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Estimating the user benefit of rail station lifts

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Abstract

The paper looks at three different approaches that have been used to estimate the benefit from passenger lifts at rail stations: mechanistic models of movement, passenger behaviour surveys and observation surveys of the profile of users. Examples of each approach are reviewed in terms of their methodology and the estimated level of user benefit which, for ease of comparison, has been standardised into a percentage of the average Sydney rail fare.

The review shows that studies that have classified rail passengers by their mobility and have been conducted after the introduction of lifts have produced higher measures of benefit than studies that did not segment the sample and were conducted before the introduction of lifts. This finding is not surprising given the convenience and comfort that lifts provide to mobility challenged passengers and the increase in rail use that lifts have thus enabled.

The paper then considers how values have been used in cost benefit evaluations of station upgrade projects. Usually a 'hybrid' approach has been adopted in which an average benefit per passenger has been augmented by an additional benefit to mobility challenged passengers.

1. Introduction

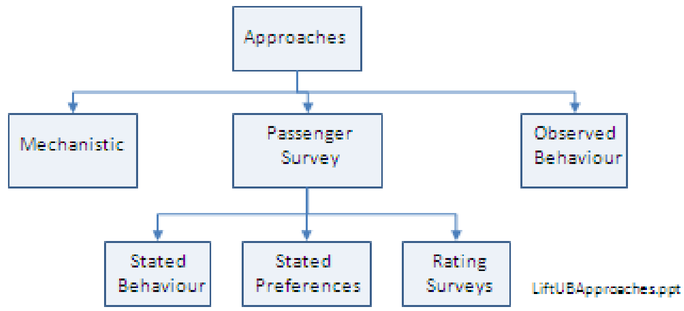
A standard cost - benefit appraisal of the installation of a passenger lift at a rail station will include the capital costs of the lift equipment and the lift shaft and the recurrent costs of lift power, lighting, cleaning and maintenance. Offsetting these costs are the convenience and comfort benefits lifts provide to rail passengers, the ticket revenue from any rail patronage generated by the lifts and any net externality benefit from reduced road use.

The purpose of this paper is not to present a cost-benefit evaluation however. Rather, it is limited to assessing the level of benefit to lift users. Nevertheless as user benefit is the primary determinant of total benefit, the estimates and their basis have an obvious importance in economic appraisals.

The paper reviews three different approaches to estimate the benefit of lifts. Examples of the size of user benefit are presented standardized as a percentage of the average Sydney rail fare. Figure 1 presents the three approaches diagrammatically. The approaches are mechanistic models of time and effort; surveys of passenger behaviour, stated preferences or ratings; and, surveys of observed behaviour.

Mechanistic pedestrian models were developed in the 1980s by London Underground Limited (LUL) to evaluate station design from crowding and safety perspectives. The models used travel time speeds and weights to reflect the relative effort and comfort of walking along the flat, up and down stairs and escalators and using passenger lifts. Section 2 discusses the approach.

Figure 1: Three approaches to estimate the passenger benefit of lifts



Passenger surveys have been undertaken into the use, preference and rating of station facilities including 'vertical transport' facilities like lifts. Sections 3, 4 and 5 review each type of survey and the benefit measures that have been derived. The alternative to surveying passengers is to observe behaviour. Section 6 reviews a lift patronage forecasting model based on observation surveys.

Section 7 summarises the approaches and shows that an accurate measure needs to take account of the accessibility and mobility characteristics of both existing rail users and rail users generated by the provision of lifts. Section 8 reviews how user benefit has been included in evaluations of station upgrade projects in Sydney. Usually a 'hybrid' approach has been adopted in which the benefit to 'non mobility challenged' passengers has been augmented by a benefit to mobility challenged passengers. Section 9 draws together the main findings of the review.

2. Mechanistic approach

The mechanistic approach compares the time, effort and comfort in using a lift versus using stairs, ramps or escalators. London Underground Limited (LUL) developed the approach as part of developing a pedestrian station movement model (LUL, 1993). LUL developed a set of speeds and weights that are presented in Table 1 to calculate the 'generalised' time for 'modelled' journeys. The weights measure the effort and comfort relative to sitting on a train and were conceptually based rather than deriving from specific market research. Importantly, the weights do not vary according to the mobility status of the passenger.

Table 1: Vertical transport speeds and time weights

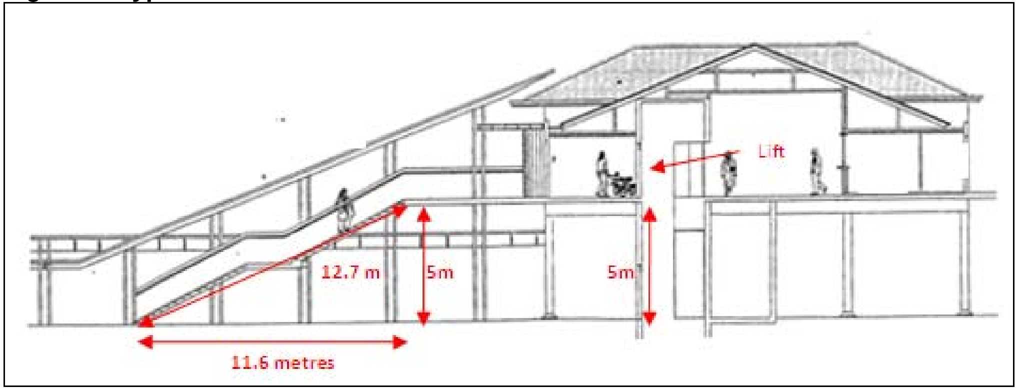
Element	M/Sec	Weight
Stairs Up	0.59	4
Stairs Down	0.67	2.5
Escalators Up	0.84	1.5
Escalators Down	1	1.5
Passageway Walk	1.53	2
Waiting Time	na	2
Riding in Lift*	0.65-1.6	1.5
Lift Penalty	3 mins	na
Riding on Train	na	1

* maximum speed for low-rise hydraulic lift 0.65m/sec, Machine Room Less lift 1.6m/sec

Source: LUL (1993) except lift speed

Most rail station lifts are in ‘low-rise’ situations connecting the platform and the concourse with a vertical ‘travel’ of around five metres. Figure 2 shows an example station with lift and stairs.

Figure 2: Typical rail station lift



The typical time for a lift to travel five metres would be ten seconds allowing for acceleration and deceleration. Allowing for the doors to open and close adds four seconds and finding and pressing the lift button another four seconds. The total time for a one way trip would therefore be 18 seconds. Assuming the lift has a 50:50 chance of being at the bottom or the top, the expected wait for the lift would be around five seconds (half the vertical travel time).

The LUL parameters weight time spent riding in a lift 1.5 times that sitting on a train with time spent waiting for the weighted twice that of sitting on a train. Thus for the example lift, the weighted travel time would be 37 seconds (27 seconds of travel time plus 10 seconds of expected wait time).

In Table 1, the stair and escalator speeds are measured ‘on the angle’ (i.e. the hypotenuse) with allowance for some passengers to walk on the escalator (particularly in the down direction). The example staircase is 12.7 metres long and would therefore take 21 seconds to ascent and 19 seconds to descend. The LUL weights attributed a weight of 4 to ascending time and 2.5 to descending time giving weighted times of 84 seconds and 48 seconds respectively.

Comparing the generalised times of the lift and the stairs gives an ‘ascent’ benefit for using a lift of 47 seconds and a ‘descent’ benefit of 11 seconds. These savings can be monetised by applying a ‘value of time’. At an average value of $11.90 per hour, the benefit of using a lift would be worth 16 cents ascending and 4 cents descending or an average of 10 cents. With these time benefits, everyone should use the lift but in fact less than 10% typically do, as can be seen from the observation surveys presented in Table 2. The limited capacity of lifts (usually 17 persons) and consequent queuing and also the location of lifts discourage use. LUL reduced the attractiveness of lifts in their pedestrian models by including a penalty of three minutes (shown in Table 1) which was supported by Stated Preference market research undertaken at Angel Islington tube station, see section 4.1.

The mechanistic approach was used in the 1990s to value the benefits of station lifts for passengers with “normal mobility” in economic evaluations undertaken. Instead of using the LUL lift penalty, benefit was only attributed to the share of rail passengers expected to use the lifts. The share was based on observation surveys undertaken at stations where lifts had been introduced.

Table 2 shows lifts were used by 4% of passengers and stairs (or escalators) by 96% based on observation surveys undertaken at five locations at Sydney stations. Applying the 4% lift share to the average benefit per station user reduces the unit benefit to just 0.4 cents (4% of 10 cents) per rail trip which is 0.14% of the average CityRail fare of $2.81.

Table 2: Percentage of passengers using station lifts by mobility category

Mobility Category	Lift Percent	Passengers Observed
Wheelchair	100%	1
Stroller or Baby in Arms	69%	74
With Bicycle	21%	9
Heavy Luggage	45%	145
Old or Infirm	50%	149
Total Mobility Challenged	53%	378
Non Mobility Challenged	3%	7,718
All Passengers	4%	8,096

PCIE Surveys at 5 Sydney stair/lift locations 1994-1996

Table 2 also shows that 'Mobility Challenged' passengers were far more likely to use lifts with an observed share of 53% compared to 3% for non mobility challenged passengers. 69% of passengers with a stroller or a baby in arms used lifts, 50% of old or infirm passengers and 45% with heavy luggage or shopping. Only one wheelchair passenger was observed in the sample of over 8,000 passengers and the passenger used the lifts.

The economic evaluations of station upgrades in Sydney only used the mechanistic approach for non mobility challenged users which reduced the unit benefit to 3 cents (3% of 10 cents) or 0.11% of the average fare. For mobility challenged passengers, the stair speeds were considered too fast and the 'comfort and effort' time weights too low. Instead, the results of stated behaviour surveys presented in the next section were used for mobility challenged passengers.

3. Stated behaviour surveys

Stated behaviour surveys can be split into surveys that ask how respondents have responded to change in circumstance or how they would behave in response to a change. The results of two surveys are reviewed: a 1997 survey of Sydney passengers and a 2009 survey of UK passengers.

3.1 Sydney surveys

Stated behaviour surveys were undertaken at four Sydney stations in 1997 to estimate the benefit of lifts to 'mobility challenged' (MC) users.[1] Passengers were asked "*what is the maximum time you would be prepared to wait for a lift before using the stairs or escalator?"* On average passengers were willing to wait six minutes. Valuing waiting time twice onboard train time gave a benefit of $2.38 per trip (6 mins x 2 x $11.90/hr ÷ 60) or 85% of the average fare of $2.81.

[1] The sample comprised 93 'mobility challenged' passengers. Seven were wheelchair bound passengers, 34 had strollers or prams, 23 passengers had heavy luggage, shopping or a bicycle and 30 were old, infirm or blind passengers.

Table 3: Willingness to wait for lift

Wait Mins	Wait Mins 0	1	2	3	5	10	Average Wait mins	Sample Size
Percent	1%	10%	7%	9%	37%	36%	6	93

Source: PCIE Surveys at 4 Sydney Stations 1997

Passengers were also asked: *"what would you have done had there been no lifts"* and whether *"the provision of lifts had increased your usage of rail".* Table 4 presents the results.

Table 4: Impact of lifts on rail use by mobility challenged passengers

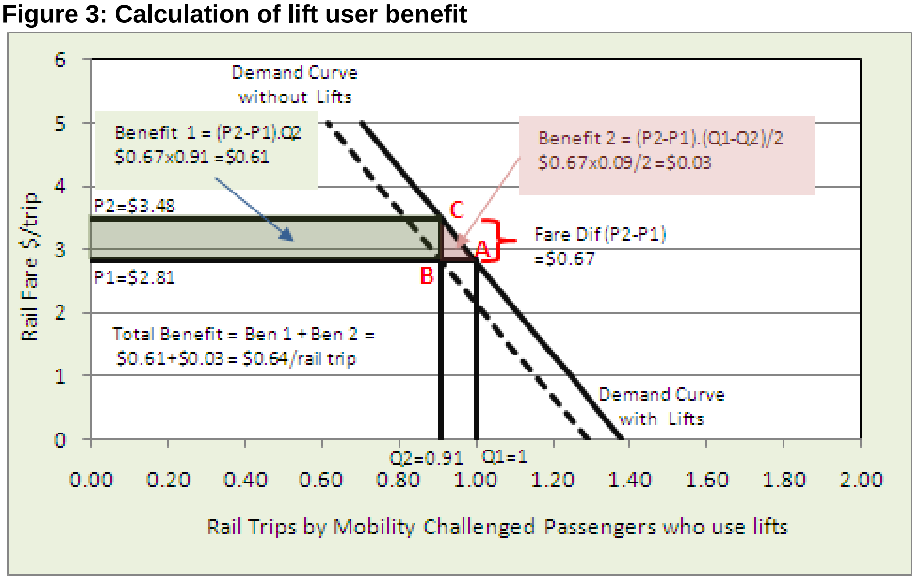
If there had been no lifts what would you have done?	Percent	Has the availability of lifts increased your use of rail?	Percent
Use Stairs without assistance	75%		
Use Stairs with assistance	16%	No - not changed use of rail	65%
Not travel by rail	9%	Yes - increased use of rail	35%
Sample	93	Sample	93

Source: PCIE Surveys at 4 Sydney stations 1997

There was a noticeable difference in the response to the two questions with 9% not travelling by rail without lifts but 35% saying that lifts had increased use of rail.

A measure of user benefit was calculated using the response to the lift 'removal' question. The calculation is shown diagrammatically in Figure 3. The outer demand curve expresses the relationship between fare and rail demand with lifts. Mobility challenged passengers make Q1=1 rail trips at a fare of P1 ($2.81) and 'equilibrium' is at point A. Without lifts at the station, mobility challenged passengers reduce their use of rail by 9%. Demand shifts inwards to the dashed line and equilibrium moves to point B with Q1 demand (0.91).

Figure 3: Calculation of lift user benefit



Instead of removing the lifts, rail demand could have been reduced by raising fares. With a fare elasticity of -0.38 (CityRail, 2010) the required fare rise would be $0.67 per trip and equilibrium would be at point C with Q2 demand (0.91) and P2 fares ($3.48).

The benefit of lifts can be calculated as the sum of the benefit to two groups: the benefit to users who continue to use rail without lifts; and the benefit to users who would stop using rail without them. The first group (Q2=0.91) benefit by 67 cents each or $0.61 in total (the blue rectangle). The second group (Q1-Q2=0.09) benefit by half the fare increase which produces the small triangle worth $0.03 per trip. Total benefit is therefore $0.61 per rail trip or 53% of the average fare.

The benefit figure is for mobility challenged passengers who use lifts and would need to be reduced if it was applied to all mobility challenged passengers since some would use the stairs (escalators or ramps if available). Unit benefit would halve to $0.34 per trip or 23% of the average fare if the lifts were used by 53% of mobility challenged passengers (Table 2).

3.2 UK Surveys

In 2009, SDG undertook market research in the UK to determine the benefits to passengers of the Access for All (A4A) programme which aimed to improve access to 146 key rail stations by creating *"obstacle free routes through the station to the trains* (Duckenfield, 2010). The program involved a range of improvements besides lifts to improve access and amenities for sight and hearing impaired passengers as well as mobility impaired passengers.

Table 5: Demand response & implied benefit of the UK A4A program
SDG surveys at sample of rail Stations 2009

Awareness/Increase in Use and Benefit	Mobility Impaired	Wheel-chair	Hearing Impaired	Sight Impaired	Encum-bered	Unencum-bered
Aware & Significant Increase	18%	47%	15%	4%	11%	2%
Aware & Slight Increase	44%	18%	19%	36%	6%	3%
Not Aware/No Increase	38%	35%	65%	60%	83%	95%
Rail Trips per Year	37	28	67	26	63	121
Increase in Trips per year	3.8	4.9	4.7	1.2	2.7	1.2
Rail Use Increase (%) *	11%	21%	8%	5%	5%	1%
User Benefit (% of Fare) ^	27%	49%	20%	13%	13%	2%
Sample Size^^	407	23	45	68	860	860

Notes: * Based on the assumption that a significant increase is 33% more trips and a slight increase is 10% more trips. ^ Calculated for Sydney using an average fare of $2.81 and a fare elasticity of -0.38. ^^ Sample size deduced from text. Source Duckenfield et al (2010)

SDG surveyed passengers at a sample of upgraded stations and asked whether they were aware of the improvements and whether they had increased their use of rail. Table 5 presents the results. The survey found that the greatest increase in rail use was amongst wheelchair passengers at 21%. Next highest was mobility impaired passengers (respondents who used a walking aid such as a stick, frail or moving slowly caused by a disability) at 11%. The lowest increase was for unencumbered passengers at 1%.

User benefit was calculated for each mobility category using the same method and parameters as outlined in section 3.1. The A4A improvements were valued at 49% of fare for wheelchair passengers, 27% for mobility impaired passengers but only 2% for unencumbered passengers.

4. Stated Preference surveys

Stated Preference (SP) surveys present respondents with trade-off situations. Thus in the context of lifts, passengers might be asked to choose between a rail journey taking 30 minutes and where stations have lifts versus a journey that takes 25 minutes but where the stations do not have lifts. By presenting a series of situations, the relative value passengers place on lifts can, in principle, be deduced.

4.1 Lift 'Penalty' survey at Angel Islington tube station

In 1988, Transecon International was engaged by London Underground to establish whether there was any underlying preference for escalators versus lifts (Transecon, 1988). The results were used to evaluate the economics of installing escalators at Angel Islington station, a deep tube station then served by a circular staircase and a slow lift that suffered from queuing. Passengers were presented with a series of pair-wise choices that featured lifts or escalators, varying station egress times and varying tube travel times. A penalty against lifts of around 3 minutes was estimated which was worth 21% of the average Sydney fare.[2] Thus on average, lifts were valued worse than escalators other things being equal but because results were not disaggregated by the mobility status of the respondents, it was not possible to determine the valuation of mobility challenged passengers.

4.2 1980s British Rail Stated Preference surveys

British Rail commissioned two SP studies to value station attributes. A study by SDG interviewed mainly intercity passengers at Bristol Parkway station (SDG, 1985). Respondents 'traded off' sets of station facilities against each other and against a 5% fare rise. For vertical transport facilities, escalators, lifts and ramps (with trolleys) were compared against stairs. The study estimated that passengers valued lifts and stairs at 1.7% of fare which was slightly lower than escalators and stairs (2.3%) but higher than ramps only (1.3%).

The second study, by MVA, surveyed London rail commuters using a self-completion questionnaire (MVA, 1985). The study used a 'priority evaluator' that required respondents to select their preferred improvements from a 'costed' list and given a limited budget. Passengers then traded off their optimal station package against journey time, fare and service frequency. The study produced a benefit for lifts worth 0.3% of fare.[3]

4.3 Sydney Stated Preference survey

In 1994-5, PCIE undertook surveys to establish passenger values of rail service quality. In the first of a two stage study, respondents were asked to rate photographs of station entrances, access-ways and platforms. The ratings were used to develop low, medium and high standards of station quality. In the second stage, interviewers presented a SP exercise that required passengers to 'trade-off' station quality, train quality, passenger security and fare. The survey found that a 10% point rating improvement in station quality was worth 4.2% of fare. Passengers were also presented with a 'shopping list' of improvements which included lifts and escalators. Combining the results with the SP gave a benefit for lifts and escalators worth 0.9% of fare.

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[2] The 3 minutes was worth 59.5 cents of 21% of the average Sydney rail fare of $2.81 when converted into money using a value of time of $11.90 per hour for Sydney rail passengers.

[3] The MVA survey did not distinguish between lifts and escalators.

4.4 2007 UK Stated Preference survey by mobility status

Maynard used SP surveys in the UK to value the benefit of lifts and ramps for rail passengers of different mobility status (Maynard, 2007). Passengers were asked to 'traded-off' lifts and ramps against fare and travel time increases. Profile questions were asked to enable the results to be analysed by mobility status. Table 6 presents the results after converting them to a percentage of the average Sydney rail fare.[4]

The overall benefit was valued equal to 37% of the average Sydney rail fare. The high value partly reflected the number of mobility challenged passengers in the sample. Impaired passengers valued lifts at 103% of fare and disabled passenger 111% of the fare whereas passengers who faced no physical barriers valued lifts at 18% of fare. Other mobility challenged passengers also valued lifts higher: passengers with children (86%) particularly women with children (98%), over 55s (77%) and passengers who considered themselves to face physical barriers (73%).

Table 6: Value of lifts & ramps - Maynard 2007
Converted to Percent of Sydney Fares

	Impaired	Disabled	With Children < 5 yrs	Woman with Child < 5 yrs	55 yrs old & Over	Face 'Physical Barriers'	Face No 'Physical Barriers"	All
Lift/Stairs	14.6	15.7	12.2	13.9	10.9	10.3	2.6	5.3
Ramp/Stairs	5.3	7.2	3.6	7.1	3.7	4.6	-	1.7
Ramp	5.0	6.3	-	4.3	4.2	3.7	-	-
Sample	82	39	62	45	107	224	187	411

The survey also established that lifts were valued more highly than ramps, typically twice to three times as much. Indeed, passengers who faced no physical barriers preferred stairs to ramps.

In consideration, the value estimated for non mobility challenged passengers (18% of fare) appears high and possibly resulted from the survey focussing attention on vertical transport.

5. Rating surveys

Market research of Sydney rail passengers in 2005 used ratings to value station and train facilities (Douglas and Karpouzis, 2008). Two surveys were undertaken. The first survey asked passengers to rate a list of service attributes. One list of station attributes included *ease of platform access including lifts and escalators*. Figure 4 shows some of the attributes and shows that an overall rating was included at the bottom of the list. The individual attribute ratings were used to explain the overall station rating. *Ease of platform access* explained 5.5% of the overall station rating. Using a similar approach, the overall station rating explained 25% of the overall journey rating. Thus, *ease of platform access* explained 1.4% of the overall journey rating.

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[4] The Maynard results were converted into percentages of the CityRail average fare. Maynard reported Willingness to Pay (WTP) values for lifts and ramps in pence per minute. Maynard also reported a value of travel time (9 pence per minute) which varied little by market segment. The lift and ramp benefits were converted into travel time using the 9p/min value of time. By first dividing by the value of time for Sydney rail passengers ($11.90 per hour) and then dividing by the average CityRail fare of $2.81 per trip, the Maynard results were converted into percentages of the CityRail average fare.

Figure 4: 2004-5 Station Rating Survey

6. Please could rate the following aspects of this station *with 1 being very poor & 9 excellent.* *Please leave blank if the facility is not relevant to you.*	*Very Poor*			*Average*				*Excellent*	
A. Ease of **getting on/off the train** from the platform	1	2	3	4	5	6	7	8	9
B. **Platform weather protection –** wind, rain and shade	1	2	3	4	5	6	7	8	9
F. Design and layout of **Main station building**	1	2	3	4	5	6	7	8	9
G. Ease of **platform access including lifts & escalators**	1	2	3	4	5	6	7	8	9
H. Station **signage**	1	2	3	4	5	6	7	8	9
Y. Your **overall rating** of this station	1	2	3	4	5	6	7	8	9

The second survey was designed to value the rating improvements. The analysis found that a 10% improvement in the rating of *ease of platform access including lifts and escalators* was worth 0.2% of fare and a 10% rating improvement in the overall station rating was worth 9% of fare.

The study also explored how the availability of facilities such as lifts influenced passengers' overall rating. On average, stations that did not have lifts achieved an overall rating of 55% whereas stations with lifts achieved a rating of 60%. Table 7 values the 5 percent difference equivalent to 4.4% of fare.[5]

Table 7: Value of lifts at Sydney stations based on passenger ratings

Station Attribute	Station Rating %			Sample Size		Valuation
	Not Available	Available	Difference	Not Available	Available	Fare %
Stations with Lifts Available	55%	60%	5%	966	1,614	4.4%

6. Observation based valuations

Observation surveys were undertaken at stations with and without lifts as part of forecasting the use of lifts (Douglas et al, 2010).[6] Observers classified passengers into six 'mobility' categories: passengers in wheelchairs, passengers with strollers or with small children; passengers with bicycles; passengers with heavy luggage; passengers who were old or infirm; and passengers observed as 'not mobility challenged'.[7]

Table 8 presents the three profiles and shows a noticeably higher share of mobility challenged passengers at stations with lifts than at stations without lifts. At stations without lifts, just less than 4% of passengers were classified as mobility challenged whereas at stations with lifts, the percentage doubled to 8%. For the lift observation surveys, the percentage of mobility challenged passengers was markedly higher at 28%.

At stations without lifts, most of the mobility challenged passengers were classified as 'old or infirm' and accounted for 1.3% of passengers observed. Passengers with heavy luggage accounted for 1% and passengers with strollers or small children 0.8%. No passengers in wheelchairs were observed.

[5] This result needs to be treated with some caution however since stations with lifts tend to have other facilities and to have been upgraded to a higher standard than stations without lifts.

[6] 22 of the 35 lifts linked the concourse with the platform and 13 linked the street to the concourse or platform.

[7] The counts included station staff but these users were omitted from the analysis.

At stations with lifts, old of infirm passengers accounted for 4.7%; passengers with heavy luggage 2.1% and passengers with strollers or small children 0.98%. Over the 94 hours of surveying, 26 wheelchair passengers were observed which produced a share of 0.05%.

Table 8: Observed Station Patronage Profile with and without Lifts
Profile of passengers (%) by observation surveys at Sydney rail stations (2009)

Mobility Category	Station Surveys 1. No Lifts	Station Surveys 2. Lifts	Lift Surveys 3. Lifts
Wheelchair	0.00%	0.05%	0.50%
Stroller or Small Children	0.82%	0.98%	7.20%
With Bicycle	0.39%	0.35%	1.10%
Heavy luggage	0.98%	2.08%	5.70%
Old or Infirm	1.34%	4.69%	13.20%
Total Mobility Challenged	3.53%	8.15%	27.70%
Non Mobility Challenged	96.47%	91.85%	72.30%
Stations Observed	4	12	12

The observation surveys of 35 lifts classified 13.2% of lift passengers as old or infirm; 7.2% had strollers or small children; 5.7% had heavy luggage; and, over the 85 hours of surveys, 23 were wheelchair passengers which gave a passenger share of 0.5%.

Table 9 forecasts the impact of installing a lift at station with a barrier throughput (entries plus exits) of 1,000. The table has five columns. The 'without lift' forecast (Column 1) was calculated by multiplying the share in Table 8 (Column 1) by 1,000 and estimates 35 trips by mobility challenged passengers. The model assumes that trips by non mobility challenged passengers remain unchanged.

Table 9: Forecast rail trips with and without lifts

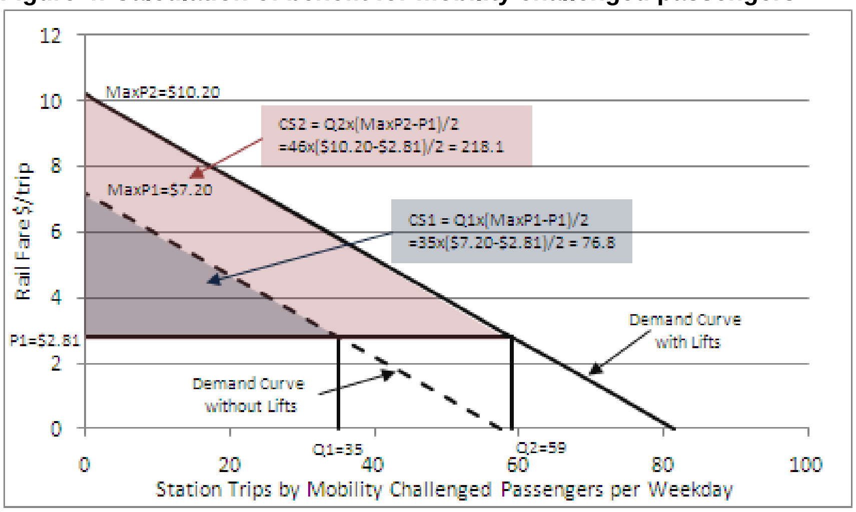
Mobility Category	Station Without Lifts: 1. Stair Trips (Q1)	Station Without Lifts: 2. Hypothetical Lift Trips	Station with Lifts: 3. Forecast Lift Trips	Station with Lifts: 4. Station Trips (Q2)	5. Lift Share %
Wheelchair	0	0	1	1	100%
With Stroller or Baby in Arms	8	6	11	13	85%
With Bicycle	4	1	2	5	40%
With Heavy Luggage	10	5	9	14	64%
Old or Infirm	13	7	20	26	77%
Total Mobility Challenged	35	19	43	59	73%
Non Mobility Challenged	965	na	110	965	11%
Total	1,000	na	153	1,024	15%

Column 3 presents the number of passengers forecast to use the lift. The forecast was made using a model based on automatic lift count data, station barrier counts and observations surveys (Douglas et al, 2010). A total of 153 lift trips were forecast of which 43 were by mobility challenged passengers.

Column 4 forecasts station trips with lifts, the sum of existing stair trips plus trips induced by the introduction of lifts. The 'forecast' used a 'hypothetical' lift share which assumes station patronage remained at the 'without lift' level. The forecast was produced by applying the lift shares in Table 2. Station trips with lifts were calculated as the sum of the trips without lifts (column 1) plus the difference between the forecast lift trips (column 3) and the hypothetical lift trips (column 2).

Total user benefit was the difference in consumer surplus with and without lifts. Figure 4 shows how consumer surplus was calculated as the difference in the maximum fare passengers were willing to pay minus the fare they actually pay (the average Sydney rail fare of $2.81). Linear demand curves were used and were drawn from an initial point where the fare elasticity was assumed to be -0.38.[8]

Figure 4: Calculation of benefit for mobility challenged passengers



The introduction of lifts shifted the demand curve outwards for mobility challenged passengers and led to an increase in the maximum fare passengers were willing to pay from $7.20 to $10.20. Taking into account the increase in demand produced an increase in total consumer surplus from $76.80 to $218.10.

Table 10 presents the estimated user benefit by mobility category. The estimates were calculated by dividing the increase in consumer surplus by either the number of station trips (with lifts) or the number of trips made by lifts. Given the lift share of 15% (Table 9), the benefit per lift trips was 6.6 times higher than the benefit per station trip.

The average benefit for mobility challenged passenger was estimated at $2.40 per station trip or 85% of the average fare. Expressed per lift trip, benefit increased to $3.29 or 117% of fare.

Including non mobility challenged passengers reduced the average benefit down to 17 cents per station trip or 6% of the average fare.

Wheelchair passengers benefited the most at $3.70 (132%) per rail trip followed by old or infirm passengers at $$2.77 (99%) per rail trip. Passengers with bicycles benefited the least at $1.33 (47%) which is reasonable given the awkwardness of getting bicycles into and out of most lifts.

[8] Total consumer surplus is the difference in the maximum fare passengers are willing to pay minus the fare they actually pay. Consumer surplus was calculated rather than the equivalent fare change (as in Figure 3) to cater for wheelchair users where zero trips were observed without lifts.

Table 10: Forecast user benefit based on observation surveys

Mobility Category	Without Lifts			With Lifts Demand				Benefit/Rail Trip		Benefit/Lift Trip	
	α1	MaxP1	CS1	β	α2	MaxP2	CS2	ΔCS/Q2 $	% of Fare	ΔCS/Lift Trip $	% of Fare
Wheelchair	0.4	2.81	0.0	-0.1	1.4	10.20	3.7	3.70	132%	3.70	132%
Stroller or Baby in Arms	12.9	7.36	18.2	-1.8	17.9	10.20	48.1	2.30	82%	2.71	97%
With Bicycle	5.9	8.73	11.8	-0.7	6.9	10.20	18.5	1.33	47%	3.33	118%
Heavy Luggage	15.3	8.09	26.4	-1.9	19.3	10.20	51.8	1.81	64%	2.82	100%
Old or Infirm	22.9	6.51	24.0	-3.5	35.9	10.20	96.1	2.77	99%	3.60	128%
Total Mobility Challenged	57.4	7.20	76.8	-8.0	81.4	10.20	218.1	2.40	85%	3.29	117%
Non Mobility Challenged	1,332	10.20	3,568	-130	1,332	10.20	3,568	0.00	0%	0.00	0%
Total	1,389	10.03	3,611	-138	1,413	10.20	3,786	0.17	6%	1.15	41%

At 85% of fare for MC users, the estimated user benefit was noticeably higher than the behavioural survey estimates and reflects the much larger (69%) increase in rail use by mobility challenged passengers.

A deficiency in the approach was that the different surveys were not linked. Therefore some of differences in the observed profiles could have reflected differences in the underlying types of people who use the stations rather than just the effect of lifts. ‘Before and after’ surveys would produce more definitive results. Also lift- stair shares could be observed at larger sample of locations and could be used to develop a lift-stair demand model that predicts lift use and benefit at the same time.

7. Assessment of methods

Three approaches have been reviewed to estimate the user benefit of rail station lifts: mechanistic models of travel time and effort; passenger surveys; and observation surveys. The estimates of benefit which were expressed as a percentage of the average Sydney rail fare, varied widely from less than 0.5% to 37% per rail trip. A summary of the approaches and benefit measures is provided in Table 11.

Low values of benefit were produced when the mobility status of rail passengers was not distinguished. In part, this simply reflected the small share of rail patronage represented by ‘mobility challenged’ passengers. Consequently, the estimates were dominated by non mobility challenged passengers who derive much lower levels of benefit.

The mechanistic approach was developed by London Underground Limited (LUL) to evaluate station design from a crowding and safety perspective rather than an equitable access perspective. With the ‘average’ travel time speeds and weights, the benefit from lifts was small at 0.11% of fare. The model was not developed for mobility challenged passengers however for whom, stair ascent and descent speeds would be slower and the weights measuring ‘comfort and effort’ higher.

The results of stated behaviour surveys have demonstrated that lifts can increase rail use by mobility challenged passengers markedly. For Sydney, 35% of mobility challenged passengers replied that lifts had increased their use of rail and that if lifts were removed, 9% would stop using rail. In the UK, wheelchair passengers were estimated to have increased their use of rail by one fifth and impaired passengers by just over ten percent at stations where lifts and other improvements had been introduced to provide ‘obstacle free’ environments. By contrast, the use of rail by unencumbered passengers had remained largely unchanged.

Table 11: Comparison of approaches to estimate the user benefit of lifts

Approach	Origin	Description	Benefit: Percent of Fare	Comment
Mechanistic	LUL UK 1980s	Travel times for lifts and stairs weighted by effort/comfort	0.11% per station trip	Parameters not reflective of speed/effort of MC passengers
Stated Behaviour Surveys	PCIE Sydney 1990s	How long would you be willing to wait for a lift?	85% per MC lift trip	Potential stated intention bias
" " "	" " "	What would you do if no lifts?	23% per MC trip	9% of MC users would stop using rail. Av fare elasticity used
" " "	" " "	Have you increased your use of rail since introduction of lifts?	not estimated	35% of MC users had increased rail use but no gradation.
" " "	SDG UK A4A 2010	Have you increased your usage of rail with lifts?	2% NMC & 13%-49% per MC trip	Assumed trip increases. Sydney fare elasticity and fares used
Stated Preference	Transecon 1987	Preference for Lifts versus escalators	3 min (21% of Sydney fare) preference for escalators	Deep level busy tube station. Value for average user.
" " "	SDG Bristol Parkway 1985	Lifts included as station attribute and traded-off with fare and time	1.7% per station trip	Intercity station. Attribute values scaled down.
" " "	MVA London 1985	" " "	0.3% per station trip	Commuter stations. Attribute values scaled down.
" " "	PCIE Sydney 1995	Lifts & Escalators as a station attribute	0.9% of fare for lifts & escalators per station trip	Used photographs to rate stations with lifts and escalators considered as a station attribute
" " "	Maynard UK 2007	Lifts, stairs and ramps trade-off with price and time	73% per MC trip, 18% per NMC trip, 37% per trip	Focussing attention on lifts probably inflated NMC value.
Rating Survey	Sydney 2004-6 Douglas (2008)	"ease of platform access" rated by passengers	Lifts valued at 4.4% of fare per station trip	Availability of lifts may be correlated with other attributes
Observation Surveys	Sydney 2009 Douglas (2010)	Patronage share of station and lift trips by mobility category	85% per MC trip and 6% per station trip	Based on forecast increase in rail use by MC users with no increase assumed for NMC users

Notes: MC Mobility challenged passengers. NMC non mobility challenged passengers

It was possible to convert the reported rail use increases into equivalent measures of user benefit. To do so, an average fare elasticity of demand was used to determine the increase in fare that would reduce patronage back to 'pre-lift' levels. A user benefit of 23% of fare was estimated for mobility challenged passengers using the Sydney survey whilst the UK survey produced benefits ranging from 13% for sight impaired passengers to 49% for wheelchair passengers. It should be stressed however that the level of benefit depends on the elasticity and average fare assumed and in the absence of values pertaining to mobility challenged passengers, system averages were used.

Observation surveys at Sydney rail stations (Douglas et al, 2010) established that stations with lifts had noticeably higher shares of mobility challenged passengers. Observed shares doubled from 4% without lifts to 8% with lifts. The observations surveys were used with a lift patronage model to forecast the increase in rail use from introducing lifts. The increase in rail use was then converted into a measure of user benefit using the fare elasticity method. At 85% of fare, the estimated benefit for MC users was higher than the behavioural survey estimates which reflected the greater increase in patronage. Benefit reduced to 6% per trip when non mobility challenged passengers was included. A deficiency of the approach was that the surveys were not linked thus some of differences in the observed profiles could reflect differences in the underlying profiles of the stations rather than the effect of lifts. Ideally, 'before and after' surveys would produce more definitive results.

Five stated preference surveys were reviewed that have valued lifts by presenting passengers with situations in which they trade-off lifts and other facilities against changes in travel time and fare. In three of the studies, lifts were combined with escalators and the combined benefit ranged between 0.3% and 1.7% per trip. In a survey of London underground passengers, lifts were compared against escalators and the result was a penalty against lifts worth three minutes or 21% of fare.

All but one of the Stated Preference surveys failed to take account of the mobility of passengers. When the mobility of the respondents was into taken into account in a UK study, the lift benefit for passengers who faced ‘physical barriers to travel’ was estimated at 73% of fare. For passengers who did not face any physical barriers, the benefit was one quarter the size at 18% of fare. The average benefit per respondent was 37% although this figure partly reflected the composition of the sample. In consideration, the benefit to non mobility challenged passengers appeared high at 18% of fare and may have resulted from the survey focussing undue attention on vertical transport.

Unlike the other studies, the rating approach was not based on the availability of lifts as such but on how passengers rated the ease of platform access and how their rating influenced their overall station and journey rating. The study found that a 10% improvement in the rating of *ease of platform access* was worth 0.2% of fare and a 10% rating improvement in the overall station rating was worth 9% of fare. On average, passengers rated stations with lifts 5% points higher than stations without lifts which was translated into benefit worth 4.4% of fare.

8. Application of benefit measures

The economic evaluation of Sydney rail station upgrades including the installation of lifts date back to the mid 1990s. Although the values and the basis of the valuations have changed, most evaluations have been characterised by the adoption of a ‘hybrid’ benefit which has added a benefit for mobility challenged passengers to an average benefit per rail user.

In the early to mid 1990s, the mechanistic approach (LUL, op cit) was used to value the benefit of lifts for passengers with “normal mobility”. Station layouts with and without lifts were compared and the calculated benefit for lifts was multiplied by the share of rail passengers expected to use the lifts. For mobility challenged passengers, the stair speeds were considered too fast and the ‘comfort and effort’ time weights too low. Thus for these passengers, the results of stated behaviour surveys were used to calculate benefit, forecast patronage response and consequent rail revenue gain.

The mechanistic value for non mobility challenged passengers was replaced by values derived from a Stated Preference survey of passenger valuations of rail service quality. The survey derived improvement values in terms of passenger ratings. Thus for example, a 10 percent rating improvement in station quality was worth 4.2% of fare. Passenger surveys were conducted to establish the rating of the existing station and forecasts made of the likely rating after the station upgrade. Where introduced, lifts were considered as part of the improvement package. The value of lifts was therefore subsumed in the value of the overall package. However, the evaluation was cognisant of the likely under valuation of the benefit to mobility challenged passengers. Thus evaluations continued to augment total benefit by adopting the values of stated behaviour surveys for mobility challenged passengers.

This ‘hybrid’ method of valuation has continued but with changes made to benefit parameters. For non-mobility challenged passengers, the values reference a 2005 rating survey (Douglas and Karpouzis, op cit). For mobility challenged passengers, the benefit has been calculated using the observation approach. To calibrate the values to a particular station, rating and observations surveys have been undertaken and for larger upgrades, the advice of project architects has been sought to gauge the likely improvement in passenger rating.

9. Concluding remarks

Three different approaches have been used to estimate the benefit of passenger lifts at rail stations: mechanistic models of movement, passenger behaviour surveys and observation surveys of the profile of users. None of the studies reviewed are without problems. Studies that did not consider the mobility of passengers tended to underestimate the benefit of lifts. Stated Preference surveys that focussed attention on attribute like lifts tended to overestimate benefit. The behavioural and observation surveys used average demand elasticities and fares to convert the increases in rail use from lifts into benefit measures.

Elements of all three approaches would be required to develop and calibrate an approach that integrates lift use with lift benefit and takes account of the specifics of the location and the mobility status of users. The mechanistic approach provides a framework to develop a vertical transport model with the passenger behaviour and observation approaches providing the parameters governing the speed, effort and comfort of using lifts versus stairs, ramps or escalators for different mobility categories of user. The development of such a unified approach has intrinsic appeal but there is a danger that the result could be a model that is cumbersome to use and places too much emphasis on the quantifiable rather than the qualitative.

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