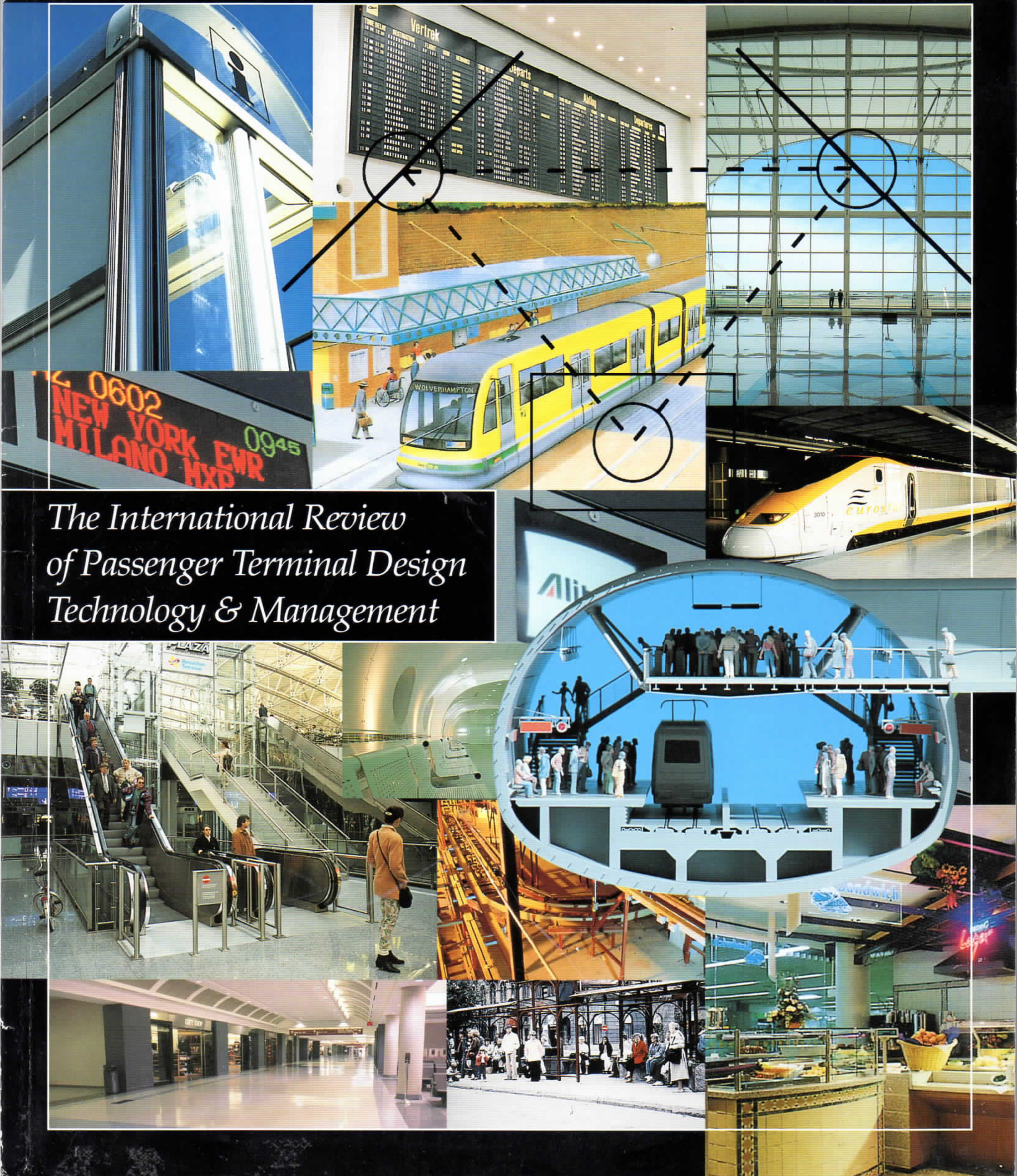
PASSENGER TERMINAL '95



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Pedestrian movement and spatial design

This article discusses the problems of gathering data on pedestrian movement in crowds and gives details of a current research project being conducted in the UK which uses image processing methods for gathering crowd movement data for the design and management of passenger terminals

The requirements of modern terminal buildings are often in mutual conflict: on the one hand there is the need for safety and efficiency of passenger transfer and security; whilst on the other hand there are demands relating to optimising retail area, which as a major source of income in transport facilities, sometimes needs to be given a high priority. There is growing recognition that concourse building design and the study of its effects on passenger movement are a major factor in resolving these issues.

"'Space Syntax' analysis describes a set of techniques for representing and quantifying the pattern of space through which people move in buildings and cities"

'Space Syntax' research conducted at the Bartlett School of Architecture, University College London, has found that the relationship between local and global visual and access fields is central to the successful design of public spaces such as concourse buildings (where the space pattern must be intelligible, rather than maze like). 'Space Syntax' analysis describes a set of techniques for representing and quantifying the pattern of space through which people move in buildings and cities. Recent studies using 'Space Syntax' techniques have found that the pattern of interconnected space in buildings (and in cities) works as a strong predictor of patterns of pedestrian movement and space use. Research also suggests that intelligibility, defined as the correlation between local and global variables in a space network, adds to the safety of buildings, making ways in and out of them more obvious.

The techniques for 'Space Syntax' analysis are as follows: first, the pattern of space is represented as a matrix of lines of sight and access, the 'axial lines', which pass through all the open space in the plan. Then various properties of that pattern, such as 'integration' are calculated, so that its effects on aspects of behaviour can be investigated. 'Global integration' measures the mean depth of all spaces in a plan from the space in question and then normalises this for the number of spaces present in the plan, so that plans of different sizes can be directly compared. Local integration is a measure similar to global integration, except that it accounts for the relationship between each line and all lines within only three changes of direction from it. The latter measure has generally proven the best predictor of pedestrian movement rates.[1]

In a study carried out for British Railways Board in 1992[2], the concourse buildings at King's Cross, Euston and Liverpool Street stations were analysed. The study found that where the patterns of pedestrian activity and movement of the surrounding area were integrated with the movement patterns of the station, the station would act to bring together the different public constituencies in the area; and where there was proximity between movement types and space usage types, (such as shoppers and people waiting for trains) this helped create a pleasant and lively atmosphere. In contrast to this, where station concourses were even slightly set back from the main movement spaces in the city, they tended to generate mono-functional uses of space and the anti-social problems that are associated with this. It was possible to show that the problems of crime and vice associated with King's Cross, had a direct relationship with the way the passenger concourse was embedded in the urban street network.

Figure 1 shows the outcome of a 'Space Syntax' local integration analysis of the King's Cross project proposal. The axial lines in the picture are coloured up in a scale from red through yellow, green and blue, to purple. The warmer the colour, the greater the integration value of the line in question. The diagram shows that the main routes of access into the proposed concourse building and into the existing stations are in the yellow and orange end of the scale. This means that they bear the relatively high rates of integration (and therefore, of movement) similar to those associated with the main streets in the area, which are dark orange and red in colour. The scattergram at the bottom of the picture shows that the proposal, highlighted in red, has a tight line of regression for the local and global measures of integration. This suggests that the proposal would be highly intelligible within the larger urban context.

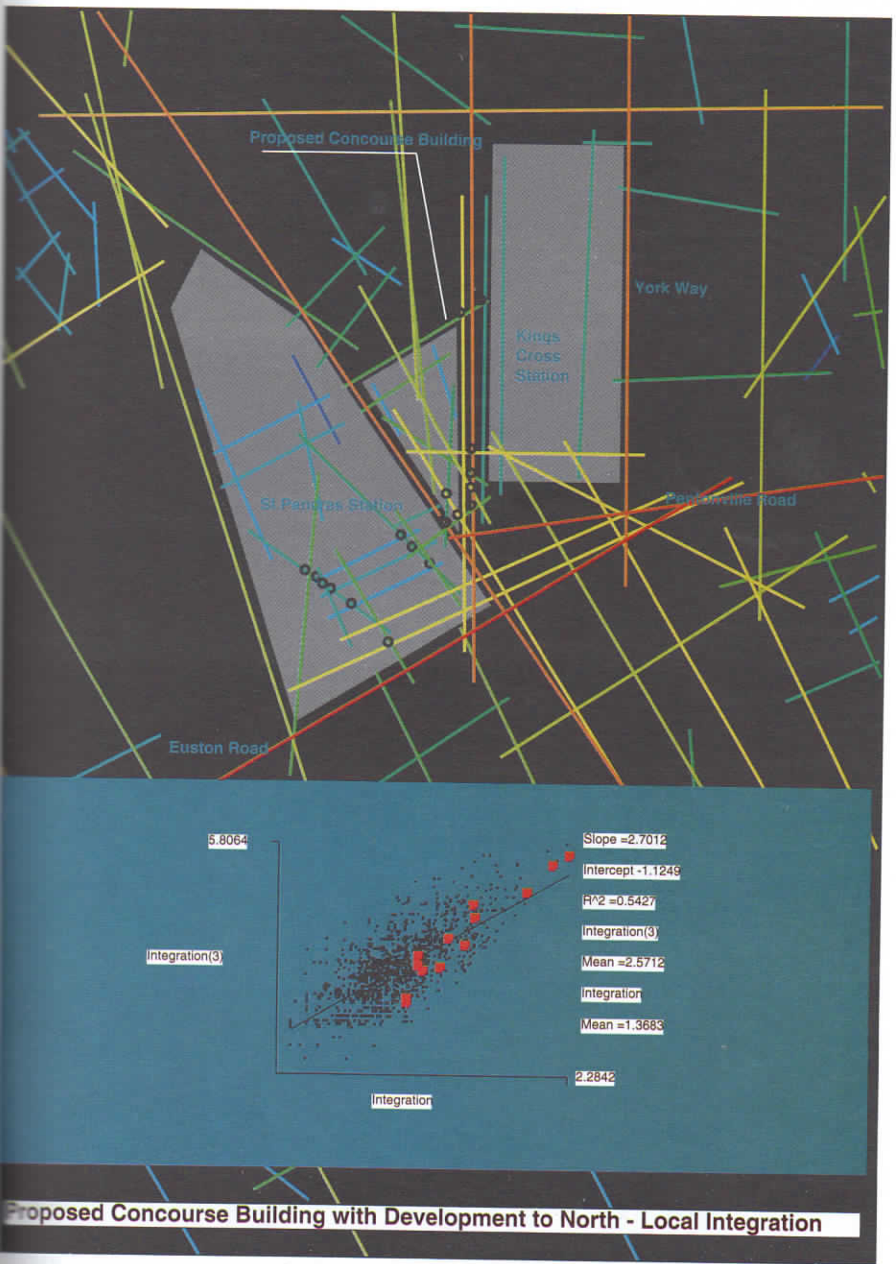

Figure 1: Radius 3 (local) integration model of the Kings Cross passenger terminal project (inset showing scattergram of 'intelligibility', highlighting the project area)

Pedestrian movement

The King's Cross study was based on manual methods for observing patterns of pedestrian movement and behaviour. However, crowd movement has proven more difficult to observe. Whereas in confined spaces such as concourses, people are likely to be moving in a small number of directions; in open spaces the number of directions possible is much more numerous and is likely to be inhibited by groups of standing people. Moreover, unlike vehicles, it is more difficult to identify the single unit of pedestrian movement as pedestrians move their limbs and head in different directions and at different rates.[3]

The current project at UCL and Kings College, London (KCL) (*Automatic Data-capture and Analysis of Crowds in Confined Areas Using Image Processing*; EPSRC GR/J49327) involves the development of an automatic data gathering system for the estimation of crowd density from video images. The study stems from past research at the Centre for Transport Studies, UCL, which developed a technique for computer analysis of 'real world' image sequences of road traffic using imaging sensors, called: *Image Processing for Automatic Computer Traffic Surveillance* (IMPACTS)[4]. The IMPACTS technique uses closed-circuit television systems (CCTV) to give an immediate visual interpretation of incidents, in addition to providing data for the long-term investigation of a site by studying recorded footage. The principle of the system is segmentation of the image into small areas or 'cells', which undergo qualitative analysis, whereby the road is classified as either being empty, or with moving traffic present, or with stationary traffic present. This system is refined further by linking the analysis of adjacent cells, resulting in an overall picture of the current state of the area of interest – making the system more similar to human comprehension of visual information. The technique has proven able to detect incidents in real time with a high degree of accuracy.

The technique being developed at UCL and KCL is based on digitised sequences of video images of pedestrian movement. It employs two methods: One uses an edge detection method, whereby crowd densities are estimated by computing the area of figures in a crowd, and the outline of the figure is measured and calculated with reference to the picture as a whole. This method is less useful in cases of high density (where the background area is too obscured to allow accurate calculation) and in cases of low contrast (where the background is similar in colour to the figures). An alternative method has been developed for such cases, using a fixed reference frame with no pedestrians, which is subtracted from the sequence for comparison.

There are two main uses for the system: The first is incident detection, whereby automatic monitoring of video images will afford back up for human operators by flagging up potentially problematic situations in real time. The system will analyse pre-set parameters such as space occupation and motion levels in order to recognise potentially dangerous situations or incidents. Any sign from the automated system that a potential incident is occurring, will attract the attention of the human operator to pay closer attention to a specific location or monitor.

The second application is the off-line data gathering of patterns of crowd behaviour to be recorded for long-term statistical analysis of site usage. One of the key subjects for study is the relationship between pedestrian flow patterns and building design. The analysis of this relationship will allow for objective comparisons of performance of the building before and after key changes of site design and will support long-term management and planning for optimising site usage. There is also clearly scope for gathering detailed information on crowd numbers for sites that include retail outlets, since the provision of this data can add detail to general information on flow rates.

Crowd behaviour

The commonest indicators of crowd problems are either a build-up in density above the norm, or a static crowd where movement would be expected. The causes of potentially dangerous overcrowding can be many and can differ from site to site. At a football stadium this can be the result of excessive pressure at a turnstile, leading to an overcrowded terrace. Whilst at railway stations the cause can be the closure of a station further down the line or the cancellation of a train, bringing more passengers than planned onto the platform. These are direct causes of overcrowding. Other causes may be due to a specific incident, such as someone collapsing from illness, or a fight, or congestion at cross-flows of movement. This factor may be related to building design, where corridor, staircase or escalator junctions are incorrectly designed, a site may suffer regularly from congestion at particular bottle-necks.

Linked to the fact that the causes of overcrowding may differ from site to site, the classification of the level at which a crowd becomes dangerously dense is also site-dependant; at a stadium, for instance, certain crowd densities would be considered the norm, at other sites, the same densities would seem excessive. It is therefore necessary to create a system that can register differing levels of movement or static occupancy.

In buildings in which we expect free flowing movement, such as passenger terminals, the most obvious indicator of an incident (whatever the initial cause) is cessation of movement. It is the absence of regular vertical head movements that tends to be indicative of a stationary crowd and hence of a potentially dangerous situation in moving crowd environments. Other indicators include:

- movement in the reverse of the expected direction;
- 'swirl effect' – caused by large groups moving in opposite directions, a packed cross-flow with multiple directions of movement;
- turbulence – caused by someone going down in a crowd;
- increase in density, especially if this is at too fast a rate, space filling too fast, too much movement;
- ripple from an epicentre – caused by someone falling down due to illness or by a fight – some people move away (to avoid involvement or trampling), whilst others move in (to intervene or help).

An additional contributory factor to incidents in passenger terminal type buildings is the combination of stationary and moving traffic that is exacerbated by the use of luggage trolleys. Other design problems occur when display boards, which can cause a crowd to collect in their vicinity, are located such that they cause an obstruction in the free-flowing part of the concourse.

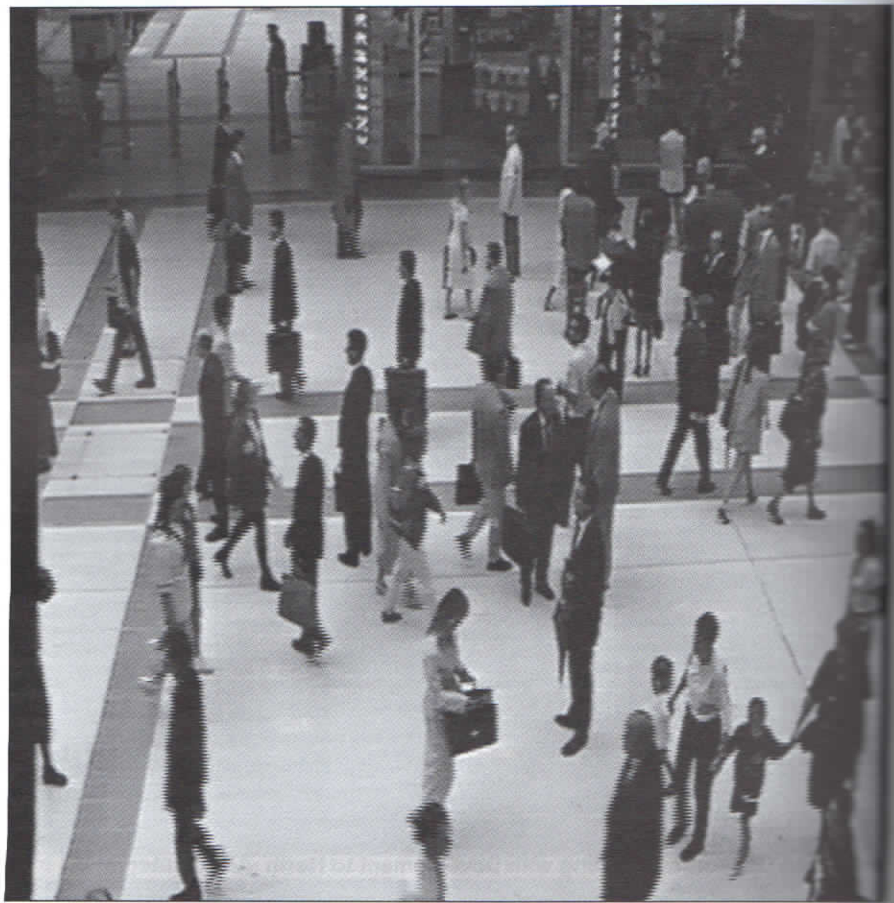

Figure 2: Sample frame taken from video footage of the free-flowing section of a station concourse

In the current project low-level image processing techniques are being used to spot characteristics of the video image that can be associated with those different types of incident. If it is possible to recognise them at this level, the system, with reference to the specific site conditions, can be set-up so that it triggers a signal to the 'Crowd Manager' that a potential incident may be developing.

Identifying patterns

The difficulties of using manual data capture for quantifying pedestrian movement patterns in high density areas have resulted in a paucity of studies into crowd behaviour. The UCL and KCL project is developing an application of image processing techniques in order to gain a better understanding of the building design characteristics responsible for dangerous or inefficient crowd movement. The application uses image processing techniques, along with the principle techniques of 'Space Syntax' analysis, to study the relationship between building design and patterns of movement.

The system currently being developed in the project is to create a graphic image of the relative density of movement at a site. The process is to calculate the relative intensity of a sequence of images. These are selected as a series of pairs of images, which are compared for relative intensity. The cumulative binary information on the pairs of images is exported as a 512 x 512 binary file, which can then be viewed in a graphic manipulation programme, such as Photoshop. The graphic programme displays the image as grey shaded pixels – each grey in the scale relating to the numerical measure of difference between pairs, added up for the total number of pairs.

The following two figures show an example of the technique, taken from video footage shot at the free-flowing section of a station concourse. Figure 2 shows a sample frame from the footage. Figure 3 shows the result of image analysis of the video footage, after colour manipulation of the grey-scale picture in the graphic programme. The grey scale has been translated into a scale of colours in a palette as follows: red, orange, yellow, green, blue, to purple; red denoting maximum movement, purple minimum.

These pictures are a graphic representation of the patterns of space use summed over time. It is this pattern that building design affects, rather than an individual's behaviour. The ultimate aim of the project is to understand this relationship so that designers can be helped to form a better picture of the effects of design decisions on patterns of crowd behaviour.

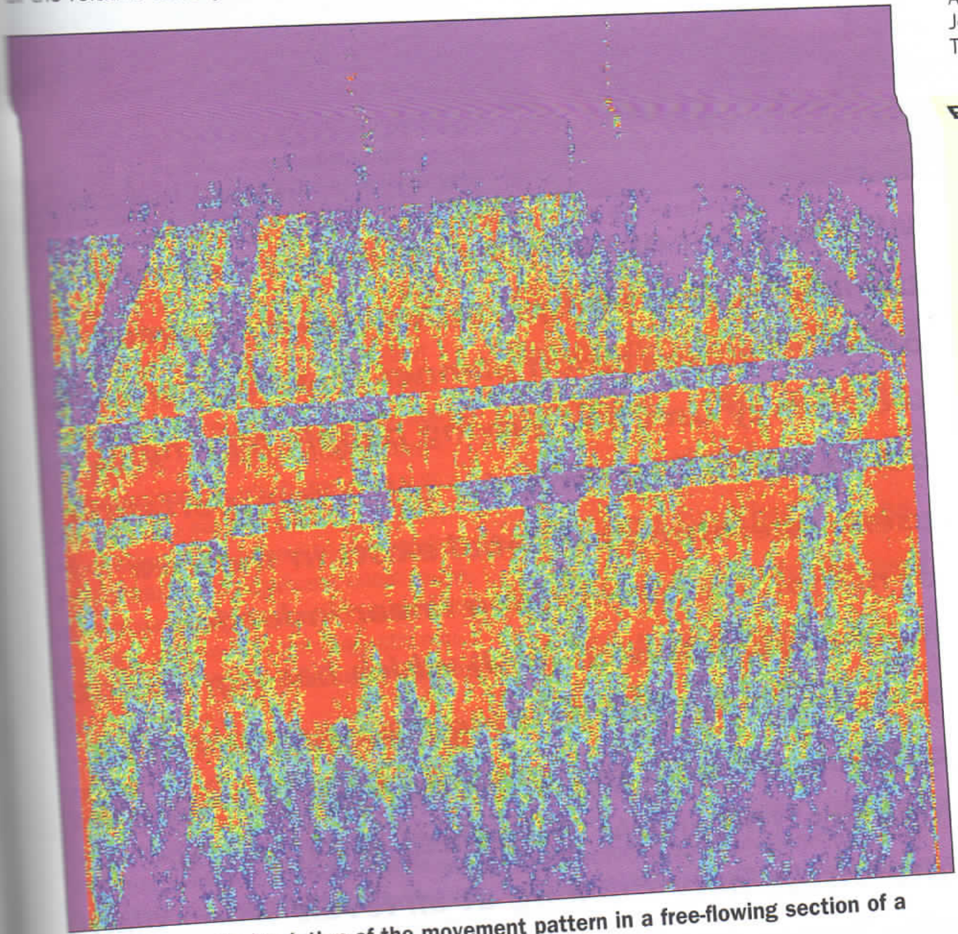

Figure 3: Graphic depiction of the movement pattern in a free-flowing section of a station concourse

Acknowledgements

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1 For full details of 'Space Syntax' methodology, see Hillier and Hanson (1984) The Social Logic of Space; Cambridge University Press.

2 The King's Cross Project: A Study of Passenger Behaviour – with regard to the alternative proposal for the new concourse building; 10 September 1992, The Unit for Architectural Studies, University College London, for Sir Norman Foster and Partners; European Passenger Terminal at King's Cross/St. Pancras, 1992.

3 This is an EPSRC funded project, conducted at the Bartlett School of Architecture and the University of London Centre for Transport Studies, both at University College London (UCL); and the Department of Electronic and Electrical Engineering, Kings College London (KCL).

4 See: Incident Detection and Traffic Surveillance using the IMPACTS Video Analysis System, Neil Hoose, Wootton Jeffreys Consultants Ltd, UK, in Traffic Technology International '94, pp 94-99.

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