Integrating ergonomics: a practical case study

INTEGRATING ERGONOMICS IN THE DESIGN PROCESS A PRACTICAL CASE STUDY

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The authors were commissioned to work as part of a design team in the production of a new supermarket checkout. The primary goals at the onset of the project were to reduce build costs and enhance customer interaction without compromising health and safety. The ergonomics issues identified through the initial literature search highlighted two key checkout operator considerations: the need to minimise the risk of musculoskeletal injury; and the importance of factors other than equipment design, such as task design and training, in minimising risk and optimising performance. This paper discusses how these two considerations were maintained and developed throughout the design process as the original project goals changed. Its purpose is not to discuss the ergonomics of checkout design; rather, it uses the checkout design case history to highlight where the ergonomics practitioner can successfully contribute to project success.

INTRODUCTION

This paper does not attempt to describe a sure process which can be followed in order to ensure that a product is ergonomically sound. Its primary purpose however is to highlight those *practical* points at which the ergonomics contribution was particularly pertinent to the design process; often beyond the expectations or scope of the project brief. For clarity these are identified throughout the text as '**ECP'** (Ergonomics Critical Point).

PRODUCT DESIGN PROCESS

The design process is a means of tackling problems in stages. The process of product design is often represented as a linear sequence of events (Wright, 1998; Jones, 1992). However, this case study demonstrates that design is not a neat linear process whereby tasks continue from one another in a logical sequence. This was also found by Wright (1998) who states: "the activities and their order of application depend upon the nature of the design task, the objectives and constraints and the preferences of the people involved." According to Wise (1990) different design problems will involve different tasks. Shown here is one example of how ergonomics feeds into the different tasks within the design process and how ergonomics tasks influence other tasks and therefore become independent within the design process.

THE NEED

The initial stage of the project was to consider and define the problem, this often being the most important stage of the design process (Wise, 1990). The standard checkout designs pose a number of problems for many customers, especially the less able, and can put operators at risk through strain injury (Anon, 2001). The need for an ergonomics input to the design of a supermarket checkout is clearly established in the Health and Safety Executive Report, Musculoskeletal Disorders in Supermarket Cashiers, Mackay *et al* (1998). The groundwork is done; this paper does not, therefore, review the state of knowledge.

THE BRIEF

The design team had been commissioned to produce an efficient and attractive checkout which facilitated excellent customer interaction. Reducing the overall cost of the checkout was a key goal. Beyond this, the design team were actively encouraged to challenge what has become a fairly standardised checkout design. In addition, a design was sought which enabled checkouts to be built in pairs to facilitate team working (e.g. reducing operator isolation and sharing packing assistants).

To achieve this, the designers elected to adopt what they termed a 'usercentric' approach, considering the checkout operator needs in the context of the tasks they performed and the equipment they used. In essence, this was a traditional ergonomics approach (see, for example Eason, 1995; Stanton, 1998), although Säde (2002) recognises the problems in applying user-centred design principles to practical cases. Oborne (1995) also suggests that a user-centred approach should not just be a 'humanised workplace', but the factors that 'contribute to the operator's wishes and abilities' must also be understood. When ergonomics principles are applied to the design process as in this case, the user is at the centre of the design process. Failure to do so may result in the creation of an unsafe and inefficient operation (Layton et al, 2001). The designers, therefore, invited the ergonomists to contribute to the design project from the outset. All product designers however, can be encouraged to consider ergonomics requirements and to include user trials in the design process but there are some arguments for keeping the roles of the ergonomist and designer distinct (Haslegrave & Holmes 1994).

RESEARCH AND TECHNICAL ERGONOMIC INPUT

The ergonomics contribution was to provide pertinent static and dynamic anthropometry data and a summary of ergonomics design recommendations gathered through literature review (see, for example Pheasant, 1996; Sanders and McCormick, 1993). This was provided in a written report that highlighted the apparent need to consider factors other than the physical design. Examples from Musculoskeletal Disorders in Supermarket Cashiers, Mackey *et al* (1998) include:

- The level of satisfaction with the work and the workplace (including the environment will influence symptom reporting *(of musculoskeletal disorders)*.
- Cashier technique, more than checkout design, can govern the extent of manual handling during checkout work.
- Ergonomically designed checkouts may reduce biomechanical loads, the evidence does not suggest that improvement of checkout design alone will reduce symptom reports.

ECP: Because of the need to consider this broader perspective, the ergonomists were invited to participate in the initial concept generation and review.

INITIAL CONCEPT GENERATION AND REVIEW

The design team had prepared a series of concept sketches (see Figure 1) based on their appreciation of the checkout operation task – they had visited each of the major supermarkets to generate background material. The ergonomists were asked to comment on each of the sketches, emphasising usability and safety issues. Of particular importance was the consideration of design factors which may contribute to the risk of musculoskeletal injury, as discussed by Baron & Habes (1992) and Harber et al (1993).

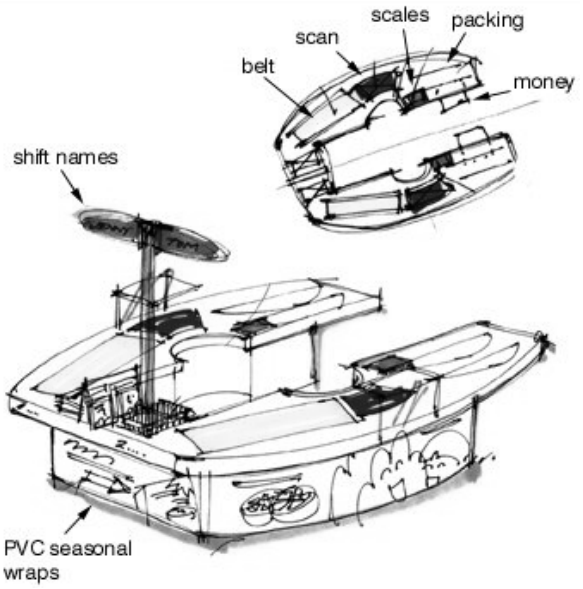


Figure 1. Initial concept sketch

ECP : It became increasingly apparent that the ergonomists were also required to introduce a thorough health and safety perspective to the project. At the concept generation and review stage, key requirements of the Provision and Use of Work Equipment Regulations 1998 and the Manual Handling Operations Regulations 1992 were identified and discussed. These regulations imply a holistic approach to compliance, considering physical provision within the nature of use. Emphasis was given to the requirement to provide design solutions which were fit for purpose. This applied to single elements of the checkout (e.g. the chair) and the checkout as a whole. The raised awareness of the legislative criteria changed the dynamic of the design process. A further challenge had now been introduced, to provide a new style and compliant checkout. It was at this stage that the design team decided that the ergonomists should assume a greater and more interactive role throughout the project. For the process to work effectively, the providers of information need to be involved in the decision making process, and the discussions that proceed it (Wright, 1998). It was at this point in the project were the design process deformed from a neat linear sequence, the order of application depended on the preferences of the people involved. This approach was reflected in the methods adopted at this stage.

CONCEPT DEVELOPMENT

To ascertain an appreciation of the key requirements to be considered, in addition to the literature review, the ergonomists also prepared a skeletal task analysis by reviewing videotapes of existing checkout use. Consideration was given to the needs of both the checkout operator and the customer. Key needs included the provision for the sit/stand operation, positioning of equipment (e.g. scales, scanner), interaction between operator and customer and customer loading and packing areas.

From this and the initial concept generation and review, four design sketches were generated. These 3-D drawings were evaluated by the ergonomists using the problem solving strategy, design-analyse-redesign (see Figure 2). Problems of design can often be more effectively solved with less effort and less iteration (e.g. Stoll, 1999).

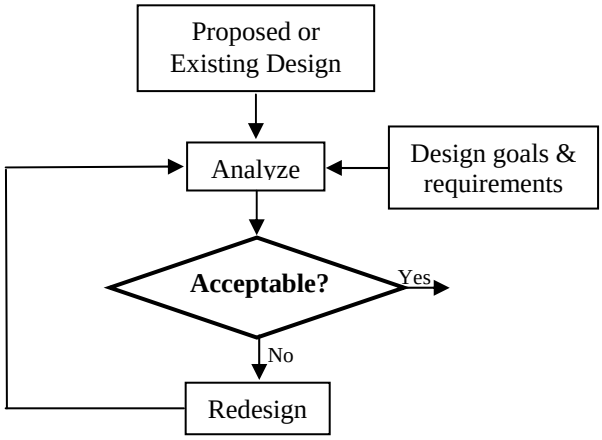


Figure 2. The design-analyze-redesign strategy (Stoll, 1999)

ECP : The feedback process was very much an iterative one, with frequent, informal discussion, typically by telephone, between the designers, client and ergonomists. According to Stoll (1999) this problem solving process is often referred to as the "iterative nature of design." This approach is time-efficient and preferable to the designers as the ergonomist can comment on proposed solutions as they are created. Pugh's model of the design process (1991) identifies that information, from a variety of sources, is a key activity. In addition to this efficiency, it might also be argued that the creative dynamics are adversely affected by inappropriate interruption by the ergonomist during the early stages of the design process. Because of its broad, multi-factorial approach, ergonomics can sometimes be perceived as being critical rather than inspirational, particularly at a detailed level.

However, because the response to action is not in true partnership – the designer and the ergonomist are not literally working together at the same workstation, on the same drawing at the same time - clear communication is essential. Otherwise "off-the-cuff" remarks may be inappropriately introduced into the design, priorities unwisely changed and designs developed in a direction which is not intended by either party. This can create a problem which is difficult to resolve as, inevitably, several elements are affected concurrently as a design evolves. It is essential that the ergonomist provides clear, balanced suggestions to avoid these potential problems.

Two designs were generated from this for consideration by the client. The first was very similar in design to the existing checkout but with operator usability improvements, particularly in relation to posture and movement. The second was a far more radical design (see Figure 3) to the typical style in which a customer loads goods on to a conveyor belt, moves down the checkout past the operator and then stops at the far end of the checkout to pack their goods. In the radical design, the operator was sat 'face on' rather than 'side on' to the customer; the customer was expected to load goods as usual but to then stay in the same place while the operator scanned the goods and placed them onto a second conveyor which returned them to the customer.

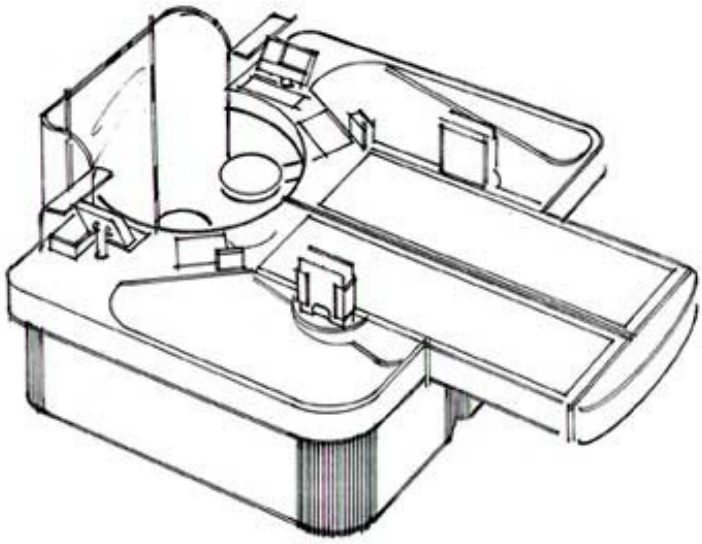


Figure 3. Proposed radical design

Both of these checkouts were constructed as full-size models and presented to a team of managers and representative users (referred to as the 'clinic team'). Mock-ups and models in their various degrees of refinement are invaluable to the designer, ergonomist and others involved in the design evaluation process. They enable proposals to be tested using task simulation, allow people to 'try things for size' and get a general feel for a design's suitability. Unrefined mock-ups provide evaluators with the opportunity to make changes. Finished models enable the designs to be assessed in the context of their intended use and environment.

Following a focus group style appraisal of the checkout designs, the client chose to proceed with just the radical design. This was primarily based on what became known as the 'wow' factor – that impression of something different, novel and innovative which creates an excitement with all those involved in the project. Even when designers have done their homework on the functional aspects on alternative models of a product, it can be difficult to not be swayed by non-functional criteria such as the appearance, the feel, the apparent solidity, or the symbolic connotations of an object (Brown et al, 1983).

FIRST DESIGN FITTING TRIALS

In addition to some design styling refinements, it was agreed that fitting trials were necessary to accurately place the equipment within the checkout. A fitting trial is an experimental study in which a sample of participants use an adjustable mock-up of a workstation (in this case, the checkout) in order to make judgements as to whether a particular dimension is 'too big', 'too small, or 'just right', (Pheasant, 1986).

ECP : The designers were unaware of the technique of fitting trials, assuming them to be simply a means of identifying user opinion. When the need for a second stage of fitting trials became apparent later in the project, the team (now aware of the benefits) planned their inclusion as an integral part of the design programme. Most product design consultancies do not have specialists in ergonomics and user research (Säde, 2002) and so this change to the design process reflects how approaches can develop during a project, particularly when people with wide ranging expertise are involved.

Four items of equipment were identified as being particularly important to healthy posture and movement: the cash till, printer, scales and 'SNIKEY' (keypad/display panel/card swipe). Each of these was modelled actual size. Through the process of fitting trials with 30 representative operators, commonality of positioning was identified.

Compromises to the optimum placement of some items were necessary. For example, the scales could not be positioned precisely as identified because of fixing limitations within the checkout surface. The fitting trials data were used to determine the consequences of altering positions. This enabled decisions to be made which minimised the number of potentially excluded users. Even after careful ergonomic appraisal through user trials, in certain circumstances it still may be a matter of reasonable choice where something is positioned (Brown et al, 1983).

In addition to identifying co-ordinates for each of the items, a number of other observations were made. The new design of checkout was well received by the operators, but it was quite clear that without appropriate training to attain and maintain healthy posture and movements any design improvements were likely to impair the manner in which operators tended to sit, stand and work at existing checkouts.

STORE TRIALS

A pair of checkouts was constructed and fitted within a store for a period of trials. The checkouts were appraised in a variety of ways including appraisal by health and safety personnel, assessment by visiting store managers, customer opinion questionnaires, direct observation and video (posture and movement) analysis by the ergonomists, operator discussion groups and operator opinion board.

The appraisals by both safety personnel and store managers yielded valuable information about how the checkout appeared to be working in terms of customer flow and operator movement. As such the comments could be usefully integrated into the overall trials assessment. It is important to remember that such opinion must not be considered in isolation as it makes limited reference to user involvement.

The customer opinion questionnaires also contributed to the overall assessment, but again cannot be considered in isolation, particularly, as was the case here, they have a tendency to represent the dissatisfied.

ECP : The direct observation, video analysis and discussion groups formed an ergonomics appraisal chiefly considering usability, musculoskeletal risk and operator acceptance. This would have benefited from customer involvement, but project constraints determined by the designers dictated the ergonomics focus be given to operators.

The operator opinion board was essentially a notice board near to the staff restaurant on which anonymous individual comments could be written. This was poorly used, with very few operators contributing. In the discussion groups the ergonomists were advised that the operators simply did not consider the board to be a convenient means of generating information – it was too far from the checkouts and required time to write things down! A series of brief discussion groups with the checkout assistants yielded the desired feedback in an efficient manner.

Whilst not all of these user-involvement methods were wholly successful, the participation of users, supported by other methods, provided a typical approach and an improved design (Säde, 2002).

The design refinements identified through the store trials are not significant to this paper, but were extremely important to the designers as they related to not only styling and, arguably more importantly, issues such as conveyor belt size and packing area.

Three key ergonomics findings of the store trials were:

- A new, improved chair was required which enabled all checkout assistants, irrespective of age, gender and size to attain and maintain healthy seated posture.
- The radical checkout design required customers to stay in the same position, to both unload their trolley and pack goods which were delivered back to them on a return conveyor belt. Customers found this confusing.
- None of the operators had been trained to use the new style design to its full advantage.

ECP : As a result of the trials the design team agreed for 10 alternative chairs to be appraised, including sit/stand models. The ergonomists argued there to be value in providing a new chair as an integral part of a new checkout. Unfortunately as the project progressed, project emphasis changed and a new chair was not pursued beyond the initial expert appraisal. This is an example of a typical compromise in design projects. The ergonomist needs to be clear about the ergonomics priorities within the design, in order that compromises are not inappropriately made.

It may be argued that training in the use of the trial checkout was the responsibility of the design team, but in large organisations the duties are often split among different departments. Nevertheless, having established the need for training in the earlier stages of the project it was imperative to deliver a holistic solution. The ergonomists were subsequently invited to work with the training department to generate a training programme which reflected the goals of the design team.

RAPID RE-DESIGN

In light of the findings of the store trials – particularly customers' inabilities to use the checkout without instruction, the design team agreed with the client that a design which returned to the more traditional style should be developed. In order to accelerate to production of a new design, the team set to work armed with the knowledge gathered through the project to date, in consultation with the clinic team. As they thought this would be largely a repeat exercise, the design team decided that it was not necessary to engage the ergonomists in this process.

ECP : Project progress was hampered by the decision to abandon the radical design. The design team was somewhat disappointed by the apparent failure of the design. It was, arguably, inevitable that the drive to find an alternative design would be accelerated to the exclusion of some of the contributions to the first (radical) design. In this case, a new design was created, based largely on 'clinic team' suggestions interpreted by the design team. While some excellent ideas were generated, this approach is limited, according to one of Pheasant's five fallacies (Pheasant 1996), "This design is satisfactory for me - it will, therefore, be satisfactory for everybody else". Without sufficient representative user involvement or ergonomics expertise, the design team were exposed to risk of misinterpreting or placing inappropriate value on suggestions offered by the clinic team.

Fortunately, the client was aware of this limitation, and commissioned a full-size model of the re-design to be constructed and evaluated by the clinic team. At this stage, the client's health and safety personnel raised some concerns about the design and requested the ergonomists be invited to make comment. This led to an agreement to conduct a two-week programme of in-store user trials, in much the same way as those conducted for the first design, but with improvements to the data collection process (e.g. questionnaires replaced the opinion board).

In addition to usability, the design process was sufficiently advanced that productivity issues were considered in depth as part of the store trials. As a consequence of several factors, including improved health and safety through the reduction of musculoskeletal risk factors, it was discovered that transaction times using the re-designed checkout were slower than with the existing design. While the safety benefits had been a target it was hoped that performance would not be reduced. Through a series of modelling scenarios improvements in performance without compromising health and safety were identified. These led to design changes such as the introduction of a second conveyor belt to transfer scanned goods to the packing area. Seven areas of improvement were identified as necessary, all of which were critical to project success. The final design is shown in Figure 4.

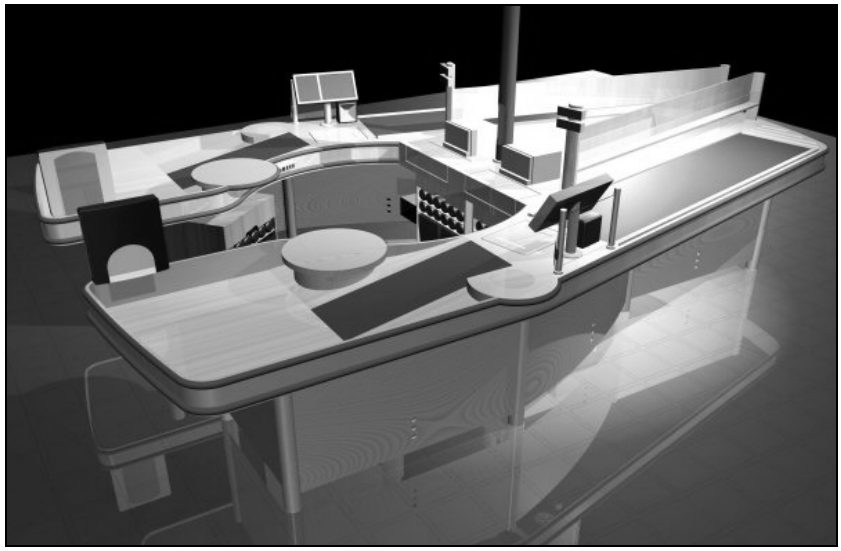


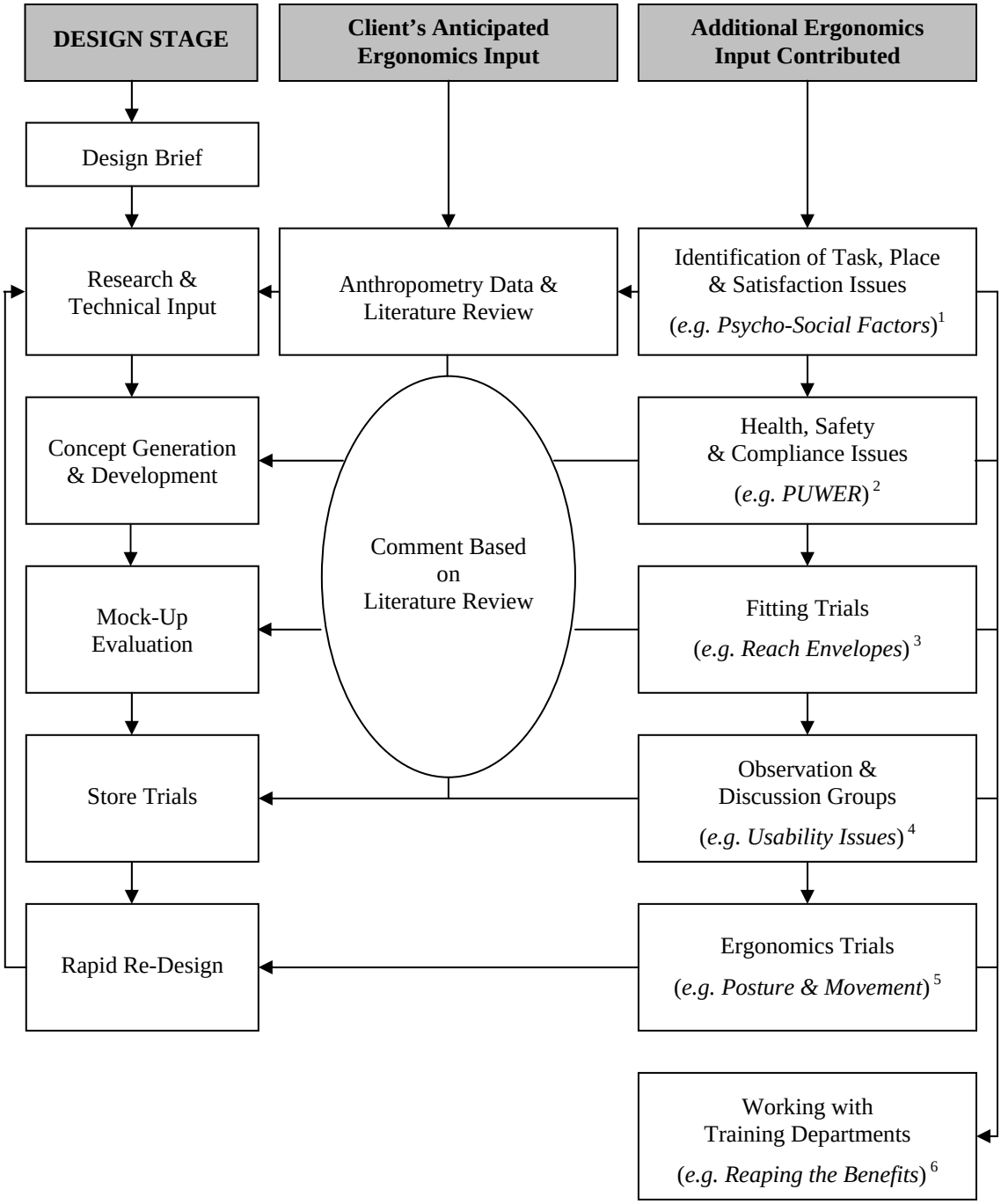
Figure 4. Final design

ECP : The authors suggest that in a project such as this, the design team has a duty to provide the client with more than design proposals. Where an approach or contribution, such as ergonomics, is clearly required, it should be communicated to the client and included in project planning. This is especially important at review and 'crisis' stages when extra resources must support the generation of rapid solutions.

CONCLUSION

The design team was enthusiastic and committed to the 'user centric' approach, and the client was proactive in insisting that user issues be given primary consideration. Even so, the ergonomists needed to establish their contribution considerably beyond that originally proposed by the designers (see Figure 5). Rather than the design process following a linear sequence of events it is evident from this case study that, in order to produce an "'inclusive' design that satisfies all health and safety demands and radically enhances usability and desirability" (Anon, 2001) a number iterative loops were needed within the design process, requiring input from a number of sources. This is backed up by Wright (1998) who states: design is an iterative process at all levels. In general the larger and more complex the product, the greater the number of iterations required. In the vast majority of cases, each of these iterations will require information from multiple sources and the involvement of many people to innovate, evaluate, analyse and make decisions.

This case study also demonstrates where it was necessary to apply adaptive strategies, where the project team decided on the next stage only once the outcome of the previous stage was known (Jones, 1992). This allowed appropriate changes during the process, including extending beyond anthropometry and physical factors of traditional ergonomics, to embrace task, environment and organisational aspects. Where, occasionally, the design process advanced without sufficient ergonomics or user involvement, in this case, usability and safety were compromised. To re-establish these critical factors actually slowed project progress and caused additional barriers to be overcome, especially as the ergonomics issues presented the designers with additional challenges which were sometimes very difficult to resolve. A host of agents influenced the ebb and flow of ergonomics input: designer expectations, changing business and project objectives and time (e.g. availability of staff and stores). The lesson to be learned? It is essential that the ergonomist clearly informs the design team of the need and benefits of an integrated and flexible ergonomics contribution.



Notes on Examples:

1 Psycho-Social Factors - including operator concerns about image and preference and customer acceptance; considerations beyond physical fit.
2 PUWER – the Provision and use of Work Equipment Regulations covering the fitness for purpose of items such as the checkout.
3 Reach Envelopes - dynamic measurements to ensure layout was acceptable to all.
4 Usability Issues – factors affecting operator and customer task performance.
5 Posture & Movement – minimising risk of operator discomfort and injury.
6 Reaping the Benefits – ensuring operators make best use of design features.

Figure 5: Summary of anticipated and actual ergonomics input

REFERENCES

Anonymous. (2001) *Design for an inclusive society.* Design Export News, 19, p3.

Baron, S.L., & Habes, D. (1992). 'Occupational Musculoskeletal Disorders Among Supermarket Cashiers'. *Scandinavian Journal of Work and Environmental Health,* 18 (2), 127-129.

Brown, S., Cross, N., & Walker, D., (1983). *Ergonomics in Design.* Design Processes and Products. The Open University. 118-130.

Eason, K.D. (1995). 'User-Centred design: for users or by users?' *Ergonomics* 38 (8), 1667-1673.

Haslegrave, C., Holmes, K., 1994. *Integrating Ergonomics and Engineering in the Technical Design Process.* Applied Ergonomics: 25 (4). Oxford: Butterworth-Heinemann. 211-220.

Harber, P., Bloswick, D., Beck, D., Pena, L., Baker, D., & Lee, J. (1993). 'Supermarket Checker Motions and Cumulative Trauma Risk'. *Journal of Occupational Medicine* 35 (8), 805-811.

HSE. (1992) *Manual Handling Operations Regulations 1992, Guidance on Regulations L23* HSE Books. London: Her Majesty's Stationery Office.

HSE. (1998). *Provision and Use of Work Equipment Regulations 1998, SI 1998 No 2306.* London: Her Majesty's Stationery Office.

Jones, J.C. (1992). *Design methods (Second edition).* London: Chapman & Hall

Layton, S,. Whitlock, A,. Chadwick, R,. (2001) *A Review of the Methodology for the Integration of Ergonomics into the Supermarket Design Process.* Contemporary Ergonomics 2001, Ed by Margaret A. Hanson. London: Taylor & Francis. 371-376.

Mackay, C., Burton, K., Boocock, M., Tillotson, M., & Dickinson, C. (1998). *Musculoskeletal Disorders in Supermarket Cashiers*. Norwich: Her Majesty's Stationery Office.

Oborne, D.J. (1995). *Ergonomics at Work (Third Edition).* Chichester: John Wiley and Sons.

Pheasant, S.T. (1986). *Bodyspace: Anthropometry, ergonomics and design.* London: Taylor & Francis.

Pheasant, S.T. (1996). *Bodyspace: Anthropometry, ergonomics and design (Second Edition).* London: Taylor & Francis.

Pugh, S. (1991). *Total Design.* Wokingham: Addison-Wesley Publishing Company.

Säde, S. (2002). 'Towards user-centred design: A method development project in a product design consultancy'. *The Design Journal* 4 (3), 20-31.

Sanders, M.S. & McCormick, E.J. (1993). *Human Factors in Engineering and Design*. London: McGraw-Hill Inc.

Stanton, N. (1998). *Human Factors in Consumer Products*. London: Taylor and Francis.

Stoll, H,. (1999). *Product Design Methods and Practices.* New York: Marcel Dekker Inc.

Wright, I. (1998). *Design methods in engineering and product design*. London: McGraw-Hill International (UK) Ltd.

Wise, D. (1990). *Design in Focus: The Design Process.* East Sussex: Wayland (Publishers) Ltd.

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