CIRCULATION IN SHOPPING CENTRES

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ABSTRACT
Fruin's book "Pedestrian design" documents a number of characteristics for the circulation of pedestrians naturally: along corridors, through entrances, on stairways and using mechanical assistance: lifts and escalators. Various formulae are given. This paper looks at these data and applies them to the circulation of shoppers in a shopping centre.

1 INTRODUCTION

"Circulation is the act of passing from
place to place." (Dober, 1969).

The interior circulation of people in buildings is a complicated activity. There are vertical and horizontal modes; and people may move naturally (as pedestrians) or be assisted mechanically (as passengers). Further complications occur owing to the complexities of human behaviour.

The interior movement of people in buildings must be designed to consider all circulation routes, with the particular objectives of ensuring that:

- All routes should be clearly marked and obvious to all users
- The circulation patterns are rational
- Incompatible types of circulation do not coincide
- The movement of people and goods is minimised

The design of natural elements such as entrances (portals, doorways, gates, etc.), corridors and stairs, and mechanical elements such as moving walkways, moving ramps, escalators and lifts must be coordinated to allow:

- The free flow of people goods and vehicles
- Minimal wastage of space
- The prevention of bottlenecks.

In a shopping centre, however, some of the good design criteria set out above may be intentionally violated, as they are not necessarily conducive to the selling of goods. For instance having attracted shoppers into a store all routes, except the exit from the store, may be clearly marked (emergency exits excepted). The free flow of people may be deliberately reduced by the introduction of display stands along the route offering goods for sale to encourage impulse buying. Circulation may be designed to be irrational, but not obviously, for instance with regard to escalator layouts to cause shoppers to walk around part of a floor, in order to reach the next facility, thus presenting merchandise to prospective shoppers.

No two shopping centres have the same structure, population or circulation patterns. Most shopping centres are designed to occupy two levels and sometimes three. Two levels are generally considered as much as the average shopper is prepared to contemplate, when in a centre. Centres with three levels often have food courts at the upper or lower levels to form an attraction and a contrast to the main sales areas.

The general intention behind the design of a shopping centre or "mall" is to encourage shoppers to enter the centre, then to stop and browse and hopefully to purchase goods on "impulse". The malls should provide a modulated sequence of conditions through side malls, a range of linking corridors, to central squares and features. The purpose is to create a feeling of bustle, excitement, sparkle, competition and a variety of experiences within an organised framework, whereby the shopper has a retreat from the effects of the weather and the motor car and is cocooned within a relatively safe environment.

This paper looks at the theoretical aspects of circulation, in general terms, relating it to observations made by the Author's researchers and then discusses how the knowledge gained may be applied to shopping centres.

This paper is not concerned with:

- the estimation of external traffic flows into a shopping centre,
- the estimation of peak flows down malls,
- shopping centre design, except where it impinges on circulation,
- in-store circulation.

Readers will find Fruin (1971) knowledgeable on some of these matters. Item one is partly the preserve of road traffic engineers, who have generated model approaches to the problem. Work is being carried out in the other aspects and will be reported later.

This paper is concerned with circulation and movement within the shopping centre. It is concerned with the two main circulatory aspects: horizontal traffic flows along malls and through entrances and vertical movement between the different levels in the shopping centre.

Surveys were carried out over two years into shoppers' movements in the Arndale Shopping Centre, Manchester. The author would like to acknowledge the help received from 11 students from the 1990/91 and 1991/92 cohorts in the Building Engineering Department, UMIST, who carried out the survey work as their final year project work and to the management of the Arndale Centre.

Analysis of the data acquired led to the general conclusions presented here. All results have been averaged and rounded. Two conditions were identified and examined: a low level of shopper occupancy (free flow), and a peak value of shopper occupancy (crowded).

The paper is arranged as follows. Section 2 looks at factors affecting movement and circulation. Sections 3 & 4 look at the theoretical factors, which influence the movement and circulation of shoppers and Section 5 provides some observed values with a summary in Section 6. Finally Section 7 gives some dos and don'ts.

Much of what follows. in the theoretical sections, can not be proved and many of the recommendations have been based on observation and experience. Fuller expositions and extensive further references can be found in Tregenza (1976) and Fruin (1971). In addition circulation is a human activity, which is subject to unpredicatable behavior patterns. Interior design is also significantly affected by regulations such as Fire and Safety Codes and these must be taken into account.

2 FACTORS AFFECTING MOVEMENT

"People flow like liquid, following the line of least resistance and greatest attraction" (Beddington, 1982).

FACTOR:	**COMMENT:**
☐ Simple layouts are best. The ability for a shopper to find their way in, through and out of a centre are prerequisites of good design. Simple floor plans overcome the problems of shoppers' unfamiliarity with a centre.	HELPS CIRCULATION
☐ Visual stimulation and variety should be provided by the shop fronts themselves. The size of every shop front affects its trading potential (and hence its revenue/m^2 and its rental).	CURBS CIRCULATION
☐ Design should centre around a series of primary nodes, which include landmarks such as intersecting malls and transfer points such as parking, entrances and exits. Nodes are activity areas where pathways (malls) meet and people relax.	CURBS CIRCULATION
☐ Standard mall designs rely on "magnet" or "anchor" stores to draw shoppers past secondary stores, which provide convenience goods and encourages impulse buying opportunities.	HELPS CIRCULATION
☐ Points of conflict should be minimised to allow shoppers to concentrate on shop displays. For example cross flows, counter flows and right angle bends all cause conflicts. People in a minor flow will alter pace and timing to fit the gaps in the major flow. Ideally shoppers should be able to pick their own speed and direction.	CURBS CIRCULATION
☐ The length of malls is important with 200 m being the maximum distance a shopper is likely to walk. The introduction of bends makes a mall appear longer than it really is. The use of magnet stores at each end of a long mall increases the attraction and reduces the apparent length.	HELPS CIRCULATION
☐ A shopping centre should be able to be explored in one trip, so pause points need to be cleverly placed. Additional breaking up of the mall by the use of courts and squares for public space, rest and recreation areas help to reduce the apparent mall length.	HELPS CIRCULATION
☐ Mall widths should be narrow enough not to discourage shoppers from crossing over to shop on the other side.	HELPS CIRCULATION
☐ Malls are often "landscaped" by the introduction of street furniture (seats, bins, etc.), planters and displays to break up and reduce the perception of space in the mall.	CURBS CIRCULATION
☐ Escalators and lifts need to be carefully sited to invite shoppers onto other levels.	HELPS CIRCULATION
☐ Shoppers have to enter and leave a shopping centre by means of entrances. These entrances interfere with the flow as they often have either a swing door or an automatic sliding door, and because the shopper may be adjusting to the new environment and even looking at a store directory.	CURBS CIRCULATION
☐ The positioning of vertical circulation elements requires great care to avoid "dead-ends" and "double-back" circulation. The elements should be provided in the natural circulation path of shoppers.	HELPS CIRCULATION

3 THEORETICAL ASPECTS OF HORIZONTAL MOVEMENTS

3.1 Mall (handling) Capacity

The capacity C_m in persons per hour (P/H) per metre width of a straight mall or corridor can be given as:

$C_m = 3600 \text{ v D} \ldots (1)$ where: v is average pedestrian speed on the horizontal (m/s), D is the average pedestrian density (P/m^2)

Pedestrian speed and density are not independent. For densities below 0.3 P/m^2 pedestrians can walk freely [*free flow design*]. Above 0.5 P/m^2 there is an approximately linear decrease of average walking speed up to about 3.0 P/m^2, when walking is reduced to a shuffle. The throughput peaks at densities of about 1.4 P/m^2 [*full flow design*]. Walking speeds also vary (systematically) with: type of population (age, sex, grouping, purpose); ability (fitness, handicap); flow direction; gradient; air temperature; floor finish; etc. Table 1 shows the typical pedestrian horizontal walking speeds (m/s) and pedestrian flow rates in persons per hour (P/H) per metre of mall width.

Within each group there will be variations in average speed.

TABLE 1 Possible pedestrian flows rates with grouping

Traffic type	Free flow design ($0.3 P/m^2$)		Full flow design ($1.4 P/m^2$)	
	Speed (m/s)	Flow rate (P/H)	Speed (m/s)	Flow rate (P/H)
Individual shoppers	1.3	1404	0.8	4032
Families, Tourists	1.0	1080	0.6	3024

Pedestrians occupy different amounts of space according to what they are doing or carrying/pushing. Table 2 presents the width requirements for different types or traffic.

Pedestrian traffic can only flow freely along unrestricted routes. Malls and corridors are rarely free of obstructions: Table 3 provides a number of examples. Thus for example the effective width of a 5 m wide mall reduces to 4 m, if a row of people are seated along one side.

TABLE 2 Occupancy widths of pedestrians

Pedestrian type	Occupancy (m)
Two men abreast	1.2
Man with bag	1.0
Porter with trolley	1.0
Woman with pram	0.8
and child alongside	1.2
Man on crutches	0.9
Wheel chair	0.8

TABLE 3 Reductions in corridor widths

Obstruction	Reduction (m)
Ordered queue	0.6
Unordered single queue	1.2 - 1.5
Row of seated persons	1.0
Coin operated machine	
one person	0.6
queue	1.0
Person waiting with bag	0.6
Window shoppers	0.5 - 0.8
Rough/dirty surface	0.2

3.2 Entrance Capacity

An entrance (gate, door, portal, turnstile, etc.) forms a division between two areas, for reasons of privacy, security, access control, etc. Basically entrances introduce a constriction in corridor width. The same general conditions apply as for corridors, but flow rates are reduced. Table 4 indicates probable flow rates in persons/hour (P/H) per metre width of entrance.

Table 4 Entrance capacities

Entrance type	Flow rate (P/H)
Gateway	3600
Clear opening	3600
Swing door	2400
Swing door (fastened)	3600
Revolving door	1500

4 THEORETICAL ASPECTS OF VERTICAL MOVEMENTS

"There is a logistical problem that all goods, which enter a shopping centre by truck, must all leave in the arms of the shoppers" (Barney, 1993)

4.1 Stairway Capacity

Stairways impose a more stylised form of movement on pedestrians, allowing higher densities than are possible on a level surface. For free movement while walking on a level surface a pedestrian requires some 2.3 m^2, whereas a stair walker needs only to perceive two vacant treads ahead (and room for body sway) and consequently occupies some 0.7 m^2. Thus a *free flow design* density of 0.6 P/m^2 is possible and a *full flow design* density of 2.0 $P.m^2$. Table 5 gives typical pedestrian walking speeds on stairs and the resulting flows in persons per hour (P/H) per metre width of stairway for different groups of shoppers.

The pedestrian speed along the slope is about half that on a level surface, but some compensation is provided by the increased densities possible. Speed however, is very much dependent on the slowest stair walker owing to the difficulty in overtaking under crowded conditions. Also higher walking speeds in the down direction are very often not possible owing to the need for greater care. This results in similar speeds in both directions.

Speed is also affected by the angle of inclination and step riser height. A rule of thumb has been to match the average adult stride (on a stairway) of 0.6 m with the sum of twice the riser height plus the tread. This results in a range of riser heights of 120 mm to 190 mm and treads of 360 mm to 220 mm, which gives possible inclinations from 18° to 40°. An efficient inclination is 27°.

TABLE 5 Stairway capacity

Traffic type	Free design flow ($0.6\ P/m^2$)		Full design flow ($2.0\ P/m^2$)	
	Speed (m/s)	Flow (P/H)	Speed (m/s)	Flow (P/H)
Young/ middle aged men	0.9	1620	0.6	3600
Young/ middle aged women	0.7	1260	0.6	3600
The elderly, Family groups	0.5	750	0.4	2400

An empirical formula for stair capacity is:

$C_s = 3000\ v\ D = 0.83\ C_m$ ... (2) where: D is the average pedestrian density (P/m^2)
v is average forward pedestrian speed (m/s),

4.2 Escalator (handling) Capacities
Escalators provide a mechanical means of continuously, moving pedestrians from one level to another. In simple terms escalators are moving stairs.

A number of factors affect escalator handling capacity: speed, step width, inclination, and boarding and alighting areas. The handling capacity of an escalator is given by:

$C_e = v\ k\ s\ 3600$

$= 9000\ v\ k$ ... (3)

where: v is speed along the flat (m/s)
k is average density (people/step)
s is number of steps/m (2.5/m)

Table 6 gives handling capacity (C_e) values in persons/hour (P/H) for a theoretical occupancy (density k) of two persons per 1000 mm step (k=2.0), three persons per two 800 mm steps (k=1.5) and one person per 600 mm step (k=1.0) for an escalator with a rated speed of 0.5 m/s. Throughput does not increase necessarily, if increased escalator speeds are employed, owing to passenger difficulties in boarding on and alighting from the higher speeds units.

TABLE 6 Escalator handling capacity (P/H)

Speed	-------- Step width (mm) --------		
	1000	800	600
0.50	9000	6750	4500
0.65*	11700	8775	5850

* not generally used in shopping centres

4.3 Lift (Handling) Capacity
The handling capacity (passengers/hour) of a lift is given by:

$C_l = 3600\ P/INT$ ... (4) where: P is the number of passengers carried
INT is the time between car arrivals

In shopping centres lifts are used to transport shoppers to/from car parks and to allow shoppers with prams and pushchairs to access all levels. Quite often observation lifts are used for this latter purpose. The handling capacity of a group of two, 16 person, lifts serving four levels probably has an interval (INT) of some 75 s, giving a possible handling capacity of some 600 persons/hour.

5 PRACTICAL MEASUREMENTS OF MOVEMENTS

Two levels of occupancy were observed: uncrowded, which could be called free flow, and crowded.

5.1 Malls and Entrances
■ The walking speed of shoppers in free flow was 1.3 m/s and in crowded conditions was 1.0 m/s. (See Table 7.)

■ The density of shoppers in free flow was 0.2 P/m^2 and 0.45 P/m^2 during crowded conditions. The density could increase to 1.0 P/m^2 at pinch points (areas where the mall size was inadequate eg at a food court).

■ Counterflows reduce mall capacity by 15% compared to unidirectional flows.

■ The effective mall width reduces (equal to actual mall width minus street furniture and window shoppers), as the condition changes from free flow to crowded. This results from more stationary shoppers looking into shop windows.

■ Mall widths should be of the order of 6-8 m wide as a compromise between too wide to cross and too narrow to pass along.

TABLE 7 Actual mall pedestrian flows rates
(per metre width of mall)

Traffic type	Free flow (0.2 P/m^2)		Crowded (0.45 P/m^2)	
	Speed (m/s)	Flow rate (P/H)	Speed (m/s)	Flow rate (P/H)
All Shoppers	1.3	936	1.0	1620

■ Walking speeds reduce to 0.7 m/s, when shoppers pass through entrances.

5.2 Stairs

The dimensions of a stair limit many aspects of locomotion. For instance pace length is restricted by tread depth (going). More accurate cones of vision are required for step placement and assistance is often required by the use of handrails. The energy consumed is related to the riser height, which should be less than 180 mm, but not too shallow else walking rhythm is affected.

■ Free flow density was found to be approximately 0.4 P/m^2 and crowded density reached 0.8 P/m^2.

■ Shoppers' speeds when using stairs varied according to group with an average of 0.7 m/s. (See Table 8.)

■ The stair capacity under free flow was about 900 P/H/m and under crowded conditions was about 1800 P/H/m

TABLE 8 Stairway (handling) capacity (P/H) (per m width of stair)

Traffic type	Speed (m/s)	Design flow Free (0.4 P/m^2)	Crowded (0.8 P/m^2)
Men	0.8	960	1920
Women	0.7	840	1680
Elderly men	0.5	600	1200
" women	0.6	720	1440
Children	0.8	960	1920
Push chairs	0.5	600	1200

■ There is a tendency for more down traffic than up traffic in the ratio 60/40.

■ A minor flow will reduce a major flow by effectively reducing the stairway width by some 750 mm.

5.3 Escalators

■ About 80% of shoppers use the escalators to reach other levels in a shopping centre, as rarely will they have to wait.

■ Even under queuing conditions 100% step utilisation is not achieved.

■ 800 mm escalators have an assumed step utilisation of k=1.5. However, the escalators observed only loaded to k=0.5 step utilization under free flow conditions to k=1.0 step utilisation under crowded conditions. The width of an 800 mm step is not large enough to accommodate two people comfortably side by side. To achieve this a 1000 mm is recommended. Then a higher utilisation can be achieved.

■ Actual handling capacities range from 33% of theoretical for free flow to 66% for crowded conditions.

An interesting point is that it takes just under one second (0.92 s) for a step to appear at a boarding point of a 0.5 m/s escalator. This is too fast for most people to get onto each vacant step.

TABLE 9 Actual escalator handling capacity (P/H)

Speed	Step width 800 mm	
	Free flow	Crowded
0.50	2250	4500

5.4 Handling Capacity of Lifts

Observation, pram lifts, car park and other lifts are provided in shopping centres, but not in sufficient quantities to serve more than a fraction of the shoppers. They are mainly used by the elderly, infirm, disabled, mothers with children and push chairs, and people with heavy packages. Observation lifts are sometimes installed as a feature to provide a visual impact in retail complexes. They do contribute to the circulation aspects of a shopping centre, but can not be considered a major constituent as passengers often ride one simply for the ride.

Lifts can not handle the traffic volumes handled by other facilities; and have a considerable throttling effect on pedestrian movement. For example a group of two, 16 person, observation lifts, serving two retail levels and two car park levels, probably has a possible handling capacity of only about 300 persons per hour. This is due to the need to have long door dwell times, slow motion dynamics, the slowness of passenger loading/unloading and low levels of occupancy owing to the presence of prams, push chairs and baggage. Thus the recommendation, to install as many escalators as possible in shopping centres, is essential for the traffic handling of the large volumes of traffic.

6 SUMMARY

Shoppers do not seem inclined to populate (in density terms) a shopping centre to the high levels found in other public places: eg. railway stations. Also the walking speeds vary widely and are close to the natural (comfortable) speed of 5 km/H.

Element	Characteristic	Range	Criteria
Malls	Density (theoretical)	0.3/1.4	free/full
	Speed (theoretical)	1.3-0.6	free/full
	Density (measured)	0.2/0.45	uncrowded/crowded
	Speed (measured)	1.3-1.0	uncrowded/crowded
		0.7	through entrances
Stairs	Density (theoretical)	0.6/2.0	free/full
	Speed (theoretical)	0.9-0.4	free/full
	Density (measured)	0.4/0.8	uncrowded/crowded
	Speed (measured)	0.8-0.5	uncrowded/crowded
Escalators	Handling capacity (theoretical)	6750	
	Handling capacity (measured)	2250/4500	uncrowded/crowded
Lifts	Not measured accurately, but ratio theoretical/actual approximately 2/1.		

Densities in P/m^2: Speeds in m/s: Handling capacities in P/H.

7 FACTORS AFFECTING CIRCULATION - DOs and DON'Ts

A shopper spends a large percentage of the time in a shopping centre walking and browsing on the level. The levels of density are probably lower so shoppers feel comfortable. The shoppers' primary (and preferred) means of transfer from one level to another is an escalator. The secondary means of transfer from one level to another is a stairway and an additional means of transfer from one level to another is a lift. Persons moving on a stairway or escalator will exhibit more body sway, in order to keep their balance, and therefore require more space.

□ Malls should be designed to avoid "pinch points".

□ Stairs should have a minimum width of 2.5 m.

□ Stairs should be "channelised" by use of a separating rail, which aids movement and can divide up and down flows

□ Stairs should always be located near to escalators to form a secondary means of vertical circulation. (Important when an escalator is out of service.)

□ To ease flows stair risers should be less than 180 mm and the slope less than 30°.

☐ All stairs should have intermediate landings for rest and circulation diversion between flights of no more than 16 steps.

☐ Adequate clear areas should be provided at access points of stairs to allow queuing and safe movement.

☐ Adequate clear areas should be provided at boarding and alighting points of escalators to allow queuing and safe movement, perhaps with barriers to discipline users.

☐ There should be at least two escalators at each location to serve two traffic flows.

☐ Escalators should be located in a parallel arrangement, probably on a slight offset.

☐ The maximum rise for an escalator should be less than 6 m.

☐ Escalator step widths of 1000 mm are to be preferred, not necessarily to permit passengers to stand side by side and to allow shopping to be carried.

☐ The escalator step riser is 230 mm which is larger than the recommended maximum height of 180 mm, so walking on the stopped escalator is tiring. [Why is this ? Historical or deliberate ?]

☐ Maintenance of escalators should be carried out when the centre is closed.

☐ The reliability of escalators leaves a lot to be desired, some investigation by manufacturers, as to the problem areas should be carried out.

☐ Car operating panels within lifts should be simple in layout and operation.

☐ Maintenance of lifts should be carried out when the centre is closed.

☐ All stairs, escalators and lifts should be adequately illuminated.

☐ All stairs, escalators and lifts should be readily visible.

☐ All stairs, escalators and lifts should be easily identified and well signed.

8 REFERENCES

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BIOGRAPHICAL DETAILS

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