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SAMMIE: Computer Aided Ergonomics

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Human modelling systems can be powerful tools for the design team as they enable predictions to be made of the percentage of future users of the product who may have problems with clearances, reaching, seeing or the combination of all these requirements may force unnatural and damaging postures. When problems are identified, it is possible for all of the design team to scrutinise the data and the assumptions used. The ergonomics problems with a proposed design can be presented visually thereby supporting efficient communication within the design team and solution-orientated action.

SAMMIE (System for Aiding Man Machine Interaction Evaluation) is a human modelling computer aided ergonomics design system that was conceived in the late 1960s and by 1978 the system was being used on a daily basis as a consultancy tool [1,2,3,4,5]. This paper will describe and discuss some of the more important issues that we have had to deal with during the development and application of SAMMIE.

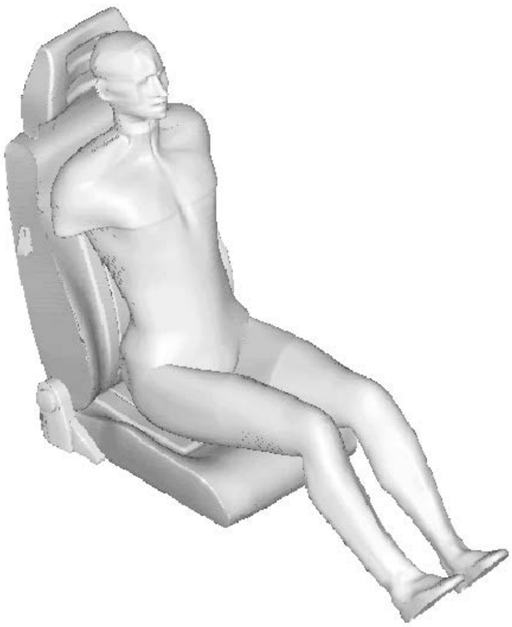


figure 01. a SAMMIE rendered image of a more realistic man-model using curved surfaces, currently under development.

functionality of the system

SAMMIE is a predictive tool to assess the postural constraints placed upon people when interacting with the designed physical environment. The basic functionality that is required is listed below.

- 3D modelling of people of the selected sex, age, nationality and occupational groups. This is achieved using published anthropometric data, if indeed it exists, for the population being examined. The current databases have several shortcomings, basically because they were established with little consideration for the needs of 3D human modelling systems. Ideally, anthropometric surveys should present data for all individuals in the sample which can then be accessed by the computer and each person can be examined in relation to the proposed prototype design in terms of fit, reach, vision and posture.

  Anthropometric data provide only a limited number of dimensions to define a 3D computer model. Should the human model remain as true as possible to the real data or should artistic licence be granted to model more ‘realistic’ models? It is appreciated that highly lifelike models will attract the attention of stylists and it is quite possible that this would be reflected in the increased usage of human modelling CAD systems, but at what cost? The danger is that the designer (be it a stylist, industrial designer, engineer or ergonomist) would come to believe the ‘added’ data and, for example, may feel confident that it is possible to design seat profiles based upon these highly detailed models.

  Recent work has however focused on two areas where a more realistic representation of the human body has been of importance for ergonomics evaluation purposes. A detailed geometric model of the spine has been developed[6] which will be used in ongoing research into the effects of product design on spinal posture and its possible consequences in terms of discomfort or long term damage. Secondly, in attempting to gain a better understanding of driver comfort and a more precise prediction of important design points such as the eyepoint and H- point, it was realised that a more accurate representation was required for both the human flesh and the car seat[7].Figure 01 shows a flesh shape that has been acquired from real subjects using a shadow scanning technique[8].

• knowledge base of comfort angles for the major joints of the body. Such data are widely available for application areas such as computer workstations and cars. However, closer examination often reveals disagreement in the literature or the recognition that the recommended postural angles are based only on theoretical analysis. For example, for many years it has been accepted that people using computers should adopt an identical posture to that taught to typists in the past, specifically sitting upright with angles around 90 degrees between the trunk and thigh and at the elbows, knees and ankles. However, a quick glance at any room full of people using computers shows that such a posture is rarely adopted. This begs the question “should we design for a posture that will only be rarely used?”

• ability to model the proposed workstation in 3D together with the simulation of ranges of adjustment to be incorporated into the design.

• ability to assess the kinematic interaction between the models of people and the workstation, specifically in terms of the issues of user fit, reach and vision. The assessment will focus on whether or not the people modelled can work efficiently at the workstation and can adopt a ‘comfortable’ posture (i.e. within the ranges of joint angles considered acceptable).

• ability to make iterative modifications to the design to achieve optimum compromises. Design is all about working within constraints, and sometimes challenging these constraints, to achieve the best compromises. The public's demand for better ergonomics in their homes, offices and lifestyle is continually increasing, as is the legislation to enforce it.

design consultancy projects

We begin any project by asking a number of basic, but essential questions. Firstly we have to determine exactly who the intended users of a design will be which, whilst seeming an obvious starting point, is often not at all clear in the client’s mind. This forces the client to make important decisions about the acceptable accommodation range (e.g. 5th to 95th percentile or wider) and the user population in terms of nationality, sex and age groups at the earliest stage of design. In an evaluation of a helicopter development (see Figure 02) we were able to demonstrate to the client that the existing aircraft chosen as a starting point, initially without particular regard to the users, was not capable of accommodating the population extremes (97.5th percentile Dutch male pilots and 25th percentile female pilots of other European nationalities) without structural changes so great as to warrant an almost completely new airframe.

The next step is to help the client to establish a clear definition of all the tasks the user is required to perform in order that we can simulate them in the evaluation. This helps to establish a specification for the workstation equipment and to set task priorities. This process often identifies conflicts between various task functions. For example, SAMMIE CAD was involved in the design of the Brussels Tram 2000 (see Figures 03, 04, 05 and 06) working for Design Triangle and Cambridge Ergonomics. It was established that the driver had two equally important but conflicting tasks, namely driving the vehicle and selling tickets to passengers. A cab designed to allow ease of operation, optimum visibility and comfortable postures whilst driving was found to be severely compromised by the requirement to have the driver swivel around and sell tickets whilst remaining seated. Since SAMMIE is a visual medium it was possible to clearly demonstrate the problem to the rest of the design team and together we were able to look for solutions by quickly developing and investigating a variety of alternative seat movement mechanisms and rotation points in the SAMMIE model (see Figure 6).

Another important consideration often over looked is

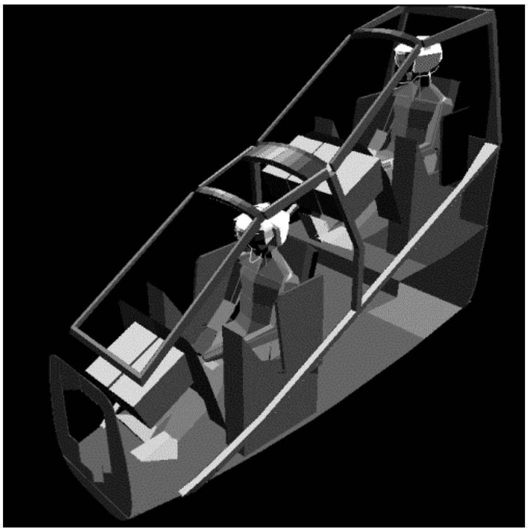


figure 02. a model of a military helicopter

the working environment and its possible effects upon user task performance. A recent project examined control design for an aircraft cockpit in which the control would only be used when the aircraft was ‘out of control’ (see Figure 07). This posed several issues which the engineers had not considered because the pilot had always expected to be ‘in control’ when considering the design of other controls. The motion conditions under which this particular control might be used are so severe that the ‘normal’ usability criteria for acceptable reach and vision identified by the client were totally inappropriate.

Determining who the users are, what tasks they perform and under what conditions they are expected to work, is important in that it forces the client to make decisions that affect the usability of a workstation at the earliest possible stages of design, thereby ensuring the early input of ergonomics expertise. This is one of the major benefits of the use of SAMMIE. Other advantages include a reduction in project time scale, the ability to have a rapid iterative design process and improved communication within the design team. Because the SAMMIE analysis is logical and objective in its approach, all of the stake holders in a project can easily visualise any design problems identified, question any assumptions made and have a direct involvement with the investigation of alternatives.

A recent project, conducted in conjunction with Design Triangle and Cambridge Ergonomics, involving the development of a cab for the new Amsterdam tram provides a good example of time savings achievable with SAMMIE. We developed a SAMMIE model based on the bare minimum of engineering hard points as soon as they were established. With a detailed ergonomics specification of the users and their vision and posture requirements we were able to quickly determine the required seat movement envelope and begin to develop a set of surfaces for controls and displays based upon the reach and vision capabilities of the user population (see Figure 08). In this case we were able to provide the engineers with 3D coordinate and modelling data for an ergonomically designed workstation, from which they could build their own CAD model, within a matter of days. A more traditional design process where engineers develop a CAD model of a workstation, produce drawings, build a mock-up and finally evaluate that with user trials usually takes weeks or months in comparison, especially if trials reveal problems requiring re-design.

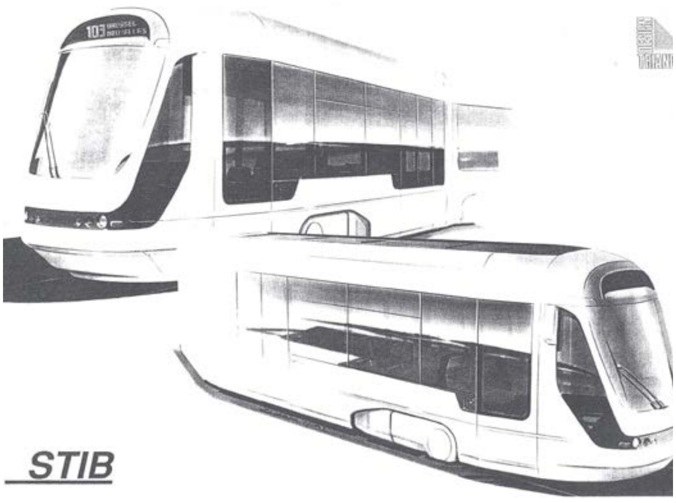


figure 03. an artist’s impression of exterior styles for the *Brussels 2000 Tram* (Courtesy of Design Triangle, Cambridge, UK)

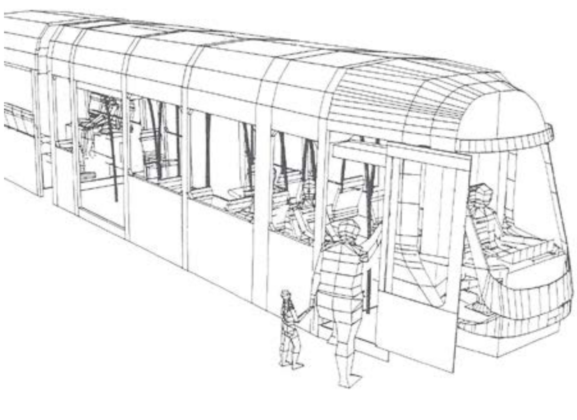


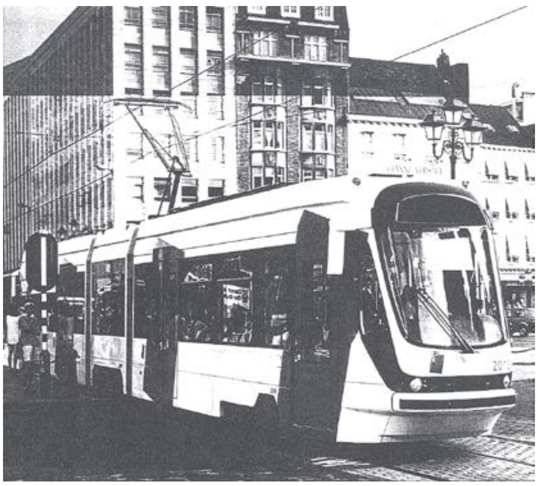
figure 04. the final version of the *SAMMIE* model of the *Brussels 2000 Tram.*

SAMMIE enables rapid and timely iteration. For example, we were involved (again in conjunction with Design Triangle and Cambridge Ergonomics) with the development of the cab for the new Lantau express train for Hong Kong's new airport where the designers developed a number of exterior forms for initial development (see Figure 10). We were able to build up a model of the cab structure and start to develop a suitable workstation before any engineering drawing or other CAD modelling was started (see Figures 09 and 11). Importantly the client had several changes of mind regarding the external form which required major changes to the cab body. We were able to make structural changes to the model as they arose and assess their effect on the workstation immediately. Indeed the client later decided that the passenger emergency evacuation route had to be through the front of the train which effectively cut the cab into three. We were able assess the implications of this on the driver's workstation and show how this requirement might be accommodated with the minimum number of compromises, mostly by reducing the amount and size of equipment required by the driver in order to fit a usable workstation into the smaller space. One novel solution that arose from this was the provision of a chair that can be slid into a recess in the rear wall to improve cross cab access and allow sit/stand operation, whilst still providing a high quality seat system. The mock-up built from the SAMMIE design is shown in Figures 12 and 13.

training issues

We had expected that the SAMMIE system would be used mainly by qualified ergonomists. However, an analysis of our userbase reveals that this is not the case and, consequently, our training course covers basic teaching in applied anthropometry and workplace design. This gloss does not make an ergonomist as one of the most important features of an ergonomist is not just their data and methods but the philosophy or change in viewpoint that they can bring to the design team. This person-centred viewpoint takes time to mature and it needs to be reinforced with the study of several related areas such as the physiological, psychological, organisational and environmental factors that are present in any given design scenario. Some of the more important differences, from our own experience, in the approach taken by engineers, designers and ergonomists are listed below:

- dealing with variability. The engineering approach is to design out variability by the selection of high quality materials and methods of manufacture. As a consequence, the statistical mean of an attribute of the product, be it a dimension, weight, strength etc., is a very good predictor of all products being produced at that time. The statistical mean is also the best predictor for people variables as well, although the variability is so great that it is of considerably less interest for design purposes. Put crudely,



Ffigure 05. the *Brussels 2000 Tram* in service.

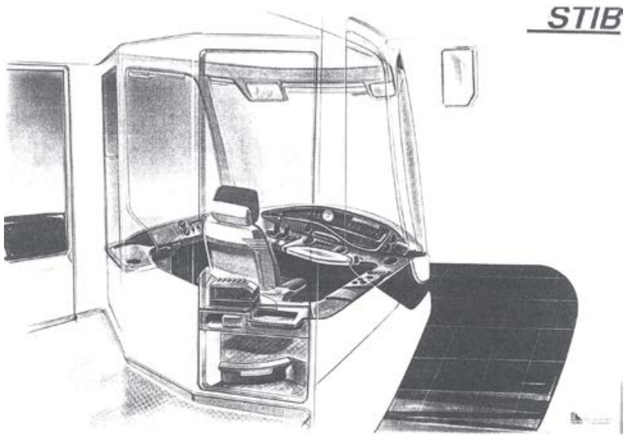


Figure 06. an artist's rendering of the SAMMIE model pf the Brussels 2000 Tram cab. (Courtesy of Design Triangle, Cambridge, UK).

designing for clearances, reach and strength using the statistical mean for the appropriate variable will result in up to half of the intended population being 'designed out'. Human variability must be embraced by designers.

A classic example of the importance of understanding human variability is in the design of a receptacle for medical products which need to be openable by adults but should be difficult to open by small children. One of the most common solutions is to require large forces and a high degree of manipulative and cognitive abilities. The trouble is, this also designs out a large number of elderly people who may be the prime users of such a product.

• jurisdiction and communication. Stylists and designers are particularly adept in communicating their ideas as they rely chiefly upon the visual image. As the major influences for a design are achieved at the concept stage then such people also have a wide jurisdiction of influence. For example, their sketches of handles and seats may be stylish but pay scant attention to ergonomics principles; however, they often form the basis for the production specification.

Engineers are also able to communicate effectively with each other through engineering drawings and technical analyses. Ergonomists typically contribute to design by providing data concerning human characteristics and by providing evaluative data concerning issues such as discomfort, usability and safety. These inputs do not directly influence the design unless the solution can be sketched or dimensioned accurately. Consequently, the ergonomist has traditionally had to rely upon the support of the other team members in order to incorporate the ergonomics specification.

Ergonomists, in our experience at least, are rarely asked to comment upon styling or engineering issues although stylists, designers and engineers are more than happy to deal with the ergonomics issues. Presumably, this confidence is based upon the assumption that introspection and the consideration of one's own problems and feelings towards a proposed design will be typical of most other people. It is not unknown, as an example, for young male design staff to be asked to design car seats for children even though they have no experience of childcare or the needs of the child and supervising adult throughout the journey. In a similar vein, senior management in the car industry are not representative of the purchasing public in some very important aspects; for example, they do not have to actually choose or purchase their car.

Human modelling CAD systems can help enormously in getting the ergonomics issues

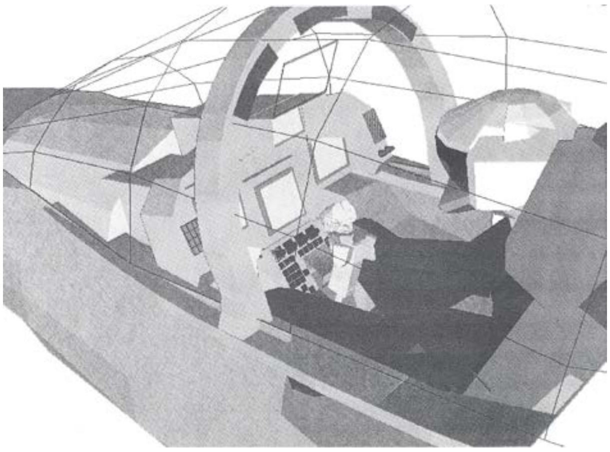


figure 07. a view of an aircraft cockpit model showing a small pilot reaching to a control stick. Notice that a functional hand model was developed for use on this project.

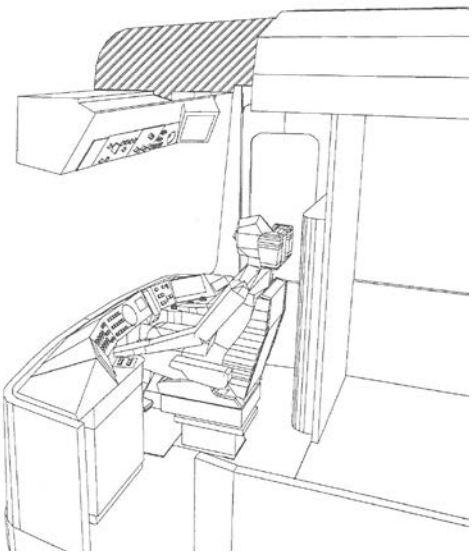


figure 08. part of the development of the driver's cab for the new Amsterdam Tram (Courtesy of Cambridge Ergonomics, UK).

considered at the concept stage of design. This is because dimensionally accurate perspective views can be presented of both the design and the users. This gives the ergonomist the opportunity to be pro-active and to support the other design team members using communication methods that are completely natural for them.

• user behaviour. There is a concern that the use of human modelling systems by non- ergonomists will lead to standardised procedures being developed taking little account of differences in user behaviour. It does not necessarily follow that people will hold dangerous pieces of equipment by the handle as intended. Computer people may do as they are instructed, but real people, particularly when poorly trained, fatigued, under stress, working to a tight schedule and so on, must not be expected to be so disciplined.

validity

The geometric evaluations of fit, reach and vision have been shown to be acceptably accurate by all of our industrial projects which have successfully undergone the transition from computer-based prototype to full-size mock-up and then manufacture.

However, whenever possible we aim to combine the use of SAMMIE with the more traditional ergonomics methods. For example, our involvement with a major supermarket chain commenced with a survey of the musculoskeletal discomfort reported by staff (Porter et al, 1991). This allowed us to expose the high risk workstations, namely the delicatessen and the cashier's workstation, and to subsequently model these using SAMMIE. A detailed postural analysis revealed several causal factors for the reported discomfort. Modifications were then made to the computer models of these workstations in order to improve the working postures. These designs were subsequently mocked-up and fine-tuned in terms of other more subjective attributes such as the aesthetic issues.

In a similar way, SAMMIE was involved in the development of the Fiat Punto, which was voted European Car of the Year in 1995. The system was used to model the prototype Punto from engineering drawings in 1992 to help ensure high levels of driver accommodation for a variety of nationalities (see Figure 14). Subsequently, the focus shifted to the design of the seats with this work being conducted by the Vehicle Ergonomics Group, which is based in the Department of Design & Technology at Loughborough University. Camouflaged prototype Puntos and competitor cars were assessed in terms of driving discomfort during a 60 mile road trial. This analysis led to the subsequent re-design of the Punto

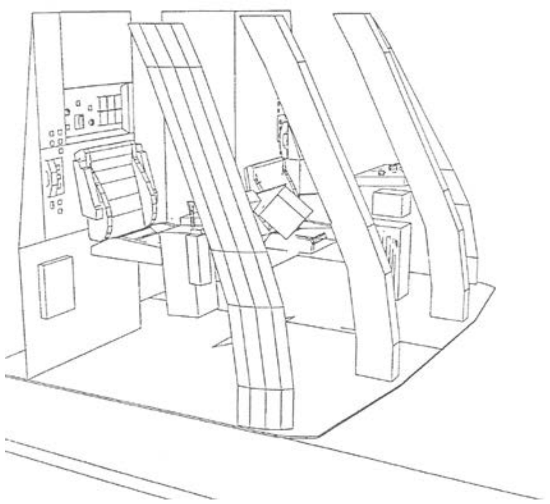


figure 09. a development of the *SAMMIE* model of the *Lantau Express* cab, showing changes to main crash resistant structure resulting from exterior re-styling.

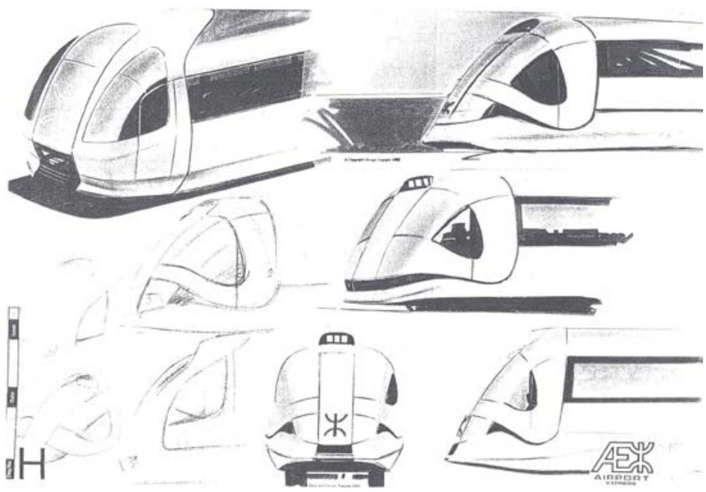


figure 10.artwork showing shoeing some of the exterior styling ideas for the *Lantau Express Train* for Hong Kong's new airport (Courtesy of Design Triangle, Cambridge, UK)

seats and a second set of road trials demonstrated that these changes were successful and that the Punto now had class leading levels of accommodation and comfort. It was essential that the fine-tuning of the seat design was based upon a sound driving package, as this is of paramount importance in the avoidance of driver discomfort[10].

We have always advocated that human modelling systems should not replace user trials with full size mock-ups, unless the design or the design modifications are so simple as to not warrant concern. In-depth user trials can reveal problems with so many more issues including long term discomfort, effects of fatigue, negative transfer of training, error rate, performance and even the acceptance of the product. Many designers, engineers and ergonomists are expectantly waiting for the all-singing, all dancing human modelling system to appear. The likelihood of such a system being developed either in the near or distant future seems remote.

SAMMIE uses CAD techniques both as a tool for ergonomics analyses and as a medium for communication. The work is conducted ‘on screen’ and it requires a high degree of interaction between the members of the design team. The working computer models are often very simple as this helps to focus on the important ergonomics issues. However, at the completion of this work, we often spend nearly as much time again constructing a more detailed and aesthetically pleasing model as this helps to impress the client and impart a greater sense of validity. We find it much easier to ‘sell’ a 3D computer model of an ergonomics design compared to the traditional written report listing recommendations. CAD tools such as SAMMIE encourage creative solutions to functional problems by allowing the design team to quickly explore a variety of options within the design constraints.

The point has been made earlier in this paper that designers and engineers often deal with the ergonomics issues themselves. In the traditional design process, before engineering CAD systems became so widespread, there was a need to make full-size mock-ups periodically for a variety of reasons, including legislative checks, visualisation and determining the appropriate method of manufacture. Many ergonomics issues would have been noticed at this stage as the various people involved interacted directly with the mock-up. CAD has changed the design process from an ergonomics viewpoint as full-size mock-ups are now made less frequently and, when they are made, it is at a later stage in the product’s development. As a consequence, there is a real concern that even some of the more basic ergonomics issues will no longer be self-evident to the design team unless human modelling systems are also incorporated into the design process.

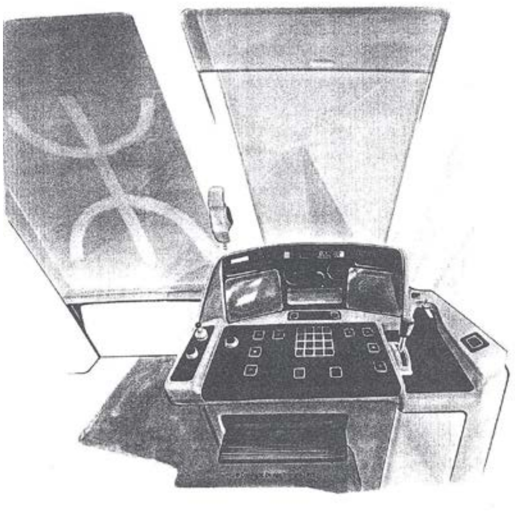


figure 11. an artist’s rendering of a *SAMMIE* driver’s eye view of the *Lantau Express* console (Courtesy of Design Triangle, Cambridge, UK)

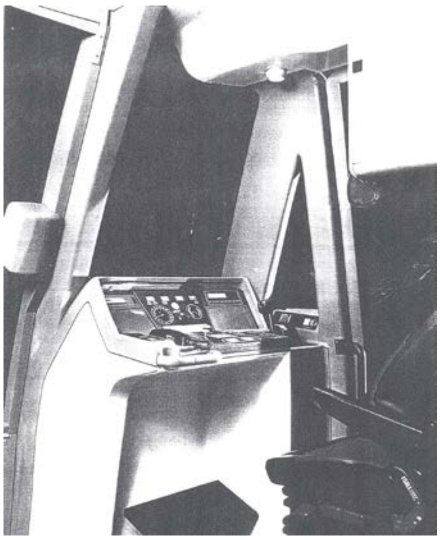


figure 12. a mock-up of the *Lantau Express* driver’s console built from the *SAMMIE* model.

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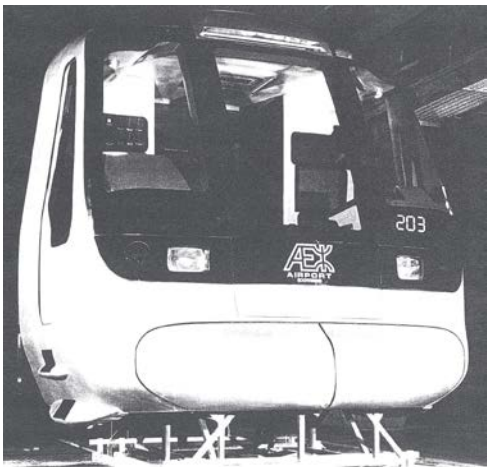

figure 13. an exterior view of the mock-up of the *Lantau Express* train.

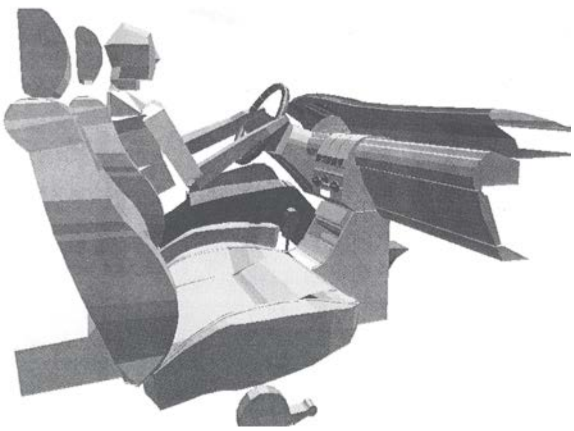

figure 14. *SAMMIE* evaluation of the prototype Fiat Punto interior.