# Experiencing mobility in underground transport systems.

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# Experiencing mobility underground.

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**ABSTRACT:** A liveable city requires accessible transport systems to serve a diverse range of people; otherwise, citizens may find parts of the city inaccessible. Socio-economic consequences of severance are well known, however the impact of what the author names as 'vertical severance' (VS) appears less understood, owing to the relatively recent introduction of step-free underground stations. This paper explains **What** attitudes and issues caused VS. **So What** were the implications and actionable insights of VS within the context of liveability within cities, and **What Next.** To serve a diverse population recommendations include incorporating new design procedures, and new design ideas for existing and new stations. Furthermore, VS could become a measure that describes the how liveable a city is for people of all ages and abilities. In conclusion, a sustainable vision for People Centred Mobility in Liveable Cities requires zero VS within stations and other transport systems.

**INTRODUCTION:** '...when a man is tired of London, he is tired of life; for there is in London all that life can afford.' Samuel Johnson (20 Sept. 1777).

In order to find solutions to mobility within liveable cities, we have to identify mobility concerns that make a city liveable or unliveable. This paper identifies Vertical Severance (VS), that is a new term defined by the author, that summarises the physical separation and suppression of specific populations from the city and consequent socio-economical mobility concerns, owing to unfavourable or missing access.We can see the impacts of VS in stations and parts of cities by observing fewer seniors who may be tired or weaker than others, children, people with mobility concerns, people with mobility aids, and people carrying shopping, luggage or pushing prams. The following case study explains the reduction of diversity of people within stations, compared to national averages and research, owing to decisions taken throughout the past 150 years of 'Tube' operations in London.

**How did VS materialise?** The first underground stations, dating from 1863, were generally shallow cut and cover stations, with stairs serving side platforms including the Metropolitan, Hammersmith and City, Circle (1870), and District Lines (1870). The first deep 'Tube' tunnelled underground stations were operational from 1890 and included the Northern (1890), Central (1900), Piccadilly (1906) and Bakerloo Lines (1906). Those mentioned deep 'Tube' stations had typically two large 40 people sized lifts, and transported passengers to the lower concourse, and stairs to descend

to ‘island’ platforms. During the 1920-30s reconstruction of interchange stations, escalators replaced lifts at Piccadilly, Bank, Holborn, and Camden Stations amongst others, owing to increasing passenger numbers. Subsequently, stations on the Victoria (1968) and Jubilee Line (1977) omitted lifts and provided only escalators and stairs. It was only in 1999 during operation of the Jubilee Line Extension (JLE) that two of the three largest employment areas, Westminster and Tower Hamlets, had step-free LUL stations (Capital, 2004). At the time of writing, the City of London has no step-free stations. The consequences were that only 18% of LUL Stations were step-free (TfL 2009a). We can see in Figure 1 an example of a busy small lift serving Westminster LUL station that commenced operation in 1999, where there is limited space for customers to distribute, queue, wait, or rest on seats. Such a design could cause delay, distress and unease with customers.

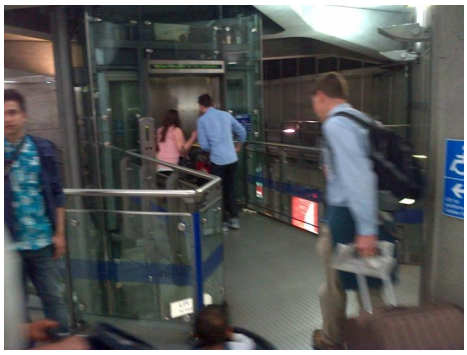

Figure 1: Queues formed early at lifts at JLE Westminster Station. (Harding 2013)

Table 1: LUL’s Estimate of PRM Groups A-E (Wood 2006)

<table>
<tr><td colspan="4">Physically Impaired</td><td colspan="4">Encumbered</td></tr>
<tr><td colspan="3">Disabled</td><td>Elderly Impaired</td><td colspan="2">Adults with young children</td><td>Heavy luggage/ Items</td><td>Medium luggage/ Items</td><td>Heavy shopping bags</td></tr>
<tr><td colspan="3">0.5%</td><td rowspan="3">1.0%</td><td colspan="2">0.5%</td><td rowspan="3">1.5%</td><td rowspan="3">3.5%</td><td rowspan="3">3.5%</td></tr>
<tr><td>Wheel-chair</td><td>Stick/ Aid</td><td>Dog/ Helper</td><td>Pram</td><td>Walk</td></tr>
<tr><td><0.01%</td><td>0.45%</td><td>0.05%</td><td>0.25%</td><td>0.25%</td></tr>
<tr><td>A</td><td>B</td><td>B</td><td>B</td><td>E</td><td>E</td><td>D</td><td>C</td><td>C</td></tr>
<tr><td colspan="4">1.5%</td><td colspan="5">9.0%</td></tr>
<tr><td colspan="9">10.5%</td></tr>
</table>

**Who experienced VS?** We can see in Table 1 observations of People with Restricted Movement (PRM) travelling within existing LUL stations, at the time when only 18% of stations were step-free (TfL 2009a). We can learn from Table 1 that LUL

stations contained only 1% of Elderly Impaired, ½ % of children and ½ % of disabled people. Those percentages are much lower than wider demographic evidence that we can see in the following analysis.

Aging Passengers. We can learn from Table 1 that there are a hundred times (1%) more elderly impaired passengers than wheelchair users (<0.01%, or less that one person in ten thousand) whilst Aging passengers have the following mobility concerns. Huppert claimed that older people had increased falling injuries owing to reduced balance from rheumatism, less flexible joints, weaker muscles and slower walking speed (2003, pp. 34-36). In addition, Huppert claimed that loss of cognition, attention, and language, numerical, spatial, learning and memory abilities affected the elderly (2003, pp 37-46). Furthermore, 13% of people aged over 55 had reduced hearing and vision; that percentage increased to almost 45% by the age of 80 years, and affected aging males most (EDC- University of Cambridge, 2005a). ONS forecasts predict that individuals over 65 years will increase to 23% of the UK population by 2035 (2013) whilst mobility will decrease by 25% from the age of 55 years, and 50% by the age of 80 years (EDC- University of Cambridge, 2005a). Older people will continue working, owing to changes in pensions and changing attitudes. Moreover, aging women need consideration owing to greater movement loss, whereas aging males suffer more sensory loss (ibid). Marsden et al claimed *confidence* was essential, and that if elderly passengers had an adverse travel experience, they would never use that type of transportation again, and that would increase their isolation in their community (2008, p.6). In explanation, aging passengers are more prone to accidents, have difficulty hearing and seeing information and finding their way in stations and get tired by lengthy and complicated routes and changes of level. Thus, to increase diversity, stations need sufficient lifts to cater for predicted and latent demand, resting areas, simpler routes with few changes of level, and better way-finding.

Younger passengers: Younger passengers and their parents or carers have mobility concerns, owing to insufficient lifts and LUL's code that forbids taking children in prams on escalators. Nevertheless, Table 1 shows that there were twenty five times more prams users (0.25%) than wheelchair users (0.01%). A possible explanation is that parents preferred to access better schooling located in better areas and risk a fine, owing to children who lived in economically disadvantaged areas suffered from worse schooling fewer skills, less access to employment, less pay (if employed) and dependence upon government benefits (Bagihole, 1997, p.165). Thus, to increase diversity, stations need sufficient lifts to cater for forecasted and latent demand, and with wider lifts and gates, suitable for double buggies (see the Copenhagen Metro exemplar in Coleman 2003, p.302), rest areas, simpler routes with few changes of level, and better way-finding.

Figure 2: Passengers waiting for a Lift in Singapore (Sim 2010).

Women passengers: We can see in Figure 2 seven women were waiting for a lift carrying small bags, compared to two men. In explanation, Bassey claimed that women were weaker than men by about a third, owing to smaller physique, reduced strength and childbearing experiences (1997, pp.289-297) and age related motion losses were greater with females (EDC-University of Cambridge, 2005a). Accordingly, specialists, such as psychologist Huppert claimed that *'older women should therefore be a priority in inclusive design'* (2003, p. 35). A further concern for women travellers was crime where prolonged routes, with multiple changes of level or course, with dead-end or areas with poor natural surveillance. Figure 2 also illustrates a 'people centric' lift design where people are willing to wait in comfort, safety and security. Nevertheless, the large queue suggests an extra lift would increase the flow and Figure 2 provides a telling example to why women's mobility concerns require attention. Thus, to increase diversity, stations need sufficient lifts to cater for predicted and latent demand, sized appropriately, in light, bright surroundings with surveillance, simpler routes with few changes of level, and clear way finding.

'Different Ability' passengers: Owen found five distinct groups, whom she called 'different ability' (2003, pp 63-65). Consumer Group 1, were independent with positive attitudes; whereas Consumer Group 5 were over 70 years old, lived in rented council housing and belonged to a dependency culture (2003, p. 62). Owen claimed all groups had trouble finding paid employment (2003, p. 63) and a possible explanation is attitudes of employers, as Payling states below (2003, p. 395):

*Disabled people in work do not highlight their problems to employers until a crisis point is reached and the retention of their job is jeopardised. People in this situation often leave employment because the negotiations required seem too difficult.*

Moreover, attitudes towards people with 'different ability' may explain a 58% unemployment rate of people with disabilities (Clarkson et al, 2003, pp 544-546), that was almost five-fold more than London's unemployment rate of 12% (ONS 2007b). To illustrate problems of mobility in cities, we can learn from Table 1 that there are forty five more people with sticks or walking aids (0.45%), and five times more blind people with dogs (0.05%) than wheelchair users (<0.01%). In contrast, TfL claimed that 17% of Londoners had disabilities (2006, p3) and Department for Transport claimed that *'around 2,500,000 people have disabled people's parking badges'.'About 8,500,000 people have arthritis (Source: Arthritis Care)' that reduces the ability to walk up stairs or escalators, 'Around 2,000,000 people have impaired sight, even with glasses or contact lenses (Source: RNIB)'. ' About 4,600,000 people have difficulty in walking, and 800,000 of these people use a wheelchair' (2011, p 16-18).* Furthermore, prior to the Equality Act in 2011, designers considered the physically impaired represented in Table 1 as 1.5%, and then afterwards we can see a seven-fold increase to 10.5%. Nevertheless, such changes did not automatically result in an increase in provisions or diversity.

In summary, this research shows that some individuals who have mobility concerns are absent from Table 1 data. To increase diversity, transportation designs must provide sufficient lift quantity, sized and located to suit forecast and latent demand and integral to VCE passenger movement calculations. Moreover, stations need to provide bright surroundings, with surveillance, simpler routes, with few changes of level and better way-finding. To accommodate increased diversity and a VS-free vision we shall examine next the attitudes that need addressing.

**Increased diversity and VS-free solutions remain elusive**

We shall examine why implementing a VS-free Vision appears elusive to clients, policymakers, researchers and designers. For example, the lack of technology does not account for the lack of step-free stations owing to availability of lifts from the 1890s. Instead, the following interdisciplinary literature review summarises four possible scenarios found within social sciences, psychological and anthropological, engineering, architecture, urban and transport planning that present obstacles to overcome. Firstly, out-dated, parochial, and discriminatory attitudes were evident in research, policy, theory, and guidance in the latter part of the twentieth century. In the seminal 1976 edition of Designing for the Disabled, Goldsmith claimed 'it was not essential' to build accessible underground stations for wheelchair users, owing to the high cost of lifts (1976, p. 401 item 77200), US$10m for the BART in San Francisco,

and US$44-60m for the Washington DC metro built in 1971 (ibid, p60, para. 1411). LUL built two underground railways without lifts during the 1960- 70s era, the Victoria Line (operational 1968) and Jubilee Line (operational 1977). Goldsmith's guidelines, published by the Royal Institute of British Architects, formed the basis of the British Standard Code of Practice on Access for the Disabled to Buildings in 1967 (CP96). Later revisions produced BS5810 (1979) and developed into Part M of the Building Regulations in 1987 (Coleman 2003b, p5). Furthermore, railway stations were exempt from Building Regulations, including Part M. In contrast, housing, government and commercial buildings incorporated lifts and reasonable adjustments.

Secondly, designers, operators, and clients of stations, who were mostly men, lacked empathy for other groups outside their own kind. For example, Warburton claimed young designers, who were predominantly male, designed specifically for themselves and other young people whom they perceived as sexy (2003, pp 255-6). Marsden et al claimed that transportation planners did not consider the extra time it took an elderly person to cross the road at a traffic light, and designed *'systems for the able-bodied, not for those who were frail. There was a desire for a gentler, more comfortable environment.'*(2008, p5). Marsden eloquently summarised that failure to understand user needs as *'transport planners from Venus, older people from Mars'*. Baron–Cohen provides a psychologist's explanation claiming that the male brain suited subjects that depended upon *'constructing systems'* such as maths; physics and engineering whereas women's 'empathizing' brain suited other professions, including law and administration (2005).

Thirdly, according to De Waal (2009) 'in group' bias created negative impacts for the less dominant group. Milroy claimed that male dominance within built environment professionals adversely affected all demographic groups (1992). To demonstrate adverse consequences for women, we can see in Figure 2 that lifts were attractive to women, whereas Table 3, Question 8 showed 95% of respondents (who were 72% male) liked to use escalators (with an 82% confidence level). Lifts may have disappeared, owing to a male bias towards escalators, and few women in decision-making roles. We can see male dominance in Architects Registration Board data that 80.5% of architects were men and 19.5% women, out of 32,754 registrants (email dated 14th May 2010). Moreover, De Graft-Johnson claimed that worse security and a less inclusive design were the consequences of having fewer women architects (2003, p21).

Fourthly, professional ethics and design processes require a 'people centred' and sustainable focus. For example, Owen et al claims we all benefit from 'cradle to grave' design principles for the built environment (2003, p 62). O'Neil accused built environment professionals of having a passive and self-serving culture that produced disappointing results (2005, p77). Whilst Porritt claimed that, a *'client dependency*

*syndrome'* harmed sustainability and the world (lecture the RIBA on Tuesday 13 October 2009). In explanation, designers may consider that forecasting trends is beyond their expertise and risks their professional indemnity. Instead, designers need specific requirements, owing to inherent inflexibility in buildings. Thus, clients could consider improving forecasting and establishing briefs, whereas designers develop professional ethics, leadership, independence, and vision.

In summary, obstacles to increased diversity, lifts and people-centric designs included established paradigms and attitudes. Moreover, the risk is that similar issues may exist elsewhere, owing to the internationalisation of attitudes and paradigms. Thus, we next consider how VS experiences and attitudes may influence contemporary design by examining experiences and attitudes of regular Tube users employed either as a client or as a designer on a major underground railway programme in London.

**Experience and attitudes of Tube users vary according to demography.**

This survey aims to see how individual experiences and attitudes were a reflection of demography and role within the surveyed organisation. The research aims were as follows: 1) Improve understanding of individual concerns relating to comfort, security, gentleness, inclusivity, and confidence of Tube users. 2) Understand how demographic backgrounds affected individual experiences. 3) Identify actionable insights to improve mobility in cities for priority groups of people, including young, elderly, different ability, Gay/Lesbian or Transsexual (GLT), and women.

**Survey Questions:**

About You: Question 1 asked about an individual's employment, as either a client or designer. Question 2 identified whether their role was Architect, Engineer or Other. Question 3 identified demographic background including age, sex, GLT, or disability.

Comfort: Questions 4 to 9 and 11 asked about how they experienced certain physical constraints within stations. Question 10 asked whether the cost of services affected their experience.

Security: Questions 12 to 18 asked how much they experienced crime in vulnerable unsupervised locations, fear of crime or anti-social actions affected users.

Gentleness: Questions 19 to 23 asked how they experienced stations from a cognitive and physical perspective.

Confidence: Questions 24 to 28 asked how much confidence they experienced.

Empathy: Question 29 and 30 asked how much awareness and empathy they had towards others users.

Table 2: Survey Data

| | Respondents | No. | % |
|---|---|---|---|
| Profession | Engineer | 18 | 38% |
| | Architect | 13 | 28% |
| | Other Disciplines | 16 | 34% |
| | Total | 47 | 100% |
| Demographics | Under25 years | 10 | 21% |
| | 25 to 55years | 21 | 45% |
| | Over 55years | 16 | 34% |
| | Total | 47 | 100% |
| | Male | 34 | 72% |
| | Female | 13 | 28% |
| | Total | 47 | 100% |
| | GLT | 1 | 2% |
| | Disabled | 0 | 0% |

Table 3: Baseline Mean Results

Q= Question, CL=Confidence Level %

| | Q | CL % | 'Baseline' Mean Response for all responses |
|---|---|---|---|
| Comfort | Q4 | 76 | 70% of the group had not found it difficult to walk up or down stairs |
| | Q6 | 69 | 61% of the group had used a lift |
| | Q8 | 82 | 95% of the group liked to use escalators |
| Discomfort | Q5 | 79 | 56% of the group had difficulty travelling with heavy baggage |
| | Q6 | 69 | 23% of the group had not used a lift |
| | Q7 | 79 | 34% of the group had experienced excessive journey times when using a lift at Tube stations |
| | Q9 | 66 | 36% of the group had not used a seat when tired |
| | Q10 | 68 | 34% of the group had found that the high cost was a barrier to travelling |
| | Q11 | 69 | 49% of the group felt exhausted after travelling on the Tube |
| Secure | Q15 | 74 | 60% of the group had felt secure at crowded Tube stations |
| | Q17 | 75 | 60% of the group had felt secure waiting by lifts by themselves at Tube stations |
| | Q18 | 74 | 74% of the group had not experienced crime on the Tube |
| Insecure | Q12 | 72 | 53% of the group had experienced anti-social behaviour on the Tube |
| | Q13 | 72 | 27% of the group had felt insecure walking along dead-end corridors at Tube stations |
| | Q14 | 71 | 44% of the group felt insecure when waiting alone at night at Tube stations |
| | Q15 | 74 | 19% of the group had felt insecure at a crowded Tube station |
| | Q16 | 68 | 46% of the group had experienced dark and poorly lit Tube stations |
| | Q18 | 72 | 14% of the group had experienced crime on the Tube |
| Gentle | Q20 | 82 | 85% of the group had helped other people carry bags or prams up stairs at a tube station |

| | Q | CL % | 'Baseline' Mean Response for all responses |
|---|---|---|---|
| Tiresome | Q19 | 72 | 60% of the group had experienced noisy and unclear announcements |
| | Q21 | 76 | 57% of the group had feared losing other members of a group at a Tube station |
| | Q22 | 71 | 55% of the group experienced excessive changes of level at Tube stations |
| | Q23 | 74 | 51% of the group had been lost or disorientated at Tube stations |
| Confident | Q24 | 77 | 87% of the group could get to most places they wanted to be, via Tube |
| | Q25 | 83 | 87% of the group were confident travelling by Tube |
| | Q26 | 68 | 59% of the group could find an alternative route, if the Tube was not working |
| | Q27 | 75 | 68% of the group found it easy to see signs and find their way on the Tube |
| | Q28 | 71 | 38% of the group talked to strangers on the Tube |
| Unconfident | Q26 | 68 | 28% of the group could not find an alternative route if the Tube was not working |
| | Q27 | 75 | 11% of the group found it difficult to see signs and find their way on the Tube |
| | Q28 | 71 | 34% of the group never talked to strangers on the Tube |
| Empathy | Q29 | 80 | 74% of the group could recognise a person with a disability, and if they needed help. |
| | Q30 | 71 | 43% of the group would like training to produce inclusive station environments. |
| | Q30 | 71 | 26% of the group did not want training to produce inclusive station environment. |

Table 4: Women's experiences compared to Baseline

| Women's experiences (CL=Confidence Level) | CL% | Q |
|---|---|---|
| **Discomfort** | | |
| 46% of the group had not used lifts | 32 | Q6 |
| 46% of the group experienced cost of Tube travel was a barrier to travel | 48 | Q10 |
| **Insecure** | | |
| 61% of the group experienced anti-social behaviour | 47 | Q12 |
| 53% of the group felt insecure along dead end corridors | 31 | Q13 |
| 76% of the group felt insecure alone at empty Tube stations at night | 41 | Q14 |
| 7% of the group experienced actual crime | 79 | Q18 |
| **Confident** | | |
| 46% of the group would talk to strangers on the Tube | 46 | Q28 |
| **Summary:** The group experienced discomfort and less use of lifts (Q6). If they had used lifts, they saw no excessive increase in overall journey time. They were more likely to use a seat if available and high cost deterred travel | | |

Survey Results and Analysis: Table 2 summarises the 47 responses separated into demography, employer and role. Table 3 provides the 'Baseline' or mean result of all 47 responses. The Confidence Level (CL), determined by using t-test statistical criteria, was strong and ranged from 60~85%. Accordingly, when the group became smaller for example, women formed 28% of the group (see Table 2), the CL reduced to between 31~79% (see Table 4). Table 5 summarises group responses as follows. We can see in Table 5, for example, that Young and Middle groups found stations

uncomfortable, whilst the Aging passengers found them comfortable. Men and Aging groups, who were 66% men, found stations most secure, whilst the Young found stations insecure. All groups had confidence within a tiring (ungentle) travelling experience. The Young group was most unhappy (3 out of 4), followed by Middle (2 out of 4), and with all other groups equalising (1 out of 4). The Aging group had the best experience (3 out of 4), followed by Men (2 out of 4). Individuals had different experiences to Comfort and Security. Table 4 and 5 results correlated with concerns raised in the literature review.

Table 5: Tube experiences compared

| | Baseline | Young | Middle | Aging | Women | Men |
|---|---|---|---|---|---|---|
| | | <25 | | >55 | | |
| Comfort | 😐 | ☹ | ☹ | ☺ | 😐 | 😐 |
| Security | ☺ | ☹ | 😐 | ☺ | 😐 | ☺ |
| Gentleness | ☹ | ☹ | ☹ | ☹ | ☹ | ☹ |
| Confidence | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ |

Good Experience= ☺ Average= 😐 Bad Experience= ☹

Actionable insights: Data generally corresponded with the literature review. Women had a greater fear of crime (Q14, CL76%) and fortunately low experience (Q18, CL7%). In contrast, men experienced less fear of crime (Q14 CL32%) and experienced more crime (Q18, CL17%). A possible explanation is that women avoided places where they could not see other people, were detached from main circulation areas, and talked more to strangers for safety reasons, whilst men felt safe so were aloof. Thus, integrating women's views within decision-making could improve security, gentleness and comfort for all groups. Thus, to develop a People-Centred or VS-free vision, we need to consider individual needs that differ from 'mean' results. Findings might explain how certain 'in-group bias' and other 'people' factors mentioned earlier could adversely impact recent station designs, owing to influential role of respondents. Researchers, designers and clients need to consider individual needs and use caution when considering aggregated or 'mean' data that may hide important differences.

**Recommended Processes to increase diversity and VS-Free solutions**

Ridership on the Tube evolved with a much lower percentage diversity of 'priority' groups, when compared to ONS data owing to the mostly inaccessible LUL network. Such a demographically selective, appears to follow a 'natural selection' or Darwinian 'survival of the fittest' scenario has both legislative, moral and socio-

economic and sustainability concerns. Possible explanations why that situation may have evolved include a) Low empathy and consideration of other group needs. b) An ‘in-group’ male bias disadvantaged less dominant groups, owing to male dominance within the railway industry and construction sector. c) Railway station research and attitude appeared out-of-date, exempted from Building Regulations, and less inclusive compared to other building types. d) Professional ethics and leadership was weak, owing to less independence, control and passive ways. e) Preferential engineering developed instead of an ‘evidence based’ design approach. f) Lack of reliable research, lack of guidelines or best practice led to passenger planners discounting lift users as an insignificant proportion of station users. g) Designers considered lifts were only necessary to meet legislative requirements and did not think forecasting ‘crystal ball gazing’ was their responsibility.

Recommended solutions to improve Processes Solutions need to address with wider inclusion, variety, diversity and interdependence concerns. For example, 1) Develop and share a Vision that includes objectives to prioritise designs and facilities suitable for all individuals to achieve improved liveability and sustainability objectives. 2) Ensure inclusion of priority group views (aging, younger, women and ‘different ability’ individuals) within design and decision-making and include a variety of individuals within demographically balanced teams and review groups 3). Consider, include and develop forecasts for demographic groups mentioned earlier 4) Accept that lifts provide a benefit to almost all users (Maynard) and when step-free stations become ubiquitous lift demand and use will increase perhaps exponentially. 5) Develop and incorporate evidence-based design requirements into ‘briefs’ and actionable insights from surveys, the examples in Tables 3-5 provide insights that correlate with the Literature Review. 6) Collaborate with a broad range of disciplines, including Planners, architects, engineers and other disciplines to produce peer-reviewed policies and integrated designs. 7) Develop Lift Guidance and evaluate relevant lift design factors, including rise, speed, and lift cycle timing, appropriate waiting time, and train interval ‘headways’ to achieve clear and congestion-free platforms before the next train arrives. 7a) Estimate amount and sizes of lifts to ensure lifts form part of VCE, and passenger transportation studies, including appropriately designed waiting areas. 7b) consider the additional space requirements for people with mobility aids, scooters, bags, single, and double prams. 7c) Compare lift usage within other metros systems that have 100% step-free access, and guidelines. 7d) Consider design affects if lift demand forms 10%, 20% or 50% of overall passenger numbers. 7e) Consider the depth of the station and time taken to travel via lift or escalators, potentially some stations require 100% lift coverage. In summary, all these processes require active leadership, support, encouragement and acceptance that increasing diversity in stations and cities is beneficial for all groups, including one’s own.

**Recommended VS-free solutions to improve existing systems**

Whilst it is difficult and costly to provide lifts at existing stations due to lack of space at grade and below grade, lifts provide benefits to almost all users (Maynard), thus designers, clients and researchers need to be creative, lack prejudice and take a moral leadership. Recommendations include: 1) learn from recent solutions, for example the recent Stockholm station retrofit showed how it is was possible to replace older and wider types of escalators with narrower escalators to make space for an 'inclined' lift. 2) Consider whether a single lift is sufficient at some stations, owing to lower passenger numbers, lift speed, size and location. 3) Consider prioritising step free stations at main employment centres and interchanges. 4). Consider alternative modes, e.g. buses, trams that have no VS issues, owing to lifts may be impracticable at all stations. 5) Consider crowding issues because changing policies towards more inclusive transportation for all groups and result in many more people using lifts, trains and stations. In summary, if there is a will, there is a way to solve VS problem.

**Recommended VS-Free solutions to improve new systems**

Designs on the 'drawing board' typically reduce diversity owing to the predominance of escalators and few lifts. Thus, recommendations for a VS-Free solution include: 1) Accept Maynard's claim that well designed lifts are beneficial to almost all individuals (2007), consequently develop designs with more and faster lifts. 2) Consider other property types that solved VS, for example, Heathrow Terminal 5 provided many lifts to serve an 'airside people mover,' whilst high-rise buildings typically have many lifts. 3) Consider alternative platform configurations including side or 'stacked' tunnels that provide space for many lifts to access platform directly to ground floor entrances and reduce overall journey time. 4) Consider introducing 'cross platform interchange' that reduces need to move vertically within a station to change trains (see examples at City Hall and Raffles Place Stations in Singapore, Taipei MRT, and Victoria Line in London). 6) Consider omitting or provide fewer spatially inefficient escalators to deeper stations, or where passengers exit and entrance numbers are relatively low, provide more space for lifts and evacuation stairs. Note that escalators cost more to build, maintain and consume far more energy than lifts. 5) Consider alternative transport modes that reduce VS have step-free access, are cheaper to build and maintain. For example buses and trams have slower speed however, overall journey time may not be ridiculously more than underground, owing to the length of time (e.g. six minutes or more) to reach platforms. In summary, such changes require a paradigm shift to provide VS-free designs whilst there appear to be several creative solutions to consider when designing new systems.

**So What is the contribution to knowledge?** VS, is a new term defined by the author, as separation from ground level to the platform that creates spatial mobility and socio-economic concerns for individuals. VS results in less diversity and more exclusivity within transport modes and the cities they serve. Moreover, VS could provide a new measure to evaluate the liveability, and diversity within cities. For example, the rate of VS is calculable as a percentage of mobility options within a city. VS could be a new way to evaluate outcomes for investments for renewal, replacement or new systems including all modes of transport, for example, mobility aids, walking, cycling, bus, tram, bus, metro options. Thus, VS-free mobility could become a specific measurable and realistic target to achieve diversity as part of a Vision for People Centred Mobility in Liveable Cities.

**Conclusion: If there is a will, there is a way.** Diversity in cities is beneficial for all of us, when we are young, as we age, or may have mobility concerns. Underground stations have unique VS problems that are less obvious and need addressing. This paper improves understanding of VS causes and 'people' issues, and impacts upon diversity. Solving VS issues require creativity, lack of prejudice and morality. In conclusion, it is in all interests to increase diversity in our transport systems and implement a sustainable vision for People Centred Mobility in Liveable Cities that produces zero VS within stations and other transport systems.

I hope that this paper provides support and 'will' for policymakers, clients, and designers to consider implementing VS-free solutions offered, so that current and future citizens can enjoy 'all that life can afford' in the cities where a diverse range of people of different ages and abilities can live.

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