent events these kind of methods are very time-consuming and expensive. It is then better to use other approaches.

One such, due to Flanagan (1954), is the critical incident method. This is a technique which has been quite widely used both for studies of accidents and near-accidents and for work analysis. In his paper Flanagan gives a good description of the method. A short summary and a review of the method is also given by Chapanis, (1959).

The gathering of information on critical incidents can be achieved through the use of questionnaires and interviews. One is mainly dependent upon open-ended responses if questionnaires are used. This is because it is difficult for the researcher to specify in advance what are likely to be critical incidents. This means that the subjects themselves have to write down and describe different kinds of situations which are critical, In turn, this means that the questionnaire can only be used for subjects with a rather high degree of skill in writing and communicating their ideas in an articulate manner.

For subjects who cannot communicate in written report form one has to rely on interviewing or a combination of interviews and questionnaires. The advantage here is that the researcher can also follow up with questions to obtain more details valuable for establishing the causes of incidents.

An important limitation of the critical incident technique is that little confidence may be placed in the relative report rates associated with the various kinds of difficulties which come out of the study. This was not of any great disadvantage in this study, as the technique was used to obtain only qualitative information.

The incidents which are critical are the ones which are important for success or failure in the fulfilment of the objectives of the task. This definition is consistent with that for an error (of whatever form) as defined by Meister (1971). The different incidents to be collected have to be organized into different categories and sub-categories. Working on a higher level the categories can be grouped together to form the main areas.

The extent of the categorizing is dependent upon what is being looked for and how comprehensive the material needs to be. However, the main basis for manner, depth and extent of categorization should be theuse to which it is intended to put the results. In the present case the results were used as a preliminary step in finding out what kind of redesign of the system and its individual pieces of equipment needed to be carried out in order to avoid errors and malfunctions and to increase the comfort and ease of the operators in the use of the system.

Equipment errors in the present context were defined as all the different critical incidents which are caused by a certain common design property of the check-out system. In practice this meant that the

different critical incidents which were reported and which were judged to be dependent upon the same kind of properties of the check-out systems were brought together in one category and that category was called an "error".

As will be seen later on, the cashiers sometimes gave not only examples of different kinds of critical incidents but also gave direct examples of properties of the check-out system which they wanted to have changed. These properties are categorized separately if they can not be associated with some kind of critical incident.

It is very important to notice, as has been said previously, that in general little may be said about the importance of a critical incident in relation to how often the incident is reported by the subjects. In this study there were however, two main types of errors. There were those very infrequent errors which were more in the nature of episodes or accidents or near accidents. There were also those kind of errors which occurred more or less every time a work cycle was performed. For the latter kind of errors it can probably be assumed that the ones which are experienced as more important may be reported more often by the cashiers. Some justification for this kind of assumption may be found in a study by Flanagan (1954). He showed that there is a selective recall of critical incidents as a function of time and that the kinds of incidents recalled depend to some extent on the kind of incident. In the present study the time between the incident and reporting is about the same for the different kinds of incidents. They occur with about the same frequency but at different reporting rates, probably reflecting the different importances attached to them.

12.2 The procedure

One of the disadvantages of an interview study compared with an observation study is that memory errors may have an effect on the description of a critical incident. In the present study the different incidents which occurred in the check-out system were very simple and some of the incidents occurred very frequently. This meant that the risk of memory errors was probably small. For very infrequent incidents of an episodic nature and where the consequencies are serious, the risk of memory error is greater. On the other hand this kind of incident will probably not be detected if the observational approach is used.

As cashiers were not used to writing reports, data gathering on critical incidents through open-ended questionnaire forms was excluded. It was decided instead that interviews should be conducted. However, in order to get the cashiers to think about their work situation and get them to try to memorize the very infrequent kinds of incidents, a special question form was written.

This form was sent out to cashiers the day before their interview was due to take place. At the same time they were told that their individual answers were to be kept confidential. The form contained questions on which the interview was built. The cashiers were asked to think about these questions as they would be interviewed on them the following day. All the interviews were recorded on a tape recorder in order to maximize the information retained. Each interview took about 15 to 20 minutes.

A small pilot study was run on twelve subjects as a preliminary to a larger scale investigation.

The intention was that the questions given on the questionnaire form would cover not only the different kinds of equipment error which were of relevance to the comfort and efficiency of the cashiers, but also the kinds of error which might be associated with the more episodic and accident type of incidents. This was true for the larger scale investigation.

In the pilot study there were only three questions put to each cashier. 1. is there anything uncomfortable or tiring in the work you do? 2. is there anything functioning in such a way that it prevents good and efficient work? 3. please describe in detail any accidents or unpleasant events at work which you yourself have seen or been involved in.

Broadly speaking the pilot study indicated that the critical incident technique use upon questionnaires was a viable method, if some slight modifications were made. It was not necessary to modify the instructions presented to subjects the day before the interview. These instructions, together with the questions are given in Appendix 4.1.

In the main study, however, the questions were extended to cover also the positive side of comfort and efficiency. According to Finkle, et al (1961), it does not matter if the positive or negative version of the question is asked first. In order to get the cashiers to think a little bit more about the work, they were asked to compare the present new cash desk with the cash desk they had been working with before. Finally a general question was introduced asking for suggestions from the cashiers. This extension was made because, in the pilot study, it was found that some subjects found the questions too abstract and reports of incidents were few.

The form containing the questions which were posed to the cashiers is shown in Appendix 4. 1.

The interviews in general strictly followed the questionnaire; no examples of critical incidents were provided as this could very easily have influenced the answers given (Andersson and Wilsson, 1961). If the cashiers had difficulty in answering a question it was re-phrased. On the first question, e. g. "is there anything which you find uncomfortable or tiring at your work?", the question was instead formulated as: "Is there any position or movement or way of work which you find uncomfortable or tiring?".

The subjects for the main study were sixty-five cashiers who had been working for some months with the new KF two-conveyor-belt cash desk. The ages of the cashiers varied between 25 and 55 years.

The cash desks involved in the study were of two different models. These two models have been described before and are illustrated in Figures 4. 1 and 4. 2. Cash desks of this type were quite new at the time of the study. They had been used for a maximum of one year.

The number of subjects in this study was not large compared with the total number of cashiers in Sweden. No attempt was made to represent the general population of cashiers in Sweden in this study. It is, therefore, impossible to draw any generalizated conclusions relating to the general population of cashiers. It was extremely difficult, even within KF, to follow a strict sampling procedure as the new cash desk was not widely available. Nevertheless cashiers with experience on the new desk were sampled from

different parts of the country, both from big cities and small towns. These different types of situations, in terms of the goods handled at the check-out system, were represented in the study. All of the situations involved check-out systems in self-service shops. The situations were:

1. Food sections in large stores
2. Supermarkets

and 3. Department stores

The type of goods passed through the check-out system for situations 1 and 2 were very similar and consisted mainly of food. There was greater variety for situation 3 where the goods included not only food but many other perishable and non-perishable goods bought for the home.

12.3 The results

From the tape recordings of the interviews, notes were made of all critical incidents and their respective frequencies.

The critical incidents that were reported were then arranged into groups. Incidents with what seemed to be a common cause were put in the same group and classified as an error. Sometimes the error class only contains one type of critical incident.

All the different critical incidents are given in Appendix 4.2. In Table 4.1 the main groups into which the different critical incidents have been classified by the author are given. The main divisions are 'transportation of goods', 'payment for goods', 'the general design and layout of the cash desk'. 'Transportation of goods' has in turn been divided into incidents dealing with the conveyor belt, the storage of goods, manouvering of goods and the loading and unloading of goods into and from the system. 'Payment for goods' is made up of incidents grouped in the following way: the location on which money should be placed to pay for goods, the cash box, the cash register, change returner and price marking. Finally the 'general design and layout of the cash desk' consists of the critical incident classes: packing, off-line storage and the size of the equipment.

In Table 4.1 the different frequencies of occurrence for the different classes and sub-classes are also given. The different incidents and factors which exercise a positive and beneficial influence on efficiency and comfort are given separately in Table 4.2.

TABLE 4.1

THE MAIN GROUPS OF CRITICAL INCIDENTS

(the frequencies of reporting of different incidents)

1.0	TRANSPORTATION	
	.1 The conveyor belt	(57)
	.2 The storage	(102)
	.3 Manoeuvering	(10)
	.4 Loading and unloading	(62)
2.0	PAYMENT	
	.1 The place to put money	(17)
	.2 The cash-box	(90)
	.3 The cash-register	(24)
	.4 The change-returner	(18)
	.5 The price marking	(20)
3.0	THE DESIGN AND LAYOUT	
	.1 Packing	(13)
	.2 Off-line storage	(19)
	.3 The size & form	(25)

TABLE 4.2

PERCENT OF FACTORS MENTIONED BY THE CASHIERS WHICH ARE OF BENEFIT IN TERMS OF THEIR COMFORT OR EFFICIENCY OF THE CHECK-OUT SYSTEM

	COMFORT		EFFICIENCY		THE CASHIER HAS MENTIONED EITHER COMFORT OR EFFICIENCY	
	Freq.	%	Freq.	%	Freq.	%
1. The conveyors	51	78.5	38	58.5	54	83.1
2. The customer unloads and packs herself	27	41.5	12	18.5	29	44.6
3. Help with packing (mainly for the customer's comfort)	6	9.2	27	41.5	29	44.6
4. There should be more boxes	0	0	1	1.3	1	1.3
5. Foot-pedal (to the conveyor)	1	1.3	3	4.6	4	6.2
6. The change-returner	36	55.8	30	46.2	44	67.7
7. The cashier should sit down	29	44.6	0	0	29	44.6
8. The touch-method, see II.15	1	1.3	5	7.7	5	7.7
9. Easy to exchange cash-slip tape	2	3.8	0	0	2	3.8
10. The keyboard of the apparatus easy	6	9.2	1	1.3	7	10.8
11. The cash-register has the right position for easy handling (see III:6 and 14)	1	1.3	2	3.8	3	4.6
12. The right height (for whole cash register)	0	0	3	4.6	3	4.6
13. Comfortable chairs	5	7.7	0	0	5	7.7

If it is desired to know more specifically what was wrong with, for example, the conveyor belt, it is necessary to refer to the complete list in the Appendix. There it may be seen that there was a greater risk for fragile goods being damaged by heavy goods when the conveyor belt was in motion. Reference to Appendix 4.2 also shows that there was a risk of getting plastic packets, newspaper, stuck in the conveyor belts. It also seems clear that the design of the boxes for storage of goods at the goods packing point was not very effective. On the right hand side of the table in Appendix 4.2, different incidents which are attributed to the same cause are gathered together and main causes given. Incidents reported for the question where the subjects were asked to compare the new with the old desk are identified by the word comparison (or comp.).

The frequency for every critical incident, in other words the number of cashiers who mentioned the incident, has been calculated as a percentage of the total number of cashiers in the investigation. If the incident was caused by a detail or property which was only present on some of the desks, the percentage of cashiers who mentioned the incident was calculated in relation to the total number of cashiers who were working on the desk with the detail or property in question. Ninety five percent confidence intervals were calculated for the relative frequencies according to the formula:-

$$p \pm 1.96\, Sp ,$$

where $Sp = 100 \sqrt{\frac{pq}{N}}$,

p = the proportion of incidents

q = 1-p

N = sample size

It can be assumed that the sampling distribution of a proportion can be approximately represented by a normal distribution. For any given value of N the sampling distribution of a proportion becomes increasingly skewed as p and q depart from 0.5. N x p (or N x q if q is the smaller of the two proportions)ought to be greater than 5.

Relative frequencies of critical incidents for the two versions of the new type of conveyor belt cash desk have been calculated separately. The differences between the frequencies have been tested by X^2 with Yates' correction for small expected frequencies.

12.4 Conclusions

In the following section the percentages of cashiers reporting incidents (or errors) are given. Here again it is important to notice that not too much faith should be placed in these different percentages. The importance of an error has also to be judged by the kind of effect it might produce, for example in terms of the reputation of the shop, accidents.

Transportation

The errors which seemed to be more frequent were ones associated with the conveyor belt and the storage place.

As the conveyor belt is not fitted tightly enough, newspaper, some packing material, etc. gets stuck in the end of the conveyor belt (38%). Money which slips on the desk falls down under the conveyor belt also due to these reasons (9.2%).

One danger is that heavier goods damage more fragile goods at the end of the conveyor belt if the cashier does not change the order of the goods, taking the heavier goods first. The problem in connection with this is that there is very little room to change the order around. This was stated by 29% of the cashiers. In fact there seems to be a tendency for the customer to pick up the most fragile goods first on the conveyor belt as they have placed the most fragile goods on the top of their basket in order not to damage them.

For the newer version of the conveyor belt cash desk which has the cash box placed between the two conveyor belts there is another complication in connection with this point. The cashiers cannot

open the lid of the cash box when there are many customers, as she has one customer's goods in front of her while waiting for the other customer to do her packing (mentioned by 27% of the cashiers).

The final conveyor belt is controlled by a special switch which is hand controlled. 7.7% of the cashiers wanted a foot pedal.

Incidents which could be interpreted as indicating that the storage boxes were too small were mentioned by 38% of the cashiers. Incidents implying that there were too few of these boxes - the customer was unable to pack her goods before her box was needed by another customer- were reported by 83% of the cashiers.

Payment

A very disturbing incident is that the customer often puts the money in the wrong place. The customer often puts the money in the space between the two conveyor belts instead of the special place for putting money. This is often due to the fact that the customer has placed her bag in that place instead (16.9%). The cashiers then have to pick up coins one at a time due to the design of that place between the two conveyor belts.

There is a significant difference between the newer and the older version of the new cash desk in the frequency of errors caused by the cash box. This means that it is better to have the cash box situated between the two conveyor belts than to have the cash box as a drawer under the cash register.

Forty two point six percent of the cashiers who work with the older version of the new cash desk have reported it as uncomfortable to turn and bend in order to reach the money in the cash box.

None of the cashiers who are operating the newer version of the cash desk made any complaints in this respect. But the cashiers operating the older version of the cash desk also experienced it as difficult and dangerous that the cash box projected in such a way that it interfered with the queue of customers at the cash desk behind the cashier. This meant that they had to watch the cash drawer while they were getting change, in order to prevent money from being stolen. (38.9 % against 0 % in the new model). The disadvantage of the new cash box seems to be that it is too small, and especially that the lid opening is too narrow, making it difficult for the cashiers to remove notes. This is reported by 63.7 % in the new version as opposed to 11.1 % in the old version. Twenty seven point three percent of the cashiers using the new version have reported that they hurt their fingers when removing money from the cash box.

The coin and change returners' function does not seem to be satisfactory. It sometimes returns too much or too little. 13.3 % of the cashiers have reported such incidents. The customers often forget to take their change from the change slot (6.2 %).

General design of layout

The design of the storage boxes for paper bags and carriages is not good (10.8 %), as they are too small and are placed in such a way that the customer does not see them.

Twenty three point eight percent of the cashiers reported that it is difficult to reach the paper bags when they try to help the customers pack. If one divides the answer as to the type of shop, one finds that 59.3 % of the cashiers in the department store (Uddevalla) complain about the positioning of the cashier's bags against 4.4 % of the cashiers in other types of shops. The difference is

significant and the reason is probably due to the different type of goods sold in the different types of shops. In department stores the cashier herself often has to put some kind of fragile goods, e.g., china and glassware in a bag to protect them. In such cases the cashiers have to bend and reach for the bags more often and the uncomfortable positioning becomes more apparent for them than for cashiers working in other kinds of shops. A better positioning of the cashier's bags is therefore important, especially for those cash desks to be used in department stores or shops which sell these type of goods.

The storage places for the cashiers are not large enough, as has been said by 9.2% of the cashiers; 15.4% of the cashiers said that it is uncomfortable and ineffective that the chair can only be moved in one direction. This means that they cannot move the chair in the direction towards the customer when they want to help the customer pack the goods.

The cashiers do not seem to differentiate between the properties of the cash desk which makes the work more comfortable or efficient. One property of the cash desk which simplifies the work was probably built to make it more effective. On the positive side, for comfort and efficiency, the conveyor belt was mentioned by 83.1 % of the cashiers, the change returner by 67.7 %, and the fact that the customer has to load and unload the desk, by 44.6 % of the cashiers. Forty four point six percent of the cashiers also said that it is helpful the desk is designed for sitting work.

As seen above, some idea of what is good and bad about the two versions of the new desk have been established by this critical incident study. If one wants to find out how important the different factors are from

the subjective point of view of both the customers and cashiers, and about how often they occur, one has to conduct further studies. The results from the present critical incident study may then be used as a basis for these further studies. These are described in the next sections.

13.0 THE CASHIER QUESTIONNAIRE

Critical incidents were revealed in the cashier interview study. The critical incidents arose from design features of physical components in the check-out system which caused difficulties for the cashiers. It was not possible to establish the frequency of incidents and to obtain a quantitative evaluation of their subjective importance to the cashiers. This accordingly was one of the primary aims of the cashier questionnaire study.

Secondly in the cashier interview study,no attempt was made to compare the cashiers'opinions about the old KF cash desks and their associated check-out system with those relating to the two versions of the new twin conveyor belt system. A second aim of the present study was to clarify this issue.

Thirdly it seemed necessary, to complete the picture of how the cashier felt in relation to her task at the cash desk, to obtain her feelings, attitudes and opinions towards more general features of her job, such features including physical working conditions, economic and socio-psychological aspects. This was the third aim of the present study.

In respect to the second and third aim, it also seemed particularly relevant to study the effect of the cashiers' age and length of experiences of cashier work.

13.1 The method

It was decided that the most convenient way of obtaining the information specified above was to ask cashiers to fill in questionnaires. (Other techniques, such as behavioural observation, might have been employed to obtain part of the required information. Essentially, however, the subjective responses of the cashiers were required about different aspects of their working conditions. The most appropriate techniques seemed to be those involving the use of questionnaires or interviews, but the latter were just not possible in terms of a large scale data gathering exercise over the whole of Sweden.

A pilot questionnaire was constructed, which consisted of three parts. The first part consisted of 12 questions relating to issues which seemed to be important, (reported with a high frequency of response or judged as important due to their causes, e.g. risk or damage to people or material), to the cashiers in the critical incident study. The twelve questions were mainly concerned with obtaining in a systematic way the opinions of cashiers on technical design features of the check-out system which seemed to give rise to difficulty. Included were questions relating to the conveyor belt, the storage place for goods, the change-returner, the cash register, the customer's carriage for transporting goods about the store, and the cashier's seat.

The second part of the questionnaire contained questions of a more general nature and have been derived from a variety of sources including Hertzberg et al (1959), Blauner (1964) and Gardell (1963 and 1971). All these authors are concerned

with work reviewed from a psychological, a socio-psychological and a sociological point of view. Gardell's work is particularly relevant. In the study which he reported in 1963, he was concerned with work conditions in retailing from a socio-psychological point of view. In the later paper, 1971, he reviewed his earlier work and divided the socio-psychological conditions of work into a number of areas, or inclines as he calls them. Using a similar kind of division to Gardell, the questions posed in part two of the present questionnaire cover the following ground in terms of the subjective feelings and attitudes of cashiers:-

(a) general job satisfaction

(b) intrinsic interest of the work

(c) physical stress imposed by the work

(d) psychological stress imposed by the work

(e) independence involved in work

(f) relation to colleagues at work

(g) relation to superiors at work

(h) organisation of work

(i) adequacy of salary

In addition the opportunity was taken in the second part of the questionnaire to pose open-ended questions relating to features of the cashier's job which were least and best liked, and to determine in what respect the cashier's job was regarded as wearing. Furthermore, a rather specific question was included in seeking reasons for miskeying.

The third part of the questionnaire consisted of three questions and sought factual information on the cashiers age, her length of experience as a cashier in a self-service shop, and the length of time she had worked (if at all) on either version of the new cash desk with two conveyor belts.

Moving from the content of the questionnaire and turning to its form, it was laid out in accordance with the general rules given in such texts as Moser and Kalton (1971) and Oppenheim, (1966).

In order to see if any difficulties occurred with the questionnaire in terms of its content and form, it was distributed in its pilot version to 30 cashiers working for KF in supermarkets in the Stockholm area. The only difficulty which was found related to the cashiers difficulties in expressing their intensity of feeling or attitude by making a mark on a continous line, where the end points of the line consisted of vertical bars and represented the extremes of feeling, thus

very convenient — very inconvenient

It was found that this arrangement, despite appropriate instruction gave rise to misunderstandings. The cashiers in the pilot study treated the response possibilities to the sort of question indicated above as dichotomous and put a mark at one or the other end of the scale. Only very rarely did they put a mark at an intervening point between the extremes.

Accordingly for this type of question a response line was provided with five intervening verticals as below.

very convenient

very inconvenient

It was thought that the six response boxes so provide for questions where feeling might be expressed on a continuous scale were sufficient for the cashiers adequately to represent their feelings.

The final version of the questionnaire, in its English translation, is given in Table 4.3. The division of the questionnaire into its three parts may be clearly seen. It will be seen that the response possibilities for the first 12 questions (Part 1), fall on six-point scales. For the second part, consisting of 25 questions, 16 (questions 13 - 28 inclusive), have six-point response scales, 4 (questions 29, 30, 33 and 34) involved dichotomous responses, one (question 31) involved responses on a five-point scale. The remaining questions in Part 2 (questions 32, 35, 36 and 37) were open-ended in nature.

Part 3 consisted of three questions (questions 38, 39 and 40), where the response was given in years (cashier age and length of experience as cashier in a self-service shop) and years and months (experience on new cash desks).

TABLE 4.3

QUESTIONNAIRE FOR CASHIERS IN SELF-SERVICE SHOPS

Part 1

Events of the kind mentioned below in the first 12 statements sometimes occur. Against each statement is a line broken up into 6 'boxes'. Put a tick in the box which best represents your feeling towards the event mentioned in the statement. Try to think how good or bad, or how convenient or inconvenient, an event is, irrespective of how frequently it occurs.

1.	The customer puts her goods onto the conveyor belt without taking them out of the basket.	It doesn't matter	very inconvenient
2.	Newspapers, packets of sausages and similar objects get stuck in the conveyor belt.	it doesn't matter	very inconvenient
3.	At the end of the conveyor belt the goods that follow on the belt press on the goods that have gone before so that the more fragile articles are damaged.	it doesn't matter	very inconvinient
4.	The customer hasn't enough time to pack her goods before the goods-box is needed for other customers.	it doesn't matter	very bad

5.	If a customer starts to pack before she had paid for the goods, the cashier has to reach for the customer's money and to return the change, or the customer has to hurry back to the cash-desk to pick up her change.	it doesn´t matter	very inconvenient
6.	The customer puts the money on the wrong place, e.g. on the plate between the moving belts.	it doesn´t matter	very inconvenient
7.	(Only to be answered by those who work at the cash register with two belts and with the cash drawer built into the cash-desk - not with a drawer under the cash register). You scrape your fingers against the lid of the cash register drawer when you take out money.	very inconventient	it doesn´t matter
8.	(Only to be answered by those who usually use a change returner). The change returner does not work as it should. It sometimes returns too much and sometimes too little money.	very inconvenient	it doesn´t matter
9.	It is not possible to push the bar over ~~the~~ it deflect purchased goods from one box to another when the customer has bought a large number of goods.	very inconvenient	it doesn´t matter

Table 4.3 cont.

10.	Some customers do not know where to put the carriages, which is the cause of the carriages being left in front of the cash-desk.	it doesn't matter	very inconvenient
11.	It is possible to adjust the chairs to different heights.	very good	very bad
12.	(Only to be answered by those who have such chairs). Some chairs are designed so that they can only be turned one way.	it doesn't matter	very inconvenient

Part 2

Here follows sixteen questions about how you find your work. Answer each question by putting a tick in the 'box' (in the same way as you did in Part 1), which best describes how you feel.

13.	How heavy do you find your job?	very heavy	not heavy at all
14.	Do you find your job monotonous?	yes, very	no, not at all
15.	How qualified or unqualified must a person be to do your job?	very qualified	very unqualified
16.	What do you think about the mental load of your job?	very mentally stressing	not mentally stressing at all

Table 4.3 cont.

17.	Do you think that your job requires attention?	yes, to a great extent ... no, not at all
18.	How do you feel about your working pace?	very hectic ... not hectic at all
19.	What do your friends think of your job?	very good ... very bad
20.	How interesting or uninteresting do you find your job?	very interesting ... very uninteresting
21.	Do you think that your job requires responsibility?	yes, to a great extent ... no. not at all
22.	Do you think that your job involves self-reliance?	yes, to a great extent ... no. not at all
23.	Are you of the opinion that there are possibilities for promotion within KF?	yes, very good possibilities ... no, no possibilities at all
24.	How do you experience contact with the public?	very unpleasant ... very pleasant
25.	How do you find the atmosphere at work?	very good ... not good at all
26.	How do you get on with your colleagues on the whole?	very well ... very badly
27.	What do you think of your immediate superiors?	very bad ... very good
28.	Would you advise a friend to take a job as a cashier?	yes, without hesitation ... no, not at all

TABLE 4.3 (cont.)

Please put a tick in the appropriate square for the alternatives given against the following 6 questions.

29. Are you satisfied with your present working hours?	yes ☐	no ☐
30. Are you satisfied with the breaks you have?	yes ☐	no ☐
31. Which of the following expressions would most correctly correspond to what you generally think of your job at Domus/ Konsum, if you were going to express your feelings about it to a friend?	1. I like it very much ☐ 2. I like it fairly well ☐ 3. I neither like nor dislike it ☐ 4. I do not like it very much ☐ 5. I do not like it at all ☐	
32. Have any of your previous colleagues finished their jobs during the last years because they did not feel happy with it? Which factor do you think was the most important cause? (Only one alternative).	1. The salary was too low 2. The work was tiring and wearing 3. Some other factor Which?	
33. Which arm do you think must work hardest at the cash register work?	left ☐	right ☐

TABLE 4.3 (cont)

34. Sometimes one keys an incorrect price. What do you think the reason is for this?

	Difficult to read the price-list	Difficult to find the correct key	One is tired	One is stressed	Another reason, (write it)
Most important					
Second most important					
Third most important					
Fourth most important					

To conclude, please answer the following questions in a few words.

35. What do you like best about your present job? .....

.....

.....

36. What do you like least about your present job? .....

.....

.....

37. All jobs have more or less tiring effects on people. In what way do you think the cashier's job is tiring? .....

.....

.....

TABLE 4.3 (cont)

Some questions about yourself.

38. Your age: _____ years.

39. I have been working as a cashier for _____ years.

40. I have been working with the new two conveyor belt cash desk for _____ years _____ months.

13.2 The procedure

It was desired to circulate the questionnaire to as many cashiers as possible within the KF Organisation. Perhaps the most effective way to ensure a very high response rate and to clear up immediately any ambiguities arising from questions would have been to deliver the questionnaires personally to all cashiers and to sit by them as they completed them. This, however, was out of the question as a large number of cashiers was to be approached.

Contacting cashiers within the KF Organisation directly by mail from headquarters in Stockholm also presented difficulties. No records were held centrally of the names of cashiers in the different shops throughout Sweden. The most viable solution seemed to be to work through KF personnel and training department staff (located in the various regions of Sweden) who had more ready access to cashiers.

Accordingly 30 identical letters were sent to KF personnel and training staff in different regions of Sweden. The letter, in translation, is shown in Appendix 4.3. Accompanying the letter were questions for distribution to the cashiers, together with another introductory letter to the cashiers, (Appendix 4.4). The average number of questionnaires accompanying each letter was about 30. Thus in all 900 questionnaires were distributed. It would have perhaps been desirable to distribute questionnaires to all cashiers in the KF Organisation. As, however, each KF personnel or training staff member is responsible for a very large region geographically this would have involved too much

time and expense. Even on a more limited basis it was only possible for the local personnel to distribute the questionnaire forms to the larger supermarkets and department stores near their own local head office. No constraints were put upon the local distributor in terms of the cashiers to whom the questionnaire forms were distributed. Thus there are two difficulties in interpreting the data obtained from the questionnaires:-

(a) the questionnaires were not distributed to a representative sample of the whole population of cashiers. The sample was restricted to cashiers in supermarkets and department stores in cities, towns and large villages. As, however, the smaller shops in the countryside are closing down, the bias introduced in the sample will probably be of small import for future planning.

(b) the sample of cashiers in the cities, towns, and villages may be non-random. Local contact KF staff may have distributed the forms to cashiers whom they thought would fill-in the questionnaire and fill it in in a favourable manner. All that may be said in reply to these problems is that the responses given by cashiers were not invariably favourable to the KF Organisation. Secondly of the 900 questionnaires circulated, 700 were returned. This is a very high response rate and may represent biased sampling. In any event 700 cashiers constitute 1 in 7 of all the cashiers working wtihin the KF Organisation, and 1 in 5 of those working in large villages, towns, and cities. Thus the bias in representing cities, town and village cashiers should be small.

When the local contact person had collected the completed questionnaires in his area they were sent back to the author for analysis.

The first step in the analysis was to encode the answers to all the questions on each form so that the data would be suitable for input to a computer.

Encoding the responses to the first 28 questions was straight-forward. For each of these questions the cashiers could put a tick in one of six locations or boxes. The furthermost position on the left was numbered 0, the next 1 and so on up to 5. In the presentation of the results in tables in this chapter the 0 is assigned to the positive or neutral point and 5 to the negative end. For questions 29 and 30 one response, 'yes', was encoded as 0, the other, 'no', as 1. A similar procedure was adopted for the other question (question 33) with a dichotomous response possibility. Question 31 has five possible responses, the best response was assigned the number 0, the next most favourable response 2 and so on. Responses to the open-ended questions 32, 35, 36 and 37 were taken off the questionnaires and written in as condensed a form as possible. These condensed responses were then classified into groups. Table 4.4 gives the groups. A number was assigned to each group of responses, as shown in Table 4.4, for each question. These numbers were transferred back as appropriate to the questionnaires. There was a limitation on the number of categories or groups that could be used for each question. The computer programmes used for analysis would not accept more than nine response categories per question. In the event nine categories were

TABLE 4.4

CLASSIFICATION OF OPEN-ENDED RESPONSES

FOR QUESTION 32,35,36 and 37

Question 32

The most important reasons for leaving the job.

0. No answer
1. Hard work
2. Low salary
3. Bad working hours
4. Moved from house
5. Marriage
6. Child
7. Friends left
8. Studies
9. Other

Question 35

What do you like best in the present job?

0. No answer
1. Meeting people
2. Good colleagues
3. Alternation and variety
4. Independent
5. Everything good
6. Work times
7. Supervisors are good
8. Like money and figures
9. Other

Question 36

What do you like least in the present job?

0. No answer
1. Work time
2. Contact with people
3. Equipment
4. Organisation
5. Physical environment
6. Stressing work
7. Monotonous work
8. Tiring work
9. Other

Question 37

In what way is the cashiers job tiring?

1. Shoulder and arms
2. Back
3. Mentally tiring
4. Headache
5. Physically tiring
6. Arms
7. Legs
8. Shoulders
9. Eyes

sufficient to characterise adequately the different sorts of responses made to each of questions 32, 35, 36 and 37.

For the final three questions the following procedure was adopted. For question 38 the cashiers were divided into 3 age groups, young, (≤29 years), young middle-age (30 to 45 years), the old middle-age (>45 years). These responses were encoded 0, 1 and 2 respectively. Similar procedures were adopted for questions 39 and 40. For the former, number of years experience as a cashier was classified into <1 year, 1 to 5 years, and> 5 years experience. For the latter question, dealing with how long the cashier had worked on the new cash desk responses were classified as, no time at all, <1 year, and 1 year or more on the new cash desk.

13.3 Statistical procedures

The encoded data on the questionnaires were transferred to coding forms and thence punched onto cards for computer analysis. Before describing the analyses which were carried out it is necessary, as a preliminary, to discuss the types of scales on which the responses fell for the different questions. It might be argued that for questions 1 - 28 inclusive and questions 31 and 34, the response scales are equal interval. It seems safer to assume, however, that the data are ordinal in form, since no explicit scaling procedures were carried out with the cashiers. There is little or nothing that is controversial about the scales on which the responses to the remaining questions fall. The scales for the responses associated with each question are given in Table 4.5.

The types of scales associated with the questions are important in that they determine the type of statistical analysis which may be applied. As the scales were all either nominal or ordinal it was only possible to employ non-parametric statistics for descriptive and analytical purposes.

Three different sets of statistical analyses were carried out on the data, as itemised below:-

(a) The first analysis consisted of a straightforward tabulation of the data for all 700 cashiers. For each question the relative frequency of each response was determined. This simple summary of the data enables the cashiers' attitude towards events mentioned

TABLE 4.5

THE DIFFERENT QUESTIONS AND ASSOCIATED SCALE LEVELS

Question No.	Scale	Question No.	Scale
1	ordinal	21	ordinal
2	ordinal	22	ordinal
3	ordinal	23	ordinal
4	ordinal	24	ordinal
5	ordinal	25	ordinal
6	ordinal	26	ordinal
7	ordinal	27	ordinal
8	ordinal	28	ordinal
9	ordinal	29	nominal
10	ordinal	30	nominal
11	ordinal	31	ordinal
12	ordinal	32	nominal
13	ordinal	33	nominal
14	ordinal	34	ordinal
15	ordinal	35	nominal
16	ordinal	36	nominal
17	ordinal	37	nominal
18	ordinal	38	ordinal
19	ordinal	39	ordinal
20	ordinal	40	ordinal

in the critical incident study to be determined as well as their more general attitudes towards their work.

An ancillary tabulation was carried out for questions 1 - 12 inclusive for those cashiers who were working on the new cash desks. This made it possible to examine in more detail difficulties found with the new desks in the critical incident study.

It is worth noting at this point that the tabulations revealed for questions 1 - 28 inclusive, and questions 31 and 34, that the frequency distributions were mainly non-normal in nature. Thus even had it been assumed that the responses for these questions fell on an equal interval scale the application of parametric statistics would have been of dubious propriety.

(b) The second set of analyses consisted of a number of tests aimed at determining whether, for each question, the pattern of responses was the same for:-

i cashiers of different ages

or ii cashiers of different lengths of experience

or iii cashiers of different lengths of experience on the new cash desks

For i, ii, and iii the cashiers were partitioned into 3 groups as described in the section dealing with "the procedure". It will be recalled that the partitions for age, length of general experience, and length of experience on the new desks were as follows:

i <30 years, 30 to 45 years, >45 years

ii <1 year, 1 to 5 years, >5 years

iii no experience, short experience (<1 year), long experience (1 year or more)

For each question the effects of age (A), general experience (E) and desk (D) were determined separately. For each question, for each of A, E and D three separate analyses were carried out.

The first was χ^2 to determine if the pattern of response was the same for each 'level' of the appropriate classificatory variable.

Thus, for example, for question 1, for age, it was desired to determine by χ^2 if the pattern of convenience responses was the same for the three age groups. Altogether 3 (classificatory variables) x 37 (questions) χ^2 tests were run.

Analyses to achieve a similar purpose were carried out involving the 'extension of the median test' and the 'Kruskal-Wallis one-way analysis of variance'. At first sight these alternative tests may appear redundant to χ^2. In view, however, of the rather curious distribution of responses exhibited for some of the questions it was felt to be the safest procedure. Another compelling reason was that in the computer analysis involving χ^2 there was an inbuilt check on the expected frequency per cell. If the expected frequencies fell to a critical level such that the application

of χ^2 was not justified the computer collapsed response categories from the outside towards the middle. In certain cases this may have reduced the sensitivity and power of χ^2.

In the analyses described above <u>interaction effects</u> between age, length of general experience, and length of new cash desk experience, in terms of the responses to each question were not examined. In other words, as has been emphasised before the effects of factors A, E and D were examined separately.

It was felt nevertheless that interaction effects should be detected, if they existed. Accordingly the data were subjected to a third major form of analysis, but only in those cases where significant results using the previously mentioned tests were obtained for differences between groups of different length of experience on the new cash desk, (and not for the 12 first questions, as they were mainly of relevance for the new desk). The length of experience on the new desk was a most important factor.

(c) A convenient technique for establishing inter alia interaction effects on data which is extensive but which falls on a very crude scale is that known as the 'logit technique', (see Armitage, 1971). The technique is one most frequently applied to data where the responses are dichotomous in nature.

As a preliminary to the logit analysis for each question a tabulation was made of the frequency of

each type of response for each of the 27 cells formed by combining simultaneously the three levels of A, E and D.

The data for each question were then examined and a split made at, or as close as conveniently possible to the median point. In each of the 27 cells responses falling below the median were assigned the value zero, those falling above it the value 1. Thus questions whose responses originally fell on a six point scale now had responses transformed onto a two-point scale. In other words some information was rejected in order to enable the logit analysis to be carried out.

As it turned out the 3 x 3 x 3 logit analyses were difficult to compute and interpret. Accordingly a further simplification was introduced to overcome these difficulties. This involved collapsing the 3 x 3 x 3 cells into a 2 x 2 x 2 arrangement. The factor age (A) was divided into less than 30 years, and 30 years and over. The factor general experience (E) was divided into short experience (up to and including 5 years) and long experience (more than 5 years). The factor experience with the new desk (D) was divided into no experience, and some experience. Of course, this simplification introduces certain difficulties in its train. It is difficult to relate the results obtained directly with the results from the χ^2 and other tests where the effects A, E and D were considered separately. There is also the possibility that the significance of some effects may be concealed. These problems, however, have to be offset against the difficulties mentioned at the beginning of this paragraph.

The logic of this data reduction in terms of the partitioning on A, E and D is as follows: on factor D it was of course most interesting to study the cashiers with experience in relation to the ones without experience of the new cash desk. On factor E it was more difficult to say what could be considered as short and what as long experience. However, it is known that in this work there are a lot of people who not only work for a few months but for a few years before they get married and have children. It would perhaps be interesting to see the relation between these short and medium-short working time cashiers compared with long term ones. As the total frequency distribution also was such that this kind of division yielded two groups of about the same size, it was decided that the short and medium-short time experience would be classified as one group and cashiers with more than five years experience as the other group.

On factor A it could probably be argued that it would be most interesting to study the oldest group of cashiers (more than 45 years of age) compared with the rest. In this way we could study the effects different kinds of ageing mechanisms (of a mental and physical health nature) might have in this kind of work. However, only 15% of the cashiers belonged to this group (more than 45 years of age). The other 85% belonged to the two groups below 45 years of age. So this most logical kind of division would have resulted in a lot of empty cells when the division into the $2 \times 2 \times 2$ matrix had been performed, (e.g. for the question relating to the heaviness of work, for long experience on the new desk and shortest experience in cashier work we would not have got any cashiers at all in the highest age bracket). For

this reason the partition in terms of age was made so that there was one group composed of cashiers of less than 30 years, and the other group of 30 or more years. By this division, 45% of the cashiers fall in the young group and 55% belonged to the older group.

In Appendix 4.5 is given a worked example of a logit analysis. The example relates to Question 13 which is concerned with the perceived heaviness of work.

13.4 Results

In this section the results are dealt with question by question.

First, the frequencies for each of the response alternatives in terms of percentage of all responses for that question are given both for all cashiers and for cashiers working only on new cash desks. The reason for this is that the first 12 questions are mainly relevant to the new cash desk.

Second, where either the χ^2-test, or the Median Test (MT) or the Kruskal and Wallis analysis of variance (KW) produced significant results these are also quoted.

Third, in order to see how much the factors A (age of cashiers), D (length of experience on new cash desk) and E (total length of experience of cashier work), contributed separately and in combination to the pattern of responses a logit analysis (see Chapter 13.2) was carried out. This was carried out for the cases where significant results were obtained for the χ^2-test, MT or KW on differences in factor D or, for some cases, when significant results were obtanied for both factors A and E. The logit analysis was not carried out for the first 12 questions, as they are mainly of relevance for the new cash desk.

The analysis of the first part of the questionnaire (questions 1 to 12 inclusive) is dealt with in the next sub-section. The analysis of the second part,(questions 13 to 40) is reported in the following sub-section.

i. Part one of the questionnaire

In Appendices 4.6 and 4.7 the relative frequencies of responses are given for each of the first 12 questions, for all cashiers and for the cashiers working on the two versions of the new cash desk. The questions are mainly of relevance for the new desk but to some parts also for some of the old desks.

Question 1

The customer put her goods on the conveyor belt without taking them out of the basket.

	It doesn't matter					Very inconvenient
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 407.	23	13	13	10	11	32
Relative frequency (in %) of cashiers working on new cash desk, N = 390.	14	12	11	14	12	36

It will be seen from the above Table that both for all cashiers and those cashiers working only on the new cash desk, a very high percentage found the customer's action in putting her goods on the conveyor belt without taking them out of the basket as very inconvenient. Thirty two percent and 36 % of the cashiers exhibited an extreme adverse response. If the next most adverse category is included, the percentages rise to 43 and 48 respectively. As the questions mainly are of relevance for the new desk not all of the 700 cashiers have answered these first 12 questions.

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The tests of significance for differences in response between cashiers of different lengths of experience on the new cash desk showed that it was more difficult for the cashiers working on the new cash desk if the customer didn't remove the goods from the basket. (χ^2 = 34, p<.01%; Median Test (MT) = 14, p<.1%; and Kruskal and Wallis Analysis of Variance (KW) = 12, p<.3%).

Question 2

Newspaper, packets of sausages and similar objects get stuck in the conveyor belt.

	It doesn't matter					Very inconvenient
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 412.	12	9	9	9	15	46
Relative frequency (in %) of cashiers working on new cash desk, N = 276.	10	9	10	9	13	49

From the responses to this question it can be seen that both for all cashiers as well as cashiers working only on new desks, large percentages found it very inconvenient that objects got stuck in the conveyor belt. As many as 46% and 49% of cashiers exhibit an extreme adverse response. The percentages rise to 61% and 62% if the next most adverse category is included.

Question 3

At the end of the conveyor belt goods following press on the goods which have gone before so that more fragile articles are damaged.

	It doesn't matter					Very inconvenient
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 413.	46	11	14	6	9	14
Relative frequency (in %) of cashiers working on new cash desk, N = 275.	14	10	7	16	12	41

This Table shows that among all cashiers, 14% (or 23%, if the next most adverse category is included) found it very inconvenient when fragile goods were damaged by other goods at the end of the conveyor belt. But as many as 41% of the cashiers working on the new cash desk exhibited an extreme adverse response, and 53% if the next most adverse category is included.

Question 4

The customer hasn't enough time to pack her goods before the goods box is needed for other customers.

Response category	It doesn't matter 0	1	2	3	4	Very bad 5
Relative frequency (in %) of all cashiers, N = 437.	28	9	12	10	12	29
Relative frequency (in %) of cashiers working on new cash desk, N = 276.	30	11	10	10	10	29

From the above Table it will be seen that both for all cashiers and those cashiers working only on the new desk a very high percentage of them found it very bad that the customer hadn't enough time to pack her goods. Twenty nine percent of all cashiers and 29% of the cashiers working only on the new desk gave the extreme adverse response. When both the most extreme and the next most adverse response categories are combined, the percentages rise to 41 and 39 respectively.

The χ^2, MT and KW tests showed that the cashiers who had been working only for a short time on the new desk did not view the problem posed in question 4 so seriously as the other groups of cashiers. ($\chi^2 = 14$, $p < 5\%$; MT = 6, $p < 5\%$; KW = 6, $p < 5\%$).

Question 5

If a customer starts to pack before she had paid for her goods, the cashier has to stretch both to obtain the customer's money and to return her change, or the customer had to hurry back to the cash-desk to pick up her change.

	It doesn't matter					Very inconvenient
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 441.	35	13	8	8	13	23
Relative frequency (in %) of cashiers working on new cash desk, N = 268.	34	13	9	10	12	22

The responses to this question show that 23% of all cashiers and 22% of the cashiers working on the new cash desk regarded it as very inconvenient if the customer started to pack before they have paid for their goods. If the next most extreme adverse response category is included, the percentages become 36% and 34% respectively.

Question 6

The customer puts her money in the wrong place, e.g. on the plate between the moving belt.

	It doesn't matter					Very inconvenient
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 408.	42	13	8	7	8	22
Relative frequency (in %) of cashiers working on new cash desk, N = 276.	45	13	9	9	8	16

From the Table above it will be seen that a high percentage 22% (or 30% if the two most extreme are counted) of all cashiers regarded the customers' action in putting money in the wrong place as very inconvenient. However, for the cashiers who worked only on the new cash desk, 16% (or 24%) regarded this action of the customer as very inconvenient.

Cashiers who worked on the new desk found it less inconvenient when the customer put the money on the wrong place than those cashiers who worked on the old desk. ($\chi^2 = 20$, $p < 3\%$; KW = 9, $p < 2\%$).

Question 7

You scrape your fingers against the lid of the cash register drawer when you take out money.

	It doesn't matter					Very inconvenient
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 225	49	16	4	8	4	19
Relative frequency (in %) of cashiers working on new cash desk, N = 187.	50	15	8	5	3	19

From this table it will be seen that 19% of all cashiers and 19% of cashiers working on the new cash desk found it very inconvenient that they scraped their fingers against the lid of the cash register drawer when they took out money. About 50% of the cashiers thought that it was an issue of little consequence.

From the tests of significance for differences in response between cashiers with different lengths of experience on the new desk, it was found that cashiers working on the old type of desk and cashiers with long experience on the new desk found it more inconvenient when they scraped their fingers on the cash register drawer than the cashiers with only a short experience on the new cash desk ($\chi^2 = 15$, $p < 3\%$; MT = 10, $p < 1\%$; KW = 9, $p < 1\%$).

Question 8

The change returner does not work as it should. It sometimes gives too much or too little change.

	It doesn't matter					Very inconvenient
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 376.	12	11	3	8	11	55
Relative frequency (in %) of cashiers working on new cash desk, N = 198.	13	11	1	6	10	59

From the responses to this question it can be seen that for all cashiers 55% found it very inconvenient that the change returner didn't work as it should. Among the cashiers working only on the new desk 59% found it very inconvenient. If the next most adverse category is included the percentages rise to 66% and 59% respectively.

Only about 12% of cashiers thought that it didn't matter if the change returner did not work as it should; this group probably also includes cashiers whose change-returners worked perfectly.

Question 9

It is not possible to push the bar over to deflect purchased goods from one box to another when the customer has bought a large number of goods.

	It doesn't matter					Very inconvenient
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 408.	12	17	8	12	12	39
Relative frequency (in %) of cashiers working on new cash desk, N = 198).	12	15	10	11	12	40

It will be seen from this Table that both for all cashiers and for cashiers working only on the new cash desk 39% and 40% respectively found it very inconvenient that it was not possible to push the bar over from one box to another when the customer had bought a large number of goods. 12% of cashiers of both groups thought the issue to be inconsequential.

Question 10

Some customers do not know where to put the carriages, which is the cause of the carriages being left in front of the cash desk.

	It doesn't matter					Very inconvenient
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 588	14	10	7	9	32	28
Relative frequency (in %) of cashiers working on new cash desk, N = 268	14	8	10	8	27	33

Twenty eight percent of all cashiers and 33% of those working only on the new desk found it very inconvenient that some customers didn't know where to put the carriages. (This meant, generally speaking, that the carriages were left in front of the cash desk). If the next most adverse category is included the percentages rise to 60% both for all cashiers and for the cashiers working only on the new desk.

Cashiers with long experience found it more inconvenient than other cashiers that the customer didn't know where to put the carriage (MT = 7, $p < 3\%$; KW = 8, $p < 2\%$).

Question 11

It is possible to adjust the chairs to different heights.

	Very good					Very bad
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 531	84	9	2	1	2	2
Relative frequency (in %) of cashiers working on new desk	89	5	1	0	2	3

As seen from the Table above, 84% of all cashiers and 89% of the cashiers working only on the new desk found the adjustability feature of the chairs to be very good. The percentages who found the principle of adjustability to be very bad were only 2 and 3 respectively.

The cashiers working on the new desk found to a greater extent than the other group who had worked only on the old desk that the adjustability feature of the chairs was very good (MT=8, p 2%; KW=8, p 3%).

Question 12

Some chairs are designed so that they can only be turned one way.

	It doesn't matter					Very inconvenient
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 330	23	12	12	10	25	18
Relative frequency (in %) of cashiers working on new cash desk, N = 279.	27	13	13	12	21	14

From the responses to this question it may be seen that 18% of all cashiers and 14% of cashiers working only on the new cash desk found it very inconvenient that some chairs were so designed that they could only be rotated one way (generally to the left). Cashiers working on the new desk were not so bothered about this as those working on the old type of cash desk. (χ^2=19, p<5%; KW=7, p<3%).

ii. Part two of the questionnaire

The results from questions 13 to 40 are also given in Appendix 4.8.

Question 13

How heavy do you find the work?

	Not heavy at all					Very heavy
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 672.	8	21	13	27	11	20

From this Table it can be seen that 20% (or 31% if the next most adverse category is included) of the cashiers find the work very heavy. When tests for differences in response between cashiers of different length of experience on the new desk were applied, it was found that cashiers seem to regard the work on the new desk as less heavy than the work on the old type of desks. (χ^2=30, p<2%; MT=28, p<.002%; KW=23, p<.01%).

The combined and single effects of factors D, A and E, on the cashiers responses to this question are given in Table 4.6. It will be seen that the factor which contributes most to perceived heaviness of work is D (length of experience on the new desk). There is also a significant interaction between factors E and D. The interaction works in such a way that the difference in perceived heaviness of work between the two types of desks is more marked for the cashiers with long experience of cashier work, (factor E).

TABLE 4.6

LOGIT ANALYSIS

Question 13: How heavy do you find the work?

		Main effect	±	S.E	
(A)	Age	= -0.262	±	0.4960	
(D)	Desk	= 2.388	±	0.6570	x)
(E)	Experience	= -0.058	±	0.1530	
AxD		= 0.768	±	0.7740	
AxE		= -0.368	±	0.7721	
ExD		= 1.057	±	0.7304	x)

x) Significant ($p < 5\%$)

TABLE 4.7

LOGIT ANALYSIS

Question 14: How monotonous do you find the work?

		Main effect	±	S.E	
(A)	Age	= -0.4620	±	0.1822	x)
(D)	Desk	= -0.4507	±	0.0954	x)
(E)	Experience	= -0.1729	±	0.1962	
AxD		= 0.7980	±	0.2627	x)
AxE		= -0.7628	±	0.2534	x)
ExD		= -0.9305	±	0.2982	x)

x) Significant ($p < 5\%$)

Question 14

Do you find your job monotonous?

	Yes Very					No, not at all
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 643.	34	32	10	9	6	9

This Table indicates that 9% (or 15% if the next most favourable category is included) of the cashiers did not find the work at all monotonous. As many as 34% (or 66% if the next most adverse category is included) of the cashiers found the work very monotonous. The test of significance for differences in responses between the cashiers of different lengths of experience on the new desk showed that it was more monotonous for cashiers working on the new desk and that it was much more monotonous if the cashier had had long experience on the new desk (MT=5, $p<10\%$; KW=6, $p<4\%$). When the test for differences in responses between cashiers of different ages were applied it was found that the medium-aged and old cashiers seemed to judge the work less monotonous than the young cashiers, ($\chi^2=18$, $p<5\%$; MT=11, $p<4\%$; KW=12, $p<.25\%$).

The logit analysis in Table 4.7 shows that both the effect of age (factor A) and the effect of experience on the new desk (factor D) contribute significantly to how monotonous the cashiers judged their work to be. In other words, this logit analysis confirms the tests reported in the previous paragraph.

There is also a very significant interaction between factors A and D, A and E, and B and D. The interactions work in such a way that the differences in how monotonous the cashiers found the work on the old and new types of desks is more marked for the old cashiers than for the young. The difference between the young and old cashiers was not so marked for the cashiers with long experience as for those with short experience. The differences between how monotonous the cashiers found the work on the two types of cash desks was not so large for the cashiers with long experience as for the cashiers with short experience. The single and combined effects of factors D, A and E are given in Table 4.7.

Question 15

How qualified or unqualified must a person be to do your job?

	Very Qualified					Very Unqualified
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 594.	31	19	31	9	8	2

It will be seen from the above Table that only 2% (10% if the next most adverse category is included) of the cashiers thought it was possible to be unqualified and do the job. On the other hand, 31% thought that they had got a job for which qualifications were very important. The KW test (8, $p<2\%$) indicated that short experience cashiers thought that their job was very unqualified to a greater extent than the other cashiers. The young cashiers were more

cynical than the older cashiers and thought that it was not necessary to be very qualified to do the job. (KW=6, $p<4\%$).

Question 16

What do you think about the mental load of your job?

	Not Mentally Stressing at all					Very Mentally Stressing
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 630.	10	13	17	22	20	18

From this Table it can be seen that 18% (or as much as 38% if the next most adverse category is included) of the cashiers thought that their job was very mentally stressing. Only 10% of the cashiers thought that their work was not mentally stressing at all. The KW test (7, $p<4\%$) indicated that cashiers working on the new desk seemed to regard their work as less stressing than the cashiers working on the old desk.

From the logit analysis in Table 4.8 it may be seen that not only factor D, but also factors A and E, contribute substantially to what the cashiers thought about the mental load imposed by the job. The cashiers of greater age or longer experience judged their work to be less stressing mentally than other cashiers. The cashiers working on the new desk judged the mental load to be less than the cashiers working on the old desk. As can be seen from the Table all interactions were significant. The difference between the old and new desks is not so great for

TABLE 4.8

LOGIT ANALYSIS

Question 16: What do you think about the mental load in the job?

			Main effect	±	S.E	
(A)	Age	=	-0.5318	±	0.1841	x)
(D)	Desk	=	-0.6309	±	0.1729	x)
(E)	Experience	=	-0.6443	±	0.1844	x)
AxD		=	-1.993	±	0.2707	x)
AxE		=	-1.1724	±	0.2326	x)
ExD		=	0.9601	±	0.2726	x)

x) Significant ($p < 5\%$)

TABLE 4.9

LOGIT ANALYSIS

Question 20: How interesting do you find the job?

			Main effect	±	S.E	
(A)	Age	=	-0.2418	±	0.1664	x)
(D)	Desk	=	0.1095	±	0.1723	
(E)	Experience	=	-0.1240	±	0.1625	
AxD		=	0.1624	±	0.2366	
AxE		=	0.1275	±	0.2059	
ExD		=	0.2518	±	0.2567	

x) Significant ($p < 5\%$)

the old cashiers as for the young. The difference between the young and old cashiers is less for the cashiers with long experience than for the ones with short experience. The difference between the cash desks is less for the cashiers with long experience than for those with the short experience of cashier work.

Question 17

Do you think that your job requires attention?

	No, not at all					To a great extent
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 640.	1	2	1	5	20	71

71 % (or 91 % if even the next most adverse category is included) of the cashiers judged that their job required attention to a great extent. Only very few thought that the job didn't require the application of any attention. The cashiers of different ages, length of experience and length of experience on the new desk seemed to judge their job in respect of attentional requirements in about the same way.

Question 18

How do you feel about your working pace?

	Not hectic at all					Very hectic
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 636.	5	14	11	28	20	22

It will be seen from the above Table that for all cashiers a very high percentage found the work pace to be very hectic. Twenty-two percent of the cashiers (and 42% if the next most adverse category is included) exhibited adverse responses. Only 5% of the cashiers thought that the work was not hectic at all. The cashiers with long experience thought that the work was more hectic than those cashiers with short experience(MT=6, $p<5\%$; KW=5, $p<9\%$).

Question 19

What do your friends think about your job?

	Very good					Very bad
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 548.	31	19	31	9	6	4

From the table above, it will be seen that 4% (or 10% if the next most adverse category is included) of the cashiers believed that

their friends thought that they had got a very bad job. However, 31% (or 50%) of the cashiers believed that their friends had got a very good (or good) job. Similar kinds of judgements were made by the cashiers irrespective of age, experience of cashier work and experience of the new desk.

Question 20

How interesting or uninteresting do you find your job?

	Very interesting					Very uninteresting
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 691.	49	25	17	4	3	2

From this Table it can be seen that the cashiers in general thought that they had a very interesting job. Forty nine percent judged their work to be very interesting.

Only a small percentage judged their job to be very uninteresting. The cashiers who had been working as cashiers for a long time found the work more interesting than others (χ^2=19, p<4%). The older cashiers also seemed to judge the job as more interesting than the other cashiers, (MT=7, p<3.5%; KW=8, p<2%).

From the test of combined and single effects one can see that age (factor A) was the only factor which made a significant contribution to how interesting the cashiers found their job. The old cashiers judged their job as more interesting than the young. (See Table 4.9).

Question 21

Do you think your job involves responsibility?

	Not at all					To a great extent
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 700).	0	0	0	3	12	84

It will be seen from the above Table that most of the cashiers thought that their job involved responsibility to a great extent. As many as 84% of all cashiers (or 96% if the next most favourable category is included) exhibited this extreme opinion.

Question 22

Do you think your job involves self-reliance?

	Not at all					To a great extent
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 678.	5	3	5	12	23	52

From this Table it will be seen that 52% (or 75% if the next most extreme category is included) of the cashiers thought that their job involved self-reliance to a great extent. Only about 5 - 8% thought that their job involved no self-reliance at all.

Question 23

Are there possibilities of promotion within KF?

	No, not at all					Very good
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 654.	26	13	8	14	13	26

This Table shows that there were about the same number of cashiers who thought that there were good possibilities of promotion within KF as there were cashiers who thought that there were only very small possibilities of promotion within KF. Twenty six percent thought that there were no possibilities at all, and the same percentage that there were very good possibilities of promotion. The old cashiers thought to a higher degree than others that there were only very small possibilities of promotion (χ^2=32, p<1.0%; KW=15, p<.01%).

Question 24

How do you experience contact with the public?

	Very un-pleasant					Very pleasant
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 696.	1	1	4	4	19	71

This Table indicates that 71% of the cashiers experienced contact with the public as very pleasant. If even the next category of response is included the percentage rises to 90%. Only a few cashiers experienced contact with the public as unpleasant. The young cashiers did not experience the contact with the public as positively as the older cashiers. (χ^2=15, p<5%; MT=5, p<8%), i.e. the young cashiers found it less pleasant than the older cashiers.

Question 25

How do you find the atmosphere at work?

	Not good at all					Very good
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 692.	2	1	3	10	16	68

From the responses on this question it can be seen that a large percentage (84% in the two most extreme categories) of the cashiers found the atmosphere at work to be very good. Only a few found the atmosphere not good at all. Cashiers of different ages, length of experience, and length of experience on the new desk, judged the atmosphere at work in a similar manner.

Question 26

How do you get on with your colleagues on the whole?

	Very badly					Very well
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 686.	1	0	1	4	11	84

From the responses to this question one can see that the cashiers thought that they got on well with their colleagues. As many as 84% thought that they got on very well with their colleagues. Only a very small percentage thought that they didn't get on well with their colleagues. This kind of pattern of response seemed to be the same for cashiers of different ages, length of experience and length of experience of the new cash desk.

Question 27

What do you think of your immediate superiors?

	Very bad					Very good
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 696).	3	2	5	4	18	68

Sixty eight percent of the cashiers who answered this question thought that their immediate superiors were good. If the next most favourable category is included 86% of the cashiers were favourably disposed towards

their immediate superiors. The cashiers of long experience thought better of their supervisors than other cashiers, (MT=6, $p<4\%$; KW=7, $p<4\%$). The old cashiers were more sceptical in their attitude to their superiors than the other cashiers, (MT =7, $p<2.5\%$; KW=6, $p<5\%$). The logit analysis reveals significant effects for factors A and D, and the interaction between factors A and E. The old cashiers liked their superiors less than the young. The cashiers working on the old cash desk did not like their supervisors as much as the cashiers working on the new desk. The difference in judgement between the old and young cashiers with long experience is greater than the difference between the old and young cashiers with short experience, (see Table 4.10).

Question 28.

Would you advise a friend to take a job as a cashier?

	No not at all					Yes without hesitation
Response category	0	1	2	3	4	5
Relative frequency (in %) of all cashiers, N = 687.	9	6	5	17	17	46

TABLE 4.10

LOGIT ANALYSIS

Question 27: What do you think of your nearest superiors?

		Main effect		S.E.	
(A)	Age	= 0.3114	±	0.2017	x)
(D)	Desk	= -0.2715	±	0.1936	x)
(E)	Experience	= 0.0329	±	0.1975	
AxD		= 0.1281	±	0.2807	
AxE		= 0.3496	±	0.2621	x)
ExD		= 0.2286	±	0.2998	

x) Significant ($p < 5\%$)

TABLE 4.11

FREQUENCIES IN PERCENT OF ALL RESPONSES

Question 29: Are you satisfied with the present working hours.

Yes	No
58	42

Question 30: Are you satisfied with the breaks you have?

Yes	No
80	20

N = 687

N = 686

From the answers on this question, it will be seen from the Table above that 46% of the cashiers would advise a friend to take a job as a cashier without hesitation. Only about 9 to 15% would not to advise a friend to take such a job. The young cashiers were less willing to advise a friend to take a job as a cashier than older cashiers, (χ^2=25, p<.07%; MT=12, p<.03%; KW=15, p<.01%).

In Table 4.11 are given the frequencies of response to questions 29 and 30 which deal with satisfaction relating to hours worked and rest pauses. From the responses to question 29 it can be seen that the majority (57%) of the cashiers were satisfied with their working hours. However, as many as 42% regarded their working hours as unsatisfactory. In general, the cashiers seemed to be more satisfied with their rest pauses. More than 80% responded positively to the question: 'Are you satisfied with the breaks you have?'. Cashiers with long experience on the new desk were more dissatisfied with the working hours than those working on the old desk, or those with only a short experience of the new desk (χ^2=7, p<4%). The young cashiers did not like the working hours to nearly the same extent as the old cashiers (χ^2=30, p<.002%).

The logit analysis of question 29 (Table 4.12) shows that only factor A has a significant effect on the responses. The young cashiers were more dissatisfied with the working hours than the old. There were, however, significant interactions revealed between factors A and D, and A and E. The difference in judgement between the young and old cashiers working on the new desk was greater than the difference in judgement

TABLE 4.12

THE LOGIT ANALYSIS

Question 29: Are you satisfied with the present working hours?

		Main effect	±	S.E	
(A)	Age	= 0.8439	±	0.1769	x)
(D)	Desk	= 0.1734	±	0.1738	
(E)	Experience	= -0.1542	±	0.1735	
AxD		= 0.7992	±	0.2735	x)
AxE		= 0.7617	±	0.2014	x)
ExD		= 0.1356	±	0.2609	

x) Significant ($p < 5\%$)

TABLE 4.13

FREQUENCIES IN PERCENT OF CODE RESPONSES

Question 31: Which of the following expressions would most correctly correspond to what you generally think of your job at the Co-Op, if you were going to express your feelings about it to a friend?

1.	I like it very much	70 %
2.	I like it fairly well	25 %
3.	I neither like nor dislike it	4 %
4.	I don't like it very much	1 %
5.	I don't like it at all	0.%

N = 689.

between old and young cashiers working on the old desk. The difference in judgement between the old and young cashiers with long experience was also greater than the difference between the young and old cashiers with only short experience. In other words, the logit analysis indicated that the effect of kind of desk was not so important as the age of the cashiers. However, it is worth noting that the difference in judgement between the young and old cashiers was greater when they were working on the new desk than when they were working on the old desk.

In Table 4.13 are given responses to Question 31 which also dealt with what cashiers thought in general about their job at KF. As many as 70% indicated that they liked their job very much. Only a few indicated that they didn't like it. The young cashiers did not in general like their job as much as the old cashiers, (χ^2=23, p<.03%; MT=20, p<.02%; KW=19, p<.02%).

The logit analysis was also applied to Question 31. It will be seen from Table 4.14 that only single factor A had a significant effect on the cashiers' responses. The young cashiers did not like their job as much as the old cashiers. There is a significant interaction between factors A and D. The difference in judgement about what the cashiers feel about their job between young and old cashiers working on the new desk was less than for the same difference for the cashiers working on the old desk.

TABLE 4.14

THE LOGIT ANALYSIS

Question 31: What I feel about my job.

		Main effect		S.E	
(A)	Age	= 0.5919	±	0.1855	x)
(D)	Desk	= -0.0236	±	0.1780	
(E)	Experience	= -0.0318	±	0.1942	
AxD		= 0.5904	±	0.2720	x)
AxE		= 0.2564	±	0.2580	
ExD		= 0.1734	±	0.2825	

x) Significant ($p<5\%$)

TABLE 4.15

THE FREQUENCIES IN PERCENT OF ALL RESPONSES

Question 32: The most important reasons for leaving the job.

	%
Hard work	33.70
Low salary	22.38
Bad working hours	16.85
Moved from town	6.91
Marriage	2.49
Child	2.21
Friends left	1.66
Studies	1.10
Other	12.71

N = 362.

In Table 4.15 the responses to Question 32 are given. On this question the cashiers had to state which single factor they thought was the most important cause for previous colleagues leaving their job during the previous year. From the Table it may be seen that 'hard work' was the most frequently mentioned, followed by low salary and bad working hours.

In Table 4.16 the responses to the question: 'which arm works hardest?', (Question 33) are given. Seventy seven percent thought that the left arm worked hardest. This is the arm which is used to move the goods between the two conveyor belts if the cashiers were working on the new desk. On the old type of desk, this arm is used to move goods from one basket to another or from one carriage to another, or similar kinds of work. The χ^2 test (16, p .1%), indiciated that the left arm worked harder on the old type of desk than on the new cash desk.

The responses to question 34 are given in Table 4.17. The cashiers were asked to give reasons for mis-keying. On four different alternatives they had to indicate which was the first, second, third and fourth most important factor. The Table indicates that difficulties in reading the prices on goods and stress are mentioned most frequently as being the most important reasons for mis-keying. Mis-keying due to tiredness or simply pressing the wrong key by mistake were not believed to be of any greater importanance. Reading errors were more frequently judged as important among the cashiers with long experience than among other cashiers (χ^2=23, p<.2%; MT=16, p<.06%;

TABLE 4.16

THE FREQUENCIES IN PERCENT OF ALL RESPONSES

Question 33: Which arm works hardest?

Left	Right
77	23

N = 662

TABLE 4.17

THE FREQUENCIES IN PERCENT OF ALL RESPONSES

Question 34:

	1st	2nd	3rd	4th
Reading %	56.05	19.49	15.50	8.96
Keying %	5.69	15.79	30.16	48.36
Tiredness %	7.68	30.16	47.37	14.79
Stress%	22.90	44.81	25.60	6.69

N = 703

KW=21, p<.02%). Errors due to stress were less important to cashiers with long experience (χ^2=16, p<2%; MT=9, p<2%). Errors due to fatigue were less important to cashiers with medium or long experience (χ^2=16, p<2%; MT=10, p<.6%). The old cashiers judged mis-keying due to reading as more important than the other cashiers. (χ^2=22, p<.2%); MT=15, p<.1%; KW=18, p<.03%). The old cashiers had less difficulty with mis-keying due to difficulties in pressing the correct key than the young cashiers (χ^2=13, p<4%). The old cashiers had less difficulties with mis-keying due to stress than other cashiers (χ^2=19, p<.5%; MT=10, p<.6%; KW=13, p<.2%).

A logit analysis was carried out on the data relating to mis-keying due to reading (Table 4.18) and mis-keying due to stress, (Table 4.19) as these two reasons seemed to be the most important of those advanced by cashiers. Factors A and E seem to have the most important effect on how the cashiers judged the importance of mis-keying due to reading. Both greater age and long experience resulted in a more frequent judgement of reading errors as the most important reason for mis-keying. There was also a significant interaction between factors A and E. The difference between the young and old cashiers with long experience was greater than the difference between the young and old cashiers with short experience.

Factors A and E were also the most important factors in relation to stress being advanced as a reason for mis-keying. The older cashiers thought that stress was a more important reason than the young cashiers. The cashiers of long experience, however, did not think stress was so important as the cashiers with short experience. There was a significant interaction between factors A

TABLE 4.18

THE LOGIT ANALYSIS

Question 34: Reasons for miskeying due to reading.

		Main Effect		S.E.	
(A)	Age	= 0.2944	±	0.2091	x)
(D)	Desk	= -0.1247	±	0.1247	x)
(E)	Experience	= 0.2445	±	0.1760	x)
AxD		= 0.1731	±	0.2373	
AxE		= 0.6752	±	0.2128	x)
ExD		= 0.1648	±	0.2625	

x) Significant (p<5%)

TABLE 4.19

Question 34: Reasons for miskeying due to stress.

		Main Effect		S.E.	
(A)	Age	= 0.6108	±	0.1675	x)
(D)	Desk	= -0.0807	±	0.1713	
(E)	Experience	= -0.3029	±	0.1650	x)
AxD		= 1.0416	±	0.2604	x)
AxE		= 0.6447	±	0.2096	x)
ExD		= 0.0265	±	0.2627	

x) Significant (p<5%)

and D and between factors A and E. The difference between the young and old cashiers working on the old desk was greater than the difference between the young and old cashiers working on the new desk. The difference between the young and old cashiers with long experience was greater than the difference between the young and old cashiers with little experience.

From Table 4.20 will be seen the different factors which the cashiers liked in their job, (Question 35). Meeting other people was mentioned most frequently (by 33%). Variability or variety in the job was next most frequently mentioned. This is followed by good and pleasant colleagues.

In Table 4.21 the factors which the cashiers liked least in their job are given, (Question 36). The bad working time was most frequently mentioned, (29%). 'Bad working time' included too early or too late starts and the fact that the job went on too long into the evening. The next most frequently mentioned factor was the negative contact with people, 22% for example, complained that the cashier had to check if anything had been stolen. The next most frequently mentioned factor was different kinds of technical matters (12%), such as problems with the cash desk, and problems with the cash register. Other factors mentioned were, bad organisation, poor physical environments (mainly draughts) stressful work, monotonous work, and tiring work. The work time was a more frequent problem for the young cashiers than for the others, ($\chi^2=8$, $p<2.5\%$). The old cashiers seemed to have more problems with the environment (especially draught) than other cashiers, ($\chi^2=14$, $p<.1\%$).

TABLE 4.20

THE FREQUENCIES IN PERCENT OF ALL RESPONSES

Question 35: What do you like best in your present job?

	%
1. Meeting people	53
2. Changeable job	17
3. Good colleagues	16
4. Independent job	5
5. Everyting well	3
6. Work times	2
7. Supervisors are good	1
8. Like money and fig.	1
9. Other	2

N = 567

TABLE 4.21

THE FREQUENCIES IN PERCENT OF ALL RESPONSES

Question 36: What do you like least in the job?

	%
1. Work time	29
2. Contact with people	21
3. Technical matters	12
4. Organisation	9
5. Physical environment	8
6. Stressing work	7
7. Monotonous work	5
8. Tiring work	4
9. Other	5

N = 425

Table 4.22 gives responses to Question 37. All jobs have a more or less wearing effect on people who carry them out. The cashiers were asked in what way they thought that their job was wearing. The answers were classified into nine different groups given in the Table. Both the responses from all cashiers and just from the cashiers working on the new desk are given in the Table. Among all cashiers,problems with shoulders and arms are the most frequently mentioned group, (22%). The second most frequently mentioned group is problems with the back (20%) and the third is that the job is mentally tiring, (16%). Fourth and partly related to the third is that the cashiers get headaches (15%). The fifth most frequently mentioned factor is that the work is physically tiring (14%). Problems only with arms is the sixth most frequently-mentioned group. Thereafter follows problems with legs, problems with shoulders and problems with the eyes. The order between the different factors for the cashiers working on the new desk is somewhat different. The only statistically significant results are that the new desk was found to be less physically tiring ($\chi^2=17$, $p<.1\%$), that it was more mentally tiring to work on the new desk, ($\chi^2=25$, $p<.1\%$), and finally that the work on the new desk was less wearing on the legs ($\chi^2=5$, $p<10\%$). The old cashiers seemed to experience more problems with the arms than the other cashiers ($\chi^2=9$, $p<2.5\%$). The young cashiers seemed to have slightly more frequent problems with their legs ($\chi^2=12$, $p<1.0\%$) than other groups.

TABLE 4.22

THE FREQUENCIES IN PERCENT OF ALL RESPONSES

Question 37: In what way is the cashiers' job wearing?

	All %	New desk (%)
1. Shoulder and arms	22	20
2. Back	20	25
3. Mentally tiring	16	29
4. Headache	15	11
5. Physically tiring	14	3
6. Arms	6	8
7. Legs	3	1
8. Shoulder	2	1
9. Eyes	2	1

N = 425

In Table 4.23 the responses to Questions 38, 39 and 40 are given. It may be seen that nearly half of the cashiers were less than 30 years of age (45%) and that only 15% of the cashiers were more than 45 years old. Forty six percent of the cashiers had 4 to 5 years' experience of cashier work. Sixty one percent of the cashiers had no experience at all of the new cash desk. Twenty seven percent had short experience and 12% had long experience of work on the new cash desk. The cashiers with long term experience on the new desk normally had long term experience in general as cashiers (χ^2=30, p<.005%; MT=29, p<.001%; KW=21, p<.01%).

TABLE 4.23

THE FREQUENCIES IN PERCENT OF ALL RESPONSES

Question 40: Length of experience of new cash desk (factor D)

No	61%
Short	27%
Long	12%

N = 703 (100%)

Question 39: Length of experience of cashier work (factor E)

Less than one	18%
One to five	46%
More than five	36%

N = 659 (93%)

Question 38: Cashier's age (factor A)

Less than 30 years	45%
30 to 45 years	40%
More than 45 years	15%

N = 681 (97%)

13,5 Discussion and conclusions

Bertil Gardell, et al (1963) carried out a study concerned with the working conditions for personnel in shops and department stores. It is of interest to compare the results of this study and those obtained from the present investigations. Gardell found that cashiers are more positive in attitude to their job than other types of personnel in shops and supermarkets. He also found that the young have a more positive attitude to their job than older personnel. This finding is contradictory to the results of the present study (Questions 15, 20 and 28) where it was found that the old are more positively oriented to their job than the young cashiers. The results of Question 20 were also analyzed using the logit technique where the relative importance of the factors age, experience of general cashier work and experience on the new cash desk were tested. In this test it was established that age was the most important of the three factors, and that the old cashiers have a more positive attitude towards the job than the young.

Gardell also found that retailing personnel in general have quite a positive attitude towards their supervisors. This finding is confirmed in the present study. Cashiers do not, according to Gardell, think that the demanded speed at work is high and the young are more positively inclined to work at speed than the old. This is not in agreement with the results of this study, eg Question 18 most of the cashiers find the job hectic.

(Bolinder et al, 1970)/
In a study conducted by the Swedish Trade Union Confederation the second most important complaint in relation to the working conditions involved draughts. In the present study other kinds of factors seem to be judged as more important, (Question 36) than the factors in the physical environment. But of all the different factors in the physical environment, draught was the most important.

The results of the present study may be summarised as follows. Consider first the question dealing with the new cash desk. The following conclusions may be drawn. 1) it is necessary to give clear instructions to the customer to the effect that she has to remove the goods from the basket before placing them on the conveyor belt. 2) the conveyor belt has to be so constructed that goods cannot get stuck in it. 3) the change returner has to be designed to give much more reliable performance. 4) the environs of the cash desk must be arranged so that it is easy to get rid of empty carriages.

Turning next to a comparison of the new and old desks, it may be concluded that work on the new cash desk is not so physically tiring and makes the job less heavy than the work on the old type of desk. On the other hand, work on the new desk is a little more monotonous and mentally tiring than work on the old. This may be due to more efficient work in that an increased number of customers can pass through the system in a given space of time. From an analysis of interactions between different factors it can be concluded that the improvements introduced by the new cash desk mainly have been of benefit for the old cashiers.

Turning finally to the working conditions in general, it is important that the prices and code numbers are stamped in such a way on the goods that they are very easy to read. It is also essential that lighting conditions are good. This is especially true for the old cashiers who believe that reading errors are an important source of errors, Older cashiers do not have much hope of promotion but it does not seem to have much effect on their general attitude towards the job. This is shown by the fact that the medium-old and old cashiers would advise a friend to take a job as a cashier. They would do this to a greater extent than the young cashiers.

It may also be seen that the young cashiers do not like the job as much as the old cashiers. The young cashiers complain to a greater extent about their working hours. The old cashiers have more problems with the physical environment than the young.

14.0 CUSTOMER INTERVIEWS

In order to obtain a good understanding of the adequacy of the check-out system, a detailed study of the customers responses to it is of very great relevance. However, it is very difficult to carry out this kind of study without interfering too much with the customer. It was, however, accepted by KF that a small study could be made in a limited period of time.

The aim of this part of the study is to give a general description of customers' understanding of the present check-out system.

14.1 The method and procedure

It is difficult a priori to specify what kinds of questions it would be most relevant to ask. As a preliminary to this part of the study it would been advisable to perform some kind of open interview with customers involving the critical incident approach. However, there was not sufficient time or money available for this.

However, a small pilot study convering twenty individuals was performed. For the pilot study 33 questions were formulated on the basis of general experience and information gained from the cashier interviews. From this pilot study which took the form of a series of structured interviews, a final set of questions was drawn up. One question of the original 33 was excluded and three new ones were added. The formulation of several questions was altered. The final form of the questions in English translation is given in Appendix 4.9.

The questions were used in structured interviews. There were four difference response alternatives for 23 of the 35 questions asked. The customer was given a card where the four different response alternatives were listed. This was done to make it easier for the customer to remember what kind of answer he or she was expected to given.

The interviews took place immediately outside the check-out system. When the customer has passed through the check-out system, the interviewer asked the customer if he or she was prepared to answer a few questions. The customers were picked out as they left the check-out system. This meant that they were not a completely random selection of customers. Altogether 230 customers were picked out and approached. Twenty percent refused to be questioned, even though it was explained that the interview would only take between ten minutes and a quarter of an hour. Most refusals occurred when the shop was very busy, as at lunch time. Altogether data on 184 customers was obtained. The study took place in a supermarket in Stockholm which had the latest and most modern cash desk, (see Figure 4.2).

It will be seen from the questions posed that information was gathered on:

(a) age of the customer (estimated by interviewer)

(b) time of day of interview

(c) whether or not customer was a member of KF

(d) whether or not the shop was used by the customer because it was near or because she liked it

(e) number of goods purchased by the customer

(f) the degree of stress felt by the customer, (i.e. the extent which the customer felt rushed).

It was thought that attitudes towards the check-out system might be influenced by these variables. Accordingly partitions were made into two sets for each variable and analyses carried out by χ^2 for each question to determine whether the two groups of subjects produced the same pattern of response for the question under analysis. The partitions for each of the variables (a) and (f) listed above were as follows:

(a) age: old (40 or more), young (less than 40)

(b) time of day of interview: morning, afternoon

(c) member of KF: yes, no

(d) use of shop: because customer liked it, because shop was close by

(e) number of goods purchased: 1 bag or less, 2 bags or more

(f) stress felt by customer, (i.e. extent to which customer felt rushed): none, some.

14.2 The results

The relative frequency in each of the response categories for each question, with no partition of the data, is given in Table 4.24. The Table largely speaks for itself. A brief commentary is, however provided in which the responses are discussed question by question. Furthermore, for each question the significant results from the χ^2 tests are given. These results are quoted in more detail in Appendix 4.11.

Sisteen percent of the customers were men and eighty four percent were women.

About 60% of the customers were above 40 years of age. Very few customers were below the age of 25. Younger customers (i.e. below 40 years) seemed to prefer to go to a shop they liked and the other customers seemed to go to a shop which was close by ($\chi^2 = 4.72$, $p<5\%$). More of the older customers were members of KF than the young customers ($\chi^2 = 9.19$, $p<1\%$). The old customers went shopping in the morning to a greater extent than the young, ($\chi^2 = 2.88$, $p<10\%$).

From Table 4.24, one can see that most of the interviews took place between 10 and 11 (20%), and between 14.00 to 15.00 (21%),

Seventy six percent of the customers were members of KF. As said before there were significantly more old than young customers who were members, ($\chi^2 = 99.19$, $p<1\%$). Most of the customers who were members had been members in at least 25 years.

TABLE 4.24

PERCENTAGE FOR EACH QUESTION AND RESPONSE CATEGORY

Sex	Males		Females				
	16		84				
Age distribution	Age	%	Age	%	Age	%	
	-24	4,5	45-49	12	70-	4,5	
	25-29	11	50-54	11			
	30-34	10	55-59	5			
	35-39	14	60-64	5			
	40-49	16	65-69	7			
Distribution of individuals per hour	Time of the day	%	Time of the day	%			
	09.00-10.00	1,5	13.00-14.00	14			
	10.00-11.00	20	14.00-15.00	21			
	11.00.-12.00	15	15.00-16.00	15			
	12.00-13.00	10	16.00-17.00	3,5			
1. Are you member of KF?	Yes		No				
	76		24				
2. When did you join the KF?	Year	%	Year	%			
	1910-15	0.9	1940-45	4			
	1915-20	1.4	1945-50	15			
	1920-25	1.4	1950-55	14			
	1925-30	1.4	1955-60	19			
	1930-35	2.9	1960-65	17			
	1935-40	5	1965-70	18			
3. How often do you use this shop?	Daily		A few times a week		Once a week		Occasionally
	21		46		18		15
4. How do you generally prefer to carry your goods when doing your shopping?	Basket		Carriage		Own bag		Nothing
	16		53		1		0.5
	Basket and carriage		Carriage and own bag		Basket and own bag		
	26		1		2.5		

TABLE 4.24 (cont)

5.	How many bags (or corresponding) have you bought?	Less than one bag	1	2	3	4	More
		0.5	29	53	14	1.5	2

6.	Does it happen that the cashier seems rushed?	Almost always	Occasionally	Hardly ever
		3	19	78

7.	Does it happen that you have to queue up at the cash-desk?	Almost always	Occasionally	Hardly ever
		31	64	5

8.	How long time do you think you generally are queuing up?	Not more than 5 min.	Between 5 and 10 min.	More than 10 min.
		59	39	2

		Do not know	Definite-ly	To some extent	General-ly not	Definite-ly not
9.	Are you going to do your shopping in this shop in the future?		87	11	2	

10.	If yes, why?	I like the shop	A suitable distance
		71%	29%

11.	Did you get insufficient opportunities for asking questions?	Do not know	Definite-ly	To some extent	General-ly not	Definite-ly not
		2	9.5	19	19.5	50
12.	Was it entirely clear to you how to behave at the desk?		91	8	1	

TABLE 4.24 (cont)

	Do not know	Definite-ly	To some extent	General-ly not	Definite-ly not
13. Did you think that you get insufficient time for paying?		2	15	36	47
14. Was it difficult for you to get enough room for your goods on the conveyor?		4	29	29	38
15. Did you find it difficult to pick out the goods?		1.5	10	4.5	84
16. Did you find it difficult to find bags for packing the goods?			9	5	86
17. Did you find it difficult to get time for packing the goods?	0.5	13	50.5	23	13
18. Was the packing worse than the picking out?	0.5	41	16	4	38.5
19. Do you find it more stressing to pack a small amount of goods during the rush-hours than to pack a large amount of goods when it is empty at the cash-desk?	0.5	43	20	1	35

TABLE 4.24 (cont)

	Do not know	Definitely	To some extent	Generally not	Definitely not
20. Do you think there ought to be a special cash-desk for those who buy only a few things (4-5 articles)?		79	13.5	6.5	1
21. Do you feel more rushed when you leave the shop than when you entered it?		4	9	30	55
22. Do you think that the number of cash-desks in this shop is insufficient?	1.5	1.5	12	35	50
23. Is the passing of the cash-desk more troublesome than the actual shopping?	1.5	4.5	41	5	48
24. Are the carriages easy to handle?	9	67	19	4	1
25. Is there too little space between the cash-desks?	1	8	11.5	29	50.5
26. Do you think that the cashiers' jobs are monotonous?		44	28	24.5	3.5

TABLE 4.24 (cont)

	Do not know	Definitely	To some extent	Generally not	Definitely not
27. Do you think that the cashier has a stressing job?	1	10	54	30	5
28. Does it happen that the cashier registers the wrong prices of the goods?	10	0.5	8.5	28	53
29. Do you have your favourite cashier if you do your shopping in the same shop?		20	17	9	54

30. Why?	Because of nice personality	Because of quickness and handiness
	91	9

31. Are you of the opinion that the cashiers shall weigh the goods?	0.5	0.5	8	16	75
32. Does it happen that the cashier mixes up your goods with other customers'?			5.5	8.5	86

33. Which of the following machines would you prefer, if they were on the market?

	%
1. A machine in which to put the money	2.5
2. A machine which reads the prices and works out the sum total	29
3. A machine which packs	37.5
4. A machine which picks out the goods from the carriage	6

Refuses: 25%

TABLE 4.24 (cont)

34. All articles are not provided with prices; the price is sometimes only stated on a sign at the place where the article is put up in the shop. Is this

1. Sufficient	32%
2. Not entirely sufficient	16.5%
3. Insufficient	38%
4. Entirely insufficient	13.5%

Forty six percent of the customers visited the shop in which they were interviewed several times per week. Twenty one percent visited the shop daily, and 18% once a week.

In Question 4 the customers were asked how they preferred to transport their goods around the shop. Fifty three percent preferred a carriage and 16% preferred the basket provided by the shop.

The customers were also asked (Question 5) to state how many paper bags (of 15 litres capacity) of goods they normally filled at each visit to the shop. Fifty three percent bought 2 full bags of goods, 29% one bag of goods and 14% three bags of goods. The customer who had done a lot of shopping (i.e. bought 2 or more bags of goods) felt a lot more rushed than the other customers ($\chi^2 = 3.57$, $p < 10\%$).

The customers were also asked to judge if they thought that the cashier seemed to be under stress (Question 6). Seventy eight percent of the customers thought that the cashier almost never seemed to be under stress and 19% thought that she sometimes appeared to be stressed. Only 3% thought that she almost always seemed to be stressed.

Question 7 asked 'does it happen that you have to stand in a queue before being served at the cash desk?'. Sixty four percent said that they sometimes had to stand in a queue, 31% responded 'nearly always', and 5% said that they almost never had to stand in a queue. In response to Question 8, fifty nine percent thought that normally they didn't have to stand more

than five minutes in a queue. Thirty nine percent thought that they normally had to stand 5 to 10 minutes. Only 2% thought that they had to stand about 10 minutes in a queue.

Eight seven percent of the customers said that they were certainly going to continue to do their shopping in the shop in which they were interviewed and a further 11% thought that to a certain extent they would continue to do their shopping in the shop which the study took place. Only 2% said that they would not in general, continue to do their shopping in that shop.

When the customers were asked why they were going to continue to do their shopping in the shop in study, 71% said that it was because they liked the shop and 29% said it was because it was close by. Significantly more ($\chi^2 = 4.72$, $p<5\%$) of the young people than the old went to the shop because they liked it. The old customers normally went to the shop because it was close by. Customers who were members of KF went to the shop because they liked it, and not because it was close by. The converse was true for non-members of KF.

Question 11 asked 'are there insufficient possibilities to ask questions?' (of staff in the shop in relation to availability of goods, location of goods, etc). Fifty percent said that there was absolutely no difficulty. Nineteen percent said to a certain extent there were insufficient possibilities. In general the customers who used the shop because they liked it thought that there were enough opportunities for asking questions.

Ninety one percent of the customers said that it was completely clear to them what to do at the check-out point.

Forty seven percent of the customers thought that there certainly was enough time for paying and abother 36% thought that in general there was enough time for paying for the goods purchased. There was a significant number of those who felt rushed or thought that they were not given enough time for paying ($\chi^2 = 2.33$, $p < 1\%$).

Thirty eight percent of the customers said that there were absolutely no problems in finding enough room on the conveyor belt for goods purchased. Another 29% thought that in general there were no difficulties in finding enough room on the conveyor belt. Twenty nine percent thought that there were some difficulties and 4% said that it was certainly difficult to find room on the conveyor belt for the goods. It was mainly those customers who bought a lot of goods (2 bags or more) who thought it was difficult to find room on the conveyor belt for the goods purchased ($\chi^2 = 7.0$, $p<1\%$). There were also significantly more of the young people than of the old people who thought that there was not enough room on the conveyor belt for the goods ($\chi^2 = 4.07$, $p<5\%$).

The customers were asked if they found it difficult to unpack their goods from the carriage or basket before they were processed by the cashier. Eight percent didn't have any problems at all and 4.5% didn't usually have problems. Ten percent had problems to some extent and 1.5% certainly had problems of this kind. The customers who used the shop because they liked it did not have so many difficulties with the unpacking of goods as the customers who used the shop because it was close by ($\chi^2 = 5.19$, $p < 5\%$).

Members did not have so much psblems with the unpacking as non-members ($\chi^2 = 37.57$, $p<1\%$).

Eighty six percent of the customers had no difficulties at all in finding the paper bags for the packing of goods after they had been processed by the cashier. Only 9% had some problems. The customers who used the shop because they liked it had less problems in finding the paper bags than the other customers ($\chi^2 = 2.39$, $p<10\%$). The customers who were members of KF had less problems in finding bags than non-members ($\chi^2 = 4.2$, $p<5\%$).

In Question 17 the customers were asked if it was difficult to find sufficient time to pack after they had been processed by the cashiers. As many as 50% thought that there were some problems and another 15% said that there were certainly problems in getting enough time for the packing of goods. It was, of course mainly the customers who bought a lot (2 bags or more) who thought that they hadn't enough time for the packing ($\chi^2 = 6.67$, $p<1\%$). Significantly more of those who felt rushed did not have enough time for packing ($\chi^2 = 10.17$, $p<01\%$), as compared with other customers.

The customers were also asked if they thought that the packing of goods was more difficult than unpacking. Forty one percent said that packing was very much more difficult. Another 16% said that there were more problems with the packing than the unpacking. Thirty eight percent said that there was certainly no more difficulties with the packing than unpacking. Proportionately more young people than old found the packing worse than the unpacking ($\chi^2 = 3.59$, $p<10\%$). Those who were

rushed found packing worse than unpacking (χ^2 = 13.34, p<1%) to a greater extent than those who did not feel rushed. Those who bought a lot (more than 2 bags) had more problems with packing than unpacking (^{2} = 2.72, , p<10%).

The customers were asked if they found it more difficult to pack a small amount of goods during the rush hour than to pack a large amount of goods when they were no people at the cash desk. On this question 20% said 'yes to a certain extent', and another 43% said 'yes certainly'. Thirty five percent said certainly not more difficult. The customer who bought a lot (2 bags or more), found it more stressing to pack a small amount during rush hours than to pack a large amount when there were no people at the cash desk (χ^2 = 5.56, p<2%).

Seventy eight percent of the customers said that there should be a special cash out desk for those who buy only a small amount of goods. Proportionately more of the young customers than the old customers thought that there should be a special check-out for those who only buy a few things (χ^2 = 3.1, p<10%).

Fifty percent of the customers thought that there were certainly enough check-out desks in the shop. Another 35% thought that, in general, there were enough check-out desks in the shop.

Fifty five percent of the customers thought that they were certainly not more rushed when leaving the shop than when entering it. Those who bought a lot felt more rushed when leaving the shop than when entering it, compared with those who bought one bag or less (χ^2 = 3.57, p<10%).

Forty one percent of customers thought that passing through the check-out desk is to some extent more difficult than collecting the goods in the shop. Another 4.5% thought that it was definitely more difficult to pass through the check-out desk than to collect the goods in the shop. Proportionately more of the younger customers than the older customers found passing through the check-out desk difficult ($\chi^2 = 3.98$, $p < 5\%$).

Sixty seven percent of the customers thought that the carriage was easy to manoeuvre in the shop in which the interviews took place. Fifty percent of the customers found the space between the cash desk too constricting. Eight per cent certainly didn't think the cash desks were too close together. Another 11.5% thought that to a certain extent there was insufficient room between the cash desks.

Forty one percent of the customers said that the cashiers' work certainly seemed to be monotonous and another 28% of the customers thought that the work was monotonous to a certain extent. The customers who went to the shop because they liked it or because they were members of KF had the opinion to a greater extent than other customers that the cashiers' work seemed to be monotonous ($\chi^2 = 11.69$, $p < 1\%$).

Ten percent of the customers thought that the cashiers' work certainly seemed to be stressing and 54% thought that it seemed stressing to a certain extent. The customers who used the shop because they liked it held the opinion to a greater extent than other customers that the cashiers' work seemed stressing ($\chi^2 = 18.76$, $p < 1\%$).

Fifty three percent of the customers, certainly, and another 28% in general, did not think that the cashier was keying incorrect prices into the cash-register.

Twenty percent of the customers had a favourite cashier. Of this 20% the vast majority said that they liked the personality of the cashier. Only a few chose a favourite cashier due to her performance.

Seventy-five percent of the customers think that the cashier should not weigh the goods.

Eighty-six percent of the customers said the cashier certainly does not mix up the goods of one customer with another. Five and a half percent of the customers thought that this could happen to a certain extent. Twenty five percent of the customers didn't want to have any new automatic machines in the check-out system. Thirty-seven percent, however, of the customers would like to have automatic machines for the packing of goods. Twenty-nine percent thought that it would be a good idea to have automatic machines for reading the prices of the goods.

Finally, the customers were also asked what they thought about the situation where no goods were provided with a price marking. The alternative was envisaged in which the prices would only be given on the shelf where the goods were displayed in the shop. Thirty-two percent of the customers thought that this was certainly sufficient, sixteen percent thought it wasn't completely sufficient, another thirty-eight thought it was insufficient and 13.5% thought it was completely insufficient.

14.3 Conclusions

Results indicate that it is primarily how many goods the customer has bought which determines how she judges the adequacy of the check-out system. It seems to be the case that the customers who buy most are more negatively inclined to the check-out system in self-service shops. The study also seems to indicate that it is not the customer tasks themselves which the customers do not accept, it is the lack of time provided by the system for completing them which is the primary cause of complaint. Functions in the check-out system causing the most difficulty are those involving transportation on the conveyor belt, payment and packing. Different kinds of technical devices which could make the work easier for the customer could be of great consequence for the customer who buys a lot. This is especially important as this type of customer is likely to become more and more common.

15.0 OBSERVATION STUDY

As said before, it is very difficult to draw any quantitative conclusions from the type of studies which have been reported up to now in this part of the thesis. However, it would certainly be of interest to have some information of a quantitative nature for the type of events which were reported in the cashiers' critical incident interviews. The attitudes of the cashers to these events were studied in the first part of the cashier questionnaire. In order to obtain quantitative information on these events, a special observation study was set up to record the behaviour of the check-out system, including actions of both the cashiers and customers.

The specific objective of this study, plus the general nature of observation studies involving infrequent events necessarily made this study rather limited from the point of view of the amount of data it contained. Some of the events which were recalled in the critical incident study with the cashiers were likely to be infrequent. This means that even if the proposed observation study continued for quite a long time, the number of different events and their frequency would be few and low respectively. Cost constraints set up time limits on how extended the observation study could be. The small amount of data which would be obtained in a limited study of this kind would necessarily make it difficult to carry out complex kinds of statistical computations on the data such as those for example involving partitioning data of different groups of subjects. This, however, need not be a serious handicap if the prime interest is in first order effects over all subjects.

15.1 The method and procedure

Mainly from the experience obtained from the cashier critical incident interviews, and to some extent from the customer interviews, a special form for recording observations on the check-out system was designed. This form is given in Appendix 4.11.

The procedure for making observations was as follows. One customer was studied at a time. The observer started to study her just before she arrived and was active in the check-out system. Customer age was estimated and sex observed. A note was made of the number of customers waiting in the queue at the time a particular customer was selected. When the customer entered the system and started unpacking the goods she had collected in the shop a stopwatch was started. The observer made a note about the means of transportation which the customer had used in the shop. It was checked if the unpacking of the goods onto the first cash desk conveyor belt was correctly carried out. The observer then determined if there was sufficient room for all the customers' goods on the conveyor belt. It was further studied if the cashier had to wait for the goods whose prices she had to enter into the cash register. In other words a check was made to determine if unpacking was effected too slowly by the customer. A note was also made of whether or not the customer removed the basket or the carriage which she had used to transport her goods around the shop from the check-out system. A record was also made of whether the following customer's goods were mixed with the goods of the customer under observation in the system. The observer then tried to establish the following: was it difficult for the cashier

to read price marked on goods whose price she did not know or remember, was the price of the goods being dealt with by the cashier unknown, did the customer read the price indicator on the cash register, were there any complications between customer and cashier, and did the customer hear how much to pay or did she have to ask the cashier to repeat the total price a second time. A note was made of whether the customer had money ready to pay for her goods and whether the money was placed in the correct location. It was observed whether the customer had trouble manipulating his or her own wallet or handbag. In other words, was there a need for a special place on which to put her own wallet or handbag?

It was also noted if the packing of goods by the customer started before payment was made, and, in these circumstances how payment was carried out. Whether the change returner was used and whether the customer took the change without comment from the cashier were also recorded.

Finally it was noted whether or not there were too many goods in the end box into which the goods were delivered by the second conveyor belt after being handled by the cashier, thus making it difficult to change around to a new box for the next customer.

A check was made on whether the goods fell over from one box to another and whether the customer was able to find the carriages and paper bags needed, and what happened when a customer was unable to complete packing before goods from the following customer arrived. It was noted how many goods were bought. When the customer

left the check-out system (i.e. having taken all her goods from the box) the stopwatch was stopped and the time in the check-out system for the customer was recorded. These observation studies were carried out at several shops all over Sweden, including shops in the large towns of Stockholm and Gothenburg. Altogether 500 observations were carried out i.e. 500 different customers were observed in the check-out system.

Even though 500 observations took place some events only occurred very rarely, if at all. For this reason, as indicated earlier it was judged fruitful only to record the relative frequency with which each type of event under observation occurred without further partition of the data, in terms of a classificatory variable such as the subject's age or sex. For similar reasons no sophisticated statistical analyses were carried out on the data.

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15.2 Results and conclusions

It will be recalled that the form used for recording observations and which was used in this study is given in Appendix 4.11. The different types of events being observed are discussed in the order given in the form.

From Table 4.25 which gives the frequencies of different age groups, it may be seen that most of the customers fall within the 21 to 40 year bracket. Customers estimated to be aged between 41 and 60 years also constituted a large group.

Table 4.26 shows customers broken down by sex. Female customers were more common than male customers. It was perhaps a little surprising to find that as many as 40% of the customers were male but this may be explained by the fact that the shops which were included in this study were mainly food shops.

Table 4.27 shows that in the shops studied most often there were only two people in the queue up to the check-out system.

Table 4.28 indicates that the most common type of transportation used by customers to carry the goods of their choice was the carriage or basket provided by the shop.

Table 4.29 gives the relative frequency of occurrence for different events. (If the relative frequency for a particular event is multiplied by 500, one obtains the absolute frequency of that event). On consulting this table it will be seen that several events of a critical nature to effective system function occur quite frequently.

On 12% of occasions the customers were observed not to have removed their baskets from the stand beside the conveyor belt when they had unpacked their goods. This would inconvenience the subsequent customer. It was also rather frequently observed (7%

TABLE 4.25

FREQUENCY TABLE FOR THE OBSERVED AGE GROUPS OF CUSTOMER.

Class interval	Frequency	Percentage
Less than 21 years	48	9.64%
21 to 40 years	185	37.15%
41 to 60 years	135	27.11%
More than 60 years	130	26.10%

N = 498 (99.7%)

TABLE 4.26

FREQUENCY TABLE FOR THE OBSERVED PARTITION OF CUSTOMER BY SEX.

Class interval	Frequency	Percentage
Female	352	70.54%
Male	147	29.46%

N = 499 (99.8%)

TABLE 4.27

FREQUENCY TABLE FOR THE OBSERVED NUMBER OF PEOPLE IN QUEUE.

Class interval	Frequency	Percentage
Less than 1	0	0.00%
1	451	90.20%
2	23	4.60%
3	9	1.80%
4	8	1.60%
5	6	1.20%
6	1	0.20%
7	0	0.00%
8 and more	2	0.40%

N = 500 (100%)

TABLE 4.28

FREQUENCY TABLE FOR THE OBSERVED MEANS OF TRANSPORTATION OF GOODS IN THE SHOP.

Class	Frequency	Percentage
Own bag	104	20.84%
Carriage	141	28.26%
Basket	166	33.27%
Other	88	17.64%

N = 499 (99.8%)

TABLE 4.29

RELATIVE FREQUENCY IN PERCENT OF HOW OFTEN DIFFERENT EVENTS OCCUR

	Type of event	Percentage
Q. 5	Wrong unpacking	7%
Q. 6	Not enough place for unloading the goods	4%
Q. 7	The cashier has to wait for the goods	4%
Q. 8	The customer does not remove the basket	12%
Q. 9	Different customers' goods are being mixed up	1%
Q. 10	The cashier cannot read the price on the goods	1%
Q. 11	The price of the goods is unknown	1%
Q. 12	Customer reads the indicator of the cash-registor	0.5%
Q. 14	The customer does not hear the first time how much to pay	2%
Q. 15	The customer has not got money ready to pay	8%
Q. 16	The customer puts the money on a wrong place	1%

TABLE 4.29 (cont)

	Type of event	Percentage
Q. 17	The customer has difficulty to know where to place her own handbag	1%
Q. 19	The percentage of times as the change returner is used	16%
Q. 20	The percentage of times as the customer forgets to take the change from the coin-returner	7% (of 80)
Q. 21	It is not enough room in the box for all goods	3%
Q. 22	The goods from different customers are mixed between the boxes	0.5%

TABLE 4.30

FREQENCY TABLE FOR THE NUMBER OF TIMES THE CUSTOMER AND THE CASHIER COMMUNICATE.

Class	Frequency	Percentage
Information	50	34.01%
Complaints	4	2.72%
Other kind of talks	93	63.27%

N = 147 (29.4%)

TABLE 4.31

FREQUENCY TABLE FOR THE NUMBER OF TIMES THE CUSTOMER START PACKING BEFORE PAYING.

Class	Frequency	Percentage
Return for paying	15	71.43%
Stretch for paying	4	19.05%
Other ways of paying	2	9.52%

N = 21 (4.2%)

of the time) that the customer performed her unpacking in an incorrect way by for example putting her basket directly on the conveyor belt simply leaving her goods in the basket and so on. Eight percent of the customers did not have money ready to pay for the goods of their choice. The change returner was only used for 16% of the 500 observations. In respect of rare events it may be seen on 4 % of occca-sions there was not enough space for the unloading of the goods onto the conveyor belt. The study also indicated that the customer didn't unpack quickly enough, as in 4% of the cases the cashiers had to wait for the goods to arrive at the cash desk. Finally, in 3% of the cases there was not enough room in the end boxes for all the goods purchased by the customers.

In nearly 13% of all cases the customer spoke to the cashier. Table 4.30 indicates that this communication consisted mainly of general talk or comments about the weather. In general therefore the communication exchange was not directly relevant to the check-out system function. Sometimes, however, the customer requested information about the shop or the goods. There were also infrequent complaints voiced to the cashier.

When the cus tomer began packing before she had paid for her goods it may be seen from Table 4.31 that the customer returned to make the payment. This normally meant disturbance for the following customer around whom the erring customer had to pass in a constricted space. Sometimes the customers stretched over the desk and conveyor belt in order to pay to avoid this contingency when they had begun packing prematurely.

If the customer didn't unpack and carry out other actions quickly enough, her goods might be mixed with those of the next customer.

As table 32 shows, this happened in nearly 4% of the cases. In order

TABLE 4.32

THE FREQUENCY OF WHAT HAPPENS THE TIMES WHEN THE CUSTOMER DOES NOT PACK QUICKLY ENOUGH

Class	Frequency	Percentage
Mixing of goods	2	3.77%
Cashier takes the goods in her knee	17	32.08%
Does not change box	18	33.96%
Waits	16	30.19%

N = 53 (10.6%)

TABLE 4.33

The frequency table for the observed service time (not including the time in queu).

Class interval	Frequency	Percentage
Less than .90 min.	163	54.33%
.90 to 1.80 min.	76	25.33%
1.80 to 2.70 min.	38	12.67%
2.70 to 3.60 min.	8	2.67%
3.60 to 4.50 min.	5	1.67%
4.50 to 5.40 min.	6	2.00%
5.40 to 6.30 min.	2	0.67%
More than 6.30 min.	2	0.67%

N = 300 (60%)

to cope with this situation the cashier frequently took the following customer's goods onto her knee while she waited for the previous customer to finish her packing. Sometimes she did not take the following customer's goods on her knees and waited for the erring customer to finish packing.

It was very difficult to obtain reliable observations on the number of goods purchased, so responses to this question has been omitted. There were no observations recorded on the events examined on questions 23 and 24 i.e. the customer could always find paper bags of the right size.

Table 4.33 gives the service time which the customer had to spend in the system, excluding time spent in the queue. More than half the customers had a service time of less than 1 minute.

A general comment on these results is that several events jointly reported by the cashiers in the critical incident interviews and examined here in the observation study occur in the latter at quite low frequencies in absolute terms (i.e. 10% of the time)

16.0 DISCUSSION AND CONCLUSIONS OF PART 4

This Part of the thesis has been divided into four chapters. The first contained a report on a cashier interview study involving the critical incident apporach. The main aim of that study was to look at errors arrising from two versions of a recently designed check-out desk(the two-conveyor belt cash desk).

The second chapter reported on a substantial cashier questionnaire investigation. The aim was partly to follow up the cashiers' attitudes to different kinds of critical incidents discovered in the cashier interview, and partly to look at different kinds of work problems experienced by cashiers, expecially in relation to the recently introduced cash desk (the two-conveyor belt cash desk).

A very small study aimed at recording the customers' situation in relation to the check-out system has also been carried out. This was reported in the third chapter of this Part. In order to obtain some objective quantitative information about the occurrence of different events reported in the cashier critical incident interview study, an observation study was carried out. This study was reported in the fourth chapter of this Part.

In the following which constitutes the fifth and final chapter of Part 4 the results of these four studies are brought together. First the results are discussed and compared. Included are some design recommendations in relation to the check-out system.

The present chapter concludes with a discussion of the advantages and disadvantages of the different methods used in Part 4.

16.1. Interpretation and implications of results

From the cashier interviews detailed information was obtained about different kinds of malfunctions and design errors in the new two conveyor belt cash desk. Most of the complaints the cashiers put forward related to the design of the means for transportation of goods through the system. In particular, the cashiers frequently mentioned different kinds of errors originating from the design of the conveyor belt. Another frequently-mentioned group of errors originated from the design of storage locations in the system. The change-returner also seemed to be an important source of errors mentioned by the cashiers.

In the cashier questionnaire study, the first part of the questionnaires dealt with various technical matters. The cashiers seemed to be mostly troubled by the fact that the customers did not remove their goods from the baskets and that goods got damaged or stuck in the conveyor belt. They were also bothered about the fact that the change-returner was unreliable. They also thought that it was unsatisfactory and inconvenient that the customers did not know where to put the carriages which they had used. From answers to other questions posed in the questionnaire study it may be concluded that the average cashier believed that her job was independent, and that the possibilities for promotion were not very good. Contact with the public was felt to be most pleasant and the general atmosphere of the job was good. The typical cashier got on quite well with her colleagues and she found her supervisors agreeable. She would, without hesitation, have recommended her friends to take a job as a cashier. However, the job was to a certain extent a little stressing. The cashiers did not like to have to check if customers had stolen anything, or were old enough to buy beer, and so on. The cashiers also thought

that the job was quite physically demanding and wearing. It was clear that the substantial percentage of the cashiers were not satisfied with their working hours. This was especially true for the young cashiers. Finally it may be concluded that the new two conveyor belt cash desk seemed in general, to have improved working conditions quite a lot compared with the old type of cash desk. The main improvement was that the work seemed to be less wearing and physically tiring on the new desk.

The interviews with the customers showed that the most important complaints related to how much was bought. It seemed as if it was the customer who bought many goods who had the most problems in getting through the check-out system. This constitutes a very severe problem as it is the customer who buys many goods who must be regarded as important from the shop's point of view (these customers also constitute a large propotion of all the customers). For example, as many as 50% of the customers thought to a certain extent that it was difficult for them to pack their goods in the limited time available. It also seemed clear that it was the packing of goods which was the most troublesome part of going through the check-out system.

The observation study showed that the most frequent events were that various things got stuck in the conveyor belt, the space on the conveyor belt was not large enough, the customer had problems when she had to pay for her goods, the change-retuрner was not reliable, and the end boxes on the cash desk were too small. The most frequent event observed was that the customers did not remove the carriages they had used from the vicinity of the check-out system.

A comparison now follows of the results obtained in the different

studies. Table 4.34 shows the differences in age between groups involved in the observation study and the customer interview. In general, the customers seem to have been somewhat older in the customer interview than in the observation study. On the other hand there were more really old people (older than 65) in the observation study.

In Table 4.35 are shown the first ten questions on the cashier questionnaire. Against them, in the first column of figures, are shown the relative frequencies, in terms of percentages of the two most adverse response categories. The second and third columns of figures in this Table contain corresponding results obtained in the observation and cashier interview studies respectively. From Table 4.35 it may be observed that there is some correlation between the different columns. A Spearman's Rank Correlation was carried out. The correlation coefficient between the responses on the cashier questionnaire and observation study was very low indeed ($\rho = +.09$). The correlation between the cashier interview and observation study responses somewhat higher, but still insignificant ($\rho = +.40$). However, the correlation between the cashier interview and the cashier questionnaire responses was quite high, $\rho = +0.65$. This correlation coefficinet is significant at the 5% level. In other words there is no significant correlation between the frequency of occurrence of certain events and the cashiers attitudes to those events. However, there is a small but non-significant correlation between the frequency of occurrence of certain events and the frequency with which those have been mentioned in the cashier critical incident study. The frequency with which the different events have been reported

TABLE 4.34

PERCENTAGES OF CUSTOMERS OF DIFFERENT AGES IN THE OBSERVATION AND CUSTOMER INTERVIEW STUDIES.

Age	Observation study	Customer interview (estimates)
20 years	10%	4.5%
21 - 40	37%	35.0%
41 - 60	27%	52.0%
61 years	26%	8.5%
Sex		
Male	29%	16%
Female	71%	84%

TABLE 4.35

RELATION BETWEEN THE FIRST TEN QUESTIONS IN THE CASHIERS QUESTIONNAIRE (FIRST COLUMN) AND "CORRESPONDING" RESULTS OBTAINED IN THE OBSERVATION STUDY (SECOND COLUMN) AND CASHIER INTERVIEW (THIRD COLUMN).

	(For corresponding variables)		
	The relative frequencies in percent of the two most extreme bad response categories	The relative frequence of occurrence in the observers study	The relative frequence in cashier interview
Q1. The customer puts her goods onto the conveyor belt without taking them out of the basket.	48	7	35
Q2. Newspapers, packets of sausages and similar objects get stuck in the conveyor belt.	63	0	47
Q3. At the end of the conveyor belt the goods that follow on the belt press on the goods that have gone before so that the more fragile articles are damaged.	54	-	29
Q4. The customer hasn't enough time to pack her goods before the goods-box is needed for other customers.	40	4	3
Q5. If a customer starts to pack before she had paid for the goods, the cashier has to reach for the customer's money and to return the change, or the customer has to hurry back to the cash-desk to pick up her change.	34	4	18

Table 4.35 (continued)

	(For corresponding variables)		
	The relative frequencies in percent of the two most extreme bad response categories	The relative frequence of occurence in the observers study	The relative frequence in cashier interview
Q6. The customer puts the money on the wrong place, e.g. on the plate between the moving belts.	24	1	16
Q7. You scrape your fingers against the lid of the cash register drawer when you take out money.	22	-	4
Q8. The change returner does not work as it should. It sometimes returns too much and sometimes too little money.	69	7	13
Q9. It is not possible to push the bar over to deflect the purchased goods from one box to another when the customer has bought a large number of goods.	52	3	30
Q10. Some customers do not know where to put the carriages, which is the cause of the carriages being left in front of the cash-desk.	60	12	28

$\rho = 0.09$ $\rho = 0.40$

$\rho = 0.65$

in the critical incident study is quite strongly correlated with the cashiers strength of attitude to the different events.

A general conclusion is that several of the events which have been reported by the cashiers in the cashier interviews seem to occur at low frequencies. It is clear that it is the cashiers' attitudes to the different events, and not the frequency of occurrence of the events which is an important determiner of whether the cashier mentions the event as a critical incident.

Most problems occured in relation to the functions of packing, paying and the transportation of goods in the system. It is clear that a change of design of certain system components can eliminate several of the more pressing problems. For example, correct design of the place where the packing is done and appropriate instructions for the customer would certain decrease the wrong and disturbing methods of unpacking goods currently employed by the customer. A slightly wider (about 5 cm) conveyor belt which goes very close to the desk (to avoid goods getting stuck between the belt and the desk) would make it possible to have enough space for the unloaded goods, and, at the same time prevent goods getting stuck in the belt. Slow payment decreased the speed of the system quite considerably , as the customer who was slow in payment easily obstructed the passage of the following customer through the system. Other means of paying, such as credit cards for regular customers would probably speed up this part of the system. The customer disliked packing her goods. This was especially a problem for the older customer. In several parts of the investigations it was shown that the customer had problems in packing her goods quickly enough. The provision of special personnel for packing the goods particularly at a busy time would be valuable. Alternatively

it would be advantageous if some kind of automatic packing and boxing system could be arranged.

16.2 The value of the different methods used in the Part of the study

Results involving several different methods of obtaining information have been reported in this Part of the thesis. It is of interest to compare the relative advantages and disadvantages of the methods employed.

The critical incident interviews are characterised by their ability to give detailed information about system function. For some situations and for some kind of functions and malfunctions, it is probably not possible to get as much information from any other method as from the critical incident interview. This is especially true for events which occur with a very low frequency. As seen in the present investigations observation studies may, for these kinds of infrequent events, give very little information in spite of the fact that they continue for quite a long time and thereby involve high cost. Due to general problems of vigilance and alertness on the part of the observer the information obtained from direct observations studies may also have quite a low validity and reliability.

The disadvantage with the critical incident approach is that it provides data which are mainly qualitative, in an enumerative sense, and not quantitative. However, the present studies reveal that the frequencies with which the different events have been reported can be relied upon as a good indicant of how disturbing respondents but not as a good indication of how frequently the events occur. regard the events in question. [Another problem with the critical incident approach is that it is time consuming in the data collection (e. g. it takes time to get the respondents to understand what they are to do) and analysis phases. Time is typically consumed in the analysis phase because there are great problems in obtaining a rational method for classifying the different events reported. This

implies, among other things, that it is probably difficult to compare the results obtained by different research workers. This problem will not arise if one is using standardized classes.

As has been reported many times before (Andersson et al, 1961), many difficulties arise in studies involving the questionnaire approach. One fundamental difficulty relates to ensuring that the right questions are posed so that relevant information may be obtained. In the present investigation some differences in results were obtained from the customer interview which was questionnaire based and the cashier questionnaire studies. These differences may have arisen from a variety of causes. The way in which the check-out system is viewed by customers and cashiers may differ. The customers were interviewed with the investigator holding the questionnaire whereas the cashiers themselves completed their questionnaires. However, it seems possible that some differences may have arisen due to differences in quality of questions between the questionnaires. The questions in the cashier questionnaire were possibly designed to a higher precision as it seems to be clear that the questions in that study were more relevant to their subjects than the questions posed in the customers' interview. This may be partly due to the fact that the questions in the cashiers' questionnaire were based upon a prior critical incident study.

If one considers the first part of the cashier questionnaire study, in other words that part of the questionnaire involving questions relating to the events mentioned in the critical incident study, one can query if any further information has been obtained over and above that from the critical incident study. If one accepts the statement made previously that from the frequency of reporting of events in the critical incident study one may predict the magnitude of

disturbance for the cashier, then it seems to be true that most of the disadvantages from a technological point of view were already revealed in the critical study. However, some further information was also obtained in the questionnaire study as more data were obtained. Partioning was then possible for different sub-groups, as for example different age groups, amount of experience of cashier work, and so on. In this way further information was obtanied. The latter was of special relevance for questions dealing with the general working conditions. This kind of division, by different groups, is very often of very high value, as in the present investigations.

One can, therefore, conclude that a good strategy for investigations involving questionnaire studies is to include an introductory open interview preferably involving the critical incident appoach. Thereafter, a large scale questionnaire study based on the results of the critical incident study can take place.

AN ERGONOMICS STUDY OF THE CHECK-OUT SYSTEM FOR SELF-SERVICE SHOPS IN SWEDEN

PART 5

DISCUSSION AND INTEGRATIVE CONCLUSIONS

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17.0 INTRODUCTION TO PART 5

In this, the fifth and final Part of this thesis, the experimental and survey findings are summarized and integrated. Recommendations for check-out system design based upon the finding are also given.

This Part is also very closely related to Chapter 1, and to Chapter 2, which, contained a functional analysis of the check-out system for self-service shops. This analysis was performed in order to provide a background for the design of a new check-out system, including new electronic cash registers and mechanical cash desks connected to a computer system for the automatic calculation of sales statistics and the automatic ordering of goods for the shop.

Chapter 1 included a general discussion about the allocation of different functions to man and machine. That section of chapter 1 concluded by posing several questions which ask whether man or machine is the better alternative to fulfil certain kinds of functions. Answers to these questions are provided in this Part. The answers are based upon the experimental and survey studies which have been carried out as part of this thesis and upon literature surveys. All this material has been presented earlier in the thesis.

Also included in Part 5 is a discussion of the value of a standard routine for functional design of the kind presented in chapter 2.

Part 5 concludes with a discussion of the different experimental and survey methods used in this thesis.

18.0 SUMMARY AND INTERPRETATION OF ALL RESULTS

In chapters 1 and 2 a series of unsolved problems was presented. These problems were of different levels of complexity. In chapter 1, for example, automation in the supermarkets was discussed in general terms. The discussion was especially directed towards the consequences for the check-out system of introducing into self-service shops devices for automatic information handling. Such devices included those particularly apt for the automatic ordering of goods and the automatic computation of sales statistics.

Problems at another level of complexity were raised in chapter 2. In that chapter, for example, was discussed the best means of inputting data into an electronic cash register. Should, for example, a ten key keyboard have the keys 1, 2, 3 in the top row or alternatively should the top row consist of the keys 7, 8, 9? Other kinds of problems at about the same level of complexity were also discussed. These included the identification of the main difficulties experienced with the cash desk, both from the point of view of the cashiers and the customers. Was it, for example, the unpacking of goods on to the conveyor belt at the beginning of the system, or the packing of goods into the customer's shopping bag at the end of the system which proved to be the most troublesome?

18.1 The keyboard design and performance

As the KF cash register factory (Hugin) was going to develop new electronic cash registers to be connected on line with a computer system, it was decided that the design of a keyboard for this electronic cash register should be subjected to a detailed experimental study. In Part 2. a literature view and a design specification for this keyboard were given. As there were some doubts about the most suitable kind of configuration of the keys on the ten-button keyboard, two different alternatives were offered.

The Hugin factory produced two prototypes in accordance with these two alternative specifications. A special experimental evaluation of these two keyboards was performed. This evaluation was reported in detail in Part 3. The main conclusion to emerge from this evaluation was that performance in general is better on a ten-button keyboard with the buttons 1 2 3 on the top row than with the buttons 7 8 9 on the top row. Performance on the 123 keyboard was better both in terms of speed and accuracy. The 123 configuration was superior both for subjects who had previous experience of the 789 configuration (office girls) and for subjects who had experience of the so-called full-keyboard (cashiers).

Mean
Accuracy of performance on the 123-keyboard was about 60% greater than on the 789-keyboard. Mean
Speed of performance was about 5 to 10% better on the 123-keyboard than on the 789-keyboard.

The subjects worked on the prototype keyboards for half an hour on each of five consecutive days. The speed of performance improved dramatically over the first three days. For the last two days, however, there was no significant increase in speed.

A similar result was obtained for accuracy of performance. It seems reasonable to conclude that the flattening-off in performance indicated that the subjects were asymptoting towards a skill level on which further dramatic improvement was unlikely. This may be taken to indicate that a reasonably good standard of keyboard skill may be obtained after five consecutive days of training with half an hour of training on each day, subject to the proviso that the subjects involved already have extensive training on keyboards of a somewhat similar design. The results obtained from the key-board evaluation study should not be taken to indicate that in-experienced operators will asymptote to a final level of performance after five days of training with only half an hour's experience per day.

The cashiers who had had previous experience of full keyboards thought that the 123-keyboard was in general better than the full keyboard. It is important to know that these subjects did not regard the 789-keyboard as superior to the full keyboard on which they had had a good deal of experience. Nevertheless it is also important to note that cashiers with full keyboard experience thought that that keyboard was better in terms of accuracy than the 123 and the 789-keyboards.

The result which showed that accuracy of performance on the 789-keyboard was 50% less than on the 123-keyboard is in agreement with results reported by Conrad and Hull (1968). Conrad (1967) pointed out that errors result not only from the keywork itself but also from memory errors. Before the comparative evaluation of the 123- and the 789-keyboards was begun, the subject's skill, in terms of serial reaction time (SRT) and short term memory (STM), was

tested. Results from these two tests were used to select and match groups of subjects. Correlations between these predictors and the variables (speed and accuracy of performance) were also calculated. Positive correlations were obtained between SRT on the one hand and speed and accuracy on the other. Effectively no correlation, however, was obtained between results for STM on the one hand and speed and accuracy of performance on the other.

It is difficult to offer a convincing interpretation of the correlations relating to STM and performance. As mentioned, however, in section 4.5 "the kind of skills which are being used in keying are changed after a long time of practise" (Leonard and Newman, 1964). The reason for this is said to be that when subjects have been working for a very long time they have achieved a high degree of skill for the more complex kinds of habits involved in keyboard operation. This would imply the subjects are not keying digit by digit, but are working from groups of digits as units.

It is possible that a very good short term memory is only of significance in the forming of these more complex habits in the keying skill. The formation of a keying skill may be as follows: In the first stage of keying skill one is mainly developing the ballistic movements which are involved in the keying action. In the second stage the ability to perform rapid ballistic movement for single-digit keystrokes has been obtained. Groups of digits are then stored in the short term memory and rehearsed from it one by one. In a third stage the ability to perform the keying of groups of digits as single units is developed. If this

is the case, the STM should be a non-significant predictor for low level of keying skill but may be a good predictor of medium skill, as someone in the medium stage of skill is largely dependent upon short term memory. To some extent STM may also be a good predictor for high level of skill.

18.2 General technical problems associated with the check-out system

From chapter 2 it may be seen that it is difficult, from purely theoretical considerations, to predict which kinds of function should be performed by man and which by machine. In order to find the best information inputting solution, special evaluation experiments were carried out (Part 2 and Part 3). This was possible as the Hugin factory was planning to introduce a new design of keyboard for inputting information at the check-out point. However, it was not feasible to carry out similar detailed studies for all the other kinds of problems associated with the check-out system. It was, however, believed that a comparative study involving surveys by questionnaire, interview and observation of the functions of the check-out system from the point of view of both the customers and the cashiers of a recently introduced new cash desk (the two conveyor-belt cash desk) in relation to the old type of cash desk, would provide valuable information.

Thus the aim of the interview questionnaire and observation studies reported in Part 4 was to study the function of a new cash desk in relation to the old cash desk in order to obtain information on the different kinds of technical problems associated with cash desks, so the future cash desks would be better designed. A further aim of Part 4 was to study the general working conditions for the cashiers.

Part 4 was comprised four different studies:

i An open interview with cashiers

ii A questionnaire study with cashiers

iii A structured interview with customers

iv An observation study of check-out systems

The secondary aim of Part 4 (i.e. the study of general working conditions for cashiers) was examined only in the cashier questionnaire study (ii). The other studies only dealt with the kinds of technical problems which could affect both cashiers and customers. The first study was substantially the basis on which the following studies were grounded. Questionnaire, formalized interviews and observation forms were designed to collect information which seemed to be significant in terms of the results obtained from the open interviews with cashiers.

In brief, the results from the four studies indicated that a number of malfunctions associated with technical problems occurred in the use of the new cash desk. Though most of the malfunctions occurred relatively infrequently. Anumber of them were very troublesome for both customers and cashiers.

The introduction of this new cash desk had doubtless improved the working conditions of the cashiers from several points of view. It is difficult to assert, however, that the introduction of a new cash desk had improved the lot of customers.

Goods got stuck in the conveyor belt; more fragile goods were damaged at the end of the conveyor belt. These problems were troublesome to the cashiers. A greater problem for the cashiers was the unreliability of the change returner. Another problem

was that the customers did not know where to put the carriages when they had gone through the system. The loading of goods (i.e. unpacking of goods onto the conveyor belt) ought to be made easier for customers in order to improve efficiency. Nevertheless the most troublesome work for the customer was packing her goods when they had been processed by the cashier and came off the end of the conveyor belt to the storage boxes.

The cashiers' work on the new two conveyor belt cash desk was not found to be as heavy as on the old design of cash desk. The cashiers generally thought that the conveyor belt was very good from an efficiency and comfort point of view. The cashiers also thought that it was very valuable that the work place was designed to permit a sitting posture and that it was the customers' responsibility to pack the goods. At the same time the cashiers suggested that it was necessary to provide help for the packing operation in order to make the system more efficient.

Some results were not directly related to the design of the cash desk, but to the environment. For example, the cashiers thought that mis-reading was the most important reason for inputting wrong prices into the keyboard. Problems of the physical environment were not judged to be very important except that there were a number of complaints about draughts.

18.3 The general working conditions for cashiers

In general the cashiers seemed to have a favourable attitude towards their work. They also felt that the new cash desk improved their working performance to some extent. The main effects which seemed to result from the use of the new cash desk seemed to be that the work was found to be less physically tiring and particularly less tiring on the shoulders and arms. The next most important factor which induced the cashiers to like their job was the contact which they had with the public who came into their shops. The cashiers also appreciated the fact that their job involve variety and that they had good colleagues who were easy to get on with.

Features of work which were most disliked by the cashiers included the hours worked and unpleasant contacts with the public. So far as the latter was concerned they did not like to have to check if the customers had stolen anything or if the customer was old enough to buy beer. The most important reasons given for leaving the job were that the cashiers judged the work to be hard, the salary low and working hours bad.

19.0 SOME COMMENTS ON THE METHODS USED IN THIS STUDY

This thesis throws some light on the relative value of different ergonomic methods which can be used in the process of product development. As said in the previous section, for rapid, effective and cheap product development one needs a substantial amount of normative data. However, when this is lacking reliance must be placed on other methods for evaluating alternative system solutions.

In this thesis two alternative key-board prototypes were produced. These prototypes were compared using both experimental performance tests and subjective evaluation methods. In this study it may be seen that it is possible to arrange for close- control of factors likely to influence results both before and after the experiment. It will be recalled that subjects were given both SRT and STM tests. The results of these tests were used to allocate subjects to experimental groups in such a way that means (and variances) of scores on SRT (and STM) for the different groups were effectively the same. In other words the groups of subjects were matched in terms of variables likely to influence performance. Thus an effort was made to sensitisecomparisons of performance between groups.

Comparisons between the groups were further sensitised <u>after</u> the experiment by using the SRT and STM scores as covariates in a series of covariance analyses. There are, however, some dangers implicit in these approaches. If it is assumed before the experiment that SRT and STM are related, for example, to speed and accuracy of keying performance, and this turns out to be substantially true in subsequent correlation

analyses, then the matching procedures and covariance analyses will exert a very powerful influence on the experimental results obtained.

So that the matching procedures do not induce biased results in the experiment it is necessary to know the form of the distribution of the matching variable in the population at large, and assuming that this is normal, the mean and variance. It may then be ensured that all the experimental groups have the same mean, for example as the whole population. If, however, population data is not available there is some risk that any matching procedures which are carried out will employ means and variances which differ somewhat from those representative of the population. This in turn implies that subjects may be examined experimentally who are superior or inferior in terms of basic skill to the whole population.

A related difficulty arises when comparisons are being made between performances on groups who come from different populations who may have, for example short term memory skills which differ. If then matching takes place on the short term memory factor there is little possibility of properly representing the performance of the populations from whom one has samples. On the other hand if one allows the short term memory scores to differ and no matching takes place, in that case differences which are observed, for example in keying performance, may relate to differences in short term memory. For the populations who were experimentally examined on the two types of key-boards in this thesis, no population data on short term memory and serial reaction time were available. Fortunately there is no

reason to suppose that the two populations differed in respect of these tests or that the levels chosen for matching on these tests were inappropriate. Here again the embarrassment of lack of good normative data was demonstrated. Not only is normative data of value in the design process in the sense that it may eliminate the need for experimentation, but it is also valuable in the sense that it may enable more effective and efficient experiments and surveys to be carried out which ultimately lead to the designed systems.

In another part (part 4) of this thesis the whole of the check-out system was evaluated, both from the point of view of the customer and the cashier. One aim of part 4 was to study what kinds of malfunctions could occur in the new two conveyor belt cash desk. Another aim of the study was to look at the working conditions for cashiers in general and also to see what kind of improvements were associated with the new two conveyor belt cash desk. This information was required for the re-design of the cash desk and general working conditions (work schedules, training schemes, selection schemes, and so on). Four different studies were carried out involving interviews, questionnaires and observation. Only the study of malfunctions of the new two conveyor belt cash desk were common to the four different studies. First, a critical incident study was used to find out what kind of malfunctions occurred in the use of this new desk. There followed an extensive questionnaire study with the cashiers which further examined the malfunctions mentioned in the control incident study. Later on an observation study also covered these malfunctions. Finally, a small customer interview was carried out which examined in a more limited way these malfunctions.

These different approaches were compared in Chapter 16. Q The general conclusions to emerge from this comparison were that there is no, or a very low, correlation between the observed frequency of occurrence of different malfunctions and the cashiers' attitude to these different functions. There is a small but non-significant correlation between the observed frequency of the malfunctions and the frequency with which the different malfunctions have been reported by the cashiers in the critical incident study. There is a significant and quite strong relation between the frequency with which the cashiers reported the critical incidents and their attitudes to the different incidents which were examined in the cashier questionnaire study.

A general comment on the methods used for this part of the study is that questionnaires have to be designed very carefully. It is very valuable if the questionnaire can be based upon an open interview study, involving for example, the critical incident approach. In the open interview study, it is possible to discover the different malfunctions which occur in a system. From the frequency with which these incidents are reported, a preliminary estimate of the relative importance of the different incidents may be established. If, however, it is wished to determine quantitative information about the conditions under which these incidents occur then further studies on larger samples are necessary. Here the critical incident study is impractical as it is very time consuming and difficult to do on large groups of people and does not give quantitative data about how frequently different events occur.

The questionnaire approach then comes into its own, particularly if the design of the questionnaire is based upon results obtained from the previous critical incident study. The large amount of

information which may be obtained at limited cost from a questionnaire study permits a large number of divisions to be made on the data and further allows the use of sophisticated statistical techniques for descriptive and inferential purposes.

20.0 CONCLUSIONS AND RECOMMENDATIONS

In this chapter conclusions and recommendations based on the experimental and survey results of this thesis will be given. In the first section recommendations based on results reported in Part 2, 3 and 4 are offered. The recommendations which are based on the results from Part 2 and 3 are technical in nature. The other recommendations, based upon Part 4,only indicate technical problems for which technical solutions have to be found which are compatible with human factors requirements. In the second section of this chapter some general conclusions about the value of the system design routine outlined in Part 1 are offered, together with some recommendations.

20.1 The design of technical parts of the check-out system

From results reported in Part 2 and 3 it may be concluded that the keyboard located at the check-out point ought to be designed in accordance with the following points:

i The keyboard should have ten keys. The keys 1, 2, 3 should be on the top row, and the keys 7, 8, 9 on the bottom row.

ii The keyboard ought to have an angle upwards from the point of view of the operator of 10^{o}.

iii The keyboard ought to be turned anti-clockwise in the horizontal plane through about 10^{o} to 30^{o}.

iv The surface of the keyboard should have an angle of 20^{o} to 40^{o} inclination downwards from left to right (for right handed operators).

v The keys should be located with a distance of 19 mm between their centers. The diameter of the keys should be between 12 and 13 mm.

vi The force required to depress the key initially should be about 80 grams. The depression distance, i.e. the distance through which the key moves when pressed, should be about 4.5 mm.

Unloading goods onto the cash desk was found to be somewhat troublesome work for the customer and this activity also markedly decreased the efficiency of the system. The provision of a

mechanical device for unpacking the customer's carrier would undoubtedly solve some of these problems. A better, and more immediately viable, solution would be to arrange for the provision of a buffer storage (e. g. two boxes with a movable bar between them) which makes it possible for two customers to unpack their goods at the same time. By this means there would always be goods ready to be transported on the conveyor belt up to the cashier. The customers would then not need to feel stressed for not unpacking rapidly enough. This is important as it is not the work itself which the customers dislike, rather it is that they feel stressed when doing the work.

Transportation of the customers' goods through the system on a conveyor belt is good from the cashier's point of view both in terms of efficiency and comfort. However, it is essential that the conveyor belts are better designed so the goods do not get stuck in them (the surface of the conveyor belt should be on a level about 2 mm higher than the surface of the desk) or become damaged when they are transported to the storage boxes at the end of the conveyor belt (e. g. the distance between the end of the conveyor belt and the end of the desk should be about 20 cm longer). The change returner is, in principal, a very good device, but its design must be improved so that it functions reliably. Because the cashiers' work is essentially sedentary in nature it is also essential that the chairs on which they sit for such long periods of time are well-designed so that the cashiers do not feel unduly fatigued by their posture.

Other factors which cannot be overlooked in relation to the design of the new two conveyor belt cash desk are:

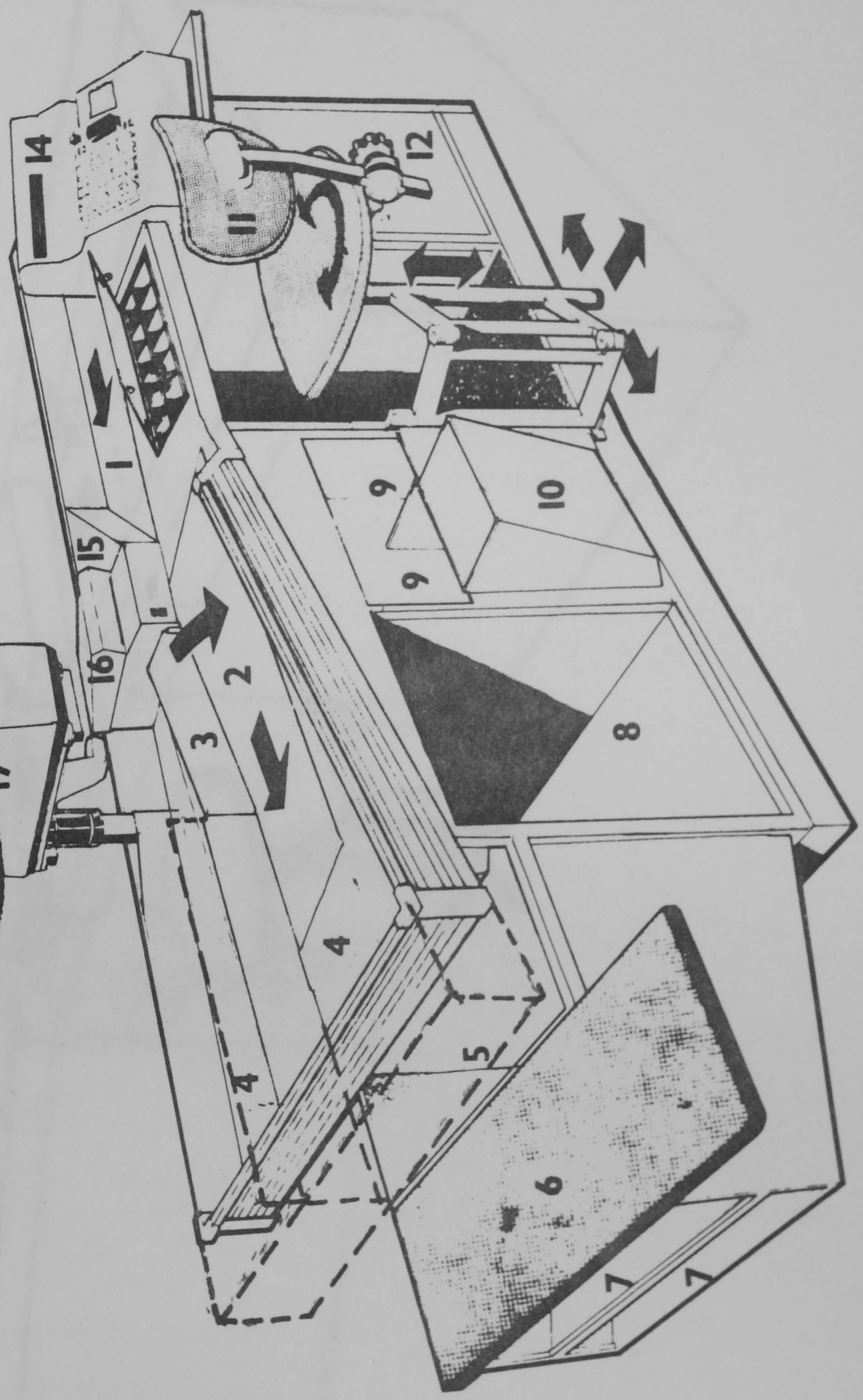
i The boxes in which the goods were stored on the cash desk were not large enough (ought to be about 20% larger). The place provided in the system on which the customer was expected to place the money for her goods was not very well designed. If the money was put down in the wrong location it caused a great deal of difficulty and inconvenience. The area between the two conveyor belts should be such that it is suitable to put money on. The bar between the boxes at the exit end of the cash desk (provided, it will be recalled, to deflect goods from one box to the other) was not high enough. This meant that when the bar was moved goods often fell over from one side of the bar to the other. This of course results in great inconvenience as different customers'goods were mixed. The bar ought to be 10 cm higher.

ii The prices and codes attached to the goods must be legible enough for the cashiers to read in all circumstances. The illumination levels in which prices and codes are read and other check-out activities carried out must be sufficiently high, and the lamp fittings and the general lighting conditions must be such that reflection glare or discomfort glare is avoided. A special lamp which could be controlled by the cashier, should be provided at the cash desk. Furthermore, the cash desk should be surrounded by small partitions in order to prevent the cashiers being exposed to draughts.

See Figure 5.1 on which these suggested modifications are shown with dotted lines. Carlsöö (1966) suggests that the movement with the left hand, from left to the right is unsuitable and that the best movement is from the body and forward (a push). The cashier is doing this movement with her left hand for the transportation of goods from the first conveyor belt to the second conveyor belt. A reversed transportation of goods, as in Figure 5.2, is therefore better for the cashier.

FIGURE 5.1

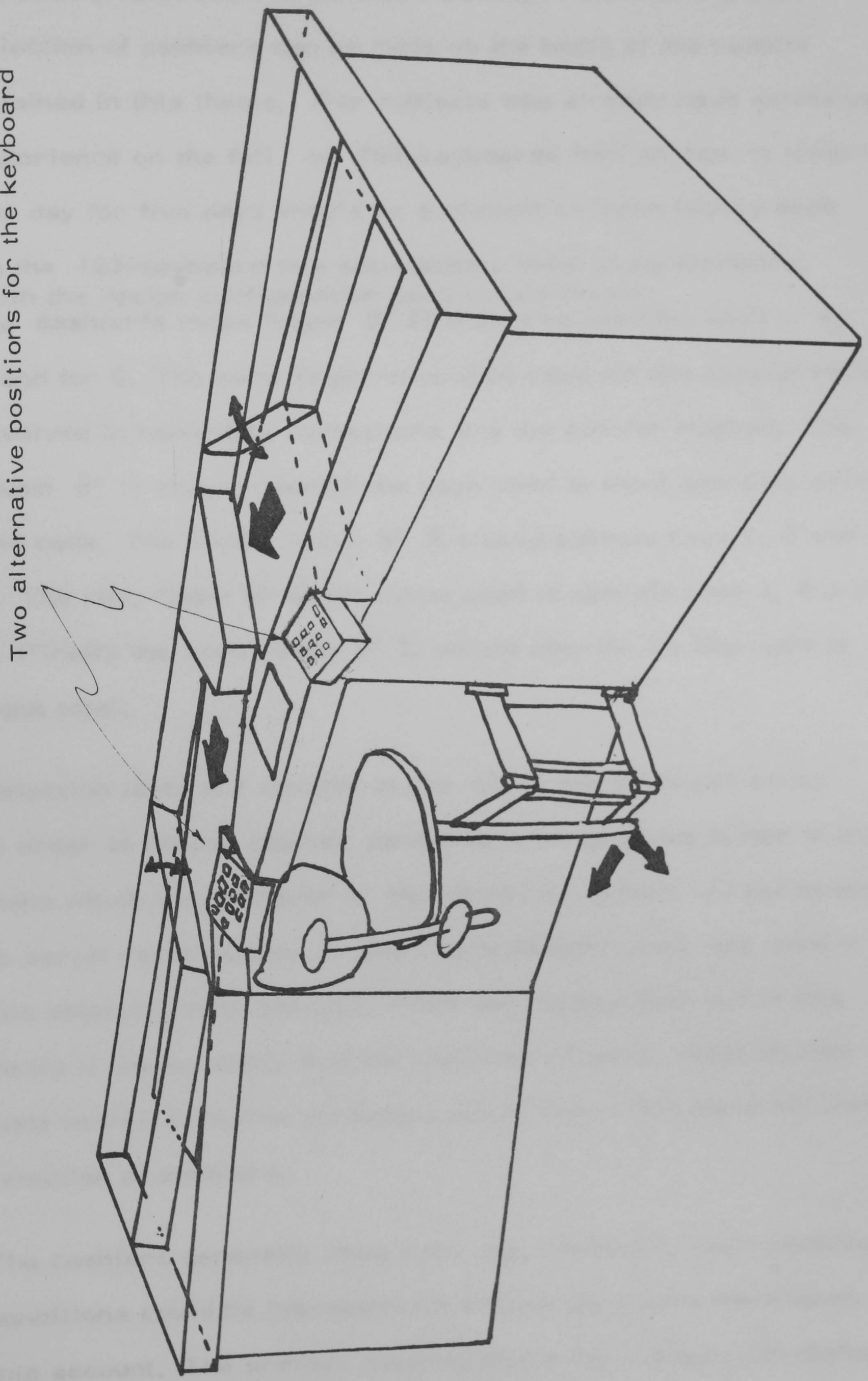
MODIFICATIONS ON THE NEW TWO CONVEYOR BELT CASH DESK SHOWN WITH DOTTED LINES.



Modifications shown with dotted lines

FIGURE 5.2

A NEW DESIGN OF THE TWO CONVEYOR BELT CASH DESK WITH A REVERSED TRANSPORT OF GOODS.



20.2 Some general recommendations

Relatively few recommendations relating to the training and selection of cashiers can be made on the basis of the results obtained in this thesis. For subjects who already have extensive experience on the full or 789-keyboards half an hour's training per day for five days should be sufficient to learn keying work on the 123-keyboard to a satisfactory level of performance. With the design configuration used in this thesis the cashier's index finger (F 2) should be used for keys 1, 4, 7 and for 0. The same finger should be used for the special keys involved in recording corrections and the cashier number. The thumb (F 1) should operate the keys used to input quantity, price and code. The middle finger (F 3) should operate keys 2, 5 and 8. The ring finger (F 4) should be used to operate keys 3, 6 and 9. Finally the little finger (F 5) should operate the key used to input total.

Selection tests are already in use within the KF organization in order to choose cashier personnel with qualities suited to the tasks which they perform in the check-out system. At the moment no serial reaction time or short term memory tests are used in this selection code process. From the results obtained in this thesis it seems likely that the inclusion of serial reaction time tests in this selection procedure would result in a more efficient selection of cashiers.

The cashiers generally liked their job. However, their working conditions could be improved if the following points were taken into account. The present working hours are viewed with disfavour by the cashiers. One alternative is to change these hours so that

they are more convenient. Unfortunately this is likely to mean that customers would suffer in that the cashiers would prefer not to work late in the evening and at the week-ends. One alternative is to recognize the inconvenience posed by working in the evenings and at the week-ends by the provision of financial incentives to compensate the cashiers. Another unpleasant feature of the working situation was that the cashiers were unable to get breaks in their work sufficiently frequently and of long enough duration. Clearly if attention was paid to this problem a solution could be found which was acceptable both to the cashiers and to management. The cashiers also clearly disliked the task of checking the customers from various points of view. If the checking function were removed from the cashier's duties it would undoubtedly make her task less unpleasant and arduous.

Turning now to the check-out system situation viewed from the point of view of the customer, it is quite clear that she is not so bothered about the actions which she has to perform as by the stress induced by the rapidity with which the actions have to be carried out when there are many other customers near or in the system. Recommendations to alleviate this problem have already been given. From work carried out in this thesis it has not been possible to make any predictions about the advantages customers would obtain from the introduction of the new automatic computer system of which the new electronic check-out system is a part. General features of the new automatic computer system were presented in chapter 1. It will be recalled that in that chapter several advantages and disadvantages were associated with this kind of system.. These advantages and disadvantages

in relation to the different groups of people involved in the new computer system, are further amplified inTable 5.1. From that Table it may be seen that most of the advantages accrue to the wholesaler, the retailer and the cashier. The customer benefits least. Also, one of the advantages from the customer's point of view (i.e. that all goods are price-marked) may not be strictly relevant to the proposed KF system as the goods will mainly be code-marked and only very infrequently price-marked.

TABLE 5.1

DISADVANTAGES AND ADVANTAGES IN DIFFERENT GROUPS OF PEOPLE, INVOLVED IN THE NEW COMPUTER SYSTEM, FROM FEATURES OF THE NEW SYSTEM.

Neutral (0), disadvantages (-) and advantages (+)

Features which will be changed in the new system	Wholesaler	Retailer	Customer	Cashier
Slow work in cash desk (codes price keying)	-	-	-	-
Fast work in cash desk (only codes keying)	+	+	-	0
All goods price-marked	-	-	+	+
Large investment cost in the computer	-	-	-	0
Turn over of goods in storage increases	-	+	0	0
No loss in sales due for shortage of goods in storage	0	+	0	+
Less loss for the shop due to keying errors	0	+	0	0
Better checking of customer	0	+	-	-
Better checking of personnel	0	+	0	-
Less manual inventories	0	+	0	+
Less investment in shop space	0	+	0	0
More impulse buying	+	+	-	0
Promote the use of credit card	+	+	-	+

20.3 Design routine recommendations

At the very inception of this thesis a functional analysis was provided which, it was hoped, would form a rational basis for the design of a new check-out system for supermarkets. In the literature of ergonomics there may be found a substantial amount of normative data and check lists of various kinds which may be used in the design process. In spite of this, when one is confronted with a practical design situation it is frequently extremely difficult to apply these normative data and check lists as they often seem to have little relevance to the situation with which one is dealing. In other words it is frequently impossible to provide the best technical design solution for a certain situation on the basis of available ergonomic data. Thus one is frequently compelled, as in the design situation under consideration at KF, to perform different empirical studies in order to find solutions to the questions which may be asked in the allocation of functions between man and machine.

In fig. 1.2 the main features of a systematic method for design were outlined. On the basis of experience gained in carrying out this thesis questions may be posed asking whether the structure for the design process is appropriate and is likely to lead to better solutions. There is, for example, no doubt that it is extremely difficult to do a functional analysis without any preassumptions except those relating to limitations and criteria, even in the definition of the system aim. A special difficulty arises in relation to the abstract identification of functions which have little relation to reality. It could perhaps be argued that a

function which is defined always has some relation to a practical situation with which the designer has some experience. This means that the functional analysis is extremely difficult to carry out in a purely abstract manner without a direct relation to the physical world. If this is true a more fruitful method of analysis might be to start with the allocation of functions and present a series of parallel concrete suggestions for systems design. In other words, a series of alternative ways of performing and fulfilling a series of tasks would be presented in concrete form in order to achieve the system aim.

The author of this thesis, having attempted the studies presented here, still believes in the value of abstract functional analysis even though it may inevitably be true that the division and identification of functions relies to a great extent upon partial experience of the system which is being designed (in this case the presently available KF check-out system). The main argument in favour of the functional analysis, as opposed to the method of using a more concrete design model involving a series of parallel system solutions, is that the use of a functional analysis <u>may</u> promote the creation of <u>new</u> kinds of concrete solutions and <u>new</u> combinations of man and machine.

A further conclusion based upon experience gained in carrying out this thesis is that it would probably be extremely difficult to integrate ergonomics properly into systematic design work to any great extent until there is a great deal more data of a normative kind available in ergonomics. In other words there is a great need for normative data in ergonomics, for both

power and information processing functions, which may be used directly in technical specifications for use by manufacturers of hard ware. The author has the impression that what normative data are available in ergonomics are human orientated and are of relatively little value to engineers and other kinds of technical designers. The engineering designer is frequently in the happy position of being able to use generalized laws and principles which are well founded on experimental data which can be used immediately in the design process. Ergonomics, on the other hand suffers from the difficulty that it is a relatively new science and relies heavily on the use of ad hoc experimental evaluations and similar methods in order to establish basic information in the design process. This inevitably means that the ergonomics specialist is at a disadvantage in the design process.

There is a lack of normative data in ergonomics. The data that are available (e. g. psycho-physical data) are normally not presented in a suitable form to be used in the design process. Even in rare situations where there is access to normative data which is presented in a language technically suitable to be used directly in the design process, one has to be aware that such data may easily be used in ansuitable way.

Quite frequently ergonomics data (e. g. anthropometric data) are used to design equipment for a large percentage, e. g. 98%, of

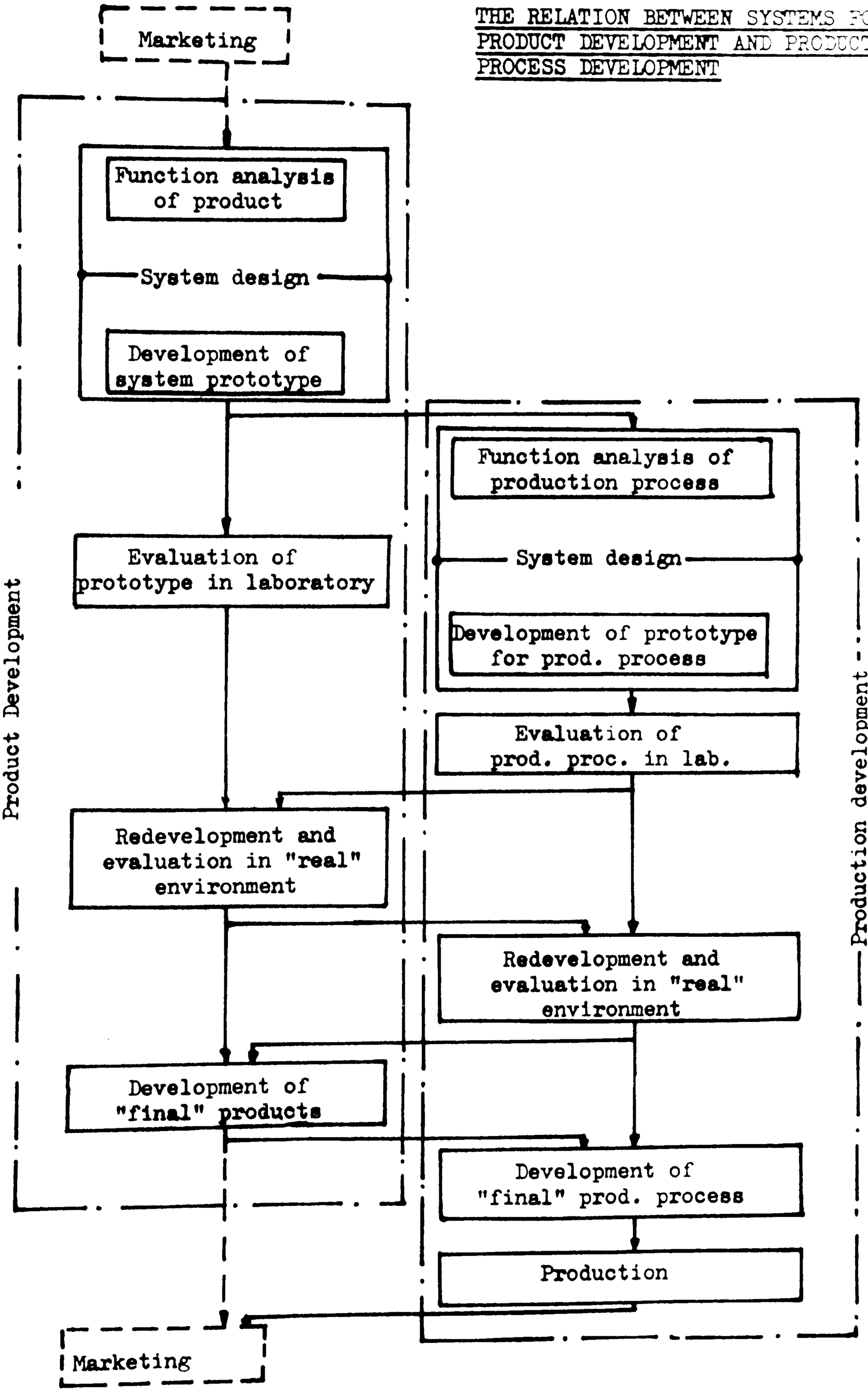
the population. This means that the equipment cannot be used, except perhaps with some difficulty, by 2% of the population. The use of ergonomics in this way means in other words that the population is being segmented. A fundamental axiom of ergonomics in the design process should be therefore that wherever possible degrees of freedom for changes in the equipment should be left to the individual operator himself. In other words one should not inevitably design equipment to be a completly fixed piece of equipment. The equipment should be such that the operator can make final adjustments and changes to the equipment to fit his own personal requirements. The eguipment should be designed with built-in flexibility. This will sometimes makeit possible for all people to use the equipment and it will always increase the proportion of the population who can be accomodated.

As stated in chapter 2,the design work of a new system does not only include the system itself. It should also include the design of the system which produces the prime system, in other words the production process for the physical system components. The development of the production line in functional terms follows very much the same kind of design routine as for the system itself. Figure 5. 3 presents a general model of how the prime system development interacts with the development of the production process. The box in figure 5.3 labelled "design" includes the same design routines as described in figure 1. 2.

There follows a short discussion of the two routines for an integrated system . System development, particularly where a system includes a mass produced product such as a cash

FIGURE 5.3

THE RELATION BETWEEN SYSTEMS FOR PRODUCT DEVELOPMENT AND PRODUCTION PROCESS DEVELOPMENT



register, probably starts from the fact that the marketing or development department feels that new products, or radical changes in old ones, are necessary, generally for economic reasons. Then the design procedures discussed in Part 1 of this thesis follow. When system prototypes have been developed, design of the production process can begin. The results of evaluations of prototypes in conjunction with evaluations in a laboratory situation of a physical model of the production process should produce a basis for the creation of a product. This in turn should be evaluated in the environment in which it is to be used. When the new product is deemed to be satisfactory finalisation of the design of the production process can be achieved. If necessary the production line can be evaluated under realistic operating conditions. In a process of re-design the old system can be used as a prototype. This could reduce the costs considerable.

In this thesis economic problems have not been subjected to study, even though they have been mentioned in passing. Such detailed studies have, of course, been carried out within the KF organization in relation to the development of the whole of the new "cash computer system", even though they have not been included as a part of this research project. A short general comment, however, will be made on this issue.

In the design of a specific system, such as a cash register, it is necessary to look not only at the system directly on the study, but also at the way it interacts with other systems related to it. When a check-out system connected to electronic computer systems or retailing systems is studied, it is important to examine potential or actual effects, not only in

shops themselves, but also on society as a whole. This, of course, is a very difficult problem as there will also be several other more important factors which affect the socio-economic and socio-geographical situation.

For the cash computer system which has been studied here, it seems reasonable to suppose that the large investments of finance involved in the introduction of the system will result in still larger supermarkets in order to get profitability out of the system. Because of land costs these larger supermarkets are likely to be located more remotely from the city and town centers, perhaps serving several cities or towns where population density is high. This has already occurred on a small scale in the United States and Sweden. Remote location of supermarkets is likely to result in longer travelling distances for the customer. These may be unwanted from her point of view. In some cases not only may travelling be unwanted, it may also be impossible for particular sections of the population such as the elderly and physically disabled. Unfortunately these kinds of predictions cannot be made with any high degree of precision. In spite of this, in the system design, it is possible to try and anticipate deleterious effects on the population so the provision can be made to avoid them in the system design.

An alternative development of information system and related electronic equipment can for example go in the direction suggested in chapter 2, where a kind of "electronic mail order" system was discussed. In small corner-shops, which can only keep a

limited number of different types of goods in store, the assortment can be extended considerably by the introduction of computer terminals consisting of a video-display (in colour) and a keyboard. Goods which the customer is unable to get in the shop can be displayed on the video screen and ordered through the keyboard. The system can also be connected to the telephone system. This makes it possible for people who are severely disabled or temporarily ill in bed to do their shopping from their homes.

Automation - both in respect of the automatic handling of information and goods - holds great possibilities for the future. However, considerable risks attach to its use if it is going to be developed without a systematic consideration of human needs and requirements. For example the new cash computer system considered in this thesis may result in all prices of the goods in the shop disappearing and the goods being marked only with code numbers. The main argument in favour of this possibility is that price marking onto goods is very expensive and it is advantageaus from several points of view for the shop not to have the goods pricemarked. It is, for example, easier to change the prices of the goods if they are not pricemarked. Changes need only be made in the computer memory. It is sometimes claimed that the customer is not interested in the price. If she is interested in prices she will be given access to a computer terminal in the shop by means of which she could find out the prices of different goods. In this way legal requirements relating to priceinformation could be met.

In a system like this it is extremely difficult for the customer to establish the relative cost of the same goods being provided by competitors, and the seller could, to a certain extent vary prices more or less at will in a semi-concealed manner. At the same time however special prices and special reductions can be offered on some goods without extensive inconvenience to get the customer into the shop.

Another possible development in the future is that all the buying and ordering of goods could be done at home, by means of the new push-button telephone. This kind of system could in turn create or exacerbate social and psychological isolation giving rise to severe problems to a large number of people. Such a system may prove to be economically profitable both for the whole-saler, the retailers and perhaps also for society as a whole. It will almost certanly not be advantageous to society in other terms.

The lines which the development of automatic information and goods handling systems follow in the near future, will not be of marginal interest for individuals or for the society at large. It is of vital importance that the consumers' social, psychological and other needs and requirements are considered in the design of new shopping and, indeed, other systems. Up till now, in the development of the main criteria for a system of this kind, generally speaking, only economical and technical aspects are considered. The Swedish government have, for example, recently formed a parliamentary committee to study

the distribution of goods in the society of tomorrow. The delegates in this group represent mainly retailing and wholesaling business interests. Up till now, the committee in its work has not considered the consumers' interest in a systematic and fundamental way. For the future it is to be hoped that the kind of systematic design methods described in this thesis will be used both in high level planning in society and in smaller independent design projects, to the advantage of man, and not against him.

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APPENDICES

APPENDIX 3.1

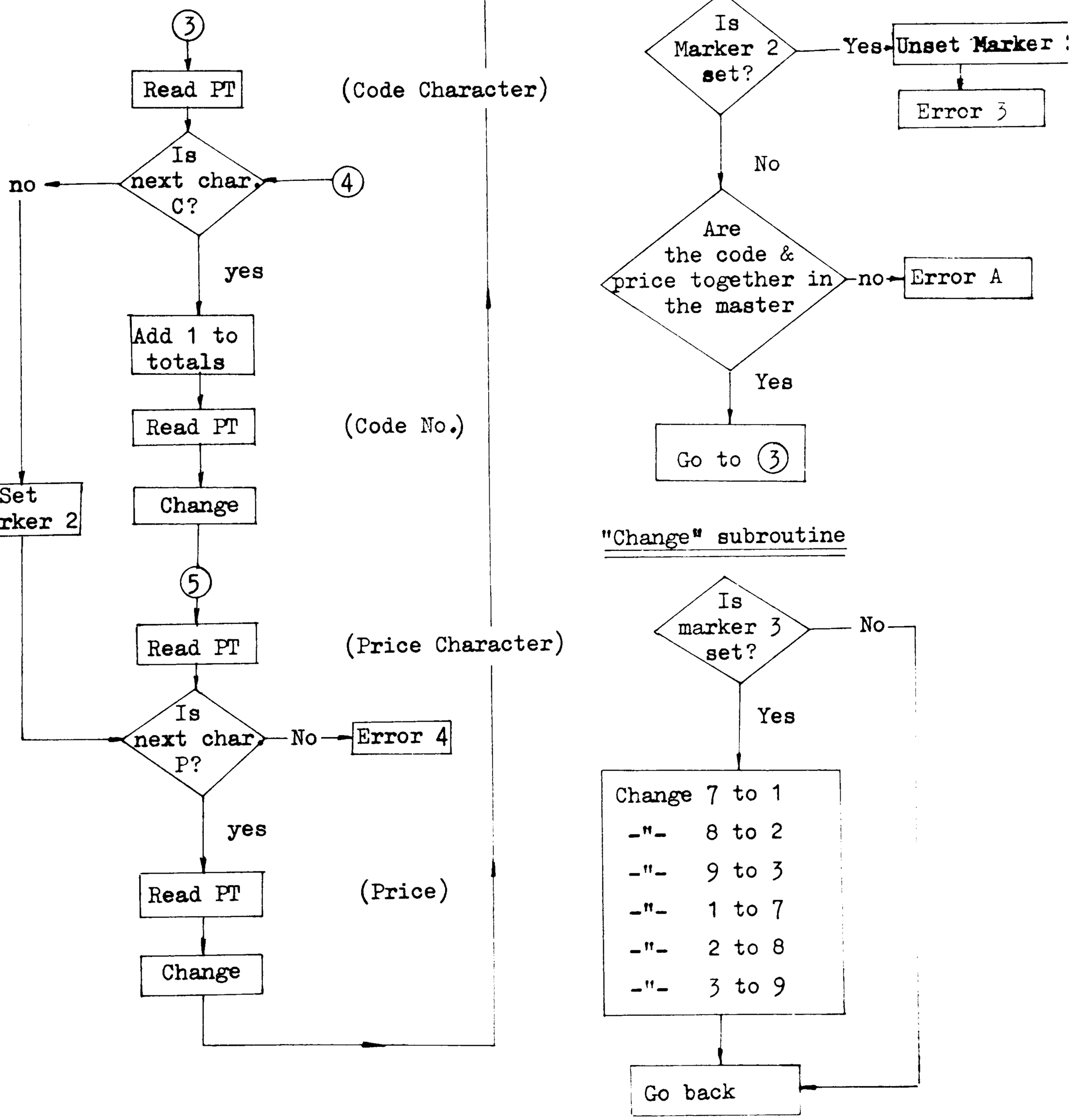
FLOW DIAGRAM OF COMPUTER PROGRAM FOR READING OF PUNCH TAPES FROM KEYBOARD EXPERIMENT

Code: xxx ⋮ Price: xxxx ⋮

(1) Read master tape, and store as:

(2) Read in heading of data tape (3 digits):
Operator no. and day no., if operator no. is > 70 marker 3, go to "change" subroutine, work out keyboard no., then to to (3)

Read "PT" in flow chart.



"Change" subroutine

(Acknowledgement: Mr Andy Nicholls of Ergolab, Stockholm, has made the draft for his computor program).

APPENDIX 3.1 (Continued)

FLOW DIAGRAM OF COMPUTER PROGRAM FOR READING OF PUNCH TAPES FROM KEYBOARD EXPERIMENT

Error A (wrong code and/or price)

- Print code no. and price
- Look in master file for correct price for the code
  - If none: leave blank, print error 1 add 1 to error totals
  - If any: print it
- Look in master file for correct code for the price
  - If none: leave blank, print error 2 and add 1 to error totals

Go to (3)

Error 3 (missed code)

- Print blank in code col.
- Print price
- Look in master file for correct codes for the same price
- Print the price and the associated codes and error 3
- Add 1 to error totals

Go to (3)

Error 4 (missed price)

- Print code no.
- Blank in price col.
- Look in master file for correct price for the code (in none leave blank)
- Print error 4
- Add 1 to error totals

Go to (4)

FORM USED FOR THE SUBJECT RELIABILITY STUDY

Vi är tacksamma om Du skulle vilja vara vänlig fylla i detta formulär.

Sätt ett kryss i den ruta som bäst svarar mot vad Du själv tycker om tangentbordet på kassaregistret Du normalt använder och om tangentbordet Du har använt i detta prov (försök att endast bedöma själva tangentborden utan hänsyn till att Du i försöket ej har haft vanliga varor och att Du har fått lov att registrera både pris och kod).

Tangentbordet på det vanliga kassaregistret

I allmänhet tycker jag att det är lika dåligt som att räkna för hand (dvs med papper & penna)	☐	☐	☐	☐	☐	☐ I allmänhet tycker jag att det är lika bra som det bästa tänkbara tangentbordet
Det är lika obekvämt och besvärligt som att räkna för hand	☐	☐	☐	☐	☐	☐ Det är lika bekvämt som det bästa tänkbara tangentbordet
Det blir lika mycket fel som vid räkning för hand	☐	☐	☐	☐	☐	☐ Det blir lika lite fel som med det bästa tänkbara tangentbordet
Det går lika långsamt som vid räkning för hand	☐	☐	☐	☐	☐	☐ Det går lika fort som med det bästa tänkbara tangentbordet

APPENDIX 3.2 (continued)

FORM USED FOR THE SUBJECT PREFERENCE STUDY

Det nya provtangentbordet

I allmänhet tycker jag att det är lika dåligt som att räkna för hand (dvs med papper & penna)

I allmänhet tycker jag att det är lika bra som det bästa tänkbara tangentbordet

☐ ☐ ☐ ☐ ☐ ☐

Det är lika obekvämt och besvärligt som att räkna för hand

Det är lika bekvämt som det bästa tänkbara tangentbordet

☐ ☐ ☐ ☐ ☐ ☐

Det blir lika mycket fel som vid räkning för hand

Det blir lika lite fel som med det bästa tänkbara tangentbordet

☐ ☐ ☐ ☐ ☐ ☐

Det går lika långsamt som vid räkning för hand

Det går lika fort som med det bästa tänkbara tangentbordet

☐ ☐ ☐ ☐ ☐ ☐

APPENDIX 3.3.

AN EXAMPLE OF STATISTICAL COMPUTATIONS FOR EXPERIMENTAL DATA

OFFICE GIRLS - ERRORS

D = Days (1 - 5)

K = Keyboards (K_1 = 123, K_2 = 789)

A. SPLIT PLOT ANALYSIS OF VARIANCE

Source	df	ssq	msq	F	Sign.
Between subjects	9	(II)14.48			
K_1 vs K_2	1	(IV) 1.84	(a) 1.84	(a/b)1.17	N.S.
Residual	8	(V)12.64	(b) 1.57		
Within subjects	40	(III) 4.98			
Days	4	(VI) 0.65	(c) 0.16	(c/e)1.48	N.S.
D x K	4	(VII) 0.86	(d) 0.22	(d/e)2.04	N.S.
Residual	32	(VIII) 3.47	(e) 0.108		
Total	49	(I)19.46			

B. CONFIDENCE LIMITS (95%)

$$\bar{Y}_{K1} \pm \left[t_{.05} \ (8 \text{ df})\right] \times \left[\sqrt{\frac{msqb}{25}}\right] = 0.733 \pm (2.31)\times\left(\frac{1.253}{5}\right) =$$

0.733 ± 0.250 = 0.533 to 0.933

$$\bar{Y}_{K2} \pm (2.31)\left(\sqrt{\frac{msqb}{25}}\right) = 1.117 \pm 0.250 = 0.867 \text{ to } 1.367$$

$$(\bar{Y}_{K2} - \bar{Y}_{K1}) \pm \left[t_{.05} \ (8 \text{ df})\right] \times \left(\sqrt{\frac{msqb}{25} + \frac{msqb}{25}}\right) = (1.117 - 0.733) \pm$$

$$(2.31)\times\left(\frac{1.775}{5}\right) = 0.384 \pm 0.817 = -0.433 \text{ to } +1.201$$

$$(\bar{Y}_{K2} - \bar{Y}_{K1})_{days} \pm 0.28 = (1.18 - 0.62) \pm 0.28 = 0.56 \pm 0.28 = +0.28 \text{ to } +0.8$$

APPENDIX 3.3 (continued)

C. MULTIPLE COMPARISON TEST (Tukey Test)

	Day 1 1.091	Day 2 0.742	Day 3 0.925	Day 4 0.971	Day 5 0.898
1. 1.091	0	0.349	0.166	0.120	0.193
2. 0.742		0	0.183	0.229	0.156
3. 0.925			0	0.046	0.027
4. 0.971				0	0.073
5. 0.898					0

The observed values must exceed the value

d = tuk x S_d to be significant at 5% level

From tables tuk = 2.90 at 5% level and df = 32

$$S_d = \sqrt{\frac{2\ msq\ (e)}{10}} = \sqrt{\frac{2 \times 0,108}{10}} = \sqrt{0,0216} = 0,147$$

d = 2.90 x 0,147 =0,426

None of the observed differences are significant at 5% level.

APPENDIX 3.3 (continued)

D. TREND - LINEAR, QUADRATIC & CUBIC

ANALYSIS OF LINEAR TREND

(1') $\frac{(1.57)^2}{10 \times 10} = \underline{0.0246}$

(2') $1/10\ (1.19^2 + 1.29 + .. + 1.63^2) = \underline{2.3590}$

(3') $\frac{4.76^2 + 3.19^2}{5 \times 10} = \underline{0.6566}$

Source of variation	df	ssq	msq	F	Sign.
Within subjects	10(2')	2.3590			
Days	1(1')	0.0246	0.0246	-	-
Days x keyboards	1(3'-1')	0.6320	0.6320	2.97	-
Days x within subjects	8(2'-3')	0.2128			

Percent of variation due to linear trend: $\frac{0.0246}{0.65} \times 100 = \underline{3.78\%}$

ANALYSIS OF QUADRATIC TREND

(1') $\frac{4.15^2}{10 \times 14} = 0.1230$

(2') $1/14\ (0.49^2 + ... + 2.17^2) = \underline{12.782} = \underline{0.9130}$

(3') $\frac{3.46^2 + 0.69^2}{5 \times 14} = \underline{0.1778}$

Source of variation	df	ssq	msq	F	Sign.
Within subjects	10(2')	0.9130			
Days	1(1')	0.1230	0.1230	1.33	-
Days x keyboards	1(3'-1')	0.0548	0.0548	-	-
Days x within subjects	8(2'-3')	0.7352	0.0919	-	-

Percent of variation due to quadratic trend: $\frac{0.1230}{0.65} \times 100 = \underline{18.92\%}$

APPENDIX 3.3 (continued)

ANALYSIS OF CUBIC TREND

(1') $\frac{(6.51)^2}{10 \times 10} = \underline{0.4238}$

(2') $1/10\ (0{,}22^2 + 0{,}22^2 + \ldots + 0.24^2) = \underline{1.3439}$

(3') $\frac{1.28^2 + 5.23^2}{5 \times 10} = \underline{0.5798}$

Source of variation	df	ssq	msq	F	sign
Within subjects	10(2')	1.3439			
Days	1(1')	0.4238	0.4238	4.4376	0.10 > p > 0.05
Days x keyboards	1(3'-1')	0.1560	0.1560	1.6335	-
Days x within subjects	8(2'-3')	0.7641	0.0955		

Per cent of variation due to cubic trend: $\frac{0.4238}{0.65} \times 100 = \underline{65.20}\ \%$

APPENDIX 3.3 (continued)

E. ANALYSIS OF COVARIANCE X- STM Y - Accuracy

	X^2	XY	Y^2	$(Y^1)^2$
K_1 vs. K_2	200.00	-19.18	1.84	1.83
(p) Subj. w. K	3998.00	1.14	12.64	12.64

$$P^1_{yy} = 12.67 - \frac{1.14^2}{3998.00} = \underline{12.64}$$

$$K^1_{yy} = 14.48 - \frac{(-19.18 + 1.14)}{4198.00} - 12.67 = \underline{1.83}$$

$$r^2 = \frac{1.14^2/3998.0}{12.64} = 0.00 \qquad \underline{\underline{r = 0.01}}$$

Adjusted analysis of variance

Source	df	ssq	msq	F	sign.
K_1 v. K_2	1	1.83	1.83	1.02	N.S.
Subj. w. K	7	12.64	1.80		

F. ANALYSIS OF COVARIANCE **X - SRT Y - Accuracy**

	X^2	XY	Y^2	$(Y^1)^2$
K_1 v. K_2	89.52	-12.83	1.84	4.01
(p) Subj. w. K	142.50	+17.64	12.64	10.46

$$P^1_{yy} = 12.64 - \frac{(-17.67)^2}{142.50} = \underline{10.46}$$

$$K^1_{yy} = (1.84 + 12.64) - \frac{(-12.83 + 17.64)^2}{89.52 + 142.50} - 10.46 = \underline{4.01}$$

$$r^2 = \frac{(-17.64)^2/142.50}{12.64} = 0.173 \qquad r = \underline{-0.42}$$

Adjusted analysis of variance

Source	df	ssq	msq	F	Sign.
K_1 v. K_2	1	4.01	4.01	2.69	N.S.
Subj. w. K	7	10.46	1.49		

COMPUTATIONS (ERRORS) - OFFICE GIRLS

I Total ssq

$$\Sigma y^2 - \frac{(\Sigma y)^2}{50} = 19.46$$

$\Sigma y_{123} = 18.34$ $\Sigma y^2_{123} = 16.58$

$\Sigma y_{789} = 27.93$ $\Sigma y^2_{789} = 45.69$

$\Sigma y_{tot} = 46.27$ $\Sigma y_{tot} = 62.27$

$$CF = \frac{(\Sigma y)^2}{N} = \frac{(46.27)^2}{50} = \frac{2140.91}{50} = 42.81$$

II Between subjects ssq

$$\frac{(\Sigma \text{ subj } 1)^2}{5} + \frac{(\Sigma \text{ subj } 2)^2}{5} \ldots\ldots \frac{(\Sigma \text{ subj } 10)^2}{5} - CF$$

$$= \frac{286.42}{5} - 42.81 = 57.29 - 42.81 = 14.48$$

III Within subjects ssq

I - II = 19.46 - 14.48 = 4.98

IV K_{123} vs K_{789} ssq

$$\frac{(\Sigma K_{123})^2}{25} + \frac{(\Sigma K_{789})^2}{25} - CF = 13.45 + 31.20 - 42.81 = 1.84$$

V Residual between subjects ssq

II - IV = 3.34 - 1.84 = 12.64

VI Days ssq

$$\left[\frac{(\Sigma D_1)^2 + (\Sigma D_2)^2 + \ldots\ldots + (\Sigma D_5)^2}{10} \right] - CF =$$

$$= 43.46 - 42.81 = \underline{0.65}$$

VII D x K ssq

$$\left[\frac{(\Sigma D_1 K_1) + (\Sigma D_2 K_2)^2 + \ldots\ldots + (\Sigma D_5 K_5)^2}{5} \right] - CF - VI - IV =$$

$$= 46.16 - 42.81 - 0.65 - 1.84 = 0.86$$

VIII Residual within subjects ssq

III - VI - VII = 4,98 - 0.65 - 0.86 = 3,47

Key board	Subjects	No.	Selection criterias RT- bits/s	Memory	Day 1 Kayings per min	Day 1 % errors	Day 2 Kayings per min	Day 2 % errors	Day 3 Kayings per min	Day 3 % errors	Day 4 Kayings per min	Day 4 % errors	Day 5 Kayings per min	Day 5 % errors	Means Mean kayings per min	Means Mean % errors
123	Office	31	31.75	-27	75.2	1.23	91.5	0.78	104.5	0.99	120.0	0.63	124.6	0.71	103.16	0.868
		32	27.03	-42	86.4	1.45	97.6	1.28	101.2	1.06	105.5	1.11	116.8	0.89	101.50	1.158
		33	29.31	-33	93.2	0.73	108.8	0.59	124.0	0.52	132.4	0.61	133.5	0.62	118.38	0.614
		34	29.33	-17	103.7	1.34	127.5	0.70	159.5	0.56	137.5	0.65	140.8	0.68	133.8	0.786
		35	30.16	-27	70.6	0.51	93.2	0.22	117.5	0.15	134.6	0.13	142.6	0.20	111.7	0.242
					85.8	1.05	103.7	0.71	121.3	0.66	126.0	0.63	131.6	0.62		
789	Office	36	26.25	-13	80.8	1.32	101.5	0.92	110.6	1.53	121.2	2.71	126.8	1.41	108.18	1.578
		37	26.10	-30	79.2	1.40	98.8	1.56	103.2	2.66	112.6	2.42	118.0	2.60	102.36	2.128
		38	25.31	-15	64.0	0.95	73.2	0.43	88.0	0.45	96.6	0.44	105.5	0.51	85.46	0.556
		39	30.45	-38	73.5	0.39	88.0	0.24	106.8	0.52	106.6	0.54	121.2	0.47	99.22	0.432
		40	26.09	-30	53.7	1.59	60.8	0.70	70.6	0.81	75.2	0.47	83.5	0.89	68.76	0.892
					70.2	1.13	84.4	0.79	97.1	1.19	102.4	1.31	110.0	1.18		

Raw data for cashiers

Key board	Subjects	No.	Selection criterias RT-bits/s Memory	Day 1 Keyings per min	Day 1 % errors	Day 2 Keyings Per min	Day 2 % errors	Day 3 Keyings per min	Day 3 % errors	Day 4 Keyings per min	Day 4 % errors	Day 5 Keyings per min	Day 5 % errors	Means Mean keyings per min	Means Mean % errors
123	Cash	12	30.33-19	84.3	0.63	94.0	0.60	94.0	0.51	106.6	0.50	108.0	0.36	97.38	0.52
		13	31.42-22	55.4	0.71	72.4	0.69	72.4	0.78	85.7	0.29	94.0	0.18	75.98	0.53
		14	27.38-31	72.0	1.14	87.2	0.81	97.5	0.44	111.5	0.25	120.4	0.13	97.72	0.554
		15	29.44-13	64.3	0.83	78.4	0.45	88.6	0.32	96.4	0.37	103.7	0.41	86.28	0.476
		21	29.06-17	86.0	1.99	109.7	0.87	139.5	0.51	142.8	0.47	150.8	0.35	125.76	0.838
		22	34.91-18	53.7	2.19	73.7	1.30	90.6	0.94	100.4	0.64	105.5	0.54	84.78	1.122
		23	21.45-27	40.6	4.04	56.4	1.38	72.8	1.37	75.2	0.57	84.4	0.46	65.88	1.564
		24	24.43-22	41.5	2.41	50.8	1.26	60.0	0.95	62.0	0.40	66.0	0.21	56.06	1.046
		25	26.62-24	52.3	3.62	69.3	2.88	79.7	2.37	89.2	0.96	94.8	0.75	77.06	2.116
				61.1	1.80	76.9	1.13	88.3	0.91	96.6	0.49	103.0	0.37		
789	Cash	17	24.89-18	64.4	3.22	77.7	2.02	81.7	3.27	88.8	3.05	95.2	1.98	81.56	2.708
		18	31.15-17	57.5	2.12	77.2	1.15	81.5	0.70	101.5	0.88	101.2	1.41	83.78	1.252
		19	30.99-22	56.8	1.95	65.2	0.93	70.6	0.80	84.4	0.89	85.5	1.42	72.5	1.198
		20	29.58-35	33.2	4.32	50.4	1.91	54.4	1.77	64.8	0.88	64.6	1.54	53.48	2.084
		26	26.96-28	70.0	3.12	85.5	3.42	89.7	2.22	91.2	1.33	89.5	1.15	85.18	2.248
		27	31.06-21	64.0	0.90	79.7	0.49	93.5	0.68	102.8	0.20	107.2	0.30	89.44	0.514
		28	29.04-15	64.4	0.89	76.8	0.83	96.0	0.52	103.5	0.31	104.4	0.23	89.02	0.556
		29	28.41-37	62.8	0.91	80.8	0.66	92.8	0.42	100.4	0.32	108.0	0.33	88.96	0.528
		30	26.61-19	51.5	4.17	70.0	2.04	74.8	1.62	83.2	1.67	86.8	1.11	73.26	2.122
				58.3	2.40	73.7	1.49	81.7	1.33	91.2	1.06	93.6	1.05		

	Day 1										Day 5									
		Full Keyboard				123-Keyboard						Full Keyboard				123-Keyboard				
Cashiers:	Q:	1	2	3	4	1	2	3	4	Θ	cm	Q:	1	2	3	4	1	2	3	4	Θ	cm
		6	4	5	6	3	4	5	6	67	12.9		4	5	5	6	5	5	5	6	-	-
		5	5	5	5	5	6	4	4	69	5.9		5	3	4	5	4	4	5	5	-	-
		5	4	5	5	4	4	4	5	82	4.8		5	5	5	5	4	4	4	5	-	-
		5	3	3	4	5	4	4	4	59	14.8		4	3	4	4	4	4	3	4	-	-
		5	4	5	5	5	6	5	5	67	6.7		5	5	6	6	2	2	2	2	-	-
		4	4	5	5	4	6	5	5	85	10.1		5	5	4	3	5	3	4	5	73	8.0
		4	5	4	5	6	5	5	6	83	5.0		4	4	4	4	5	6	5	6	84	1.9
		6	6	5	5	5	6	5	5	71	10.5		5	5	6	5	5	5	6	5	69	10.7
		4	5	4	4	5	5	6	6	70	5.9		4	5	4	5	6	5	5	6	65	1.9
		3	3	5	4	3	3	2	2	79	8.2		5	4	4	4	5	5	4	4	73	3.8
Office girls:										72	12.9										-	-
										60	12.9										-	-
										60	13.8										68	8.9
										87	10.8										82	10.3
										64	8.7										75	8.7

APPENDIX 3.6

SUBJECTIVE PREFERENCES FOR THE FULL KEYBOARD VERSUS THE 123-KEYBOARD

Q1: General opinion

Q2: Comfort

Q3: Accuracy of performance

Q4: Speed of performance

The subjective positioning of the 123-keyboard

Θ = Degrees of angle

cm = Distance

	Day 1										Day 5									
	Full Keyboard				123-Keyboard						Full Keyboard				123-Keyboard					
Cashiers:	Q: 1	2	3	4	1	2	3	4	Θ	cm	Q: 1	2	3	4	1	2	3	4	Θ	cm
	4	5	6	6	5	6	6	4	75	7.3	5	6	6	5	5	5	6	6	-	-
	4	5	4	4	6	6	1	5	80.5	6.4	4	5	5	5	6	6	5	6	-	-
	5	5	6	4	5	5	5	3	64	8.4	4	5	5	5	4	3	3	2	-	-
	4	5	5	4	5	4	2	2	78	13.3	4	5	4	5	5	5	5	4	-	-
	6	5	6	5	5	6	5	5	68	8.0	5	5	6	5	6	6	5	6	-	-
	4	4	5	5	5	5	5	5	84	5.5	4	4	5	5	6	6	5	6	77	6.6
	4	4	4	5	5	5	5	5	68	6.5	4	4	4	5	5	5	5	5	78.5	6.8
	5	4	5	5	6	6	5	5	74	9.7	5	5	5	5	4	5	5	4	62.5	8.9
	4	4	6	6	4	4	5	5	74	10.8	6	6	6	6	5	6	6	6	69.5	17.6
	4	5	4	4	4	3	2	3	81	10.0	3	3	3	3	5	5	3	5	73	3.2
Office girls:									73	14.3									78	16.5
									80.5	7.3									65	12.0
									80	9.0									58	21.5
									91	10.0									80	21.0
									75	8.3									71	8.0

APPENDIX 3.7

SUBJECTIVE PREFERENCES FOR THE FULL KEYBOARD VERSUS THE 123-KEYBOARD

Q1: General opinion

Q2: Comfort

Q3: Accuracy of performance

Q4: Speed of performance

The subjective positioning of the 123-keyboard

Θ = Degrees of angle

cm = Distance

APPENDIX 4.1

TRANSLATION OF QUESTION FORM FOR CASHIERS INTERVIEW STUDY

The Cooperative Union is carrying out an examination with the purpose of improving the exit through the cash-desk.

That is why we would like to give you some questions, and ask you to think them over until tomorrow morning, when we will hear your opinion.

Your opinion will not be carried forward to anyone in charge of you.

We ask you not to talk to your friends about this, until we have heard your answer.

The questions we would like you to think over are as follows:

1. a. Is there anything you find uncomfortable or tiring at your work?

   b. Is there anything particularly you think would make your job easier and more comfortable?

2. a. Is there anything that does not work so well at the cash-desk, anything that you think prevents efficient cash-work?

   b. Is there anything at the cash-desk which makes the work quick and efficient?

3. Could you please tell in detail about any mishaps or troubles which you have seen delaying the cash work?

APPENDIX 4.1 .(continued)

TRANSLATION OF QUESTION FORM FOR CASHIERS

4. If you previously worked at another type of cash-desk, would you please compare that one with your present job and tell us:

   a. In what way is the cash-desk on which you are now working, better than the one you worked at before?

   b. In what was is the cash desk on which you are now working, not as good as the one you worked at before?

5. Is there anything missing at your cash-desk which you think could improve and simplify your work?

You might find it useful to make some notes from your memory and bring them tomorrow.

APPENDIX 4.2

THE DIFFERENT CRITICAL INCIDENTS MENTIONED BY THE CASHIER

		Number of incidents reported from 65 cashiers	%	Comments
1.0	TRANSPORTATION			
.100	The conveyor belt			
.101	Newspapers, packets with slices of meat or cheese, and plastic packets get stuck in the conveyors (both).	25	38.4	Problems with the fastening equipments of the conveyors
.102	Does the money fall down into the slot of the conveyors if the customer empties or drops them on the desk (difficult to get them up again)?	6	9.2	27 41.3%
.103	Goods following put pressure on the goods at the end of the second conveyor so that bread, lettuce and son get squeezed. The cashier either has to keep damageable goods to the side, or to sort out and mark the heavy goods from the first conveyor first.	18	27,8	Problem with the heavier goods damaging the fragile goods when conveyor 2 goes
.104	Too narrow when one pulls the goods from the first to the second conveyor, when one has to rearrange the goods.	2	3,8	19 29.2 %

		Number of incidents reported from 65 cashiers	%	Comments
.105	Better When the cashier herself decided in which order to pack the goods.	1	1.3	
.106	One has to be careful when sending the bottles, so they do not fall on each other and break.	1	1.3	
.107	Having to lift, among other things, the milk because it does not slide on the plate between the conveyors.	1	1.3	Difficult to ~~push plate~~ pull/place the goods on the slide between the conveyors.
.108	The arm can sometimes ache from pushing the goods (some have to be lifted).	3	4.6	3 4.6 %
.200	The storage			
.201	When there are a lot of people, the customers have not enough time to pack their goods before the box is needed for the next customer. (The cashier then will have to help with the packing or take the next customer´s goods in front of her - or on her lap.)	51	78.5	Too few boxes (see next page)

		Number of incidents reported from 65 cashiers	%	Comments
.202	If the customers start packing before they have payed, the cashier has to stretch far with the money + change, or the customer has to hurry back and there will be confusion at the cash-desk.	12	18.5	Too few boxes 54 83,1 %
.203	The box is not big enough if the customer buy a lot; the other box cannot be used because the cross-bar between them does not close.	20	30.8	The boxes too small 25 38.4%
.204	The goods fall over the cross-bar into the other box or on the floor, if the customer buys a lot.	7	10.8	
.205	Some customers put their goods too early on the first conveyor so that their goods get mixed up with previous customers´, when it goes forward.	8	12.3	
.206	People forget their goods at the farthest edge of the box, specially if the goods stand on the edge or on the side.	2	3.8	

(Appendix 4.2 cont.)

(Appendix 4.2 cont.)

		Number of incidents reported from 65 cashiers	%	Comments
.207	Not able to see when or if it is empty on the first conveyor; small things sometimes get standing on the edge against the cash-register or behind "the pillar" and cannot be seen.	2	3.8	
.300	Manoeuvering			
.301	Do not want a button to turn for the second conveyor, but a button to press or rather a foot-pedal.	5	7.7	
.302	Difficulty in reaching the button for the first conveyor; have to sit uncomfortably to reach it.	3	4.6	
.303	Have got an electric shock from the button for the first conveyor.	1	1.3	
.304	Would like the conveyor behind to be divided into one conveyor for each box, and each part to be manoeuvered separately.	1	1.3	
.400	Unloading and loading			
.401	Would like a carriage for the removal of the baskets.	2	3.8	

		Number of incidents reported from 65 cashiers	%	Comments
.402	The carriages will only be left in front of - or behind the cash-desk - after being used by the customer, and there be standing in the way.	16	24.7	The problem: Where to put the carriage when the customer has emptied it at the cash-desk. 6 9.29 %
.403	Would like a place where the customers can put their carriages, or somebody who takes care of them.	2	3.8	
.404	Comparison. The carriages were taken better care of in the old system.	1	1.3	
.405	It is delaying when all customers are making ~~dubble~~ bags.	5	7.7	
.406	Too small bags (the brown ones).	5 of 43 cash. (One shop has other bags)	11.6	
.407	Would like plastic bags for frozen things.	1 of 43 cash. (One shop has other bags)	2.3	
.408	Difficult for the cashier to reach the bags when she wants to help a customer to pack, or to put something in a bag.	Total 65 cash. 15 23.8 %	One shop 22, 13 59,3 %	the rest 43 2 4.4 %

		Number of incidents reported from 65 cashiers	%	Comments
.409 (comp.)	The customer had time to pack while the cashier unloaded in the old system.	1	1.3	
.410 (comp.)	The customer took the goods and disappeared. (Obs. cash-desk.)	1	1.3	
.411	The customer puts the basket on the conveyor without picking out the goods.	The shop has had the check-out system for: 1 month: 3 of 11, 27.2%; 5 months: 6 of 17, 35.3%; 6 months: 2 of 11, 18.2%; 1 year: 12 of 26, 46.2%; Total: 23 of 65 cashiers, 35.5%		

		Number of incidents reported from 65 cashiers	%	Comments
2.000	PAYMENT FUNCTION			
.100	The place to put the money on			
.101	The customer puts the money on the wrong place (on the plate between the conveyors).	11	16.9	The customer puts her handbag where she should put the money, and therefore she puts the money on the wrong place. 11 16 %
.102	The customer puts her handbag where she should put the money.	3	4.6	
.103	A place for the customer, where she can put her handbag.	1	1.3	
.104	Do not want an edge on the plate between the conveyors (impossible to count the money there - when the cash shall be counted or when the customer makes a mistake).	2	3.8	

.200 The cash-box

		Number of incidents reported from 65 cashiers						
		Total	%	Two shops with the box between the conveyors. (11 cashiers)		Other shops, with the box diagonally to the right. (54 cashiers)		χ^2
.201	The boxes in the cash-register are too small. (There should be more divisions, cannot get the paper-money out. The lid is too small.)	13	20	7	63.7%	6	11.1%	12.62 +++)
.202	The cashier hurts her knuckles when she takes the money out of the cash-box.	3	4.6	3	27.3%	0	0%	9.9 ++)
.203	The cash-box comes out as far as to the queue at the cash-desk beside, and one has to check the money all the time.	21	32.3	0	0%	21	38.9%	4.69 +)
.204	The paper-money slips out of the divisions and behind the box in the cash-register; too few clips.	2	3.8	0	0%	2	3.8%	
.205 (comp.)	The cash-register is not so good in the new system (cash-desk with two conveyors).	8	12.3	2	18.2%	6	11.1%	
.206	One has to turn - bend to reach the money in the new cash-register.	23	35.4	0	0%	23	42.6%	5.52 +)

note:+ 5% level of sign.
++1% -"- -"-
+++ 0,1% "- -"-

(Appendix 4.2 cont.)

		Number of incidents reported from 65 cashiers						
		Total	%	Two shops with the box between the conveyors. (11 cashiers)		Other shops, with the box diagonally to the right. (54 cashiers)		x^2
.207 (comp.)	It is better with the cash-box straight forward.	15	23.8	0	0%	15	27.8%	—

		Number of incidents reported from the cashiers in Granlo	%	Comments
.208	One cannot open the cash-box when it is between the conveyors and there are a lot of goods in one box (or in both), and when the customers are not ready in time for the cashier to pick up the third customer's goods in front of her.	3 of 11 cash	27.3	
.209	Difficulty in reaching the money on the shelf for payment, when the lid of the cash-box is open.	1 of 11 cash	9.1	
.210	A place - a box or a clip - in which to put the payed note until the change is given.	Number 7 incidents reported from 65 cashiers 1	1.3	

(Appendix 4.2 cont)

		Number of incidents reported from 65 cashiers	%	Comments
.300	The cash register			
.301	Back-ache because of having to sit in a crooked position to reach the cash-register.	4	6.2	Bad Posture
			6 9.2%	
.302	Is it an uncomfortable movement of the hand and the head if you do not know the touch-method?	2	3.8	
		(Nobody uses the touch-method)		
.303	Would prefer the keyboard to be more horizontally.	1	1.3	
.304	Would like all cash-registers to have a "plastic cover" on the keyboard; that would make it possible to feel if one is right or wrong when touching.	1	1.3	
.305	Would like a ten-button system.	1	1.3	
.306	The cash-register is so low that children in the queue beside can pluck at the buttons and then happen to register the sum.	1	1.3	
.307 (comp.)	There is an A- and B-button, but it is bad that there is only one box.	1	1.3	

		Number of incidents reported from 65 cashiers	%	Comments
.308	The old cash-register had a button for the memory; that was very good.	2	3.8	6.2 5 7.7
.309	Would like a button for the memory.	4	6.2	A button for the memory would help.
.310	When making a mistake (difficult to explain to the customer why they have to sign),	1	1.3	
.311	Would like the customer to be able to see the sum total better.	2	3.8	
.312	Would like the apparatus to show how much change to give.	1	1.3	
.313	Would like the apparatus to be completely under; a misjudgement with the legs, and the apparatus falls down.	1	1.3	
.314	The apparatus stopped to work; had to creep behind it and turn on switch-buttons.	1	1.3	
.315	The cash-slip get stuck, if one happens to touch it (difficult to loose it again).	1	1.3	

(Appendix 4.2 cont.)

		Number of incidents reported from 65 cashiers	%	Comments
.400	Change-returner			
.401	The bowl, for returning of change, is on the wrong side of the apparatus, if people forget their change, it is difficult to reach it and give it to them, and difficult to check.	1	1.3	The bowl, for returning of change, is on bad place.
		4	6.2%	
.402	The customers forget their change.	4	6.2	
.403	The change-returner does not work properly (it returns too much or too little change).	8 of 60	13.3	
.404	The change in the change-returner will be finished if there are a lot of people, and it is very delaying to exchange.	4	6.2	
.405	A little child, who sat on the seat for children on the goods-carriage, put the finger in the change-returner (where the money comes out) and got stuck.	1 of 22	4.5	In one of the shops, with the bowl towards the passage.
.500	The price marking			
.501	The marking of prices is bad.	20	30.8	

		Number of incidents reported from 65 cashiers	%	Comments
3.000	DESIGN			
.100	Packing			
.101	The box for the carry-bags is too small (the customers').	7	10.8	The boxes for the customers' bags are not satisfying.
.102	Some customers do not find the bags.	4	6.2	
.103	Boxes for small bags for the customers (one for every type).	1	1.3	
.104	Not enough space for the customers to put away their packed bags.	1	1.3	
.200	Off-line storage			
.201	Would like more room, for cash-slip rolls, pens, etc.	6	9.2	The cashier's place of storage is of insufficient size.
.202	Would like a drawer above the cupboard, which one should be able to open without opening the cupboard (to avoid taking away the chair and bending down on the floor).	2	3.8	
.203	A better type of "lock", which locks itself when one shuts the cupboard and one does not have to lock.	1	1.3	
.204	Boxes for the bags for the cashiers.	3	4.6	

		Number of incidents reported from 65 cashiers	%	Comments
.205	Somewhere for the customer to put her handbag.	1	1.3	
.206	The waste-paper basket is too small.	3	4.6	The waste-paper baskets not satisfying
.207	Would like waste-paper baskets of plastic instead of metal, which ladders the stockings.	3	4.6	
.300	<u>The size and form</u>			
.301	Do not like that the chair is made so that it only can be turned in one direction; to come out to help the customer one has to do a whole turning.	10	15.4	
.302 (comp.)	The cash-desk with two conveyors is so big that one has to stand up to reach all over.	2	3.8	
.303	Would like to sit higher up in relation to the customers.	2	3.8	
.304	Too narrow between the cash-desks.	9	13.9	
.305	Do not get room to touch, when there are a lot of people at the next cash-desk, and they are standing beside each other.	2	3.8	

APPENDIX 4.3

A TRANSLATION OF THE LETTER TO THE CONTACT PERSONS (NORMALLY IN THE PERSONNEL DEPARTMENT.)

To the chief of personnel or education department:

The ergonomics and the environmental laboratory of KF have for some years been working on a research project about cashiers and their working conditions. The main aim of this research project is to give basic data for the design of new cash desk and cash registers. Further on the investigation shall give material for a re-design of traning and selection systems for the cashiers.

This investigation consists of several different parts. One part of the investigation consists of a questionnaire study. As an introduction to this questionnaire study, a large interview study has been performed where cashiers have been asked to describe their work and their working conditions. This interview study has been the basis for the design of the enclosed questionnaire. It is desirable that the questionnaire is answered by as many as possible of the cashiers working within KF.

We would be most pleased if you would like to distribute the questionnaire to your cashiers. At first would you like to fill in, on the first page of the questionnaire, where the cashiers shall return the questionnaire. We would also be most pleased if you would like to collect all the distributed questionnaires and return them to us latest on November 10, 1970. Would you like to

APPENDIX 4.3 (continued)

notice how many you receive completed. It is very important for us to get as high a response as possible.

If there are not enough questionnaires, you can order more by phoning Lena Wretman 08/44 90 60 extention 1762.

With best wishes,

KOOPERATIVA FÖRBUNDET

Ergonomi- och miljövårdslaboratoriet

Toni Ivergård

APPENDIX 4.3 (continued)

The questionnaire is to be returned to:

Toni Ivergård

The Swedish Cooperative Union Wholesale Society

Ergonomics and Environmental Laboratory

Fack

104 65 STOCKHOLM 15

Enclosed questionnaires completed by the cashiers are returned.

In total _____ questionnaires have been distributed to

cashiers and of these _____ have been completed.

_____ 1970 (before 10th November 1970).

Cooperative Society:_____

Name:_____

APPENDIX 4.4

A TRANSLATION OF THE INTRODUCTION LETTER TO THE CASHIER.

To the cashier:

QUESTIONNAIRE-STUDY

The ergonomics and environmental laboratory of KF have for several years been working with an investigation about the working conditions for the cashiers. This investigation consists of several different parts. Among other quite a large interview study with cashiers has been performed. This interview study has been the basis for the design of the enclosed questionnaires. The aim of these investigations is to obtain information about how to design and improve the working conditions for the cashiers. The investigation will, among other things, be the basis for the design of the work place and further on the investigation will give information for the design of training programmes etc.

We would be most pleased if you would like to help us with this investigation by completing the enclosed questionnaire as carefully as possible. We would also be most thankful if you would like to fill in the questionnaire on your own and not look at how your friends are completing their questionnaire.

Many thanks for your kind help.

APPENDIX 4.4 (continued)

With kind regards,

The Swedish Cooperative Union and Wholesale Society,

Ergonomics and Environmental Laboratory. Toni Ivergård.

Enclosure: Questionnaire

APPENDIX 4.5

AN EXAMPLE OF THE LOGIT ANALYSIS FOR THE QUESTION (Q 13) "HOW HEAVY DO YOU FIND THE WORK?"

This is an example of the data reduction for question 13 (How heavy do you find the work?). On the third page of this appendix and in the first matrix on the left hand side of the page is found the matrix d_1 for cashiers without any experience of the new desk, d_2 for cashiers with limited experience and d_3 for cashiers with long experience of the new desk. In the columns of the matrix is found the 3 different levels of experience and in the rows is found the 3 different age levels. The matrix on the right is the reduction made on predictor E $(e_1 + e_2)$ and A $(a_2 + a_3)$, and the last matrix is the combination of the predictor D $(d_2 + d_3)$. The values given in the cells in the different matrix' are the posibives, (r) on page 2, is found the same procedure but for the total number of cashiers responding in each cell (n).

On the fourth page of this appendix we find the n and r and the proportion (p) for each combination of the three predictors, each on two levels. From tables (Armitage, 1971) we can from p find the logit value (y) and the weighting coefficient (w). In the next to the last column we multiply n and w. In the last column we take the inverse value of the previous column. The last column is an estimate of the variance.

APPENDIX 4.5 (continued)

The effect from the factor A is then estimated in accordance with the calculations on the rest of this fourth page. This is done in such a way that the effects from factor A is made sure by subtracting the effects from the other factors. In the second column (d), there is a subtraction between the corresponding values, for example in the first line 0.49 - = -0.50. In the third column the variance given is a summation of the respective values of the last column of the previous table (in this case 0.528 + 0.482 = 1.010). The effect of predictor A is then achieved in accordance with the formula given and the same for the variance and the estimate of the standard error. The same procedure is then followed (on page 5) for factor E and factor D. The double interactions (AD, AE and ED) are calculated in a similar manner. If there is a negative or positive value upon the different effects is dependent upon the definition of positives and negatives. The 0 point for the predictors is dependent upon the selection of split points for positives and negatives when the multi-point scale on the variables were reduced to a two-point scale.

APPENDIX 4.5 (continued)

Q 13 (How heavy do you find the work?)

Data reduction:

d: 1; 2 + 3

e: 1 + 2; 3

a: 1; 2 + 3

The totals (n)

d_1	a_1	a_2	a_3
e_1	36	14	05
e_2	60	53	16
e_3	29	55	32

	d_1	a_1	$a_2 + a_3$
$e_1 + e_2$		96	88
e_3		29	87

d_2	a_1	a_2	a_3
e_1	29	16	04
e_2	38	28	10
e_3	13	26	12

	d_2	a_1	$a_2 + a_3$
$e_1 + e_2$		67	58
e_3		13	38

d_3	a_1	a_2	a_3
e_1	01	0	0
e_2	25	15	03
e_3	21	23	03

	d_3	a_1	$a_2 + a_3$
$e_1 + e_2$		26	18
e_3		21	26

$d_2 + d_3$	a_1	$a_2 + a_3$
$e_1 + e_2$	93	76
e_3	34	64

APPENDIX 4.5 (continued)

The positives (r)

$d_2 + d_3$	a_1	$a_2 + a_3$
$e_1 + e_2$	72	64
e_3	31	49

d_1	a_1	$a_2 + a_3$
$e_1 + e_2$	71	55
e_3	17	53

d_1	a_1	a_2	a_3
e_1	23	11	2
e_2	48	33	9
e_3	17	32	21

d_2	a_1	$a_2 + a_3$
$e_1 + e_2$	51	47
e_3	11	27

d_2	a_1	a_2	a_3
e_1	23	12	3
e_2	28	25	7
e_3	11	17	10

d_3	a_1	$a_2 + a_3$
$e_1 + e_2$	21	17
e_3	20	22

d_3	a_1	a_2	a_3
e_1	1	0	0
e_2	20	15	2
e_3	20	19	3

APPENDIX 4.5 (continued)

		n	r	p	y	w	nw	$\frac{1}{nw}$
1	$d_1e_1a_1$	96	71	0.7395	0.99	0.1971	18.9216	0.528
a	$d_1e_1a_2$	88	55	0.6250	0.49	0.2356	20.7328	0.482
e	$d_1e_2a_1$	29	17	0.5862	0.32	0.2436	7.0644	0.141
ea	$d_1e_2a_2$	87	53	0.6031	0.41	0.2400	2.0880	0.478
d	$d_2e_1a_1$	93	72	0.7741	1.21	0.1771	16.4703	0.607
da	$d_2e_1a_2$	76	64	0.8421	1.66	0.1344	10.2144	0.979
de	$d_2e_2a_1$	34	31	0.9117	2.31	0.0819	2.7846	0.359
dea	$d_2e_2a_2$	64	49	0.7656	1.15	0.1824	11.6736	0.856

Σ = 4.430

A	d	var(d)	$\overset{w}{1/var(d)}$	dw
a - 1	-0.50	1.010	0.9901	-0.4950
ae - e	+0.09	0.619	1.6155	0.1454
ed - d	+0.41	1.586	0.6305	0.2585
ade -de	-1.16	1.215	0.8230	-0.9547

Σ w = 4.0591 Σdw = -1.0658

$$A = \frac{\Sigma dw}{\Sigma w} = \frac{-1.0658}{4.0591} = -\underline{\underline{0.262}}$$

$$var(\bar{d}) = \frac{1}{\Sigma w} = \frac{1}{4.0591} = 0.246$$

$$(ES\bar{d}) = \underline{\underline{0.496}}$$

$$A = -0.262 \pm 0.496$$

APPENDIX 4.5 (continued)

E	d	var(d)	w	dw
e - 1	-0.67	0.669	1.4947	-1.0164
ea - a	-0.08	0.960	1.0416	-0.0833
ed - d	1.10	0.966	1.0351	1.1386
ead -ad	-0.51	1.835	0.5449	-0.2770

$\Sigma w = 4.1563 \quad \Sigma dw = -0.2390$

$$E = \frac{\Sigma dw}{\Sigma w} \qquad E = \frac{-0.2390}{4.1563} = -0.0575$$

$$var(\bar{d}) = \frac{1}{\Sigma w} = 0.240$$

$$(ESd) = \sqrt{var(\bar{d})} = \sqrt{0.24} \approx 0.489$$

$$E = -0.0575 \pm 0.489$$

D	d	var(d)	w (d)	dw
e - 1	+0.22	1.135	0.8811	0.1938
da - a	+1.17	1.461	0.6845	0.8009
de - e	+1.99	0.500	2.0000	3.9800
dar -ae	+0.74	1.334	0.7496	0.5547

$\Sigma w = 2.3152 \quad \Sigma dw = 5.5294$

$$D = \frac{\Sigma dw}{\Sigma w} = \frac{5.5294}{2.3152} = 2.388$$

$$var(\bar{d}) = \frac{1}{\Sigma w} = \frac{1}{2.3152} = 0.4319$$

$$(ESd) = \sqrt{var(d)} = 0.657$$

$$D = +2.388 \pm 0.657$$

The relative frequencies (%) of responses for the technical questions (Q.1 - Q.12). All cashiers.

	0	1	2	3	4	V. Bad
Q.1 Don't take the goods out of basket	20.39	12.78	13.27	10.07	11.30	32.19
Q.2 Things get stuck in the conveyor belt	12.38	8.98	8.74	9.47	14.56	45.87
Q.3 Goods damage goods at the end of conveyor belt	46.00	11.14	14.29	6.05	8.72	13.80
Q.4 Goods box is not large enough	28.15	9.15	11.90	10.30	11.44	29.06
Q.5 Have to reach for paying	34.69	13.15	8.16	8.39	12.47	23.13
Q.6 Put the money on the wrong place	42.16	13.48	8.09	7.35	7.60	21.32
Q.7 Scrape the fingers on the cash register drawer	49.33	15.56	3.56	8.44	4.00	19.11
Q.8 The change returner is unreliable	12.23	10.64	2.93	7.98	11.17	55.05
Q.9 Too many goods prevent the exchange of boxes	11.76	16.91	6.86	11.76	12.75	39.95
Q.10 Don't know where to put carriages	13.95	9.69	7.31	8.67	31.63	28.74
Q.11 The adjustablity of the chairs	83.62[x)]	8.85	2.26	0.19	2.64	2.45
Q.12 The chair can only be turned one way	23.44	11.72	12.45	9.89	24.54	17.95

x) In this case 0 stands for very good and is not a neutral point.

The relative frequencies (%) of responses for the technical questions (Q.1 - Q.12). Only cashiers working on new desks.

	0	1	2	3	4	V. Bad
Q.1 Don't take the goods out of basket	13.67	12.07	11.15	14.45	11.52	36.16
Q.2 Things get stuck in the conveyor belt	10.25	8.75	9.64	9.03	13.51	48.84
Q.3 Goods damage goods at the end of conveyor belt	13.59	10.18	6.89	15.78	11.88	41.69
Q.4 Goods box is not large enough	29.76	10.97	10.42	10.50	9.67	28.69
Q.5 Have to reach for paying	33.74	13.39	8.91	9.73	11.91	22.34
Q.6 Put the money on the wrong place	44.75	13.18	8.70	8.89	7.98	16.51
Q.7 Scrape the fingers on the cash register drawer	50.07	15.22	7.66	5.27	3.12	18.68
Q.8 The change returner is unreliable	12.64	10.86	1.44	6.40	9.76	58.90
Q.9 Too many goods prevent the exchange of boxes	12.33	15.08	9.58	11.47	11.59	40.47
Q.10 Don't know where to put carriages	13.65	7.88	9.69	8.21	27.64	32.94
Q.11 The adjustablity of the chairs	89.21 x)	5.40	1.13	-	1.52	2.76
Q.12 The chair can only be turned one way	26.68	13.28	13.28	12.16	20.59	14.03

x) In this case 0 stands for "very good" and is not a neutral point.

The relative frequencies (%) of responses for the technical questions (Q.13 - Q.28). Cashiers working on old or new types of desks.

	0	1	2	3	4	5
Q.13 How heavy do you find the work?	7.75	21.20	12.82	27.37	11.23	19.62 (v. heavy)
Q.14 Do you find the job monotonous?	33.59	31.88	9.64	9.49	6.22	9.18 (v. monotonous)
Q.15 How qualified or unqualified do you think your job is?	31.31 (v. qualified)	19.02	30.47	9.09	7.91	2.19 (v. unqualified)
Q.16 What do you think about the mental load of your job?	10.48	13.02	16.67	22.06	19.68	18.10 (v. mentally stressing)
Q.17 Do you think your job requires attention?	0.47	1.72	1.25	5.00	20.78	70.78 (to a great extent)
Q.18 How do you feel about the working pace?	5.35	13.68	10.69	27.67	20.44	22.17 (v. hectic)
Q.19 What do your friends think of your job?	31.39 (v. good)	19.34	31.02	8.94	5.84	3.47 (v. bad)
Q.20 How interesting or uninteresting do you find the job?	49.35 (v. interesting)	24.75	16.93	4.34	2.46	2.17 (v. uninteresting)
Q.21 Do you think your job requires responsibility?	0.19	0.10	0.29	2.71	12.29	84.43 (to a great extent)
Q.22 Do you think your job is independent?	4.65	3.20	4.65	12.21	22.84	51.45 (to a great extent)
Q.23 Are there possibilities of promotions within the coop?	26.30	12.69	7.65	14.07	12.54	26.76 (v. good)

ANNEXE 4.8 (continued)

The relative frequencies (%) of responses for the technical questions (Q.13 - Q.28). Cashiers working on old or new types of desks.

	0	1	2	3	4	5
Q.24 How do you experience the contact with the public?	1.15 (unpleasent)	1.15	3.45	4.31	19.11	70.83 (v. pleasent)
Q.25 How do you find the atmosphere at work?	2.46	0.43	2.89	9.97	15.75	68.50 (v. good)
Q.26 How do you get on with your colleagues?	0.58 (v. badly)	0.14	0.72	4.17	10.94	83.45 (v. good)
Q.27 What do you think of your nearest superiors?	2.77 (v. badly)	1.46 1.	5.39	4.37	18.37	67.64 (v. good)
Q.28 Would you like to advise a friend to take a job a cashier?	9.02	5.68	5.09	17.03	16.59	46.58 (without hesitation)

APPENDIX 4.9

CUSTOMER INTERVIEW FORM

(The sex and age were estimated by observation.)

1. Are you member of Coop.?

Yes No

2. When did you join the Coop.?

3. How often do you use this shop?

Daily
A few times a week
Once a week
Occasionally

4. How do you generally prefer to carry your goods when doing your shopping?

In a basket
In a carriage
In your own bag
In nothing at all

5. How many bags (corresponding) have you bought?

Not a full bag
1 "
2 bags
3 "
4 "
or more

APPENDIX 4.9 (continued)

6. Does it happen that the cashier seems rushed?

Almost always
Occasionally
Hardly ever

7. Does it happen that you have to queue up at the cash-desk?

Almost always
Occasionally
Hardly ever

8. How long time do you think you generally are queuing up?

Not more than 5 minutes
Between 5 - 10 -"-
More than 10 -"-
I do not know

	Do not know	Definite-ly	To some extent	General-ly not	Definite-ly not
9. Are you going to do your shopping in this shop in the future?					

10. If yes, why?

____ I like the shop

____ A suitable distance

11. Did you get in-sufficient opportunities for asking questions?

APPENDIX 4.9 (continued)

	Do not know	Definite-ly	To some extent	General-ly not	Definite-ly not
12. Was it entirely clear to you how to behave at the desk?					
13. Did you think that you get insufficient time for paying?					
14. Was it difficult for you to get enough room for your goods on the conveyor?					
15. Did you find it difficult to pick out the goods?					
16. Did you find it difficult to find bags for packing the goods?					
17. Did you find it difficult to get time for packing the goods?					
18. Was the packing worse than the picking out?					
19. Do you find it more stressing to pack a small amount of goods during the rush-hours than to pack a great amount of goods when it is empty at the cash-desk?					

APPENDIX 4.9 (continued)

	Do not know	Definite-ly	To some extent	General-ly not	Definite-ly not
20. Do you think there ought to be a special cash-desk for those who buy only a few things (4-5 articles)?					
21. Do you feel more rushed when you leave the shop than when you entered it?					
22. Do you think that the number of cash-desks in this shop is insufficient?					
23. Is the passing of the cash-desk more troublesome than the actual shopping?					
24. Are the carri-ages easy to handle?					
25. Is there too little space between the cash-desks?					
26. Do you think that the cashiers' jobs are monotonous?					
27. Do you think that the cashier has a stressing job?					

APPENDIX 4.9 (continued)

	Do not know	Definite-ly	To some extent	General-ly not	Definite-ly not
28. Does it happen that the cashier registers the wrong prices of the goods?					
29. Do you have your favourite cashier if you do your shopping in the same shop?					

30. Why?

___ Because of nice person-ality

___ Because of quickness and handiness

31. Are you of the opinion that the cashiers shall weigh the goods?

32. Does it happen that the cashier mixes up your goods with other customers'?

33. Which of the following machines would you prefer, if they were on the market?

1. A machine in which to put the money
2. A machine which reads the prices and works out the sum total
3. A machine which packs
4. A machine which picks out the goods from the carriage

APPENDIX 4.9 (continued)

34. All articles are not provided with prices; the price is sometimes only stated on a sign at the place where the article is put up in the shop. Is this

1. Sufficient
2. Not entirely sufficient
3. Insufficient
4. Entirely insufficient

35. Is there anything else you think is wrong or badly planned at a cash-desk exit?

APPENDIX 4.10

All significant X^2-results together with mean values and standard deviation (assuming that the data are normal and on interval scale).

Question	Partitions	M	S	X^2-value	Levels of sign.
Dependent variable: Age					
Membership Q. 1	Younger people Older -"-	-	-	9.19	0.01
Attitude towards machines Q. 33	Younger people Older -"-	- -	- -	8.58	0.01
Volume of goods per shopping Q. 5	Younger people Older -"-	- -	- -	5.81	0.02
The distance between the cash-desks Q. 25	Younger people Older -"-	3.08 3.34	1.08 0.83	5.67	0.02

Question	Partitions	M	S	X^2-value	Levels of sign.
The preference of a shop Q. 10	Younger people Older -"-	- -	- -	4.72	0.05
Time for packing the goods Q. 17	Younger people Older -"-	2.22 2.47	0.84 0.87	4.64	0.05
Sufficient room for the goods on the conveyor Q. 14	Younger people Older -"-	2.81 3.14	0.98 0.84	4.07	0.05
The passing of the cash-desk more troublesome than the actual shopping Q. 23	Younger people Older -"-	2.77 3.09	1.06 1.04	3.98	0.05
Is the packing of the goods worse than the picking out Q. 18	Younger people Older -"-	2.10 2.60	1.32 1.35	3.59	0.10

Question	Partitions	M	S	X^2-value	Levels of sign.
A special cash-desk for those who buy only a few things	Younger people Older -"-	1.16 1.39	0.44 0.73	3.01	0.10
Q. 20					
Dependant variable: Volume of goods per shopping					
Sufficient room for goods on the conveyor	1 bag or less 2 bags or more	3.33 2.88	0.77 0.94	7.00	0.01
Q. 14					
Time for packing	1 bag or less 2 bags or more	2.67 2.25	0.87 0.84	6.76	0.01
Q. 17					
Do you find it more stressing to pack a small amount of goods during the rush-hours than to pack a great amount of goods when it is empty at the cash-desk?	1 bag or less 2 bags or more	3.29 2.73	1.12 1.33	5.56	0.02
Q. 19					

Question	Partitions	M	S	X^2-value	Levels of sign.
Is the cashier's job monotonous Q. 26	1 bag or less 2 bags or more	1.66 1.99	0.78 0.95	3.61	0.10
More rushed when leaving the shop than when entering Q. 21	1 bag or less 2 bags or more	- -	- -	3.57	0.10
Is the packing of goods worse than the picking-out? Q. 18	1 bag or less 2 bags or more	2.71 2.27	1.36 1.34	2.72	0.10
Dependent variable: The grade of stress					
Is the packing of goods worse than the picking-out? Q. 18	Rushed Not rushed	1.95 2.45	1.22 1.67	13.45	0.001
Not enough time for paying Q. 13	Rushed Not rushed	3.05 3.46	0.86 0.67	12.33	0.001

Question	Partitions	M	S	X^2-value	Levels of sign.
Not enough time for packing Q. 17	Rushed Not rushed	2.15 2.56	0.81 0.88	10.17	0.0001
Volume of goods per shopping Q. 5	Rushed Not rushed	- -	- -	3.57	0.10
The cashier keys incorrect prices. Q. 28	Rushed Not rushed	3.29 3.64	0.75 0.59	3.03	0.10
Dependent variable: Use of shop; if customer liked it or if shop was close by					
Does the cashier have a stressing job? Q. 27	The shop close by Likes the shop	2.36 2.29	0.81 0.70	18.76	0.001
Does the cashier have a monotonous job? Q. 26	The shop close by Likes the shop	1.93 1.88	0.87 0.93	11.69	0.001

Question	Partitions	M	S	X^2-value	Levels of sign.
The attitude towards machines Q. 33	The shop close by Likes the shop	- -	- -	6.13	0.02
Difficult to unpack the goods Q. 15	The shop close by Likes the shop	3.57 3.76	0.82 0.66	5.19	0.05
Age Q. -	The shop close by Likes the shop	- -	- -	4.72	0.05
Not enough opportunities for asking questions Q. 11	The shop close by Likes the shop	2.89 3.20	1.12 1.02	4.47	0.05
Not enough room between the cash-desks Q.25	The shop close by Likes the shop	3.39 3.18	0.77 1.00	2.93	0.10
Difficult to find bags Q. 16	The shop close by Likes the shop	3.64 3.82	0.74 0.52	2.79	0.10

APPENDIX 4.10 (continued)

Question	Partitions	M	S	X^2-value	Levels of sign.
Dependent variable: Membership					
The use of a shop Q. 10	Member Not a member	-	-	60.51	0.001
Difficult to unpack the goods Q. 15	Member Not a member	3.94 3.00	0.35 1.02	37.57	0.001
Age Q. -	Member Not a member	- -	- -	9.19	0.01
Difficult to find bags Q. 16	Member Not a member	3.82 3.62	0.51 0.78	4.77	0.05
Dependant variable: Time of the day					
Age Q. -	Morning Afternoon	- -	- -	2.88	0.10

APPENDIX 4.11

FORM FOR OBSERVATION STUDY OF CHECK-OUT SYTEMS AND THE CUSTOMERS BEHAVIOR IN THE SYSTEM.

Comments	Observed variables	Customer no. 1	2	3	4	5	6	7	8	9	10
	1. Age 1. 20 2. 21 - 40 3. 41 - 60 4. 61 -										
	2. Sex 1. Female 2. Male										
	3. No. of customers in queu										
	4. Transport of goods in the shop 1. Own bag 2. Carriage 3. Basket 4. Other										

Comments	Observed variables	Customer no. 1	2	3	4	5	6	7	8	9	10
	5. Wrong unpacking of goods on the conveyor belt (i.e. the customer puts the basket on the conveyor belt, etc.)										
	6. Insufficient space on the conveyor belt for the unpacked goods										
	7. The cashier has to wait for the goods (the customer does the unpacking too slow)										
	8. The customer does not remove the basket or the carriage										
	9. The next customer's goods are mixed up with the ones just in front										

Comments	Observed variables	Customer no. 1	2	3	4	5	6	7	8	9	10
	10. Difficult for the cashier to read the price										
	11. The price of the goods unknown										
	12. The customer reads the indicator of the cash-registor										
	13. Speaks to the cashier a) asks for information b) makes complaints c) other kind of talks										
	14. The customer does not hear at first how much to pay										
	15. The customer has not got money ready										

Comments	Observed variables	Customer no. 1	2	3	4	5	6	7	8	9	10
	16. The customer puts the money on a wrong place										
	17. The customer has difficulties in handing her own handbag (needs a place to put it on)										
	18. The customer starts the packing before paying and in this case a) returns for paying b) reachs for paying c) other										
	19. The change-returner is used										
	20. The customer does not take the change from the coin-returner										

Comments	Observed variables	Customer no. 1	2	3	4	5	6	7	8	9	10
	21. Too much goods in the box, so that it cannot be closed										
	22. The goods fall over from one box to another										
	23. The customer cannot find the paper bags										
	24. The customer cannot find the type of bag she wants										
	25. The first customer has not finished the packing when the goods from the third customer arrive a) the goods are mixed b) the cashier takes the goods in her knee c) the cashier does not change the bar between the boxes d) waits										

APPENDIX 4.11 (continued)

Comments	Observed variables	Customer no. 1	2	3	4	5	6	7	8	9	10
	26. No. of goods bought - 2 3 - 5 6 - 10 11 -										
	27. Time for service										
	28. Observed check-out desk (no.)										

Comments:

Date:

Shop:

Observer:

Total number of desks in the shop: