Cost-benefit Analysis of Ramps versus Lifts

Y. M. Jung, C. Bridge, & S. Mills

Abstract

Objectives: As an unprecedented research endeavour on economic comparison between ramps and lifts, this study aimed to investigate factors that affected their costs and benefits. Comparisons of the cost ranges of each alternative and relative benefits of one option over the other were also explored. The findings of this study will provide useful information to guide cost-benefit analysis of ramps and lifts within home modification practice. On a practical level, this study aims to reduce uncertainty among consumers and practitioners when considering economic implications of choosing ramps or lifts.

Design: This study employed a multi-strategy method. Firstly, a systematic literature review was conducted in order to identify variables that have relevance to the costs and benefits of ramps and lifts. Secondly, a preliminary cost estimation of various ramps and lifts was conducted using the latest versions of the cost guides, including the Rawlinsons Construction Cost Guide and the Cordell Housing Building Cost Guide. The research design is also based, for more realistic information, on case studies provided by the New South Wales Home Modification and Maintenance Services (HMMS).

Summary & conclusion: The main factors that have significance in the economic dimensions of ramps and lifts were: type of ramp or lift, materials, initial purchase and installation, maintenance and replacement, safety, aesthetics, property value, natural environments, spatial utility, adaptability and flexibility, operation, assistance and care, abandonment and durability, and construction period. As every intervention is customised, costs and benefits cannot be standardised across diverse types and models. In general, the findings of this research indicated that the cost of a particular intervention was related to its long-term benefits. While lifts were found to be a more expensive option than ramps, people with more physical problems, deteriorating mobility and limited access to personal assistance could expect more benefits through lifts rather than ramps.

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Background

The benefits of home modifications for older people and people with disabilities have been well documented (de Jonge, Ainsworth, & Tanner, 2006; Duncun, 1998; Tanner, Tilse, & de Jonge, 2008). For example, home environment interventions can delay and reduce the need for older people and people with disabilities to to enter a health care facility (Kiel, O'Sullivan, Teno, & Mor, 1991; Tinetti & Williams, 1997). Home modifications reduce the risks of accidents and the incidence of falls and injuries among the elderly (Clemson, et al., 2004). Furthermore, improved accessibility of the home increases independence (Connell, Sanford, Long, Archea, & Turner, 1993), enabling participation in the community and facilitating ageing in place (Johansson, Lilja, Petersson, & Borell, 2007). When these benefits are synthesised, home modification is seen as a starting point for positive and healthy ageing.

Despite strong evidence for the benefits of home modification, there has been little systematic analysis of the costs and benefits of home adaptations (Lansley, McCreadie, Tinker, et al., 2004). As a whole, research on cost-benefit or cost-effectiveness of home modification has focused on comparisons between in-home or community care and residential or institutional care (Anderson, Mhurchu, Brown, & Carter, 2002; Anderson, et al., 2000; Lansley, McCreadie, & Tinker, 2004; Ling, et al., 2008; Mann, Ottenbacher, Fraas, Tomita, & Granger, 1999; Salkeld, et al., 2000; Smith & Widiatmoko, 1998; Svensson, Edebalk, & Persson, 1991). In these studies, costs were estimated for the purchase of equipment, modifications, and the involvement of occupational therapists, and benefits were estimated through savings from reduced healthcare costs including decreased hospital admission rates and decreased home visits from nurses or case managers.

Discussion of the benefits of home modifications has not yet extended to critical analysis of alternatives from a cost perspective. Research to date has not sufficiently examined the financial layout and diverse impacts of different interventions. In addition, cost-benefit approaches in the field of home modification have not been specific in distinguishing different types of intervention (Grisbrooke, 2003). Home modification has been recognised as a package of programs rather than any one isolated intervention. This lack of specified information applies to major home modifications such as ramps and lifts. As a result, consumers are uncertain about the differentiated costs and benefits of ramps and lifts.

Defining ramps and lifts

Ramps and lifts are common adaptations for improving the accessibility of the entry (Goodacre, McCreadie, Flanagan, & Lansley, 2007). A no-step entry is one of the essential architectural features for promoting accessibility and visitability (Kochera, 2002). The provision of an accessible entrance through the use of ramps and lifts can allow people with mobility impairments to engage in outdoor activities and tasks with greater ease (Pynoos, Mayeda, & Lee, 2003). However, improving accessibility in and out of the home is one of the most expensive adaptations. Constructing ramps or installing lifts may involve structural alterations and thus can be complex and costly compared with other home modifications such as railings, rearrangement of furniture, and changes in lighting (Pynoos & Nishita, 2003).

Ramps and lifts have common functions in that they facilitate the movement of a person, particularly a person using a wheelchair or walker between levels and floors and are intended to eliminate the need walk up or down stairs

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(Johnson, Duncan, Gabriel, & Carter, 1999). However, ramps and lifts represent completely different systems. Each has its own advantages and disadvantages, and there are significant differences in costs and benefits between them.

A ramp is defined as 'an inclined surface on a continuous accessible path of travel between two landings with a gradient steeper than 1 in 20 but not steeper than 1 in 14' (Standards Australia, 2009, p. 7). Ramps can be constructed with a range of design features using diverse materials. While ramps offer an accessible means of traversing in different elevations, they take up a large amount of space as according to the criteria set by the Australian Standards, a ramp of at least 4 metres is required for 30 centimetre rise in gradient. Thus, when a home does not have adequate space for the required length of a ramp, it can not be considered as an option.

Lifts are an alternative option for moving between levels. Australian Standard 1735.1 defines a lift as 'an apparatus or contrivance within or attached to a building or structure, comprising a platform or car running between approximately vertical guides and used for the purpose of raising or lowering passengers and/or goods or materials' (Standards Australia, 2003, p. 15). While this definition is intended to elevator, a range of types of lifts are available depending on individual needs. Interests in lifts for short-range elevation changes has been increasing because of 'their convenience, relatively small footprint and enhanced safety features' (Bridge, 2005, p. 3). However, any installation of lifts requires careful inspection of the surrounding areas of the existing building including space and construction system of the home. As a mechanical device, they may be subject to failure of operation, and, thus, have to be certified and regularly serviced and monitored.

Aims of research

There has not previously been an attempt to compare the costs and benefits of ramps and lifts. This may be explained by the complex processes of home modification. Home modification involves multiple interventions across the modification process, from need assessment and building/construction to follow-up services. The engagement of many agencies and personnel including occupational therapists, suppliers and builders, as well as a wide range of variants in the products used to build ramps and lifts make estimations of cost extremely complicated. In addition, major outcomes of home modification such as accessibility and independence are intangible, which also makes estimation of benefits difficult.

Despite these difficulties, systematic information needs to be developed to assist consumers with decision-making about which modification represents the most affordable option with the greatest amount of benefit. The primary purpose of this study was to provide information about the differences in costs and benefits of ramps and lifts which are perceived to be interchangeable interventions. This report compared the costs of each alternative, and the relative benefits and advantages of each option over the other in various situations.

With increased access to reliable information about each of these home modification options, consumers are able to make better informed financial decisions. This information will also assist in making good use of the limited funds available for home modification in both private and public sectors. This study also offers suggestions for further research in this area. The findings of this study are expected to guide and trigger future cost-benefit analyses within home modification practice.

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Methods for economic evaluation

There are many methods for comparing interventions based on their costs. The major forms of economic evaluation include cost analysis, cost-effectiveness analysis, cost-benefit analysis, and cost-utility analysis. The simplest of these methods, cost analysis, deals solely with economic input. In this method, the consequences of two or more alternatives are not compared, with an assumption that the same amount of economic input generates equal outcomes in other arenas. It is often used to informally compare alternatives and is useful when choosing the cheapest option.

All the other methods listed above consider both inputs and outcomes. Cost-effectiveness analysis (CEA) is a method of evaluating the benefits and resources used between two or more alternative interventions. CEA compares alternative interventions to determine the least costly means to obtain a desired benefit (Getzen & Allen, 2007). It is applicable when benefits may be intangible or difficult to value monetarily (Culyer, 2005). CEA has been shown to be a practical approach to analysing the effectiveness of health services as it allows comparison of costs that achieve non-monetary objectives such as lives saved (Folland, Goodman, & Stano, 2007). However, it is not suitable for comparison across different interventions because primary effectiveness may differ from program to program (Drummond, O'brien, Stoddart, & Torrance, 1997).

Cost benefit analysis (CBA) is distinct from CEA as it assigns a monetary value to the measure of effect and evaluates the benefits produced by resources within a given program or intervention (Penner, 2004). Thus, unlike CEA, CBA requires that resources and benefits be converted into dollar values. CBA ultimately aims to yield the net benefit (total benefits – total costs) or the benefit-cost ratio (total benefits ÷ total costs). There are many similarities between CEA and CBA, and, thus, CEA is sometimes considered as a form of CBA. According to Getzen & Allen (2007), the only difference between them is whether the benefits are translated into a monetary unit or not.

Cost-utility analysis (CUA) is another method of economic evaluation commonly used in health services. In CUA, different dimensions of outcomes such as lives saved, years of life extended, and cases prevented are considered under the simple measure of the quality-adjusted life year (QALY). The QALY is a generic measure of health-related quality of life that takes into account both the quantity and quality of life generated by intervention. It is a health preference score where consequences of programs are measured by weighting length of life by quality of life (Gerard, 1992) [1]. With the use of the QALY, CUA enables comparison across different intervention with different effectiveness, which is not allowed in CEA. Despite the uniqueness of CUA, some authors such as Gold, Siegel, Russel, & Weinstein (1996) do not make a distinction between CEA and CUA, viewing CUA as a broader form of analysis than CEA.

Each of these different forms of economic evaluation has both methodological similarities and disparities. Each method shares a goal of determining the benefits achieved by a specific intervention through some sort of cost analysis, but they employ different techniques for slightly different analytical purposes. They are practically identical on the cost side, but differ on the outcome side (Drummond, et al., 1997). Overlaps between methods made it difficult

[1] A year of perfect health is scaled to be 'worth' 1 and a year of less than perfect health 'worth' less than 1. Death is indicated by 0. An intervention which results in a patient living for an additional five years rather than dying within one year, but where quality of life fell from 1 to 0.6 generates 5 years' extra life with a quality of 0.6 (=3.0) less 1 year of reduced quality (1-0.6) (=0.4), so the net QALYs generated by the net intervention are 3.0-0.4 (=2.6) (Culyer, 2005, p. 285).

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to choose one specific approach for this study. However, the purpose of this study was seen to match with the notion of CBA best. This study goes beyond cost comparison but does not produce the QALY like in CUA. Although this study admits an assumption of CEA that many benefits expected through installation of ramps and lifts are inconvertible into monetary values, it seeks to compare the costs and benefits between two options. That is, unlike CEA, it inquires about relative superiority in the outcomes of one intervention over the other.

Conceptual model for costs and benefits of home adaptation

In an economic assessment of costs, life cycle costing provides a useful framework, as it can present the full range of initial and continuing costs of a given intervention. 'The life cycle cost of an item is the sum of all funds expended in support of the item from its conception and fabrication, through its operation to the end of its useful life (G. E. White & Ostwald, 1976, p. 39).' Life cycle costing considers all the significant costs of ownership over its economic life, expressed in terms of equivalent dollars (Kirk & Dell'Isola, 1995). Life cycle costs can be divided into the following categories: initial capital costs, financing costs, operation and maintenance costs, repair and replacement costs, alteration and improvement costs, functional use costs, and salvage costs.

Table 1 Life cycle cost elements

Categories	Definitions
Initial capital costs	Costs associated with buying the physical asset and bringing it into operation: purchase costs, installation/commissioning/training costs, land costs, construction costs
Financing costs	Cost associated with financing capital investment: loan fees, one-time finance charges associated with borrowing, interest costs
Operation and maintenance costs	Costs used for the on-going operation and maintenance of the facility: fuel and personnel costs required to operate the facility, regular planned maintenance, unplanned maintenance responding to faults
Repair and replacement costs	Costs to be incurred in the future to restore and maintain the original function of the facility
Alteration and improvement costs	Costs involved in planned additions, alterations, and major reconfigurations: costs of labour, materials, equipment, overhead for design, relocation, and disposal
Functional use costs	Costs associated with performing intended functions within the facility: property taxes, denial-of-use and lost revenue costs
Salvage costs	The value of competing alternatives at the end of the life cycle period. The value is positive if it has residual economic value and negative if demolition is required.

Sources: (American Institute of Architects, 1977; Kirk & Dell'Isola, 1995; Woodward, 1997)

The life cycle costing framework can be applied differently depending on the characteristics of the equipment or facilities used in any particular intervention. However, regardless of the types of facility, the life cycle costing can be phased into initial up-front and operation/maintenance stages, and the key elements of costs at every stage are comprised of materials/equipment and human resources mobilised by each of the tasks.

Synthesising the concepts of life cycle costing and the characteristics of home modification, this research has established the following cost-benefit analysis model for ramps and lifts (Figure 1). Initial input costs include purchase of the product, structuring costs such as clearing and levelling ground, service costs including wiring and plumbing, and labour costs. Operation/maintenance costs involve expenses for routine maintenance costs, repair/replacement parts in case of an operational failure, utility costs such as electricity use, and labour costs.

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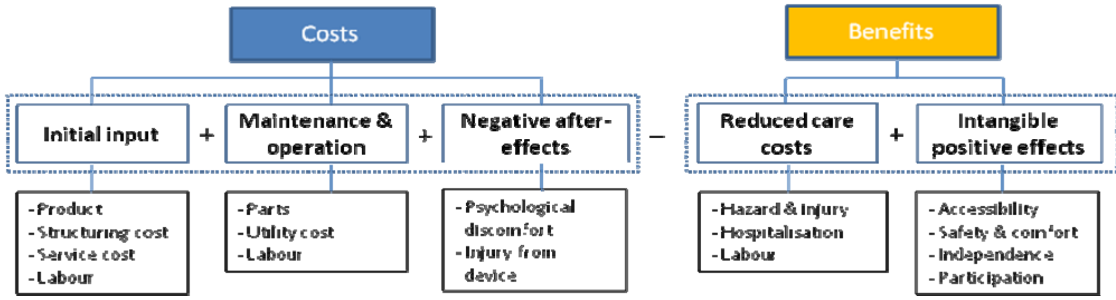

Figure 1 Cost-benefit components

Unlike determining the costs of ramps and lifts, estimating the benefits gained is more difficult due to their intangible attributes. Some aspects of benefits can be monetarily valued through placing figures on saved care costs and reduced healthcare costs as proxies for increased safety and independence. However, the benefits of improved functional ability and social participation can not be fully converted into a dollar value. In addition, home modification interventions have been found in some cases to cause adverse effects such as psychological discomfort, personal injury and damage during the use of the new equipment or device (Tuntland, et al., 2009), which will off-set the initial benefits. These after-effects make the estimation of costs and benefits even more complicated because they need to be taken into account after the modification has been implemented. In summary, a comprehensive economic evaluation of ramps and lifts needs to consider all the components identified through the life cycle costing framework including long term after-effects.

Design and methodology

This study employed a multi-strategy method, where various data was obtained from different sources. Firstly, a systematic literature review was conducted in order to identify elements that affect the costs and benefits of ramps and lifts. A systematic review was considered to be the best way to search published evidence as it allows comprehensive search for the most relevant literature (Mulrow, 1994; NHMRC, 2000). Secondly, a preliminary cost estimation of ramps and lifts was conducted using the latest versions of cost guides including the Rawlinsons Construction Cost Guide and the Cordell Housing Building Cost Guide. These documents have been published and updated by professional quantity surveyors and construction cost consultants, and is used by builders, architects, consultants and contractors for estimating the building costs, cost per square metre rates, elemental break downs, labour constants and building construction data. However, cost guides were not enough for a comprehensive comparison of costs of ramps and lifts because they did not reflect the whole process of home modification and the variations in the design plan. Thus, to obtain more realistic information, this research used case studies of clients who have experienced a lift or ramp installation, provided by the New South Wales Home Modification and Maintenance Services (HMMS).

Process of a systematic review

Based on the Home Modification Information Clearinghouse's systematic review protocol (Bridge & Phibbs, 2003), the research question was refined into an operational format which comprises five key components: problem, intervention, comparison, outcome, and target population. This format ensures that all the important and relevant publications on the costs and benefits of ramps and lifts are covered. The list of key words and synonyms were developed from preliminary study and trial searches.

Table 2 Search frame

Problem	Intervention	Outcome	Comparison	Target population
Home modification, assistive technology	Ramps	Maximum benefit for minimum cost	Lifts	Frail aged, mobility impaired and their carers
Architectural accessibility Home modification Home adaption/adaptation Housing adaption/adaptation Housing modifications Universal design Inclusive design Barrier free design Access to buildings Barrier freedom Self help devices Assistive technology Mobility aids Building accessibility Home accessibility Housing accessibility Wheelchair accessibility/access Wheel chair accessibility/access Architectural barriers	Ramp Incline Wheelchair ramp Wheel chair ramp Wheelchair incline Wheel chair incline Access ramp	Cost benefit analysis Cost benefit Cost analysis Cost model Cost effectiveness Cost effectiveness analysis Benefit analysis Benefit cost analysis Benefits and costs Costs and benefits Feasibility study Cost utility Costs and cost analysis Life cycle cost Whole life cost Whole life value Comparative analysis Comparative study Cost comparison Economic models Models, Economic Economic analysis Economic policy Financial model Pricing Health economics Health care costs Benchmarking Cost of illness Consumer/Customer satisfaction Usability/ Useability User needs User satisfaction User preference Affordability	Lift Elevator Elevators and escalators Lifts and escalators Access lift Wheelchair lift Wheel chair lift Vertical wheelchair lift Stair lift Stairlift Stair climber Stairway lift Powered lifts Powered van lifts Porch lifts Platform lifts Vertical lifts Waterlift Through floor lift Residential lift	Aged Aging Ageing Elderly Older Senior Geriatric Carer Caregiver Disability Disabled Mobility impaired Mobility Limitation Impaired physical mobility Impaired mobility Physical mobility impairment Rehabilitation Wheelchair users Wheel chair users

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All materials that included the above keywords were considered to be potentially relevant. However, inclusion criteria were applied to ensure that the results found had the best chance of being useful for this study. This systematic review particularly sought information that provided practical implications for costs and benefits of ramps and lifts. Thus, those publications that employed a cost-benefit approach on home adaptations but did not specifically indicate ramps or lifts were not included for review. However, materials that provided directly relevant information in relation to methods for estimating the costs and benefits of ramps and lifts were included, even if they were more conceptual than practical in focus. The following table summarises the criteria for inclusion and exclusion of materials applied in this systematic review.

Table 3 Inclusion and exclusion criteria

Inclusion criteria	Exclusion descriptions
English language	Publications that are written in a language other than English
Human subjects	Ramps and lifts that are used for other purposes than assisting people with mobility problems such as equipments in the industry settings or for transferring stocks
Home-use	Publications on buildings other than residential housing such as curb ramps in the street or lifts for public use or ramps or lifts for accessible vehicles
Methodological validity	Publications that deal with residential ramps or lifts but have no indication on costs and benefits, presenting only design and functional features, or those that are not in depth such as newspaper articles and advertisements

A comprehensive list of electronic databases available through the University of New South Wales Library was searched, covering the topic areas of housing, ageing, design, business and science disciplines. These databases included PubMed, Ageline, Scopus, Web of Science (includes Conference Proceedings Citation Indexes), ScienceDirect, Family & Society Studies Worldwide, Proquest Social Science Journals, Proquest Academic Research Library, ABI/INFORM Global, ABI/INFORM Trade & Industry, Business Source Premier, Emerald Fulltext Ergonomics Abstracts Online, ICONDA, Avery Index to Architectural Periodicals, BUILD: Australian Building Construction and Engineering Database, APAIS: Australian Public Affairs Information Service, AMI: Australasian Medical Index / Meditext, APAIS-Health: Australian Public Affairs Information Service - Health. Full text materials that were not available within the University library were sought through inter-library loan services. The Home Modification Information Clearinghouse library, Google Scholar, and references within articles were also useful sources for relevant materials.

The following figure summarises the review process and the final number of papers included in this systematic review. All material retrieved from these sources were judged against the inclusion and exclusion criteria. Initially the titles and abstracts of all material recovered were assessed. If they were deemed to be relevant to the research question and met the inclusion/exclusion criteria, the full texts of the articles were sought. Finally the full texts were fully reviewed and judged as to the relevance to the inclusion criteria. This research finally included 32 publications for review.

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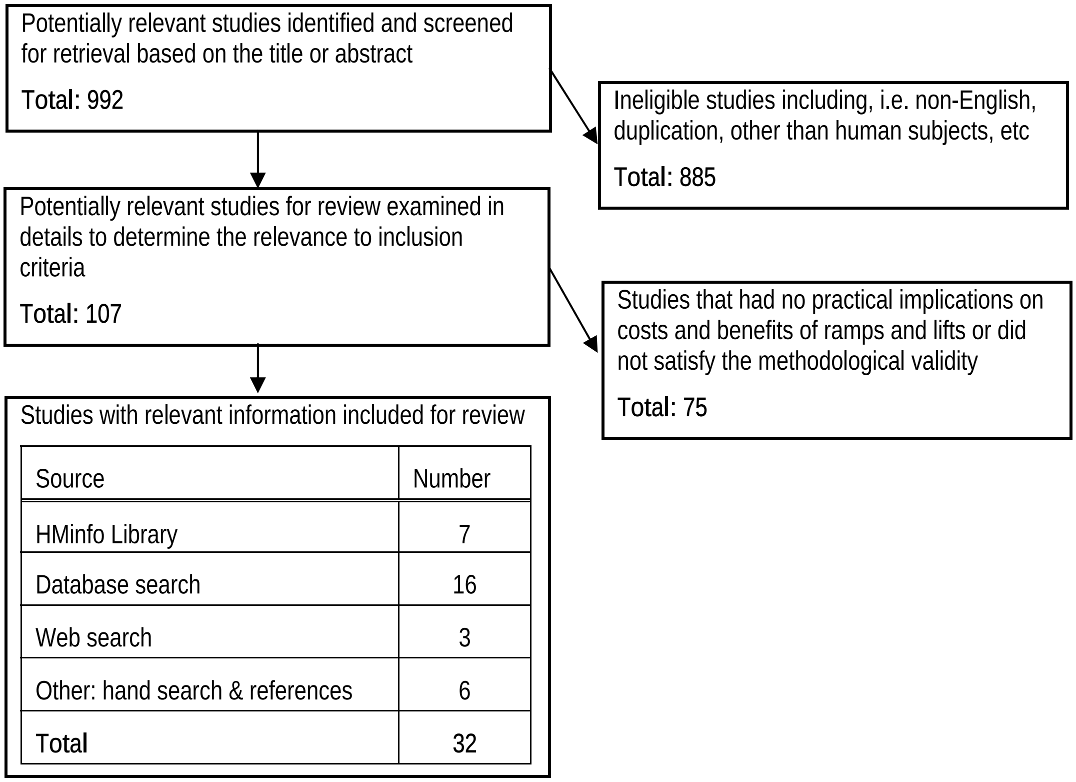

Source	Number
HMinfo Library	7
Database search	16
Web search	3
Other: hand search & references	6
Total	32

Figure 2 Review process

Outcomes of search

Publication year

No criterion was applied for the time span of the publication during the literature search. The earliest research identified in this review traced back to 1979, which indicated that improving entrance accessibility through ramps or lifts has been a classic issue in the home adaptation field. However, it was since the 1990s that materials with indications of the costs or benefits of ramps and lifts have been published in earnest. Particularly, cost-benefit discussion on ramps and lifts is a recent trend in Australia as all the Australian materials were published in the 2000s (see the Appendix: Analysis matrix for publication years of the papers reviewed).

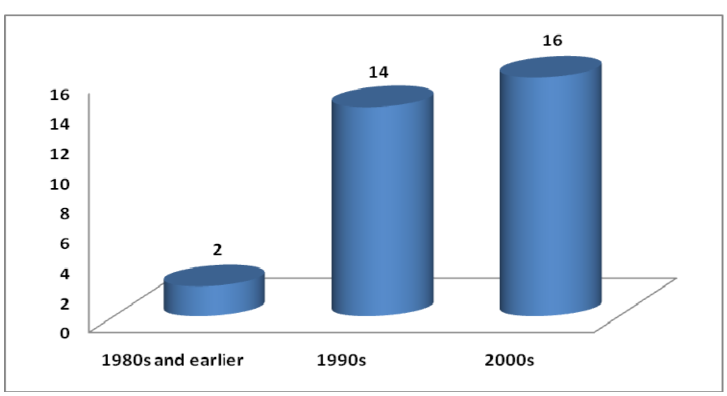

Figure 3 Publication year

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Nationality

Figure 4 illustrates the breakdown of the materials by the authors' countries of origin. Although the publications analysed in this review were mostly from English speaking countries, this does not mean that research on this topic has not been conducted in non-English speaking countries in Europe and Asia. Lower turn-up rate from these regions is likely to have resulted from the inclusion criteria that required sources to be written in English. The majority of the studies were conducted in the 'USA' (34.4%) and the 'UK' (31.3%). Four articles were identified to have been published in 'Australia' (15.6%). The major sources of Australian publications on ramps and lifts were the Home Modification Information Clearinghouse and the Independent Living Centre, with each organisation publishing two papers respectively.

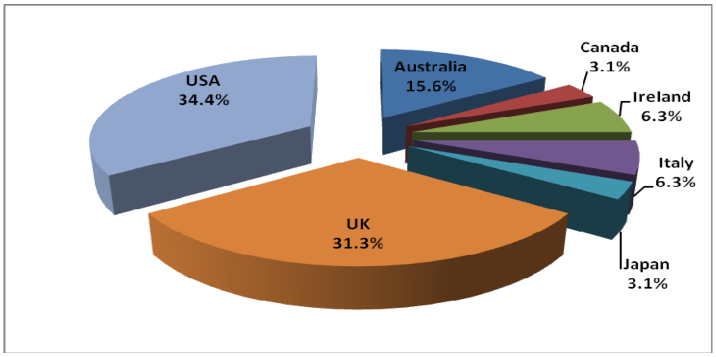

Figure 4 Nationality of literature reviewed

Focus

The publications examined were not necessarily comparative research between ramps and lifts. Strictly speaking, no research has been conducted under the context of comparative cost-benefit analysis of ramps and lifts. In most cases, articles dealt with only one intervention: either 'ramps' (34.4%) or 'lifts' (34.4%). Only one in five publications (21.9%) considered 'both' options at the same time, presenting advantages of one option over the other. Some materials that dealt with 'general home modification devices' (9.4%) were included because of their theoretical relevance, even if they did not focus on either ramps or lifts specifically.

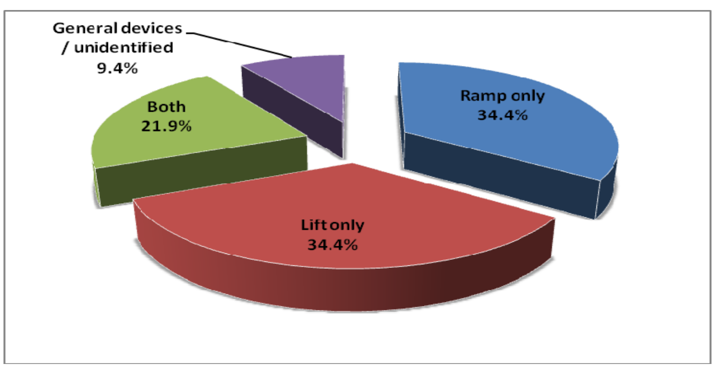

Figure 5 Option investigated

Cost-benefit factors discussed

The cost-benefit factors investigated in this review were categorised within a matrix (see the Appendix: Analysis matrix). The initial categories were created during the preliminary literature review and developed with the progress

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of review. Figure 6 demonstrates the percentage of the frequency of the factors that were discussed in the publications. As was anticipated, the factor discussed the most was 'up-front purchase and installation' (14.6%), followed by 'types of ramps or lifts' (13.6%), and 'maintenance and replacement' (12.6%). 'Safety' (9.7%) and 'space' (9.7%) issues were also identified as being of considerable importance in the materials of the literature review.

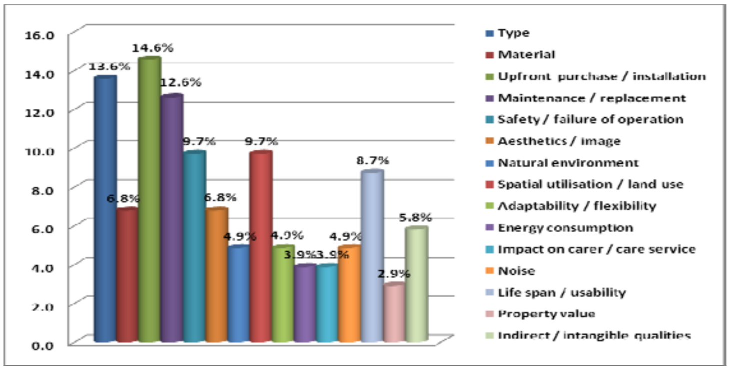

Figure 6 Cost-benefit variables discussed

Methodology

A systematic review also examines the methodologies that were employed in the publications in order to aid the interpretation and evaluation of research findings. The validity of the results of research varies depending on the methods employed, and thus hierarchies of evidence have been used in interpreting literature materials in a systematic review (Evans, 2003). In general, systematic reviews and randomised controlled trials (RCT) have been regarded as providing the most reliable evidence, with case studies and expert opinion ranked lowest in the hierarchy (Evans, 2003; NHMRC, 1999).

Figure 7 depicts the methodologies used in the 32 sources included in this review. As can be seen below, the findings of this systematic review were not based on the highest level of evidence because no paper included for review employed a systematic review or RCT methodology. Instead, considerable evidence was provided from 'expert opinions' (31.3%) and 'case studies' (12.5%). This suggests that there is room for further exploration in terms of empirical evidence. While there was an absence of the highest level of empirical evidence, more than two in five papers (43.8%) used a 'quasi-experimental' research design, which included experiments with people with mobility impairments and surveys or interviews with ramp and lift users.

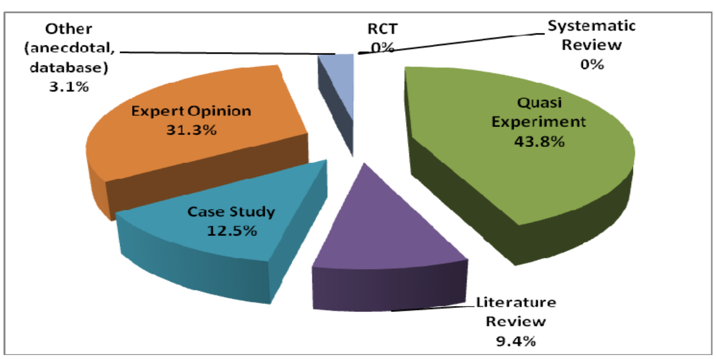

Figure 7 Methodologies

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Cost-benefit factors

Types

There is a wide range of lifts and ramps available in home modification. This variety adds complexity to comparing the costs and benefits of each option. However, it is evident from the literature that the type of device used in this intervention is a key determinant of costs and benefits experienced by the consumer.

There are basically three types of ramps: permanent, modular and portable. In many cases, ramps are constructed as permanent fixtures. Modular ramps are usually constructed by connecting parts such as platforms, landings, handrails with the use of bolts, clamps or fitting. As semi-permanent fixtures, they can be relatively easily removed and resited (Belknap, 1997; Travers, 1991). Although modular ramps are a rather new option in Australia (Alam, 2003), statistics from the Department of Veterans' Affairs (DVA) showed that more than one in three ramps (36.5%) installed for the DVA clients in NSW were modular ones (Dinley & Cheng, 2008). Portable ramps refer to movable ramps that can be carried or transported. They are useful for active people with a disability.

There are also various types of lifts with different features, performance and capabilities. Lifts for residential use can be categorised broadly into four types: lifting platforms (short-rise lifts), wheelchair platform lifts, stairlifts, and elevators (through-floor lifts) (Bridge, 2005; Disabled Living Foundation, 2006; Meldrum, 2003). A lifting platform rises vertically for a short distance to overcome difference in floor levels where there would normally be a few steps. A wheelchair platform lift consists of a platform that moves along the stairway via a set of rails mounted on an adjacent wall or onto the stairway. A stairlift, like a wheelchair platform lift, is mounted on stair-fixed tracks which follow the line of the stairs, but transports the individual seated in a chair. In general, wheelchair platform lifts are wider than stair lifts to accommodate a wheelchair (Perr & Barnicle, 1994). A home elevator has an enclosed car capable of transporting people in a wheelchair. Home elevators rise vertically from a lower level floor to a higher level floor.

Material

The type of material used to construct the device was also identified within the literature as an important factor to influence the costing and usability of ramps and lifts. The type of material used is particularly important in the case of ramps. Ramps can be constructed with a variety of materials including concrete, steel, aluminium, fibre-glass, and timber. Each of these materials has different advantages and disadvantages when it comes to both cost and usability.

According to the statistics from the DVA NSW, timber ramps constituted more than half (53.3%) of those installed in 2008, with concrete ramps accounting for only 10.2% (Dinley & Cheng, 2008). Concrete ramps have advantages in terms of strength and maintenance, but they are difficult to resite or destroy and expensive when installing. Timber ramps can be the more cost-efficient alternative as they are cheaper, quick to install, and easily removed when no longer required (Travers, 1991), however timber ramps are also more vulnerable to external conditions such as weather or termites. Steel or aluminium ramps have advantages over timber ramps in terms of durability. However, steel construction is more expensive than timber due to the higher cost of materials and labour involved (Alam, 2003). Aluminium and fibre-glass are alternative materials that can be used in place of concrete or timber as they are strong for their weight and resistant to rust, rot and corrosion with minimal maintenance (Travers, 1991).

In the literature, construction material was discussed in conjunction with the type and usability of the ramps. To maximise the cost-effectiveness of implementing a ramp, the weight of the intended user and the frequency of the ramp use should be considered when choosing materials (Belknap, 1997). For example, portable ramps for a child can be constructed using fibre-glass, but more durable material would be more appropriate for frequent and heavier users. Aluminium is usually suitable for portable or modular ramps (Zackowitz, Vredenburgh, & Hedge, 2005), while concrete, steel or wood are generally more appropriate choices of material for permanent and semi-permanent ramps.

It was inferred from the literature that the costs involved in each of these material types may be proportionate to the long-term effectiveness and use of the ramp. In other words, material that costs less may result in less durability and more maintenance, and vice versa. Other conditions being equal, concrete ramps are the most expensive option and timber ramps are the cheapest. However, cheaper materials may not always be a cost-beneficial option, depending on user characteristics and the intended or projected usage of the ramp.

Initial purchase & installation

In most cases, the publications included in this review defined initial capital costs as upfront purchase cost and installation cost. Few publications presented direct prices for installing ramps and lifts, and this was particularly the case for ramps. This is not surprising because ramp designs were customised according to the mobility needs of the individual user and the particular physical conditions of the home. Ramps are not purchased as products in themselves, and thus an infinite variety of installation costs is possible. Despite these limitations, it was roughly inferred that permanent ramps constructed with concrete are the most expensive options, followed by permanent steel ramps, with modular and timber ramps being the least expensive options (Alam, 2003; Travers, 1991).

Unlike ramps, prices for the purchase of some types of lifts were presented in the publications reviewed. However, the prices could not be directly compared because of the variety of currencies and publication years involved in these articles. The purchase and installation costs varied between types and from model to model (Kelsall, 1996; Meldrum, 2003; Stowe, 1990). According to the literature, through-floor lifts were the most expensive to install as they normally required building alterations, and stairlifts and platform lifts were relatively cheaper options than through-floor lifts (Bridge, 2005; Disabled Living Foundation, 2006; Madley, 1999). However, design feature was another variable for the costing of lifts related to staircases. If stairlifts and platform lifts are installed along curved staircases, their costs may exceed those of through-floor lifts because of extra expense for customising units to fit the stairwell (Disabled Living Foundation, 2006).

Maintenance & replacement

Most of the publications that discussed the initial investment cost of installing lifts also took the ongoing maintenance costs involved into consideration. The cost of regular maintenance is relatively low compared with the initial installation cost (Meldrum, 2003). However, maintenance costs could be a problem for people on a fixed or low income, particularly in the event of a breakdown or when replacement was required (Carne & Carne, 1991; Meldrum, 2003). Maintenance may be seen as a concern of lifts only as they are mechanical equipment that is subject to wear and tear. However, the installation of ramps also involves regular maintenance and after-care issues, particularly in the case of timber ramps as timber can be lifted or warped, decking oils may be removed, and nails may protrude (Alam, 2003; Dinley & Cheng, 2008).

It was difficult to compare the maintenance costs of ramps and lifts. While the maintenance-related costs of lifts were presented in some publications, no articles mentioned the real expenses of maintaining ramps. However, it was inferred that ramps would require less maintenance and replacement costs than lifts, as they required less frequent check-ups. For example, lifts need to undergo regular inspections and tests every six months and to be serviced by qualified engineers at least once a year (Disabled Living Foundation, 2006; Kelsall, 1996). In contrast, it is recommended that timber ramps be checked every two to three years, and steel ramps require a general review within five years of the ramp construction (Alam, 2003).

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Safety

Safety was discussed in the literature as one of the key issues in the use of ramps and lifts, as any incidence of unexpected injury might result in additional health care costs. Lifts have potential risk factors such as a failure of operation and there is also the possibility of users not operating the lift correctly. One article reported on accidents that can occur during lift use, for example a sudden stop in the middle of travel, a jerky start and stop to the ride, and a catch of the leg or ankle on the footrest of the lift (Auld & James, 1999). However, according to Carne & Carne (1991), there are in fact few incidences of operational failure during the use of lifts.

The literature reviewed for this report raised more concerns regarding the safety of ramps than lifts. For instance, ramps have been frequently reported as the setting of accidents among wheelchair users (Kirby, Ackroyd-Stolarz, Brown, Kirkland, & MacLeod, 1994). Ramps that are poorly designed and fail to satisfy the safety requirements set by the Australian Standards' such as incorporating grabrails and standard inclines in their design can lead to serious accidents. The tests results of Sanford, Story & Jones (1997) suggested that wheelchair users feel a fear of tripping over backwards on slopes greater than 1:12. They also found that steep ramps are particularly problematic in descent in regard to balance because they caused the wheelchair users to descend too quickly. In addition, for some disabled people with mild mobility problems, stairs were preferable to ramps as better balance and control can be experienced while using stairs (K.G. Wolfinbarger & R.L. Shehab, 2000). Thus, the literature suggested that ramps should be installed in addition to stairs rather than as an alternative to stairs, since many ambulatory individuals found stairs easier to climb than walking on an incline (Belknap, 1997).

This review did not reach an evident conclusion as to which was, in general, a safer option. What was obvious was that both options fail to remove all the risk factors presented by stairs, and ramp design contained many safety issues to be addressed. Some essential safety features for ramps such as ramp edge protection and handrails could create new barriers and hazards for wheelchair users. For example, 'if a wheelchair gets entrapped in the edge protection, this may result in the user's hand striking part of the handrail system' (Zackowitz, et al., 2005, p. 805).

Aesthetics

Aesthetics is an intangible attribute that is hard to convert into a monetary value. However, aesthetics should be taken into consideration as an important element in accessible housing design. As a whole, the literature paid more attention to ramps rather than lifts regarding aesthetic matters. This is probably because ramps occupy more space and are thus more visible. However, lifts also raise aesthetic concerns. The primary aesthetic concern is the appearance of the home. A ramp may have a negative impact on the beauty of a home, particularly if it is constructed in an incompatible style (Madley, 1999). The prospect of an unattractive ramp may also discourage home owners from considering a ramp installation in their home (Center for Universal Design, 2004).

Home adaptation at the entrance of a home may also have the side effects of threatening the self identity of the residents and the relationship between residents and neighbours. These side effects can compromise the functionality and expected benefits of ramps and lifts. The results of consumer research indicated that ramps could have a negative impact on the self-image of the resident. Handrails, level thresholds and ramps have been found to be associated with institutional design for low income housing and can be seen by residents as symbols of disability (Heywood, 2005; Madigan & Milner, 1999). For example, a ramp to the front door would signal that the occupants are different from their neighbours:

> *"The ramp would symbolise the family's 'deviance' by extending evidence of the disability from the family to the house. A home that departs too far from the norm stigmatises its occupants by announcing deviancy. Part of the difficulty on adapting their homes arose from what the adaptation symbolised. …*

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> *When an outward sign such as a ramp informs the world of the occupant's physical status, the residents may feel less secure, even 'vulnerable' (Lewis, 1986).*

Property value

The literature revealed that a decline in property value after home adaptation was a common concern of home owners considering installing ramps and lifts. As was indicated above, unattractive looking ramps that detract from a home's appearance have the potential to reduce the market appeal of the property (Center for Universal Design, 2004; Lewis, 1986), and this could also be the case for installing lifts (Meldrum, 2003). If adding ramps or lifts negatively affects the re-sale value of a home, the benefits should correspondently be seen as depreciated.

However, these concerns were also disputed by many publications. Some evidence has shown that building ramps or lifts does not adversely affect the market value of a home (Brooks, 1999). Rather, correctly installed lifts can increase a home's re-saleability (Meldrum, 2003). This argument was supported by the suggestion that physically fit old people also tend to seek accessible houses in established neighbourhoods (Brooks, 1999). This implies that installing ramps or lifts does not necessarily decrease property values, although there may be variations in the demand for accessible housing according to the population structure of the areas it is located within. The key point for consumers and providers of ramps and lifts to keep in mind is, particularly in the case of ramps, whether adaptations at the entrance are designed so that their types and materials match the home's style and blend into the surroundings (Center for Universal Design, 2004).

Natural environments

For the purposes of this review, the natural environment refers to the natural features of an area and the surroundings of a home. It includes topography such as the steepness of the land and climatic factors such as temperature, the amount of precipitation, the level of humidity, geological stability, and incidences of flood and drought etc (Oram, Jung, Millikan, & Bridge, 2008). This factor was of relevance in terms of ease of installation and the functionality of ramps and lifts. For example, for houses in areas that are flood-prone, a more practical alternative would be stairlifts rather than ramps (Bride & Martindale, 2002).

In the literature, the natural environment was mostly discussed in relation to ramps rather than lifts. In particular, it was raised that the durability of ramps made of timber was subject to the influence of external conditions such as weather, number of daylight hours, degree of shade and so forth (Alam, 2003). The performance of metal ramps was also influenced by rain, ice, and hot temperatures (Dinley & Cheng, 2008). Thus, Belknap (1997) recommended that outdoor ramps be designed to avoid water accumulation in summer and to prepare for conditions during winter by adding canopies and integrating heating coils into the surface materials to melt ice and snow. All these special design considerations increase the costs of ramps, devaluing their relative superiority of cost-efficiency.

Spatial utility

This category refers to the size of the space that is required to install and operate ramps and lifts. As a matter of course, reduced space due to adaptations leads to increased opportunity cost. That is, diversion of land for ramps or lifts decreases the chances for residents to use the space for other alternative purposes. All the publications reviewed for this report agreed that lifts were more efficient in terms of spatial utilisation. As mentioned earlier, ramp design should comply with the standard grade of 1:14, which means that the greater the elevation, the longer the length of the ramp. In addition, for a change of level greater than 75 centimetres, at least two successive ramps with a landing would have to be installed (Belknap, 1997).

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Expert opinions presented many problems derived from the spatial constraints of ramps. One of the key concerns is the limits that ramp construction can place on alternate uses of spaces for residents. For example, ramps can take space that would otherwise be used for a yard or garden (Brooks, 1999). More serious problem arose when installation of ramps was not viable due to limited space of a home. It is possible that installing a ramp might be a difficult project to accomplish if a home is built close to a sidewalk, such as in a city (Madley, 1999).

The spatial restrictions represented by ramps are the primary reason that lifts have emerged as alternatives to ramps. A relatively small footprint has made lifts a more viable adaptation for aiding vertical transfers within an existing building (Bridge, 2005). In addition, they can provide design solutions to accommodate the needs and preferences of residents. For example, Okada and Togashi (1990) observe that aged people or physically handicapped people often prefer rooms located high for the sunshine and the view, but their rooms are generally located at ground level. Elevators can allow their rooms to be located at the highest floor. However, it should be noted that lifts also have negative impacts on the spatial arrangements of a home. For instance, stairlifts take up space at the top and bottom of the stairs to allow the users to approach the lifts and to transfer on the seat (Kelsall, 1996; Stowe, 1990). Vertical lifts require even more space than stairlifts and sometimes also require structural alterations to the home (Disabled Living Foundation, 2006). If installed inside a building, elevators require rearrangement of room space (Grisbrooke, 2003).

Adaptability & flexibility

Flexible housing refers to housing that can adjust to the changing needs of the user and accommodate new technologies as they emerge (Till & Schneider, 2007). Long-term economic efficiency was one of the major motivations for developing adaptable design (Gu, Hashemian, & Nee, 2004). Thus, applying the concept of flexible design can be understood as a cost-saving way of adapting the home. The significance of adaptability was supported by the statistics that the average age of ramp users among Australian veterans at the time of installation was 77.3 and a third of them died within 3 years after installation (Dinley & Cheng, 2008). It is not uncommon that the need for ramps or lifts is temporary, for example families may plan to move. In these situations re-usable home adaptations may be both appropriate and economical (Center for Universal Design, 2004).

The level of adaptability offered by ramps and lifts is different depending on the type of ramp or lift in question. Most ramps, excluding concrete, can be easily removed when no longer required. However, the most adaptable and flexible option is modular ramps as they can be reused and installed in various layouts (Dinley & Cheng, 2008). Although they are more expensive in the initial installation, they are efficient option from a longer-term perspective (Alam, 2003). Their flexibility and adjustability allows easy dismantlement and installation at another home (Center for Universal Design, 2004; Zackowitz, et al., 2005). In effect, modular ramps can save $1,691 each on average if they are re-used (Dinley & Cheng, 2008).

Compared to other lifts, stairlifts are regarded by the literature as adaptable devices, as they are made up of component parts including a seat and a modular rail and thus could easily be recycled and resited on staircases (Auld & James, 1999). On the other hand, elevators are difficult to replace or resite. A study of the post-installation experiences of elevator users revealed that resiting was often necessary, particularly when elevators were placed on a party wall, and that this requires costly extra work (Grisbrooke, 2003).

Operation

Operational costs are typically discussed in relation to lifts, as the operation of lifts involved energy consumption. In most cases except for portable wheelchair lifts, lifts run using electrical power. Although running costs are low (Kelsall, 1996) and vary depending on the amount of use, this expenditure should be included when estimating the costs of lifts. Lifts can be designed to use standard household power or battery power (Perr & Barnicle, 1994), but many stairlifts are changing to a battery-driven power source because battery powered lifts continue to operate in the event of power failure (Auld & James, 1999). However, it must also be noted that battery-operated lifts require batteries to be recharged, which also entails additional costs.

Assistance and care

Although home modification solutions aim to improve the independence of residents in their daily activities, it is acknowledged that home modification cannot completely eliminate the need for human assistance and care services (Jung & Bridge, 2009). Costs are attached to the use of care services, and thus, the amount of human care assistance over a certain period of time involved in the particular home modification option chosen should be considered in estimating costs and benefits, whether or not it is paid for or offered for free by family members or volunteers. As Andrich and Caracciolo (2007) revealed, the home modification option that appears to be the cheapest at first glance could eventually prove to be the most expensive, and the need for human assistance was a significant factor in explaining additional costs. For example, they found that a mobile stair climber was the cheapest option at the initial purchase stage when compared with a stairlift and an elevator, but when additional social costs over 10 years were considered, it was found to be the least cost-efficient option as people using this device often required assistance from a carer.

None of the publications reviewed in this research made comparative conclusions around the amount of care and assistance required in the use of ramps and lifts, or the costs saved when a reduced level of care is required. However, some literature presented positive impacts of installing lifts on the users and carers. Lifts are able to facilitate independent transfers from one level to another, which is a benefit for both lift users and their carers as assistance is not generally necessary (Carne & Carne, 1991). It could be presumed that elevators can also maximise the benefit of independent moves, as no transfer is involved. According to the Disabled Living Foundation (2006), elevators are the best long term solutions for those whose physical conditions are deteriorating and require increasing care assistance.

Abandonment & durability

No research in the field of home modification has paid attention to the cost of ramp and lift equipment that has been abandoned. Some studies (Phillips & Zhao, 1993; Verza, Lopes Carvalho, Battaglia, & Uccelli, 2006) evaluated the abandonment rates of some assistive devices or mobility aids such as walkers, wheelchairs and electronic scooters, but the costs involved with the disuse of permanently fixed facilities including ramps and lifts have not been sufficiently considered. However, this factor is seen to be significant in estimating the costs and benefits of ramps and lifts, because early abandonment results in an increase in expenses as well as decreases in functional ability and independence among users (Phillips & Zhao, 1993). Specifically, the disuse of ramps or lifts involves a high disposal cost, which includes the cost of demolition and scrapping (Woodward, 1997). Therefore, the durability and project life-span of the home modification option should not be ignored.

The life-span of ramps and lifts varies according to the material used in construction and the maintenance required. The literature showed that ramps in general last at least ten years. More specifically, the life expectancy of modular ramps is relatively short (Alam, 2003), and metal ramps offered longer durability than wooden ramps (Center for Universal Design, 2004). If timber ramps are properly maintained, they can last longer than modular ramps. Compared with ramps, durability was not discussed as much in lifts. Only one publication presented the durability of stairlifts, stating that they have a reasonable level of durability of over twenty years (Stowe, 1990).

Construction period

The duration of the construction period has multiple implications for the costs and benefits of ramps and lifts. Above all, time spent for installation was directly related with labour cost. However, reduction of the construction period to save costs can compromise the quality of the device because high quality products in general require high quality components and longer period of construction. Timely intervention is also crucially important. According to Carne and Carne (1991), most people consider major adaptations to their home when an illness worsens, or after sudden onset of illness or trauma, and thus delayed installation negatively effects the effectiveness of the home adaptations. Evidence shows that beneficial effects of home modifications decrease as the waiting period before the installation of home modification increases (Petersson, Kottorp, Bergström, & Lilja, 2009). Therefore, strategic decision making in consideration of both financial concerns and intervention timing is required in relation to the construction period required to install the device.

No literature reviewed in the research presented comparative information about the installation periods of ramps and lifts. However, two publications mentioned the short installation period of stairlifts as an advantage over the other options available (Disabled Living Foundation, 2006; Kelsall, 1996). According to these articles, the installation of stairlifts could be completed in a day, while all the other options took considerably longer to install. In general,, lifts are seen to be quicker to install than ramps as they are manufactured ready for installation (Kelsall, 1996).

Costs of ramps versus lifts

Costing using cost guides

Building Cost Guides provide the building industry with price references across a range of building materials. There are two types of reference guides that are regularly used in Australia, and these are the Rawlinsons and the Cordells. No significant difference between them was identified as they both provide a meterage cost based on selection of raw materials. However, unit prices of the residential lifts were available from the Rawlinsons only. As is shown in the following table (Table 3), the Rawlinsons demonstrated the usage of lifts for people with mobility problems. Although the Cordell also presented prices for several types of lifts, they did not include pricings for lifts specifically designed for people with disability.

As is illustrated below (Table 4), the price of lifts that serves two levels range from $15,000 to $59,000 depending on their type. As a whole, stairlifts are the cheapest type, followed by platform lifts and then elevators. It should be noted here that the following prices represent the indicative cost of complete installation of custom equipment by a specialist company (Rawlinsons, 2010). That means that they represent real costs for lift installation.

Table 4 Prices of lifts

Types of lifts			Prices ($)
Wheelchair lifts	Platform lift serving two levels	Straight	37,000
		With bend	50,000
	Stairlift serving two levels	Straight	15,000
		Curved/spiral	22,000
Handicapped persons lifts	Serving two levels, push button operation		59,000

Source: (Rawlinsons, 2010)

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Unlike lifts, it is difficult to estimate the costs of installing ramps using cost guides, as there can be virtually infinite variations in design features and materials. The amount of resource inputs required varies depending on the dimensions of the ramps. Therefore, it is practically impossible to present the real costs of installing ramps and reflect every aspect of possible design plans. Hence, cost guides for ramps can be useful only when comparing the cost per metre of materials. According to the following table (Table 5), concrete is the most expensive material to be used in the construction of ramps, followed by steel, wood and sheet metal. To obtain the costs of installing ramps, this research calculated the amount of material required for a ramp with a specific dimension. As there are no standard dimensions of ramp, this research assumed a ramp of 7 metres in length (0.5 metre elevation) and 1.5 metres in width, and then estimated input costs of different types of ramps (see the column of 'prices of material input').

Table 5 Unit prices for ramp materials (selected items)

Materials		Unit of measure	Unit prices ($)	Prices of material input ($)	Costs to be added
Concrete (stairs and landings use)	20 MPa*	m^3	336.00	1,764.00	Wages of labourer, structuring, hand-rails & balustrade
Steel (galvanized)	150 × 150 × 10 mm	m	163.95	1,147.65	
Sheet metal	Aluminum; 1.0mm thick	m^2	30.76	322.98	
	Stainless steel; 0.45mm thick	m^2	21.87	229.64	
Wood (Pine timber board)	190 × 25mm (width × thickness)	m	10.26	378.49	

* MPa denotes the strength of concrete. Source: (Reed Construction Data, 2010)

It is acknowledged that even with these measures taken, the prices presented are well under-estimated, as they do not represent the full cost of installation. The largest cost missing is that of labour. According to the Cordell Cost Guide, the wage rate for an ordinary construction labourer is $48.07 per hour. When assuming a month of construction with an input of 2 labourers, approximately $10,000 would be additionally required. If other trades and services personnel such as a carpenter, joiner, or welder were involved, higher rates would need to be applied. The amount of material required is also subject to under-estimation because only the faces of the slopes were considered in the above calculation without consideration of the sides and bottom of the ramps. Other missing elements are the costs of adding hand-rails and balustrades, which are essential parts of ramps. Lastly, the construction of ramps and lifts inevitably involves site work to adjust sloping sites, ground conditions, unusual shapes of homes and other design considerations (Rawlinsons, 2009), but cost guides cannot integrate all of these additional costly elements of installation.

Costing using cases from the HMMS

For this research, more realistic cost information about some types of ramps and lifts were available through the cases from the New South Wales HMMS. The cases were based on the assessment records undertaken by occupational therapists, which recommended suitable options for home modification. These were particularly useful because they presented not only the real costs for ramps and lifts, but also the decision making process involved in choosing an option. The environmental circumstances and the needs of a resident were comprehensively investigated in the assessment. Key factors that affected the selection of a final alternative included the mobility status of a resident, housing conditions, and the availability of a carer. Through the discussion around the decision making process in each case study, the relative benefits of one option over the other were also identified. The next section of this report summarises the NSW HMMS cases provided, highlighting the options selected in each case, the grounds for this choice, and their estimated costs. They were collected over the period of 2010.

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Case 1: Wheelchair platform lift (low-rise)

A home owned by a male electric wheelchair user with poor functional ability was assessed for a ramp or a lift in the backyard entrance to his home. The wheelchair had large footprints and turning circle, and required a rise of 880mm to access the back entrance. The backyard was small and the entrance to the home was close to boundary fences. Thus, if a ramp was constructed it would need to be U-shaped and would take up a large proportion of the backyard as U-shaped ramps require a landing at the change of direction point. However, there was not sufficient space for a standard size landing. Therefore, despite the higher cost involved, a wheelchair platform lift was recommended by the occupational therapist assessor. The estimated cost of a ramp in this case was around $18,000 and the cost of a lift was estimated at around $40,000, including remote controls to operate the device.

Case 2: Timber ramp

A 79 year old woman with a past medical history of arthritis affecting the joints of her shoulders, knee ankles and hands had difficulty in accessing her home as there were 2 steps both in the front and back entrances. She had a daughter as a primary carer and her husband assisted with activities of daily living and other care tasks. A timber ramp to the back entrance of the home with an elevation of 535mm was proposed. Complying with a gradient requirement (1:14) of the Australian Standards, the ramp was recommended to have dimensions of 7,490mm in length and 1,200mm in width. It was also recommended that the ramp be designed with a level landing at the top before the entrance and a concrete base pad from the lower end of the ramp to the garage gate. The cost was estimated at $5,995.

Case 3: Stairlift

The client in this case was an 86 year old woman living alone. She could ambulate indoors utilising a walking frame and outdoors using a wheelchair. The house was at the top of a large sloping block and sharply inclined from the driveway. The street was too narrow for a car to be parked on the road. Access to the front of the house was via an enclosed verandah and then up an inclined drive. Rear access was via a steep driveway to two flights of timber stairs, which comprised of 8 steps to the first landing, 5 steps to the second landing, and one into the house. Two options were investigated: first, installing a ramp; and second, reconstructing the stairs to allow the installation of a straight outdoor stairlift. Installing a ramp in the front of the residence was not viable due to a lack of space and steep land slope. Therefore, the installation of a stairlift following reconstruction of the stairs was chosen in this case. The estimated cost of reconstructing the stairs was $10,399, and that of the stairlift was $7,250.

Case 4: Elevator

In this case the client was a woman with symptoms of rheumatoid arthritis in the joints of her ankles. Her home had an additional natural environmental issue for consideration because the area in which she lived had a high wind factor. Due to her mobility impairment and balance difficulties from restricted joint ranges, she could not protect herself from a fall if she was blown over on to the inclined driveway whilst walking or carrying items such as laundry. The installation of a vertical lift was proposed as a lift was expected to make the access pathway become level, maintain her joint integrity, and minimise the total distance she needed to walk. The estimated cost was $43,371.

Benefits of ramps versus lifts

More difficulties have been presented in assigning monetary value to the benefits of home modification solutions than the real costs of implementing these solutions (Duff & Dolphin, 2007a). Some attributes of benefits such as reduced heath care cost, decreased needs to purchase private care, and increased opportunities for informal carers to participate in the paid labour force are easier to convert into monetary units. However, many other essential benefits

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including improved social participation through increased community visits (G. W. White, Paine-Andrews, Mathews, & Fawcett, 1995), less fatigue, more comfort (K.G. Wolfinbarger & R.L. Shehab, 2000), a decreased care burden, and feelings of independence and well-being have been considered as intangible and inconvertible into monetary value.

There have been some limited research attempts to explore the economic benefits of home modification, such as Duff and Dolphin's cost-benefit analysis of assisted technologies for people with dementia (Duff & Dolphin, 2007b). However, this research has used alternative indicators to those used in this research report, such as indices of usefulness and satisfaction, recommendation, willing to pay, and carers' well-being score. Moreover, its measurements of benefits have not been specific to a particular adaptation as the research focused on the impacts of the whole package of interventions.

This research did not identify any research conclusions on the comparative benefits of ramps and lifts. However, Carne and Carne (1991) implied a theoretical assumption that people with more physical demands but less assistance available could expect more benefits through installation of lifts rather than ramps. Particularly, this would be the case if the residents were manual wheelchair users who had to travel on their own (Disabled Living Foundation, 2006). Contrastingly, some long and steep ramps presented barriers for some manual wheelchair users (Sanford, Story, & Jones, 1997). Another test conducted using a 12 metre long ramp to determine manageable slopes and length of ramps by disabled people also revealed that many wheelchair users were unable to travel the length of long and steep ramps or needed a very long time to negotiate the full length of the ramp (Steinfeld, Schroeder, & Bishop, 1979).

It is recognised in this research that ramps had advantage over lifts in terms of initial installation costs. However, it was inferred that more benefits could be expected from lifts than ramps from a longer term perspective. As was identified both in the findings of the systematic review and the case studies from the NSW HMMS, lifts would be better options to those with deteriorating mobility problems. While lifts were more expensive investments, they could relatively easily overcome the physical and natural environmental restrictions of an inaccessible home. It was found that elevators in particular would be the best home modification option for those with severe mobility problems and limited care and assistance available, because they do involve the least transfer.

Summary of findings

The systematic review identified fourteen factors that have the potential to affect the costs and benefits of ramps and lifts. These are type of ramp or lift, material, initial purchase and installation, maintenance and replacement, safety, aesthetics, property value, natural environments, spatial utility, adaptability and flexibility, operation, assistance and care, abandonment and durability, and construction period. These are all regarded as important variables that have significance in determining the economic dimensions of ramps and lifts.

Costs were estimated using cost guides, and the cases from the NSW HMMS. Cost guides proved to be good resources as they presented prices of some types of lifts and unit prices of construction materials for ramps. They uncovered that the cost of stairlifts was the lowest among lifts for creating an accessible entrance, followed by platform lifts and elevators. Unlike lifts, it was difficult to estimate the costs of installing ramps because of variations in design plans. However, all the other conditions such as length and width being equal, concrete ramps were the most expensive, followed by those made of steel and then wood.

Due to the limitations of cost guides in providing costs that encompass the whole building project, there was a restriction in obtaining realistic information about costs, particularly of ramps. This research supplemented the cost guides with cases from the NSW HMMS. By providing estimated costs of some selected ramps and lifts, these assisted in reaching a general comparison of the costs between ramps and lifts. According to the case studies,

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ramps were, as a whole, more affordable options than lifts. More specifically, timber ramps cost the least, whereas elevators were the most expensive interventions.

It was acknowledged that there was a risk in schematising the costs of ramps and lifts. This is because every intervention is customised and, thus, costs can not be standardised across diverse types and models. In addition, it is common that ramps are built using mixed materials such as in the case of ramps with a concrete base path. However, the costing study conducted in this research reached a rough conclusion that timber ramps involved the lowest costs and elevator involved the highest costs amongst ramp and lift home modification options. All the other options are located in-between these two, overlapping one another depending on their specific design plans.

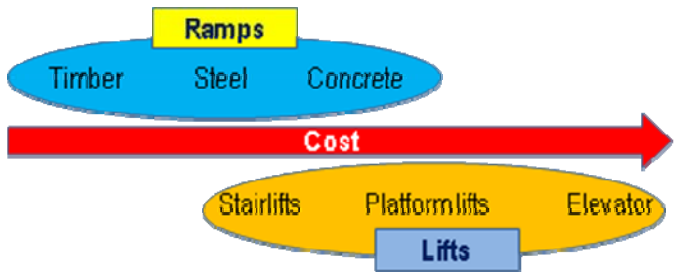

Figure 8 Costs of ramps and lifts

The above diagram should be interpreted carefully because the cost of the various options may not, in reality, be arranged in a linear way. For example, timber ramps are not necessarily always cheaper than any type of lifts, and steel ramps do not necessarily imply similar costs to stairlifts. The costs involved in installing ramps depend on the particular housing conditions concerned such as the required elevation, which is directly related to the length of the ramp, the construction period and the amount of human and material resources needed. In general, timber ramps can be installed with less expenditure than concrete ones. However, in some cases they must have a texturised finish to allow access in rainy weather or to prevent warping or rot. Costs accrue from these special treatments. When the cost of maintenance is combined, the costs of timber ramps may exceed those of other ramps or even some types of lifts.

It is conceded that, compared with costing components, the benefits of ramps and lifts have been less explored in this report. This is because, firstly, many essential attributes of the benefits expected through home adaptations are difficult to quantify, and secondly, there has not been reliable evidence of differentiated benefits between ramps and lifts. Possibly there has been a lack of motivation to distinguish the benefits because the two alternatives can be seen to serve the same purpose of facilitating travels between different heights.

Due to limited information, determining the relative benefits of one option over the other has a risk of generalisation. However, the outcomes of the systematic review and the case studies from the HMMS indicated that lifts provide more benefits from a longer term perspective. That is, lifts can more effectively off-set the growing need for assistance as people age. Elevators in particular can represent the best option for those with severe or deteriorating mobility problems. While lifts might be more expensive interventions, they can relatively easily overcome the spatial and natural environmental restrictions of a home. In addition, lifts have an advantage in terms of timely intervention as they are manufactured ready for installation and thus involve a shorter installation time than ramps.

Implications for further research

This research employed a multi-strategy method in order to uncover more comprehensive and realistic information. Different types of data were obtained from different sources: a systematic review, costing guides, and case studies

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from the NSW HMMS. This was because individual method alone was not sufficient to cover the diverse aspects of costs and benefits of ramps and lifts and the variations in models. The need for a combination of different methods also resulted from a lack of reliable literature. In addition, the unit of analysis of previous cost-benefit studies has been the package of home modification program including various home adaptations and follow-up services from occupational therapists. This means that they have not differentiated the effects of individual interventions. However, it is evident that each intervention is different in terms of both the mechanism and the extent of their contribution even if they are aimed at achieving the same goals. Given that home modification as a policy is cost-effective, the best customised practice should be selected and implemented. Thus, it is suggested that future research should differentiate the costs and benefits of specific types and material of ramps and lifts.

Although the systematic review has identified some studies that compared the costs of some types of ramps and lifts, no research that measured the different benefits of between the two was found. This is understandable because many benefits are difficult to convert into economic values. In addition, it can be risky to quantify the non-economic effects because policy initiatives of home modification are not driven by economic considerations only. However, demonstrating the benefits of home modification in monetary values is helpful in justifying the programs and decreasing the uncertainty in decision making among both home modification consumers and practitioners.

Acknowledging the necessity for quantitative increase in economic evaluations of ramps and lifts, future research is suggested to be based on scientific approaches. In particular, reliable outcomes will be best achieved through experimental research design where major variables are controlled. For instance, the ideal design would be installing some typical types of ramps and lifts in homes with the same environmental conditions where residents have the same mobility needs. In this situation, initial installation and maintenance costs can be realistically compared, and economic benefits can also be measured after the lapse of time. However, it is practically impossible to control every relevant variable at the same time. There are too many variables to be considered and one study is not likely to produce reliable evidence. Therefore, the accumulation of information through many different experiments that control different variables would be a more pragmatic strategy. For example, it is possible to conduct comparative research with participants who have similar physical needs but use different options. Surveys and interviews with consumers, practitioners and suppliers of ramps and lifts are other viable research options to find out on-going maintenance costs and track after-effects of ramp and lift installation.

Conclusion

Despite a long practice of installing ramps and lifts in home modification, economic evaluations of these options have been few. In particular, the systematic review undertaken in this research showed that there has previously been no comparative research using a cost-benefit analysis method. Although the review captured some literature that presented the costs of installing some types of ramps and lifts, no economic comparison of benefits between them has been identified. The paucity of research could be explained by many possible reasons. First, it is difficult to convert diverse aspects of costs and benefits into economic values. Second, there has been recognition that the effects of ramps and lifts are not significantly different, as they both serve the same purpose of improving accessibility at the entrance to the home. Third, economic evaluation may not be the most appropriate method of assessment as the main outcomes of installing ramps and lifts, such as safety, independence, and social participation, are intrinsically non-economic. Whatever may be the reason, lack of research leads to insufficient consumer information, and subsequent uncertain decision-making.

Despite a focus on the economic side of ramps and lifts in this research, it should be noted that economic information is not necessarily the most important to consider in choosing ramps and lifts. As the cases from the NSW HMMS demonstrate, selection of an option was based on comprehensive consideration of all the other conditions including mobility status of a resident, housing conditions, availability of carer, etc. Thus, it is suggested that economic factors are to be regarded as just one of many major considerations.

This attempt to compare two alternatives to stairs has faced obstacles due to internal variations in types, materials, and design plans. In particular, every ramp is unique and custom designed, which allowed limited comparison in ballpark figures. Despite these restrictions, this research has reached a general conclusion that ramps had an advantage over lifts in terms of installation costs, whereas lifts could provide more long-term economic benefits. Despite this contrast, they are seen as complementary rather than exclusive options because the spatial efficiency of lifts has provided a solution where ramps are not viable due to spatial restriction and the standard requirements on the degree of incline.

While there is certainly room for further examination, as an unprecedented comparative research attempt concerning the costs and benefits of ramps and lifts, this report has provided significant implications for future research. Most of all, this research has affirmed the necessity of further rigorous economic evaluation in the field of accessibility. Quantifying benefits has been identified in particular as an important issue for further exploration. In addition, the outcomes of the systematic review in terms of the variables identified are expected to be used as frameworks for broader economic evaluation of home adaptations. The factors identified will be useful in guiding future experimental research designs that aim to estimate costs and benefits of specific home adaptation interventions.

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Appendix: analysis matrix

Reference	Nationality	Main Findings	Process & Issues	Device				Cost/benefit factors															Method						
				Ramp only	Lift only	Both	General devices / unidentified	Type	Material	Upfront purchase / installation	Maintenance / replacement	Safety / failure of operation	Aesthetics / image	Natural environment	Spatial utilisation / land use	Adaptability / flexibility	Energy consumption	Impact on carer / care service	Noise	Life span / usability	Property value	Indirect / intangible qualities	Systematic Review	RCT	Quasi Experiment	Literature Review	Case Study	Expert Opinion	Other (anecdotal. database)
(Bridge, 2005)	Australia	This summary bulletin presents some critical factors when selecting a residential lift and relevant Australian Standards.	It was mainly based on review of standards material, and main focus is not placed on the costs and benefits. It only deals with lifts, thus comparison with the ramps was not presented.		√			√		√	√															√			
(Perr & Barnicle, 1994)	USA	Residential lifts enable people with limited mobility to travel up and down stairs within home. Choosing the appropriate one involves considering the user's abilities, caregiver situation, and environment.	It does not directly deal with cost and benefit factors, mainly focusing on architectural concern when installing lifts. However, it contains some relevant information that other papers did not considered such as noise and aesthetic concerns		√			√		√			√				√	√	√	√								√	
(Meldrum, 2003)	Australia	A commonly expressed fear is that installing a lift will reduce the value of a home. However, a correctly installed lift is relatively unobtrusive and may increase the saleability of a home.	Installing a lift can cost from $10,000 to over $4,000, with annual on-going maintenance service fees for around $200.			√		√		√	√	√			√						√							√	
(Alam, 2003)	Australia	Concrete is an expensive and permanent option for building a ramp at home. Durability is also an importance maintenance issue that affect life-span cost.	This paper does not provide costs in money values for different materials for ramps.	√				√	√	√	√					√				√								√	

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Reference	Nationality	Main Findings	Process & Issues	Device				Cost/benefit factors															Method						
				Ramp only	Lift only	Both	General devices / unidentified	Type	Material	Upfront purchase / installation	Maintenance / replacement	Safety / failure of operation	Aesthetics / image	Natural environment	Spatial utilisation / land use	Adaptability / flexibility	Energy consumption	Impact on carer / care service	Noise	Life span / usability	Property value	Indirect / intangible qualities	Systematic Review	RCT	Quasi Experiment	Literature Review	Case Study	Expert Opinion	Other (anecdotal. database)
(Andrich & Caracciolo, 2007)	Italy	When additional social cost considered, the solutions that appeared the cheaper at first glance eventually may prove to be more expensive. In this vein, elevators can decrease the cost gap with stair lifts.	This paper focuses on the cost aspects of particular assistive technologies. However, it presented the costs of lifts only. This is, maybe, because ramps are not considered as kinds of assistive technology.		√			√		√	√									√							√		
(Phillips & Zhao, 1993)	USA	Technology abandonment has serious repercussions. Non-use of a device may lead to decreases in functional abilities and independence, and increases in monetary expenses.	This paper presents abandonment rates for some assistive technologies, but ramps and lifts are not considered.				√													√					√				
(Verza, et al., 2006)	Italy	An interdisciplinary approach to evaluating assistive technology needs decreases the risk of equipment abandonment.	It only deals with assistive devices, excluding ramps. Sample size of this research was not big enough for reliable outcomes for lifts. But it demonstrated that decrease in the abandonment rate significantly decreases expenditures on devices.		√															√					√				
(Duff & Dolphin, 2007a)	Ireland	This paper presents an overview of the cost-benefit methodology used in the field of assistive technology.	This paper categorises cost-benefit factors into economic and social. It deals with the analytic framework, not presenting practical results of cost-benefit analysis. It is a theoretical paper.				√			√	√											√				√			

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Reference	Nationality	Main Findings	Process & Issues	Device				Cost/benefit factors															Method						
				Ramp only	Lift only	Both	General devices / unidentified	Type	Material	Upfront purchase / installation	Maintenance / replacement	Safety / failure of operation	Aesthetics / image	Natural environment	Spatial utilisation / land use	Adaptability / flexibility	Energy consumption	Impact on carer / care service	Noise	Life span / usability	Property value	Indirect / intangible qualities	Systematic Review	RCT	Quasi Experiment	Literature Review	Case Study	Expert Opinion	Other (anecdotal. database)
(Duff & Dolphin, 2007b)	Ireland	This research tested methodology developed to test cost and benefit of assistive devices. Overall, the benefits of using technologies exceeded their costs.	Unfortunately, ramp and lifts were not included in this research. However, it presented the framework to estimate intangible benefits, which is useful for home adaptations.				√			√												√			√				
(Brooks, 1999)	USA	Ramping cost less but would take more space. A platform chair lift cost more but required smaller installation space. Installation of lift can also increase the resale value of the property.	This paper does not present actual costs. Although it is based on the real case, it seems insufficient to meet the methodological criteria.			√				√					√						√						√		
(Madley, 1999)	USA	Using wood keeps the cost of the ramp down. The price for chair lift ranges about $3,500 and up, with chair lift about $3,500 and up and wheelchair lifts from $5,000 and up depending on length of travel and customisations.	This paper is useful as it presents the price range of some options of ramps and lifts. However, it is based on the US dollar, and data is outdated.			√		√	√	√			√		√													√	
(Grisbrooke, 2003)	UK	This paper focused on the diverse outcomes of lift installation.	It explores the consequences of lift installation based on qualitative interviews with housing lift users and carers. It presents evidence of positive and negative outcomes of lifts. However, it does not present money values of them.		√						√				√			√	√			√			√				

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Reference	Nationality	Main Findings	Process & Issues	Device				Cost/benefit factors															Method						
				Ramp only	Lift only	Both	General devices / unidentified	Type	Material	Upfront purchase / installation	Maintenance / replacement	Safety / failure of operation	Aesthetics / image	Natural environment	Spatial utilisation / land use	Adaptability / flexibility	Energy consumption	Impact on carer / care service	Noise	Life span / usability	Property value	Indirect / intangible qualities	Systematic Review	RCT	Quasi Experiment	Literature Review	Case Study	Expert Opinion	Other (anecdotal. database)
(Auld & James, 1999)	UK	This paper introduces changes and new developments to improve safety of stair lifts.	It is based on the survey with the 114 stair lift users. Despite some relevant information, it has focused only one type of lifts, stair lifts.		√							√				√	√								√				
(Lansley, McCreadie,	UK	Adaptations and AT can substitute and supplement care. For many older people adaptations and AT can be cost-effective.	It estimated costs of home adaptations. However, costs were not differentiated by specific interventions and benefits were not presented in money values.			√				√	√											√					√		
(Steinfeld, et al., 1979)	USA	Manual wheelchair users have difficulties on gradients of 1:12 and steeper. Many required a long time to negotiate the full length of the ramp at a slope of 1:12.	These outcomes are based on the experiment that 124 disabled people were tested.	√																		√			√				
(Sanford, et al., 1997)	USA	30-foot ramp at a slope of 1:12 or higher presents a barrier for some manual wheelchair users. People who use wheelchair fear tipping over backwards on slopes greater than 1:12.	Test was conducted with a total of 171 subjects with mobility impairments. It tested participants' performance on the slope and length of the ramps.	√								√													√				
(Kirby, et al.,	Canada	Ramps are the frequently reported location for accidents such as tips or falls.	Data was collected through postal questionnaire answered by 577 wheelchair users or an appropriate designate such as spouses.	√								√													√				

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Reference	Nationality	Main Findings	Process & Issues	Device				Cost/benefit factors															Method						
				Ramp only	Lift only	Both	General devices / unidentified	Type	Material	Upfront purchase / installation	Maintenance / replacement	Safety / failure of operation	Aesthetics / image	Natural environment	Spatial utilisation / land use	Adaptability / flexibility	Energy consumption	Impact on carer / care service	Noise	Life span / usability	Property value	Indirect / intangible qualities	Systematic Review	RCT	Quasi Experiment	Literature Review	Case Study	Expert Opinion	Other (anecdotal, database)
(Okada & Togashi, 1990)	Japan	Setting up home elevator gives the aged and physically handicapped persons more flexibility in room location. Noise of home elevator in detached house is no problem.	The detailed outcomes could not be accessible as only abstract was presented in English.		√										√				√								√		
(Madigan & Milner, 1999)	UK	Level thresholds and ramps often became associated with in the public mind with bleak 'institutional' design for low income housing.	Housing design is associated with disability discrimination. This paper advocates the necessity for space standards and access standards. Ramps were dealt as part of accessible housing design.	√									√													√			
(Kimberly Graves Wolfinbarger & Randa L. Shehab, 2000)	USA	Older people are not homogeneous in their preferences for ramps or stairs. Despite more frequent use of ramps, ramps have still risk factors.	43 community-dwelling adults aged 57 and 95 participated in the survey. Although sample size was not big enough, important implications were identified. It implied that ramp did no remove all the risk factors of stairs.	√								√													√				
(Kelsall, 1996)	UK	Lifts can be divided broadly into three categories; lifting platforms, through-floor lifts and stair lifts. The cost of buying and installing a lift varies from model to model.	This article outlines the range of lifts available, giving points to consider when selecting a lift. Focusing on design features and functions of lifts, it did not present cost and benefit information in details.		√			√		√	√	√			√		√		√									√	

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(Heywood, 2005)	UK	Considerable expenditures for home adaptations may end up with ineffective or even harmful outcomes in terms of 'meaning of home' factor.	This paper focused on the meaning of home factors when evaluating major home adaptations. Particularly lifts can have harmful effects on the sense of control, self-image and relationships inter and intra family.			√							√		√				√			√			√				
(Center for Universal Design, 2004)	USA	Although ramps are the most familiar home accessibility modification, they take up a lot of space, and can be quite expensive it they accommodate rises above 30 inches.	This booklet is a mainly construction guide of a wood ramp. Although it deals with only one material; wood, it present a range of factors relevant to cost and benefit of ramps in general.			√		√	√				√	√		√				√								√	
(Travers, 1991)	UK	Ramps may be portable or fixed and constructed with various materials.	This paper looks like a general introduction of ramps.			√		√	√		√	√		√		√												√	
(Belknap, 1997)	USA	This paper covers all types of incline devices for travelling raised or lowered levels including portable and permanent ramps.	It is a factsheet on ramps. It did not present direct price figures for ramps discussed.	√				√	√			√		√	√													√	
(Disabled Living Foundation, 2006)	UK	Stairlifts are often cheaper to install than through floor lifts. Curved stairlifts cost approximately twice as much as straight stairlifts.	This factsheet provides first stop information on lifts and describes details about the features of different types of lifts.		√			√		√	√				√		√			√								√	

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(Lewis, 1986)	USA	The addition of an external ramp had the potential of affecting the resale value of the house. I addition, the ramp would symbolise the family's deviance from the rest of the society and neighbours.	Unforced interviews in the home were conducted with parents of six families raising a child with severe mobility problems.	√									√								√				√				
(Carne & Carne, 1991)	UK	There are very few incidents of lifts stopping midway. People on a fixed income have problems meeting annual costs for lift maintenance.	Information was based on interviews with 152 stairlift users.		√					√	√	√						√							√				
(Zackowitz, et al., 2005)	USA	Attempting to provide better accessibility in one area may create new barriers in another. Edge protection, handrails, landing, and ramp-ground transition are the potential areas that may cause unexpected harms.	79 participants with a variety of disabilities ascended and descended 2 ramps for a total of 8 trials. Manual and power wheelchairs were used by people with a broad range of experience levels.	√				√	√			√													√				
(Stowe, 1990)	UK	There are different stairlifts available, costing from £1,500 to £3,000. It is an expensive piece of equipment that also takes up quite a lot of space at the top and bottom of the stairs and on the staircase itself. The life expectancy of a stairlift can be over 20 years.	This article is a brief description on the stairlift and through floor lift, based on expert opinion. No experimental treatment or interview was conducted.		√			√		√	√				√			√		√								√	

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(Bride & Martindale, 2002)	Australia	The knowledge on the natural environment surrounding the home can have large ramifications for success or otherwise of project outcomes. The more practical alternative is a chairlift than a ramp in certain areas that are prone to flood.	The geographical issue was dealt limitedly in the paper. Information was extracted from interviews with 28 Home Modification and Maintenance Service coordinators across NSW.	√										√											√				
(Dinley & Cheng, 2008)	Australia	Timber ramps were the most dominant type of ramps across Australia. Average age of the clients at the installation of ramps was 77.3.	This unpublished paper was based on the DVA database. Although it presented only the statistics about DVA ramp clients, it was useful in estimating the whole picture of ramp installation in Australia.	√				√	√	√	√		√	√		√				√									√

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