An ergonomic evaluation of equipment to support patient movement and transfer in the ambulance service

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By Anna Jones

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Abstract

It is commonly accepted that ambulance staff undertake a large amount of lifting and handling in their daily work. Their primary role is to provide pre-hospital care and to transport sick and injured people to hospital. The emergency nature of the job means that ambulance workers have to assist people who are incapable of moving themselves in awkward and potentially hazardous environments. While safer lifting policies have been introduced ambulance workers still lift weights which other healthcare workers can avoid.

However since the introduction of manual handling regulations and more recently CEN standards, ambulance services and manufacturers have been trying to find new ways of moving and transferring patients. Ambulance services have purchased new equipment to reduce musculoskeletal risks but there is little scientific evidence to support their purchasing choices. This thesis presents two case studies describing ergonomic equipment evaluations of stretcher loading systems and mobility equipment to provide a scientific basis to support purchasing decisions.

Case study one is a comparative analysis of stretcher loading equipment used in UK ambulance services. The study was carried out in two phases. Phase 1 was a field study which used observation and interview methods to identify issues affecting equipment use in a range of environments. Phase 2 was a simulation study which used task simulation to assess the postures adopted during loading and unloading activities with each system. Both phases identified the tail lift as the preferred system to reduce manual handling and improve patient and operator safety.

Case study two is a comparative evaluation of mobility equipment. User trials were carried out to evaluate 12 transport chairs and 4 stretchers for Accident and Emergency and Patient Transport Service staff to identify preferred equipment for each team. 16 staff assessed the equipment by conducting task simulations and completing questionnaires for each product. Postures adopted during the tasks were assessed using Rapid Entire Body Assessment. The mechanised stair climber chair was the preferred chair for both teams. The stretcher analysis was inconclusive.

This thesis has used two case studies to establish a protocol for field and lab based evaluations of movement and transfer equipment in the future for the ambulance vehicle. A more comprehensive procurement process is recommended to include detailed ergonomic evaluation, ensuring that the end user is fully represented. The thesis concludes that automation is way forward to reduce manual handling risks posed to ambulance workers.

The output from case study 1 (tail lift) has been included in the national specification for future Emergency Ambulances in the UK.

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Publications

Conference proceedings

Jones, A.L. and Hignett, S., 2005. A comparative analysis of ambulance stretcher loading systems. *Contemporary Ergonomics*, In P.D. Bust & P.T. McCabe, Taylor & Francis, London, 2005, pp 261-265.

Jones, A.L. and Hignett, S., 2005. A Comparative Analysis of Stretcher Loading Systems. *Proceedings of the Healthcare Systems and Ergonomics and Patient Safety Conference*, In R. Tartaglia et al, Florence, Italy, 2005, pp 517-518.

Jones, A. and Hignett, S. (2006) Postural analysis of loading and unloading tasks for emergency ambulance stretcher-loading systems. In P. D. Bust and P.T. McCabe (eds.) *Contemporary Ergonomics.* London: Taylor and Francis. 308-312.

Coleman, R., Hignett, S., Evans, O., Crumpton, E., Jones, A. (2006). Designing Future Ambulance Transport for Patient Safety *Proceedings of the Annual Ambulance Services Association Conference 'Embracing the New Era - Challenges, Choices and Change in Emergency Care'* Harrogate, UK. 28-30th June 2006.

Jones, A. Hignett, S, 2006. An ergonomic evaluation of mobility devices and the loading equipment used in UK Ambulance services *Proceedings of the Annual Ambulance Services Association Conference 'Embracing the New Era - Challenges, Choices and Change in Emergency Care'* Harrogate, UK. 28-30th June 2006.

Jones, A.L. and Hignett, S., 2006. Postural analysis of loading and unloading tasks for ambulance stretcher loading systems. *Proceedings of the XVth Triennial Congress of the International Ergonomics Association*, Meeting Diversity in Ergonomics, RN Pikaar, EAP Koningsveld and PJM Settels, Maastricht, Netherlands, July 2006.

Jones, A.L. 2006. Design of ambulance stretcher loading equipment, *Proceedings of National Back Exchange Annual Conference*, Telford, September 2006.

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Glossary of Terms

Term	Explanation
Emergency Medical Service Worker (EMS worker)	A US term for Emergency Medical Services staff. An EMS worker is trained to provide pre-hospital care and as a fire fighter.
Emergency Medical Technician (EMT)	A UK term for pre-hospital care provider trained to provide a basic level of care before transporting the patient to hospital. This term is also used in the US.
Paramedic	A UK term for pre-hospital care provider trained to provide a higher level of care, administering drugs, intubating patients and preparing them for hospital.
Emergency Care Practitioner (ECP)	A UK term for a care provider trained to treat the patient in the home. Advanced Paramedic, with the skills such as suturing.
Morbidity	Occurrence of injury of illness; number of people affected by an illness or injury
Locus for control	An individuals perception of responsibility, choice and control over events in their lives
CPR (Cardio Pulmonary Resuscitation)	A life saving technique used to help pump oxygen around the body. It involves a combination of mouth to mouth and chest compressions
Intubating / Intubation	Placement of a tube into an internal or external oraphus of a patient (Often the throat)
Rater	Researcher analysing the data
Inter-rater reliability	When two researchers analyse the data to ensure the results are reliable
Bariatric	Clinically obese patient

List of Acronyms

Acronym	Description
ANOVA	Analysis of Variance
ASA	Ambulance Service Association
A&E	Accident and Emergency
BSI	British Standards Institution
CBA	Cost Benefit Analysis
CEN	The European Committee for Standardisation
CEO	Chief Executive Officer
CIPS	Chartered Institute of Purchasing and Supplies
CIT	Critical Incident Technique
CHI	Commission for Health Improvement
CPR	Cardio-Pulmonary Resuscitation
DH	Department of Health
EAAT	East Anglian Ambulance Service
ECP	Emergency Care Practitioner
EMAS	East Midlands Ambulance Service
EMS	Emergency Medical Service (USA)
EMT	Emergency Medical Technician
EPSRC	Engineering and Physical Sciences Research Council
ERS	Erecto-Spinae
ETV	Elevate and Transfer device
GP	General Practitioner
HEPSU	Healthcare Ergonomics and Patient Safety Unit
HSE	Health and Safety Executive
HTA	Hierarchical Task Analysis
KTP	Knowledge Transfer Partnership
LAS	London Ambulance Service
LOLER	Lifting Operations and Lifting Equipment Regulations
MAC	Manual Handling Assessment Charts
MAUDE	Manufacturer and User Facility Device Experience Database
MDA	Medical Devices Agency

MHOR	Manual Handling Operations Regulations
MREC	Multi-centre research Ethics Committee
MSD	Musculoskeletal Disorders
NHS	National Health Service
NPSA	National Patient Safety Agency
NIOSH	National Institute of Occupational Safety and Health
NRLS	National Reporting and Learning System
NSW	New South Wales
OWAS	Ovako Working Analysis System
PCT	Primary Care Trust
PTS	Patient Transport Service
PUWER	The Provision and Use of Work Equipment Regulations
QEC	Quick Exposure Check
RAF	Royal Air Force
RAIS	Research Assistants Industrial Secondment
REBA	Rapid Entire Body Assessment
RTA	Road Traffic Accident
RoSPA	Royal Society for the Prevention of Accidents
RPE	Rate of Perceived Exertion
RULA	Rapid Upper Limb Assessment
SAS	Scottish Ambulance Service
SHA	Strategic Health Authority
TSAT	Two Shires Ambulance Service
US	United States
UK	United Kingdom
VCA	Vehicle Certification Agency
WLC	Whole Life Costs
WRI	Work Related Injury

Chapter 1: Introduction

1.1 The problem

The UK ambulance services have seen a number of advances in recent years both in terms of culture and the technology used in the healthcare field. The services offered to patients are continuing to diversify (Department of Health, DH, 2005; Coleman, 2007) with more patients being treated in the home. Despite these advances, between 2004 and 2005, over 17.8 million patients attended emergency departments and minor injuries units across England. In 2006 / 2007 the figure had risen to over 18.9 million (DH, 2007). Between 2006 and 2007 5.1 million emergency incidents were attended and 3.6 million emergency patients travelled to hospital by ambulance (National Statistics, 2007).

It is the role of the ambulance worker to transport the patient to hospital. This involves patient handling activities which place ambulance workers at risk of musculoskeletal damage. Ambulance work has been recognised as a high risk occupation in the UK (Birtles and Boocock, 2003). It has been well documented that ambulance workers have a high exposure to physical and physiological stress which can lead to the development of musculoskeletal conditions (Nakata et al., 2006). Healthcare services across the UK have significantly reduced the level of manual handling carried out by staff, with nursing homes and some hospitals adopting minimal lift policies. However, the need for these manual handling activities still exists and because of the emergency nature of their work the majority of manual handling tasks now fall on the ambulance service.

With the introduction of standards and regulations such as The Manual Handling at Work Regulations (HSE, 1998a) and the voluntary standards provided by the European Committee for Standardisation (CEN, accessed on 07/12/2007), ambulance services have had to administer reasonable adjustments to ensure the risk to their staff is reduced. This can be done by investing in technology to assist in manual handling tasks. Vehicle manufacturers and ambulance services are placing a high priority on ambulance design and safety to protect patients and staff (Overton, 2001). Many nursing homes and some ambulance services have begun to purchase hoists to further reduce lifting (Doherty, 13/06/2006, *Personal Communication*), but without new technology some high risk activities such as transporting patients up and down stairs remain unavoidable. Automated equipment which reduces manual handling have been introduced to the market and some ambulance services have begun to purchase these systems.

Ambulance workers have little influence over the equipment which is purchased on their behalf, whilst manufacturers and those involved in the procurement process often have little experience of ambulance operations. By observing the work carried out with this equipment first hand, interviewing staff who use it on a regular basis and involving them in the evaluation process, it has been possible to identify the usability issues and the risks associated with manual handling equipment. This approach allowed recommendations to be developed based on scientific evidence for future equipment purchase. This has the potential to reduce the manual handling incidents which occur during patient transfers, therefore reducing the risk to patients and staff. Reducing usability issues can reduce worker related injuries which can have a positive impact on transportation times. This benefits the ambulance service and patient wellbeing. Incorporating ergonomic methods at the equipment selection stage could begin to influence other aspects of ambulance work such as ambulance design, control room design and system processes.

1.2 Aims and objectives

This thesis aimed to investigate whether:

1) Ambulance services are procuring the most suitable movement and transfer equipment to reduce the risk of MSD's
2) Ambulance services are procuring the most suitable manual handling equipment in terms of usability
3) A more ergonomic approach towards equipment evaluation is beneficial to the ambulance services

The objectives of this thesis are to:

1) Evaluate old and new technologies in patient handling equipment used in the UK ambulance services and on the international market
2) Use ergonomic methods to identify products which reduce the risk of developing musculoskeletal disorders (MSD) and which are most suited to the task
3) Provide robust scientific evidence about equipment needs to inform future purchasing decisions

4) Compare ergonomic methods of evaluation, with those adopted by the ambulance services, to advise on future procurement strategies.

In order to address these aims the thesis describes two studies (Chapters 4 and 5) which comparatively evaluated two types of patient movement and transfer equipment. The two case studies give examples of how large scale evaluations can be carried out using different ergonomic methods, identifying the results of each evaluation and the conclusions drawn. The case studies are used to demonstrate how ergonomic methods can be used to identify whether the correct equipment is currently being purchased by the ambulance services and how procurement in the future could be improved.

1.3 Conceptual framework

A realistic evaluation approach was adopted in this thesis. Realistic evaluation deals with the real, the realist and the realistic. 1) Real: an understanding of the balance of resources and the choices available to all participants needs to be developed. 2) Realist: evaluation should follow a realistic, scientific methodology. 3) Realistic: evaluation should be realistic, carried out as a form of applied research to inform the thinking of policy makers, practitioners, participants and the public. Realistic evaluation involves perfecting a particular evaluation method which will work for a specific class of project under circumscribed conditions (Pawson and Tilley, 1997).

A mixed method approach was used in the two studies (Chapters 4 and 5). Qualitative and quantitative methods were combined in two ways; 1) Qualitative data were collected to provide information on context and the formation of hypotheses which were tested using quantitative data, 2) Triangulation was carried out to validate the findings of each method (Robson, 2005).

1.4 Scope and limitations

There is a breadth of literature describing musculoskeletal risks affecting ambulance staff (Wiitavaara, et al., 2007; Nakata, et al., 2006). The moving and handling of patients carried out by healthcare workers means that the risks of injury are high (Smedley et al., 1995). To address these risks manufacturers have developed products which reduce the amount of manual handling carried out during patient movement and transfer tasks. Without scientific procedures for evaluation it is difficult for procurement teams in the ambulance services to make informed decisions.

The case studies in this thesis describe comparative evaluation of patient movement and transfer equipment specific to the ambulance services; however the ergonomic methods and techniques demonstrated are transferable and could be used to evaluate products, systems or tasks in other sectors. The results of the evaluations will have a limited life-span as new technology is introduced to the market but the underlying message about the procurement process will remain valid. This thesis provides a protocol for equipment evaluation which could be followed for the assessment of patient transfer and manual handling equipment required to carry out complex or high risk tasks.

1.5 Thesis outline

Chapter 2 reviews the literature relating to use of patient movement and transfer equipment in the ambulance services. Chapter 3 outlines the data collection methodology for the field and lab-based research. Chapter 4 describes the first study; 'The Comparative Evaluation of Stretcher Loading Equipment'. Chapter 5 describes the second study; 'The evaluation of mobility equipment'. Chapter 6 discusses the findings of both studies in the context of the procurement processes used by the ambulance services. It provides recommendations for future procurement, drawn from the findings of the two case studies. The conclusions are presented in Chapter 7.

Chapter 2: Literature review

This chapter reviews literature which is relevant to this thesis topic. It looks generally at the service provided by the UK ambulance services and how they fit into the bigger picture of the UK's National Health Service (NHS). This chapter more specifically reviews literature related to vehicle designs and equipment used by ambulance services and the impact manual handling tasks have on the health and safety of healthcare staff. The literature review is set out in four sections:

1) Service delivery structure
    a. Role of the ambulance service within the NHS
    b. The culture of the service and its impact on staff
    c. Service delivery and how the service is changing
2) Epidemiology of MSD and Work Related Illness (WRI)
    d. MSD's and WRI
    e. Stress in the ambulance service
3) Manual handling risks
    f. Manual handling
    g. Stretcher related manual handling
4) Design and evaluation of equipment used in the ambulance service
    h. Stretcher loading systems
    i. Stretchers
    j. Carry chairs

The terms referred to in this literature review vary depending on those used by the researchers referenced, and are influenced by the country in which the research was conducted (See glossary of terms).

2.1 Service delivery structure

2.1.1 Role of the ambulance service within the NHS

The NHS was formed in 1948 to provide an equal quality of healthcare to the whole population, regardless of the patient's ability to pay. Since its introduction the NHS has changed significantly but the underlying principle remains the same (NHS, 2007a). Figure 2.1 shows the structure of the NHS in 2007.

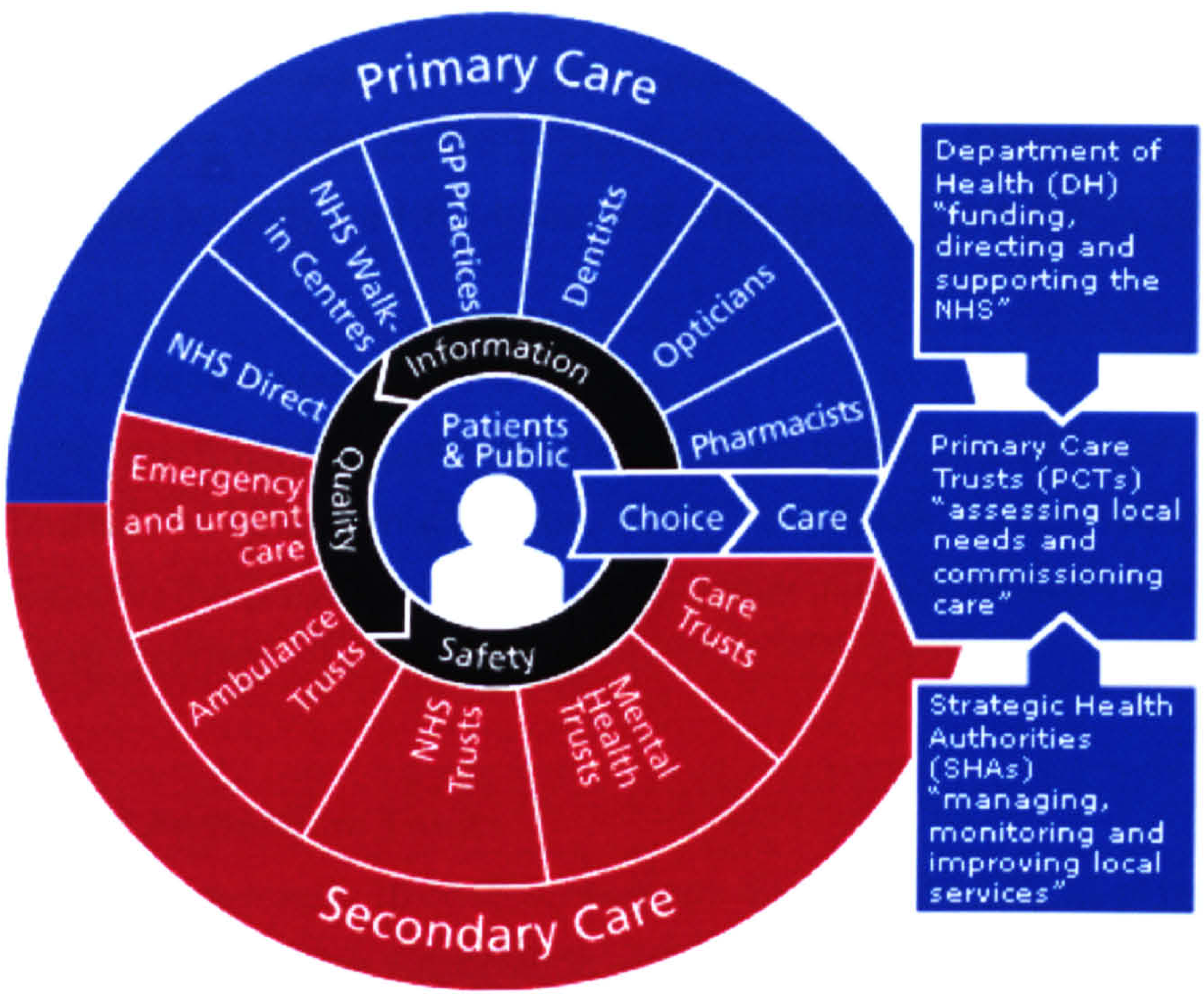


Figure 2.1 Structure of the NHS Source: http://www.nhs.uk/

2.1.1.1 Governing Bodies

Three governing bodies oversee the management and funding of the NHS at a national and local level. These are the Department of Health (DH), the Strategic Health Authorities (SHA) and the Primary Care Trusts (PCT). The DH aims to improve the health and wellbeing of people in England, setting standards and working practices for the NHS and local social services. SHA's manage and set the strategic direction of the NHS at a local level. They support the PCT's and other NHS organisations ensuring good performance. PCT's manage 80% of the NHS budget and they are locally based to understand the needs of the community. PCT's are responsible for assessing the needs of the local population and ensuring the necessary services are provided to everyone. The Trusts report to the SHA's and other bodies (The NHS confederation, 2004; NHS, 2007a).

2.1.1.2 Primary and secondary care

The care provided by the NHS is divided into two categories, Primary care, and Secondary care. Primary care providers are those at the first point of call, who are responsible for the general health of the population, such as General Practitioner (GP) surgeries, Pharmacies, Opticians and Dentists. Secondary care providers are those who provide elective or emergency care, usually delivered at hospitals. The secondary care sector is divided into the Emergency and Urgent Care sector, Ambulance Trusts, NHS Trusts, Mental Health Trusts and Care Trusts. Emergency and Urgent Care is provided by both the NHS trusts and Ambulance Trusts (NHS, 2007b).

2.1.1.3 NHS Trusts

There are three types of NHS Trusts, Acute trusts, Mental health trusts and Ambulance Trusts (The NHS Confederation, 2004). The Acute Trusts manage the local hospitals, ensuring the provision of high quality healthcare and efficient spending of budgets (NHS, 2007b).

2.1.1.4 Ambulance Trusts

There are currently 16 NHS Ambulance Trusts in the UK, 13 of these are in England (Ambulance Service Association, ASA, 2007). Ambulance Trusts are local organisations responsible for responding to emergency calls, transporting patients and providing out of hours care to the local population (NHS, 2007b).

Each emergency call is prioritised into one of three categories; A) Immediately life threatening emergencies; B) Serious but not immediately life threatening conditions; C) Non-urgent conditions (DH, 2007). Based on these categories the Ambulance Trust control room decides on the response level, for example an ambulance with a technician and paramedic crew, a fast response vehicle or an emergency care practitioner (ECP) (Figure 2.2). On arrival the ambulance staff assess the patient and then either stabilise the patient ready for transport to hospital, or treat at the scene and advise on the most suitable follow up care. The Trusts also provide other services such as providing care outside of GP working hours, transporting patients to and from hospitals and day care centres, and providing first aid. Figure 2.2 outlines the activities carried out by the ambulance service when responding to a call.

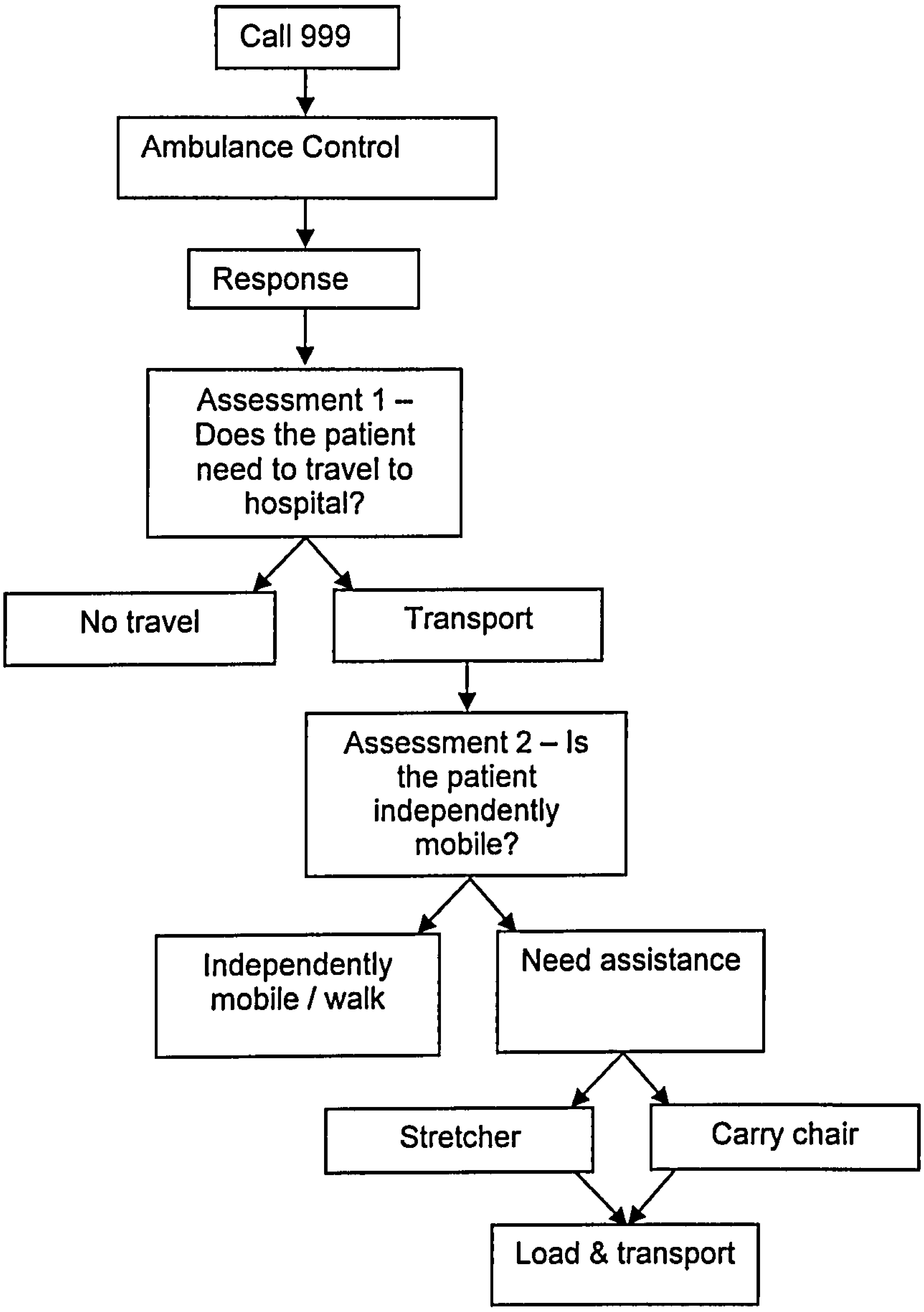


Figure 2.2 The ambulance service system

2.1.2 The culture of the service and its impact on staff

The culture of the ambulance service can have a profound effect on the physical and mental health of the worker. Suserud (2001) identified that pre-hospital care-giving can be needed virtually anywhere, the work is considered exciting but usually attracts a certain kind of person. Ambulance workers have been defined as a special breed of people, who do the work because they like new and exciting situations (Suserud, 2005). Glendon and Coles (2001) recognised three broad categories of stressors affecting the ambulance service; 1) those which are associated with the organisational context in which the work is undertaken, 2) intrinsic aspects of the job routinely encountered and, 3) critical incidents which are rarely encountered but have dramatic consequences. Given that these cultural stressors have an impact on ambulance workers and their health, it is necessary to consider the body of literature relating to cultural aspects of the ambulance service in this review.

Five studies have identified cultural issues and highlighted the effect of culture on ambulance staff (Steen et al., 1997; Suserud, 2001; Suserud, 2005; Lau, 1998; Glendon and Coles, 2001). Suserud (2005) highlighted four main themes which impact on the work carried out by healthcare workers. These were; 1) caregivers and the environment, 2) working in teams, 3) patients and pre-hospital emergency care, and 4) providing good care, poor care, and non-caring. Steen et al., (1997) highlighted seven themes which were; 1) caring for relatives, 2) total situation analysis, 3) experiences from meeting other health professionals, 4) Relationships with colleagues (specifically crew mates), 5) debriefing and reflection, 6) exhaustion and burnout, and 7) management support and organisation of the Emergency Medical Service (EMS) system. The issues identified by both studies have been considered and the overall cultural factors have been summarised in the following section.

2.1.2.1 Caring for relatives and total situational awareness

Participants from Steen et al., (1997) identified concerns relating to time spent with the relatives of patients, especially the relatives of non-responsive patients. Many participants claimed to struggle with the grieving process and the pressure of dealing with those who were grieving. There is a need for cultural change within the ambulance service, with paramedics changing their personal goals of care for the patient into shared goals, allowing reflection and discussion after stressful jobs, preventing the build up of emotional tension in individuals (Steen et al., 1997). Ambulance workers can establish good relationships with their patients but these relationships almost always end when the patient is delivered to hospital (Suserud, 2001).

2.1.2.2 Meeting health professionals and expectations of others

Difficulties have been identified in dealing with other health professionals and to some extent, a lack of respect for their position within the ambulance service (Steen et al., 1997). Lau (1998) found that the public have unrealistic expectations of ambulance officers, often becoming dependent on their services and being overly critical of the assistance received (Glendon and Coles, 2001). Steen et al., (1997) suggested that greater levels of information provided to doctors, politicians and the public would provide a better understanding of the paramedic role, increasing the respect given to ambulance workers, hence improving self esteem.

2.1.2.3 Relationships with colleagues and working as a team

Team work was seen as both good and bad as staff could become too comfortable with another staff member (Steen et al., 1997). Functioning as a team is vital in this line of work and the type of team functioning can have an impact on the care received by the patient (Suserud, 2001). Experienced care givers become role models for newer members of staff and novices become dependent on older more experienced colleagues. Suserud (2005) report advantages of this, but state that it can also encourage the transfer of unwanted methods and attitudes especially towards patients.

2.1.2.4 Debriefing and reflection after a call

Debriefing after distressing patient calls was highlighted as another issue by staff, some felt it necessary others felt it was not. It was considered unhealthy by some if debriefing was not allowed by colleagues (Suserud, 2005).

2.1.2.5 Exhaustion and burnout

Exhaustion and burn out was discussed in the interviews described by Steen et al., (1997), with many staff experiencing physical tiredness.

2.1.2.6 Management support and organisation of the EMS system

The need for professional backing and lack of managerial support was discussed by Suserud (2005). These factors are part of the inherent culture of the ambulance service and could contribute to worker stress. Glendon and Coles (2001) suggested that those who manage the ambulance services do not develop strong enough relations with their personnel, which hinders the progress of change.

2.1.3 Future care delivery

The delivery of care provided by the ambulance service is continuously changing. Government initiatives have been carried out to improve the service for the 21st century (DH, 2005). In 2000 the ambulance services were set a target of reaching 75% of life threatening calls within 8 minutes by the end of March 2001. The DH invested £21 million to aid the ambulance services in meeting these targets, to provide extra front line vehicles and staff. Ambulance services were also encouraged to improve operational efficiency and work more closely with other members of the health service. In order to aid this improved efficiency the public were urged to think before they call for an ambulance and ensure that the ambulance service was the most appropriate service for their health requirements (DH, 2000).

In 2004 Peter Bradley, Chief Executive of London Ambulance Service (LAS) was invited by the DH to lead a review of Ambulance Trusts in England. The outcome of the review was a vision for future ambulance services, whereby its primary focus would move away from resuscitation, trauma and acute care and move towards becoming a mobile health resource for the NHS, taking healthcare to the patient (DH, 2005). The review set out a five year plan for the ambulance services to:

1. Work with patients and the public to improve the speed and quality of call handling
2. Provide and coordinate mobile healthcare for patients needing urgent care
3. Provide an increasing range of additional services such as primary care and health promotion
4. Continue to provide for patients emergency care needs with speed and quality of service

Following this review Lord Warner announced improvements to England's ambulance service. A number of changes were introduced to revolutionise the delivery of care provided by the ambulance services, including faster response time to save more lives, better advice provided over the telephone, more care provided in the home, more treatment at the scene and home visits (DH, 2005).

The Bradley report recommended that, in order to improve the performance and management of the ambulance service, national targets should be reduced to concentrate on the small number of life threatening emergencies. These targets included: 1) response times capturing the time between the emergency call connection with control and the arrival of the ambulance at the call scene; 2) resources should be used efficiently to allow reinvestment in improved patient care through national procurement processes; 3) there should be a reduction in the number of ambulance services by at least 50% (DH, 2005).

One of the many outcomes of the Bradley report was the restructure of the English ambulance services in 2006. The 31 services in England merged into 13 regional services (ASA, accessed 10/04/2007).

Hassan & Barnett (2005) carried out a survey amongst senior directors of Ambulance Trusts in the UK to develop a consensus of opinion on future design traits of EMS systems. The research looked specifically at advanced life support skills in the ambulance service. A Delphi questionnaire was distributed in two phases. The Delphi method allows the researcher to obtain the most reliable consensus of opinion from experts, using a series of questionnaires, combined with controlled opinion feedback (Dalkey and Helmer, 1963). A thorough rationale for the Delphi method is provided by Clayton (1997). Hassan and Barnett (2005) recommended the optimal system as a tiered service, which was better integrated into the other UK emergency services offering a dual response to emergency calls. Development of additional advanced life support skills was required in some circumstances. It was concluded that reduced emergency response times to immediately life threatening conditions would improve outcomes.

In 2006 a research team conducted a national investigation into the design of future ambulances for patient safety, on behalf of the National Patient Safety Agency (NPSA) and the Helen Hamlyn Trust (Hignett et al., 2007). As part of this study an analysis of incident reports was carried out. The sources used to collate and analyse the reports were the UK database, National Reporting and Learning System (NRLS) (NPSA, accessed on 19/09/2007) and the US database MAUDE (FDA, accessed 10/04/2005). 1,352 NRLS reports were analysed, less than 1% of total reports on the database. The results showed that the equipment most often reported for fault or incident was the heart monitor equipment, (28%). The second most frequently reported equipment were pumps and stretchers (12%). The stretcher incidents reported included collapses and toppling incidents associated with easyloader stretchers. Ramp failure (2%) and tail lift failure (8%) were also listed. Incidents with other mobility equipment were reported, such as carry chairs (2%) wheelchairs (4%) and lifting aids (5%). 95 MAUDE reports were relevant to the study out of a total 1259. The analysis found that stretchers and defibrillators were responsible for the majority of incidences with stretchers accounting for 44.2% of reports and Defibrillators accounting for 37.9%.

2.1.4 Response times and patient access to care

Response times have become one of the performance measurement criteria for ambulance services (DH, 2003). With the response time targets set by the government and the recommended treatment times for trauma patients such as the platinum ten minutes (Calland, 2005), and the golden hour (DH, 2005), there is an increasing recognition that time is a vital factor in the treatment of emergency patients. Trauma patients are prioritised into category A, immediately life threatening emergencies. For patients who have been involved in road traffic accidents (RTA) ambulance staff have the platinum ten minutes to extricate the patient from the vehicle and get them into the ambulance. To achieve the platinum ten minutes the ambulance staff must work in harmony with other emergency workers to secure the scene and extricate the patient safely without causing further harm (Calland, 2005).

Recent years have also seen the introduction of the air ambulance for trauma patients. Air ambulance teams have been set up across the UK to attend to incidents which are life threatening, where access by land is restricted or if the patient's quality of life would be affected as a result of the incident (Warwickshire and Northamptonshire Air Ambulance, WNAA, accessed 11/04/07). They carry trauma teams, consisting of a doctor, paramedic and pilot (Great North Air Ambulance, accessed on 11/04/07) whose aim is to provide specialist treatment to the patient within 60 minutes of the incident, ('golden hour'). The air ambulances are funded by charities and are based out of airports (WNAA, accessed on 11/04/07) or RAF bases (County Air Ambulance, accessed on 11/04/07).

An audit has been carried out to identify the appropriateness of helicopter attendance at trauma scenes which found a high number of inappropriate flights by air ambulance crews, and as a result of the study developed a criteria for helicopter attendance. The researchers identified that the criteria for helicopter transport should be based on markers of critical physiologic patient status matched to unique care provided by helicopter attendants. The resultant intervention saw a drop in transports by air (Norton et al., 1996).

In a study carried out to identify whether hospital mortality is the same whether the patient travels to hospital with the EMS, Demetriades et al., (2003) found that EMS patients had twice the mortality rate of the non-EMS patients. Patients with severe trauma stood a better chance of survival if travelling privately than through the EMS system. The study did not identify the factors responsible for this difference.

Rural environments cause problems for the Ambulance Services, requiring ambulances to travel greater distances to reach patients and across a number of terrains, leading to prolonged delays for treatment. A study assessing patients access to care in rural communities in British Columbia found that provincial standards of access to emergency care were not met in Northern British Columbia (McGregor et al., 2005). It was also highlighted that ambulance diversion can lead to delays in the emergency medical care provided to patients. Between 1986 and 1990 there was an increase of 453% in diversions which were found to be most common in the winter and at night and most commonly affected elderly patients. Those who were diverted had longer travelling times and spent longer at the call scene (Redelmeier et al.,1994).

2.2 Epidemiology of MSD's and work related injury

Ambulance workers have been suffering from MSD's associated with the work carried out in the emergency field for many years (Turnbull et al., 2003). These can often develop into chronic MSD's resulting in early retirement, high morbidity and long term sickness absence which impact on the worker, their colleagues and the organisation (Rodgers, 1998). Factors recognised to contribute towards these MSD's include excessive manual handling (HSE, 2004), culture, working practices and occupational stress and violence (Suserud, 2001). The following sections outline the literature relevant to these aspects for both acute and chronic MSD's affecting the ambulance service. It also looks at contributory factors, proposed solutions, and interventions.

Lavender et al., (2000a) suggested that emergency rescue workers are highly susceptible to musculoskeletal injuries. This was agreed by Stevenson (1995), who found evidence to suggest that the back injury incidence rate for ambulance officers in New South Wales (NSW) was approximately ten times the average for the population of workers in the state. Between 1992 and 1994 ambulance officers in NSW suffered 3003 back injuries during patient handling activities. The annual incidence rate was 6.7%.

The health care sector as a whole is recognised as a high risk profession with regard to spinal pain (Turnbull et al., 1992). A study conducted by Turnbull et al., (1992) found that different professionals suffer different types of pain, with ambulance workers experiencing more severe pain, for which they take analgesics, and nurses complaining of a greater level of moderate, chronic pain due to the nature of their work.

2.2.1 Prevalence of Injury

Six papers reported the occurrence of injuries amongst ambulance workers and EMS workers (Leyshon & Francis, 1975; Hogya & Ellis, 1990; Schwartz, 1993; Tortella & Lavery 1994; Gershon et al., 1995; Furber et al., 1997). Leyshon & Francis, (1975) described two studies carried out with British ambulance workers, investigating lifting injuries sustained over 41 months during 1964 and 1967, and the five year period between 1968 and 1973.

Study 1 identified that one in five participant's sustained injuries whilst carrying patients. On average the study identified 30 staff members injured per year. Study 2 identified an average of 31 lifting injuries in 30 staff during the 5 year period. Schwartz et al., (1993) also found a high prevalence of injuries, finding that 10.3% of participants experienced back injuries in a six month period. Amongst medical personnel in general the frequency is higher still, with 47% of medical personnel who participated in a study in Sweden receiving injuries (Öhman et al., 2002). The annual incident rate amongst NSW ambulance staff was identified as 10.6 per one hundred officers over a 2 year period between 1992 and 1994 (Furber et al., 1997).

Schwartz et al., (1993) found that in a random 2% sample of ambulance technicians in New England of the 10.3% of respondents, who reported back injuries, 73% had experienced one injury, 18% experienced 2 injuries and 9% had experienced 3 or more back injuries in a six month period. 54% of respondents with back injuries claimed they were recurrent.

2.2.2 Body part most commonly affected

The back has been identified as the most affected injury site in ambulance MSDs (Leyshon and Francis, 1975). Although this research was based in the UK, the studies were conducted over 30 years ago. More recent literature has also found injury rates to be high amongst ambulance workers, most specifically back injuries (Hogya & Ellis, 1990; Schwartz, 1993; Gershon et al., 1995). Hogya and Ellis (1990), conducted a retrospective study of 254 injuries amongst staff in an urban emergency service in the US over 3.5 years and found that lower back pain was the most common injury. Schwartz et al., (1993) carried out a study to characterise the prevalence and morbidity of injuries to Emergency Medical Technicians (EMT) in the United States through a survey sent to a random 2% sample of ambulance technicians in New England. 10.3%

of respondents reported back injuries, the most common sites for injury were found to be the back (20%) and the respiratory system (10%).

The results of these studies differed from the findings of Tortella and Lavery (1994). On investigation of data regarding serious disabling injuries which resulted in hospitalisation or death among EMS staff in New Jersey, they found that the most frequently occurring injuries affected the hand (22%) head (19%) foot (16%) and eye (14%). Leyshon & Francis, (1975), Hogya & Ellis, (1990) and Schwartz et al., (1993) however investigated patient handling and lifting injuries in which the back plays a primary role. Öhman, (2002) carried out an analysis of injuries among medical personnel and found the upper extremities to be the most common injury site. This was also found by Buckle, (1997).

2.2.3 Sustaining injury

The most common types of injury reported amongst ambulance workers have been identified as sprains (23%), strains (20%) and exposure to blood and bodily fluids (15%) (Gershon, et al., 1995). Ambulance workers under 30 years of age are believed to be at higher risk of developing back injuries (Hogya & Ellis, 1990). Furber et al., (1997) had similar findings stating that staff between 25 and 34 experienced the largest number of patient handling injuries, although the overall injury rate was highest amongst staff aged 55 to 64. They highlighted that those working for the service for between five and nine years had a higher injury rate than those working for less than five years. The injury rate was significantly higher in urban areas than in rural areas. EMT's have been found to experience more injuries than paramedics (Hogya & Ellis, 1990). In the US some EMS workers respond to both health and fire related emergencies. Tortella and Lavery (1994) found that non-fire based EMS workers sustain more injuries to the head and hand than fire based EMS workers, due to a lack of provision of personal protective equipment.

Hogya and Ellis (1990) found that 62.4% of back injuries occurred at the call scene. Furber et al., (1997) established that in NSW 65% of incidents occurred during day shifts while 29.1% occurred during a night shift. Females were considered more likely to experience injury than their male counterparts. The researchers went on to highlight that the most common sites for injuries were at a private residence (49.3%), the hospital (18.6%), the ambulance (9.3%) and the site of a road accident (3.1%).

2.2.4 Cause of injury

According to the Royal Society for the Prevention of Accidents (RoSPA) (2000) approximately a third of all accidents reported to the Health and Safety Executive (HSE) are manual handling related, and in the health-care industry half of all injuries are caused through handling loads in the workplace. Hogya and Ellis (1990) identified that 62.4% of back injuries were caused by lifting activities. This is agreed and expanded by Furber et al., (1997) who identified that lifting, carrying or putting down objects was the mechanism of 91% of reported injuries. Heavy and uncooperative patients or those who demonstrated a lot of movement during transfers were also a factor associated with injury. EMS workers engage in heavy lifting tasks in most of the calls they attend. The prime function of ambulance staff involves lifting and transporting patients, which results in high back injury rates (Lavender et al., 2000a).

2.2.5 Staff absenteeism and morbidity

Lower back pain in healthcare workers is seen to be primarily caused by accidents and often results in long periods of absenteeism (Gershon et al., 1995; Öhman, 2002). Staff with injuries are at best less productive and at worst have to give up their work due to spinal pain and other ailments (Turnbull et al., 1992). Ambulance workers have historically suffered from high rates of morbidity, sickness absences and early retirement due to the nature of work carried out by the emergency services. A number of studies have been conducted to identify the rates and causal factors of long term problems occurring as a result of emergency work (Boocock, et al., 2002; Rodgers, 1998; Stillwell & Stillwell, 1984; Sarfas, 1993).

Three studies have been carried out investigating the morbidity of ambulance staff in comparison to other occupations (Stillwell & Stillwell, 1984; Sarfas, 1993; Rodgers, 1998). Stillwell and Stillwell (1984) conducted a comparison between staff in the West Midlands Metropolitan Ambulance Service, the General Post Office and the Fire Service over a two year period. Sarfas (1993) carried out a study in an English Health Authority between 1986 and 1991, and Rodgers (1998) conducted a comparison of morbidity between ambulance staff and other healthcare sectors in Northern Ireland. Ambulance workers in the UK took more time off sick than the driving and nursing staff in one health district, the General Post Office workers and Fire Service staff over a two year period. The main cause of sickness absence was identified as musculoskeletal injury which was heightened by the nature of work carried out by ambulance workers. The study found that the rate of sickness absence was two thirds higher for women than for men (Stillwell and Stillwell, 1984). Between 1986 and 1991 the highest proportion of the population retiring due to ill health were ambulance staff; back injury was found to be the major cause of retirement among ambulance workers (Sarfas, 1993). Rodgers (1998) found that musculoskeletal, circulatory and mental disorders were the common cause of early retirement in all groups at the time of the study. According to the results MSD's caused staff to retire earlier than circulatory and mental disorders.

2.2.6 Stress

Ambulance work is recognised as an inherently stressful profession. The nature of health care makes those who work in the service particularly susceptible to stress-related illnesses. Ambulance staff in particular have been found to suffer higher levels of stress than the rest of the working population (Young and Cooper, 1997). Stress has been recognised as contributing to sickness absence and early retirement in ambulance staff and therefore was considered an important factor to consider within this review (Young and Cooper, 1997; Stevenson, 1995; Glendon and Coles, 2001).

Four studies highlighted the stressors affecting ambulance staff (Stevenson, 1995; Young and Cooper, 1997; Glendon and Coles 2001; Van der Plog and Kleber, 2003). Low job satisfaction has been recognised as a major contributor to occupational stress in the ambulance service. Ambulance workers have been recognised as experiencing more job pressures than the normal population (Young and Cooper, 1997). Locus of control (Young and Cooper, 1997) and lack of support from superiors and colleagues (Van Der Plog and Kleber, 2003) have also been recognised as contributors towards stress in the ambulance service.

Young and Cooper (1997) present a systematic investigation of job stress experienced by ambulance workers in the North West of England. The researchers measured and compared stress outcomes in the ambulance service with those of other occupational groups. They found evidence of poor mental and physical health which resulted in major stress outcomes.

Glendon and Coles (2001) recognised that the potentially dramatic effects of critical incidents experienced by ambulance staff can act as a stressor for ambulance staff. Van Der Plog and Kleber (2003) confirmed this in their investigation of acute and chronic job stressors among ambulance workers. Over 10% of participants were found to experience a clinical level of post traumatic stress. Other stressors highlighted by their study included debilitating levels of fatigue and exhaustion.

Stevenson (1995) suggested that stress amongst ambulance staff stems from the risk of suffering chronic back problems, resulting from the extensive lifting required to do the job. From the outlined research it is not clear where the line is drawn, does stress create ill-health or is ill-health created by stress? Regardless of the answer, the literature has identified a clear link between physical and mental health and therefore both need to be considered when looking at the impact of physical activities carried out by ambulance staff.

2.3 Manual handling

Health and safety issues such as manual handling injuries are an inherent risk of ambulance work. This type of work can be physically demanding placing strain on the back and limbs of staff. It is important that ambulance trusts take action to reduce or eliminate the imposed risks, through introducing new lift reducing equipment, training and revised vehicle layouts (East Midlands Ambulance Service, EMAS, accessed on 27/05/04).

Due to current legislation such as the Manual Handling Operations Regulations (HSE, 1998a) the ambulance services have to manage risk effectively, ensuring that the risks to staff and patients are kept to a minimum. The Government has introduced management systems such as Controls Assurance, which should be adhered to, to prevent accidents or at a minimum, reduce their impact on staff and patients (Flowers and Hinxman, 2002). Organisations are legally required to manage health and safety risks to protect their employees as far as is reasonably practicable. Risk assessment is an important step towards doing this (HSE, 2006).

A number of the studies (Lavender et al., 2000a; Lavender et al., 2000b; Furber, et al., 1997) have indicated that manual handling activities are a prime mechanism for injury and also some of the more long term problems experienced by ambulance staff. The following section discusses a number of causal factors in more detail.

Four papers highlight manual handling activities carried out by ambulance staff which have been recognised as contributing to injury occurrence. It has been highlighted that between 16% and 29% of ambulance staffs working shift is spent in awkward postures, the most strenuous of tasks include attending to the patient in the patient compartment and transporting and fetching the patient outside the vehicle (Doormaal et al., 1995). Stevenson (1995) highlighted that ambulance staff were active between 34% and 64% of their time on a shift. Landeweerd and Kant (1996), used similar methods to Doormaal et al., (1995) and identified that the most strenuous activities carried out by ambulance staff were transporting the patient outside the vehicle and operating and checking equipment. Both studies combined the Ovako Working Analysis System (OWAS) observation method, with various methods of measuring perceived workload.

All four studies used observation methods to identify frequently occurring or high risk tasks. The tasks identified by McGill et al., (1990) and Stevenson (1995) show similarity as they have identified and specified the high risk lifting tasks. Doormaal et al., (1995) and Landeweerd and Kant (1996) identified more frequently occurring activities, not specifying lifting tasks. Furber et al., (1997) identified that lifting, carrying or putting down objects was the mechanism of 91% of reported injuries. Heavy patients and patients who were uncooperative or who demonstrated a lot of movement during transfers were also a main factor associated with injury. McGill et al., (1990) describe the manual handling tasks carried out by ambulance staff in Ontario; staff were required to lift immobile patients under awkward conditions or constraints, for example, lifting a cardiac arrest patient from a bath tub, who then had to be carried or transferred to a mobility device, transferred over a variety of terrain, under conditions of stress due to the need to act quickly.

Massad et al., (2000) found that the highest risk of injury to staff occurred when transporting patients and equipment across staircases, in elevators or in the street. Other high-risk activities included patient handling, equipment handling and the loading and unloading of stretcher bound patients. It was further established that the poor design of ambulances and their equipment, was responsible for a large proportion of accidents. This is considered in more detail in the design and evaluation of equipment section (section 2.4).

Letendre and Robinson (2000) carried out a survey amongst ambulance workers in British Columbia, Canada. The findings indicate that the tasks reported to require the highest mean level of effort were performing Cardio Pulmonary Resuscitation (CPR), loading the stretcher, writing, intubating patients and working from a seated position. Complex manual handling activities are further complicated by uneven terrain, confined corridors and doorways, stairways and other environmental constraints. In more extreme cases the incident itself can cause the complex environment, for example in the case of RTA's which require patient extrication (Guha, 1989; Stevenson et al., 1995; Lavender et al., 2000a and 2000b).

2.3.1 Training and staff ability

Studies have identified that training can help reduce the impact of manual handling on ambulance and healthcare staff (Massad et al., 2000; Pheasant and Stubbs, 1992). Massad et al., (2000) developed an intervention plan to train staff and reduce the number of workplace accidents occurring in ambulance services in Quebec. New ergonomic patient handling strategies were identified and implemented. The technicians were trained in the new strategies in a one day training programme. The strategies were then trialled, modified and validated through everyday use, undergoing thorough field assessment by the technicians and instructors. The principle message to staff was to respect both the capabilities of their patients and the biomechanical limitations of their own bodies. Emphasis was placed on sliding patients rather than lifting, and allowing the patient to assist themselves where possible. The researchers concluded that the high number of requests for instructor training from ambulance companies across Quebec confirmed that the intervention strategies were successful and beneficial to staff. However the success of this intervention was measured on a subjective level. Massad et al., did not measure the success objectively with measures such as sickness absences or incident reporting.

2.3.2 Stretcher-related manual handling

Most injuries have been reportedly caused by accidents with stretchers (Gershon, et al., 1995). In 1995 stretchers were used in almost every transfer to and from the ambulance and over 51% of injuries were found to be associated with stretcher usage (Stevenson, 1995). Furber et al., (1997) identified a relationship between injuries and stretcher use, identifying that 7.1% of injuries to ambulance workers were caused by problems with stretchers. This was the second highest cause of injury, following over-exertion and over-reaching. The mechanism for injury was found to be lifting a patient. In 23.7% of these cases the injured party was lifting the patient onto a stretcher. 41% of injuries occurred while staff were using a mechanical aid.

According to Mitterer (1999) when lifting an object, the force on the lumbar-sacral region is ten times the actual weight lifted. Therefore if an ambulance attendant lifts a stretcher of 51Kg, which is the maximum weight compliant with BS 1865 (British

Standards Institution, BSI, 2000) the force exerted is approximately 510Kg. The study determined that 41% of injuries occurred when a manual aid was being used, the most common of which was a stretcher.

Ambulance staff carry out patient transfer activities, on a daily basis, whereby the patient is physically assisted from one position to another. For example from stretcher to bed, bed to stretcher, or chair to bed. Lavender et al., 2007b and McGill and Kavcic (2005) tested interventions designed for use during lateral transfer tasks. Lavender et al., (2007b) tested ergonomic interventions for use by paramedics and fire-fighters, including a bridgeboard to reduce frictional force, the use of rods along the sides of the patient to improve coupling, and a rod rolled in the bed sheet to transform the task into a pulling task rather than lifting. McGill and Kavcic (2005) quantified the friction reducing ability of three sliding patient transfer devices and measured the consequences on the low back loads. Both studies compared lateral transfer tasks when carried out with a single bed sheet, with tasks carried out with the interventions. The single rod technique tested by Lavender et al., (2007b) was found to increase Latissimus Dorsi activation when transferring patients between a bed and stretcher, and between a stretcher and hospital gurney. The ratings of perceived exertion supported this intervention. Assistive devices tested by McGill and Kavcic (2005) were found to reduce friction by over 50%.

Successful lifting interventions have also been identified in the past (Stevenson, 1995; Collins, 1994). Stevenson highlighted that extending the handles on the [easyloader] stretcher was found to reduce the load carried by one officer but increase the load for the crew mate. Further analysis showed that extending the handles at the foot end when loading reduced the load. Collins (1994) found that during lifting exercises, using pre-lifting tension back support was the only successful intervention.

Two studies have considered the physiological implications of stretcher lifting tasks (Knapik and Harper,1999; Barnekow-Bergvist et al., 2004). Knapik and Harper (1998) identified that muscle cross-sectional area and upper body muscular endurance are important physiological factors in the ability to carry a casualty on a stretcher. Assessment of cardio respiratory capacity, coordination, muscular strength and endurance carried out by Barnekow-Bergvist et al., (2004), highlighted that the task of carrying a loaded stretcher imposes a high physical strain. These studies add strength to the idea that healthcare workers need to be selected on the basis of their physical ability (Pheasant and Stubbs, 1992).

Lavender et al., (2000b) conducted simulations of five frequently occurring strenuous work tasks carried out during emergency rescues. From these simulations biomechanical data were collected and analysed using the University of Michigan's Three-dimensional Static Strength Prediction Program. They measured the risk of developing lower back disorders. Ten teams of two ambulance staff simulated the following tasks; 1) transferring a patient from a bed to a stretcher using bed sheets, 2) transferring a patient from the ambulance stretcher to a hospital gurney, 3) carrying a patient down a set of stairs and through a landing using a stair chair, 4) carrying a patient down a set of stairs and through a landing using a backboard and 5) carrying a patient down a straight set of stairs using a stretcher. The study found that strength capabilities would limit a significant proportion of the population when carrying out these tasks. More strenuous tasks included transferring a patient on or off a stretcher and initially lifting transport equipment. These same tasks were identified as posing a high risk of low back disorder. The tasks posing the highest risk to staff were those involving forward bending of the torso. As a result of this study the researchers recommended that staff should avoid carrying stretchers up or down stairs, the stair chair should be the equipment of choice.

Lavender et al., (2000b) carried out a postural analysis of the frequently performed strenuous work tasks identified in Lavender et al., (2000a). Trunk posture and hand force data were collected from the task simulations for analysis. The study concluded that when transferring patients from a stretcher to a bed, postures were more stable when the participants were standing. When transferring from stretcher to bed, friction forces could be reduced by using an interface board. When transporting patients, especially when travelling down stairs, the leader should face forwards, resulting in a potentially safer descent. The study carried out by Stevenson (1995) also considered the position of the operator, identifying that when lifting stretchers the head end attendant had a heavier lift than the foot end attendant.

2.4 Design and evaluation of equipment

Massad et al., (2000) highlighted that the poor design of ambulances and equipment was responsible for a large proportion of the accidents reported in association with ambulance workers. Since the introduction of manual handling regulations (HSE, 1998a) and CEN standards (EN1865, 2000a; EN1789, 2000b and EN1789, 2007), manufacturers and the ambulance services concentrated their efforts on improving design of equipment. This section considers evaluations of manual handling equipment designed to reduce risks associated with manual handling. It was not possible to consider all types of ambulance equipment, therefore only literature which is relevant to the loading equipment and mobility devices evaluated in Chapter 4 and 5 of this thesis has been considered.

2.4.1 Stretcher and stretcher loading equipment evaluations

2.4.1.1 Stretcher evaluations

Figure 2.3 Ferno 35a (left) and Ferno Falcon 6 stretchers (right)

Kluth and Strasser (2006) present an analysis of three combinations of stretchers used in the German Rescue Service. The aim of the study was to assess the ergonomic quality of the equipment, conducting work analyses and measuring strain placed on the circulatory system during equipment use. Participants carried stretchers down stairs at a rapid carrying speed (the speed of transportation when working under emergency conditions) and a normal carrying speed (the speed of transportation when not under emergency conditions). The results showed that rapid carrying led to substantially increased strain on the circulatory system. Lifting and loading tasks were found to cause less strain but still resulted in physiological problems. Another finding suggested that increased speed led to increased muscle strain. The study highlighted that design changes are needed with regard to weight, shape and position of handles, and the height adjustment mechanism for the stretcher.

Two Shires Ambulance NHS Trust (TSAT) (2003a) conducted a risk assessment of the locking mechanism (see Figure 2.4) used with the Ferno Falcon 6 stretcher (see Figure 2.3), and discovered a number of hazards (Table 2.1). The Falcon 6 is the stretcher most commonly used by Ambulance Services across the UK, and is currently used on vehicles with modern, mechanised loading systems.

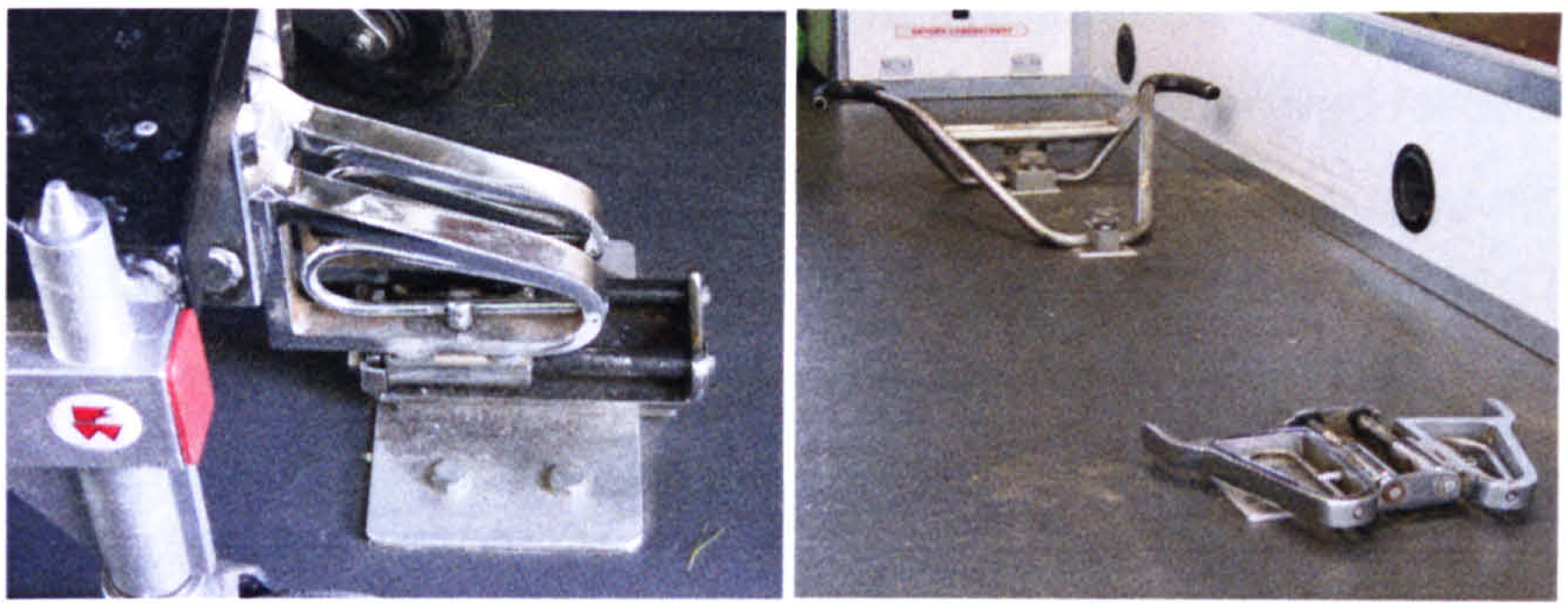


Figure 2.4 Old generation of Ferno stretcher locking mechanism

It was found that the movable clamp which secures the stretcher, offered no risk in normal operating conditions, but in the manual override mode the cover had to be removed, exposing the mechanism, where staff could trap or pinch fingers. In the event of chemical spillage on the foot end clamp, fluid could potentially pass underneath the bracket, this would not affect operation but cleaning would be difficult, and the ambulance could not be kept in a hygienic condition (TSAT, 2003).

Trip hazard	Injury	Trapping/pinching	Clinical waste	Posture
When stretcher is removed there are two large structures in centre of vehicle creating trip hazard	Head end bracket is pointed, if it is kicked it will cause injury to shin	If locking mechanism is uncovered for manual operation it poses risk of trapping and pinching	Can allow fluid to flow under bracket. The bracket is a permanent fixture and its not possible to clean underneath	Operating the manual override involves staff bending in awkward posture. In normal circumstances not a problem

Table 2.1 Hazards created by Ferno Falcon 6 foot end locking mechanism

Source: TSAT generic risk assessment

McDermott and Warwick (2002) highlighted the increased bending and awkward kneeling that crews experienced as a result of the foot end stretcher securing mechanism. The TSAT risk assessment of the Ferno electric foot end lock confirmed this. It was established that during normal operation there were no risks, but when using the system in manual override mode, much bending and kneeling was required to uncover the mechanism (TSAT, 2003a).

2.4.1.2 Stretcher loading equipment evaluations

In recent years stretcher loading equipment has improved following a number of developments. With the introduction of Manual Handling regulations in 1992 (HSE, 1998a) and CEN standards EN1789 (2000b; 2007) and EN1865 (2000a), manufacturers have been driven to developing improved equipment for use in the ambulance market. Mechanised systems have been introduced to reduce the level of manual handling carried out by ambulance staff. Use of such equipment in the ambulance field has required some adjustment by staff and issues of practical use have occurred as a result. The following section identifies issues with the three types of stretcher loading equipment used in the UK at the time of this study, between 2005 and 2006.

2.4.2 Loading equipment used in the UK

In 2003 there were three main types of stretcher loading equipment used across the UK; The Easyloader Stretcher, the Ramp and Winch and the Tail lift. A preliminary study was carried out by the ASA to identify which ambulance services used which equipment (Pillin, 01/2003, *Personal communication*). Twenty four of the thirty two UK Ambulance Services responded to the survey, with three stretcher loading systems used across the UK (Table 2.2). More services were using easyloader stretchers than mechanised systems but the difference was marginal.

Stretcher loading system	Ambulance services with one or more system
Easyloader	10
Ramp and winch	7
Tail lift	7

Table 2.2 Stretcher loading system used in 2003 in the UK

Stevenson (1995) found that the task of loading and unloading a stretcher posed a risk of back injury. In reference to an easyloader stretcher Stevenson claimed that loading a stretcher could put a significant demand on strength, especially when carrying a heavy patient. It was further noted that extending the handle was advantageous when loading. The combined weight of the stretcher and patient was shared between the front wheels of the trolley and the two attending officers. Without a patient on board the force required for this act was calculated as 48.3Kg when the handles were in a shortened position.

2.4.3 Easyloader stretcher

The easyloader stretcher is loaded onto a receiving platform as shown in Figure 2.5. When loading, a lever positioned under the operating handles is pulled to release the legs. As the stretcher is pushed further onto the platform the legs fold underneath the stretcher allowing it to lie flat on the platform. This happens in reverse when unloading the stretcher. On some designs when unloading the stretcher a safety catch must be released before the support of the vehicle is removed, preventing the stretcher from collapsing. Some easyloader ambulances have lowering air suspension to reduce the vehicle height for loading (Medical Devices Agency, MDA 2003).

Figure 2.5 Unloading easyloader stretcher

The Ferno 35A trolley is an easyloader stretcher, which was designed to reduce manual handling during loading and unloading tasks (Boocock, et al., 2002). Although easyloader stretchers were designed to reduce lifting, they have introduced new problems (MDA, 2003). Recent years have seen the development of the CEN Standards, EN 1685 (2000a) and EN 1789 (2000b; 2007), to which easiload and self load stretchers do not comply (2000a, 2000b and 2007). Easyloader stretchers are designed to be pushed and pulled, in order to reduce lifting; however there is evidence to suggest that these actions can lead to spinal loads equal to those involved in lifting tasks, and in some instances greater risk of injury. The main actions carried out by the ambulance crews when using this system are pushing and pulling (Bentley, 1995).

Stevenson (1994) highlighted that tasks involving lifting and loading [easyloader] stretchers required substantial lifting effort. The task of raising the stretcher when inside the vehicle was found to be close to the lifting capacity of an ambulance worker. He recommended that this task be carried out one end at a time and the loading be carried out using two attendants at the foot end.

The operating environment has also been recognised as one of the influential factors in the performance of easyloader stretchers. Use of the system on uneven terrain has often resulted in a near miss or injury. Hospital loading bays can be built on an incline to prevent rainwater flowing into the Accident and Emergency (A&E) department (MDA, 2003). The leg height of an easyloader trolley is often key to safe operation when unloading as for many forms of easyloader systems, the legs have to move through a set arc before reaching the locking position. If the stretcher is unloaded on a negative incline it may not be able to reach this position, preventing the legs from being secured, which can result in a collapse. Equally, if the unloading occurs on a positive incline the legs can lock too far away from the ground. One solution to this problem is to park in alternative locations where the road has less of a camber (MDA, 2003).

The Scottish Ambulance Service (SAS) conducted a staff evaluation of four varieties of easiload stretcher: the Stryker EZ load; the Spencer; the Phoenix by Ferno; and the Stollenwerk by Paraid. The Stryker and the Stollenwerk were found to be significantly more popular amongst staff than the other two stretchers; despite this it was found that staff did not highly rate any of the four systems (Watt and Dickson, 1999).

The easyloader has been seen to create a number of postural problems for ambulance staff. The frame is quite frail, becoming unstable if the patient is active or being moved over rough ground. Ambulance staff may have to compensate for the instability, creating potential strain (Brodie, 1996). In an ergonomic evaluation of the Ferno 35 A stretcher, arm strength was found to be the most influential human factor on the ability to carry out the loading task. The arm strength needed for loading was mostly influenced by the vehicle tailgate height (Boocock et al., 2002).

TSAT (2003b) conducted a risk assessment, on the Phoenix easiload stretcher. The report concluded that the system had a number of risks including trap and pinch hazards, risk of repetitive movement when raising and lowering the stretcher, and risk of the head end wheels failing to lock when unloading on inclined road surfaces. The systems must be well maintained to avoid failure.

2.4.4 Ramp and winch

This system has two separate components, a ramp and a winch. The hydraulic ramp and winch is the main ramp system investigated in this study. There is a hydraulic ramp which opens out at the push of a button. The vehicle air suspension is operated at the same time as the ramp is deployed, to lower the vehicle and provide an incline of 12 degrees. The stretcher can then be manoeuvred up this ramp to load the stretcher. Although there is no lifting involved in this task there is still an element of manual handling. The winch can be used to reduce the manual handling. The winch is attached to the front legs of the stretcher and drawn in mechanically with the operation of a control panel. The operator then guides the stretcher into the vehicle ensuring that it stays within the limits of the ramp (Figure 2.6).

Figure 2.6 Hydraulic ramp and winch

There are other types of ramp and winch which are not automated. A manual ramp was also considered in this study (Figure 2.7). The manual ramp is stowed in the back of the vehicle and is pulled down for use. The winch works in the same way as the previous system.

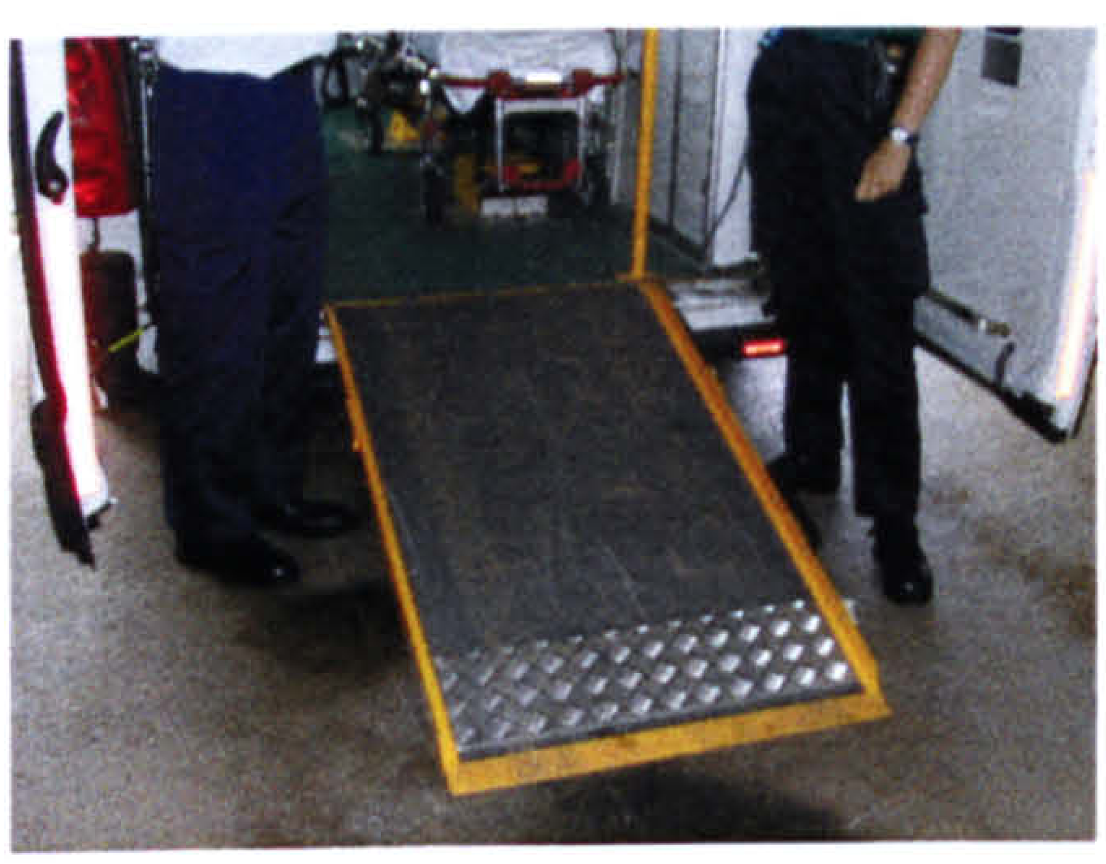


Figure 2.7 Manual ramp

A number of studies have suggested that the ramp and winch is an alternative to the easyloader stretcher as a means of reducing manual handling (Boocock et al., 2002; MDA, 2003). In 1994 Collins recommended that redesigning vehicles to reduce loading problems should be a priority. He suggested that the hydraulic ramp system could be considered for use by ambulance services. Boocock et al., (2002) highlighted however that the systems need to be evaluated and alternative approaches considered before suitability and practicality of the ramp and winch could be confirmed.

Watt and Dickson (1999) discussed an evaluation of a manual ramp and winch by the SAS. They reported that a ramp loading system, unless used with a winch, was more hazardous than easyloader stretchers due to the particular body movements required to carry out the task. It was considered that a winch would fully mechanise the task, and therefore solve the manual handling issue. Staff feedback was much more positive with regard to the ramp than the easyloader stretchers. It was considered that converting a fleet of ambulances to the mechanised system could cost millions, yet the benefits from reduced staff absence, early retirement and fewer litigation cases would offset this in the long-term. A risk assessment carried out by the health and safety department of SAS (SAS, 1998) found the incline on the ramp to be steeper than desirable, but there was no information available at the time governing the level of incline. The BSI (2002) has now disclosed that the appropriate incline for the ramp as specified in BS EN 1789 is 16°.

In a further study SAS carried out an operational evaluation of the UVModular Premia body vehicle with the electric step ramp. The assessment was carried out with staff throughout Scotland and the total of number of participants was not reported. The study found that 26% of respondents had experienced difficulty using the ramp. Staff found the lowering suspension favourable, but felt it should lower further (SAS, 1998). The NHS Trent Region Procurement Consortium (2002) (including East Midlands Ambulance Service NHS Trust and the Lincolnshire Ambulance and Patient Transport Service NHS Trust), highlighted the need for grab rails at the side of the rear doors and warning tape around the stretcher loading system, be that ramp and winch or tail lift.

2.4.5 Tail lift

The tail lift is an automated platform which is used to load and unload the patient without staff manually lifting the stretcher (Figure 2.8). On a modular tail lift vehicle the offside rear door is an electro-hydraulic lift to raise and lower a patient into the ambulance. The aluminium platform is lowered to the ground and then raised with the patient on board until it is level with the floor of the patient compartment. The stretcher is then pulled off the tail lift platform (Ray Smith Group, Ltd, 2001).

Figure 2.8 The Modular Tail Lift

In 2002 McDermott and Warwick, from LAS carried out an evaluation of the Jakab and Modular tail lift vehicles. The evaluation highlighted a vast number of trip hazards such as the bullhorn locking mechanism and the large horizontal hinge connecting the tail lift to the ambulance. The locking mechanism is part of the stretcher design rather than the loading system.

The Ray Smith Group (2001), who manufacture and supply many ambulance services with tail lifts, claimed that the lift allows crews to wheel the stretcher onto the platform when loading and unloading, without lifting or manual handling and without having to push or pull a stretcher up a ramp. They believe the system to be safer and easier to use, and provide a jolt-free passage in and out of the vehicle.

2.4.6. Carry chair evaluations

Figure 2.9 Ferno Compact 2 source:http://www.spservices.co.uk/images/ch022.gif

In the UK the carry chair is the preferred equipment for transporting patients down stairs (Lavender et al., 2000a). It is the one of the most commonly used manual handling aids in UK ambulance services, but for many years the design has remained unchanged (Birtles and Boocock, 2003). Boocock et al., (2002) identified that manual handling activity carried out with the carry chair is one of three main tasks linked to the cause of accidents and injury in UK ambulance services. The other two tasks were use of the stretcher and patient transfers. In recent years equipment has been developed to aid stair descent, incorporating assistive mechanisms to aid the manoeuvring of chairs up and down stairs (Birtles and Boocock, 2003). Ambulance services however have been reluctant to adopt recent advances in technology, opting for traditional equipment because they have been found to introduce additional risks and usability issues (Ponting, 2005). For example EMAS purchased a C-max chair (seen in this study as the Ferno Stairclimber) and, due to the size and inexperience of the staff in using the equipment, staff chose not to use it (Smith 15/07/2005, *Personal communication*). Thorough training and correct integration of the equipment could resolve these issues.

Lavender et al., (2007a) carried out a study to test ergonomic interventions developed for transporting patients down stairs using focus groups. The researchers evaluated four interventions, which included, a foot strap which attached to a back-board (spinal board) to prevent the patient slipping during descent, a new configuration of handle on a stair chair, and two devices which change the back board and stretcher descent tasks from lifting tasks into rolling and sliding tasks. These two devices were a 'backboard wheeler' and a tank tread-like device for a stretcher. The aim of the interventions were to reduce the level of trunk muscle exertions in fire fighters and paramedics. Eleven crews used each intervention to transport a 75Kg mannequin down stairs. Surface electromyographic data were collected from 8 muscles in the participants' trunk. The results showed that three out of four interventions had a positive effect. The foot strap intervention reduced the erector spinae (ERS) activity for the leader position by an average of 15%. The back-board wheeler reduced ERS bilaterally in the leader position by 28% and unilaterally in the follower position by 24%. The tank tread like device reduced the 90 percentile ERS activity for both positions and the stair chair handle intervention had no effect.

Birtles and Boocock (2003) conducted a study to identify the risks associated with transporting patients seated on carry chairs. The study identified three main carry chairs used by three ambulance trusts in the UK; the Ferno Mobyle, the Ferno Compact 2 and the Ibex TranSeat. The results showed that the carry chair was used in 38% of calls where transportation from the call scene was required compared with walking (35%) and stretcher usage (17%). The most common mode of transport from the ambulance was identified as the stretcher (70%). No significant difference was identified between the differences in operating the carry chair at the head end and the foot end. Patient transfers involving movement from ambulance mobility equipment to hospital beds and chairs were common. Issues identified were carry chair stability during transfer, equipment height mismatch and the effect of the back rest height on operator positioning. The study also identified issues with specific equipment features such as handle height, wheel design, chair stability and foot rest design. The study concluded that the functional requirements of A&E work were not met by the carry chairs. They suggested that greater consideration needed to be given to the provision of equipment to assist ambulance crews in high risk environments and handle the extraordinary situations which staff encounter in the field.

Research by Ferreira and Stanley (2005) evaluated force, posture, and anthropometric data, collected during tasks carried out using carry chairs to estimate the physical demands and risk of injury. Four tasks associated with carry chair work were simulated by eight participants. The tasks included transporting a patient up and down stairs, lifting a patient into the back of an ambulance, wheeling a patient up a ramp and moving a chair over a kerb. The study identified that the foot end operator was at high risk of injury when lifting the chair from a low level. The operators' arms were found to be under high physical demands. The task of transporting patients up stairs was found to be physically demanding, but when descending stairs the ability to support the load on the stairs reduced the risk to the upper and lower back. Ferreira and Stanley concluded that the use of more recently developed chairs was hindered by environmental constraints such as confined spaces. Versatility was reported as a key feature for carry chairs.

2.5 Summary

This literature review has outlined the problems experienced by ambulance staff as a result of their work and culture in terms of physical and mental stress, and identified the problems associated with manual handling activities carried out in the ambulance services making specific reference to stretcher related manual handling.

Manual handling tasks have been recognised as a major contributor to musculoskeletal injuries and have also been linked to mental disorders such as stress. Other contributing factors include culture and the pressures put on staff by the public and others in the health profession.

It is evident from the literature that manual handling is a major part of working in the ambulance service and although equipment design has improved there is still a long way to go in terms of reducing the manual handling risks.

Ambulance services have gone some way towards reducing manual handling activities. However many of the tasks carried out by ambulance workers are difficult to control in terms of environment, so removing manual handling from their role completely is virtually impossible. As a result of Controls Assurance, ambulance services have been required to manage risk effectively and so have begun to carry out equipment evaluations and risk assessments. Much of the research carried out is 'quick and dirty' and has little scientific background. Limited evidence of robust scientific evaluations were found in the literature, identifying a gap in the research. In the following chapters, this thesis will describe two case studies; A comparative evaluation of three stretcher loading systems (Chapter 4) and an evaluation of mobility equipment designed for the ambulance market (Chapter 5), these studies were carried out to address the gap in the literature.

Chapter 3: Methodology

This chapter describes the methods available for analysis of equipment and tasks in the studies conducted for this thesis. The methods selected for use are described further in Chapter 4 Section 4.2. and Chapter 5 Section 5.2.

3.1 Interview methods

3.1.1 Interviews

Interviews are the most commonly used method in knowledge elicitation exercises and range from the formally planned structured interview, to the unstructured interview which has no pre-determined agenda (Shadbolt, N, 2005). With unstructured interviews the participant is provided with a broad question which they may answer in whichever way they please with little prompting from the researcher (Robson, 2002). Unstructured interviews are beneficial if the goal is to develop a rapport between the expert and participant. However, the lack of structure can lead to inefficiency (Shadbolt, 2005) with the potential for crucial information to be ignored. Semi-structured interviews have pre-determined questions but the researcher can change the order, wording and, if appropriate, omit or add questions at their own discretion (Robson, 2005). The benefit of this type of interview is that new and unexpected issues can be uncovered, making this the most common type of interview method adopted (Stanton, et al., 2005). Structured interviews are formal, with pre-determined questions which must be asked in the specified order, using specific wording. This provides structured transcripts which simplify the analysis process (Shadbolt, 2005) but limits the scope for the interview (Stanton, et al., 2005).

Interviews lend themselves to being used in combination with other data collection techniques. For example relatively formal interviews can complement observations (Robson, 2002). King, (1994) suggests that interviews may be used where exploratory work is required before conducting a quantitative study, or where quantitative data are being collected and qualitative data are required to validate the findings. The process of interviewing is time consuming. Time must be allowed for preparation, interviewing, data transcription, cleaning and analysing (Robson, 2002).

3.1.2 Critical Incident Technique

Critical Incident Technique (CIT) is a qualitative method which uses semi-structured interviews to determine significant incidents experienced by the subject. The procedure identifies the event, how it was managed and the effect it had on the respondent, highlighting the cause and effect of the incident (Chell, 1998; Shepherd, 2001). The recorded incidents are events or features within an area of work which have had significant impact on the system objectives. Although this impact would usually be of a negative nature, the technique also presents a way of identifying positive influences (Kirwan and Ainsworth, 1992).

Kirwan and Ainsworth (1992) argue that CIT is particularly useful in outlining the aspects of a task which make system components vulnerable. This makes it an appropriate tool for highlighting rare events which cannot be drawn from other methods such as observation. They also suggest that little has been reported in terms of the reliability and validity of the technique, although one study conducted by Edwards and Hahn in 1980, predicted a high validity, suggesting that it is useful in underlining potentially hazardous situations (cited by Kirwan and Ainsworth, 1992). Chell (1998) argued that the reliability of the results was built into the quality of the interview and therefore relied on the interviewer being skilled at acquiring information which is not forthcoming. The key strength to CIT is its ability to rapidly draw out the core problems in a system (Kirwan and Ainsworth, 1992).

CIT has been used in a number of applications in healthcare research. Aveyard and Woolliams (2006) used CIT to identify incidents concerning the collection of informed consent prior to nursing care procedures in clinical practice. They collected critical incident data from 30 nurses. The researchers carried out a thorough analysis of the data using the constant comparison method with two researchers independently coding the interview transcripts to increase validity. They highlighted that the administration of sedation to patients who can not consent, was a serious concern. This study shows that CIT can be used as a single method to collect exploratory data to reach conclusions in the healthcare setting. Mixing the technique with other methods will increase validity.

3.1.3 Focus groups

Focus groups are a purposefully selected assembly of individuals who take part in a group discussion (Bruseberg and McDonagh-Philp, 2002). Sinclair (2005) describes focus groups as an interview with a group instead of an individual. Group interaction encourages participants to talk, ask questions and discuss their experiences and points of view (Kitzinger, 1995). The researcher's role is to organise and prompt the participants (Sinclair, 2005). This method is an effective way of collecting a large amount of data in a short space of time, generating opinions from of a greater number of participants than interviews. Focus groups provide the participants with a positive experience and the data collection benefits from group dynamics. Negative aspects of focus groups include difficulties in managing and facilitating the group, conflicts between participant personalities and a limit on the questions covered in the time (Robson, 2002). No data is available regarding the reliability and validity of focus groups (Stanton et al., 2005).

They have been used in a number of studies to gain information from a group of end users (Lavender et al., 2000a; 2000b; Woods & Buckle, 2005). Studies carried out by Lavender et al., 2007a used focus groups to develop interventions which were evaluated in task simulations.

3.1.4 Questionnaires

Questionnaires are a flexible way of collecting large amounts of data in a short amount of time (Stanton, et al., 2005). They are usually used in market research (Stanton and Young, 1999) and are generally used if breadth of information is required (Shipman, 1997). Questionnaires are a popular method of collecting data for human factors design and evaluation (Stanton, et al., 2005). Questionnaires are particularly good at comparing opinions of a large group of people. By using statements and rating scales correctly the researcher can gain answers which can be weighted for reliability and consistency (Kirwan and Ainsworth, 1992). Limitations of using questionnaires include a limited output, and they can only usually be applied to an existing product (Stanton and Young, 1999).

Questionnaires are often used for evaluations in user trials and are a good way of ascertaining user perceptions of products (Stanton et al., 2005). Previous studies have used questionnaires alongside other methods, to evaluate equipment (Woods and Buckle, 2005; Simpson et al., 1999; Okunribido, 2006). Simpson et al., (1999) carried out user evaluations to evaluate the Hephaestus smart wheelchair system. A mixed methods approach was used, collecting qualitative and quantitative data from four able bodied participants and four disabled participants. Qualitative user responses were measured using questionnaires and quantitative measures were taken of the chairs assistive behaviour. This study emphasises that valid data can be obtained through as few as four questionnaire respondents.

3.2 Observation methods

3.2.1 Observation

Observation is when data is collected from an operational system by observing this system without changing it (Drury, 1990). Observation falls under 3 categories; direct observation, indirect observation and participant observation. All three are similar in application (Stanton and Young, 1999). Direct observation is when measures are taken directly by visually observing participants, and behavioural phenomena is assessed (Wilson, 1990; Stanton et al., 2005). It is the most common form of observation used (Stanton et al., 2005). Indirect observation is when measures of behavioural phenomena are taken from reports, including the opinions and attitudes of participants (Wilson, 1990). Observation is generally carried out with the participant being given a product and a number of tasks to carry out (Stanton and Young, 1999).

Observation methods have been well used as a tool for data collection in ambulance related studies (Ferreira and Hignett, 2005; Doormaal et al., 1995; Stevenson, 1995; Alves and Bissell, 2002; Schiro and Drury, 1981 cited in Drury, 1990). Observational methods have a high face validity (Drury, 1990) and ecological validity when carried out in the field. There are concerns that there is an observer effect, with participants acting differently in front of the observer than they would under normal conditions. There is also a trade off when carrying out laboratory and field based evaluations. Laboratory based evaluation offers more control, whilst field observations offer ecological validity (Stanton and Young, 1999).

3.3 Task description methods

3.3.1 Hierarchical task analysis

Hierarchical Task Analysis (HTA) is used to break a task down into a hierarchy of operations, providing a more in-depth analysis. The analyst must consider the conditions necessary for the subtasks to be carried out in completion of the overall goal. By breaking down the goal in this way, HTA allows data to be analysed in as much or as little detail as required. The method is used to show how the activities of the operator are linked to the requirements of the system.

HTA is a core ergonomics approach which has been used for over 30 years in a number of applications, including interface design and evaluation, allocation of function, job aid design, error prediction and workload assessment (Stanton et al., 2005). It has also been used to analyse work organisation, training and human error (Kirwan and Ainsworth, 1992). The expanse of applications, and over 30 years of continued use adds to the validity and reliability of the method (Stanton et al., 2005).

The analysis is displayed in an HTA diagram. Computer software, such as Task Architect (accessed on 12/06/2005), can be used to assist in the development of these diagrams.

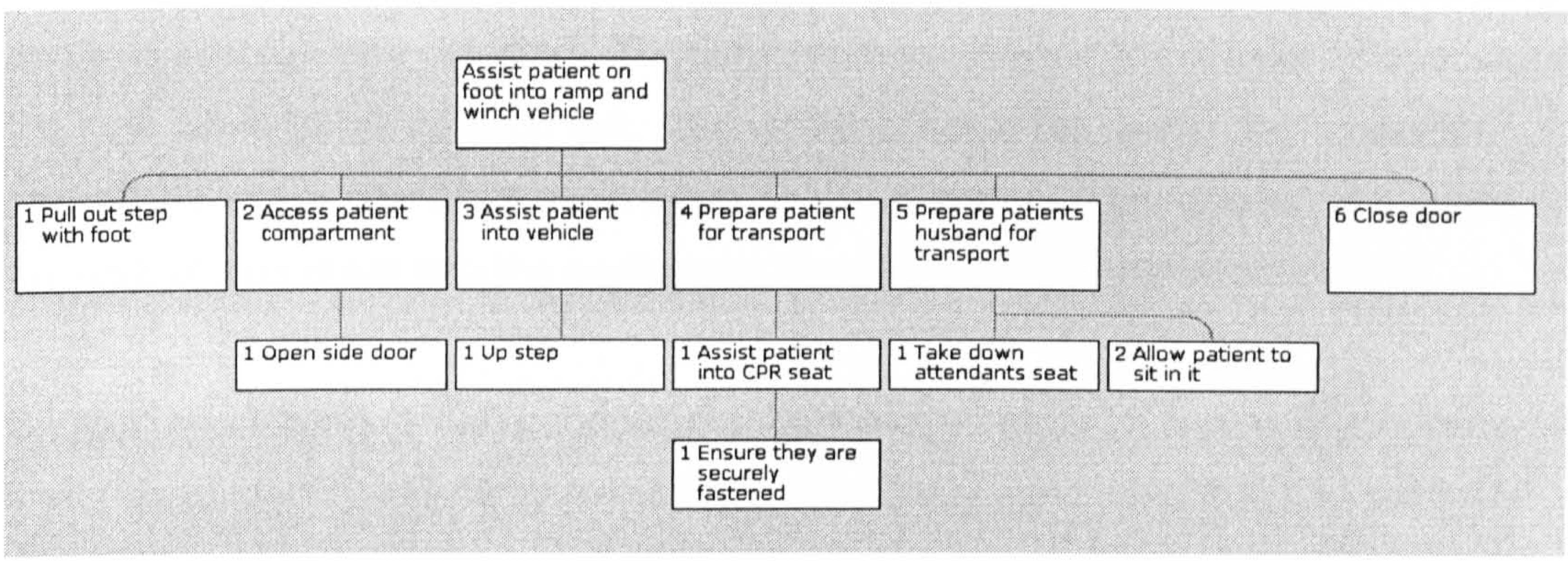


Figure 3.1 HTA diagram representing task of assisting patient into vehicle on foot

In 1999 Stanton and Young reported an acceptable level of validity but a poor level of reliability due to different interpretations and different ways of using the tool adopted by the analysts. A sufficient data sample has never been collected to assess the reliability of HTA, but the care taken during data collection has a substantial impact. The validity of data relies on the analyst addressing the correct questions and providing effective solutions (Annett, 2005).

HTA has been used in a number of healthcare related studies in recent years for example Lane et al., 2006 used HTA to model drug administration in hospitals. The researchers used the method as a way of analysing how people interact with equipment and their work environments in the healthcare setting.

3.3.2 Link Analysis

Link Analysis is used to analyse movement between components within a system or product. It can be used to identify problems with the layout of a working area. A link occurs when an individual shifts attention or physically moves from one part of the system to another (Kirwan and Ainsworth, 1992).

LA can be used to optimise the arrangements of the links in a system, by highlighting the complexity of a task and informing on the layout design. Following an observational study, a list of links within the task system can be constructed. The technique relies on the observation of a task to establish movement between the various parts of a system (Hignett, 2005). It allows the researcher to understand how different parts of the system are linked to each other through the execution of the task. This can be used to analyse workplace layout and job design (Shepherd, 2001).

There are limitations in terms of what can be analysed using link analysis. For example it can only measure spatial relationships and it fails to record aspects of an analysis such as task duration. The links represent frequency of links as opposed to the time taken to create each link. Link analysis has often been used to assess operations where operators must move between system components. It focuses on the task environment and the equipment used (Kirwan and Ainsworth, 1992).

Stanton and Young (1999) conducted a comparative study of twelve ergonomics methods to identify validity and reliability. The study concluded that Link analysis demonstrated high intra-rater reliability, high predictive validity, and poor inter-rater reliability.

Ferreira and Hignett (2005) used link analysis to examine the layout of ambulance patient compartments, in terms of task performance. The analysis identified the most frequently used components within the patient compartment, allowing recommendations to be made about equipment placement based on frequency of use. The output of this study demonstrated how link analysis could be used in spatial and layout design applications.

3.4 Evaluation methods

3.4.1 User trials

User trial, is a term synonymous with the terms 'user testing, and 'usability testing' referring to the evaluation of artefacts under controlled conditions, with users (McClelland, 1990). It involves product or system end-users performing a series of tasks with a new product or device to evaluate various features. The flexibility of user trials allows the assessment of features including usability, situation awareness, task performance times and user reactions (Stanton, et al., 2005). It provides a reliable way to estimate quantitative user performance and subjective satisfaction with products (Wichansky, 2000) under controlled conditions (McClelland, 1990).

Studies have shown that four or five participants is sufficient to gain reliable results through user trials (Virzi,1992). Virzi identified that 80% of findings were detected with four or five participants. Having more participants was less likely to provide any new information, and the majority of severe usability problems would be highlighted by the first few participants. Evaluation studies have incorporated a range of subject numbers with some incorporating groups of four participants (Simpson et al., 1999) and others incorporating ten or more participants (Woods & Buckle, 2005; Le Bon and Forrester, 1997).

A number of studies used mixed methods for product evaluation incorporating user trials, expert evaluation and performance tests or convenience checklists (Le Bon and Forrester, 1997; Butters and Dixon, 1998). Le Bon and Forrester (1997) ergonomically evaluated a patient handling device called the 'Elevate and Transfer Vehicle' (ETV). They collected data with user trials, expert evaluation and critical performance tests. It was found that the problems could be overcome with minor design improvements. The findings are strengthened by the triangulation of the three methods ensuring that the important aspects of evaluation were covered.

3.4.2 Task simulation

A number of studies have used task simulations, which are a form of user trials, to evaluate equipment or task procedures (Lavender et al., 2000a and 2000b; Kluth and Strasser, 2006; Barnekow-Bergvist et al., 2004). These studies used quantitative methods to measure the effects of the tasks. For example Lavender et al., (2000a and b) conducted biomechanical and postural analyses of frequently occurring tasks, Kluth and Strasser (2006) measured the strain placed on the circulatory system during equipment use, and Barnekow-Bergvist (2004) considered the physiological implications of stretcher lifting tasks, such as strain measurements.

3.5 Manual handling assessment tools

3.5.1 Postural analysis tools

Although a number of studies have used postural analysis during task analysis (Doormaal et al., 1995; Ferreira and Hignett, 2005) few have used it as a method of product evaluation (Jones and Hignett, 2007). The equipment evaluated in this study were used in manual handling activities and therefore postural analysis was considered an important part of the equipment evaluation. A number of postural analysis tools were available to be used:

1. OWAS is a direct observation method (Corlett, 2005) for evaluating the discomfort of a working posture and assessing the urgency of remedial action (Siemens, accessed on 14/11/2007)
2. Rapid Upper Limb Assessment (RULA) was designed to ergonomically investigate work places where work related upper limb disorders occur (McAtamney and Corlett, 1993)
3. Rapid Entire Body Assessment (REBA) is a postural analysis tool which was developed specifically to evaluate the unpredictable postures characteristic of the healthcare profession (Hignett & McAtamney, 2000)
4. Quick Exposure Check (QEC) was designed to assess changes in exposure to musculoskeletal risk factors before and after ergonomic intervention. QEC considers risk exposure to the back, shoulders and arms, hands and wrists and neck (University of Surrey, accessed on 14/11/2007)

3.5.2 Lifting assessment tools

The National Institute of Occupational Safety and Health (NIOSH) developed the NIOSH lifting equation, which calculates the recommended weight limit for a lifting task carried out by a worker over a specified period without increased risk of low back pain.

Manual handling assessment charts (MAC) was designed by the HSE to help Health and Safety Inspectors identify and assess common risk factors in lifting activities. It is used to assess three types of lifting task which include lifting, carrying and team handling activities (HSE, 2003a).

3.5.3 Benchmarking of manual handling assessment tools

Coyle (2005) compared REBA with New Zealand Manual Handling Hazard Control Record and found that 'REBA may be more useful if specific ergonomic or biomechanical changes are being implemented to decrease risk of work-related injury, particularly if an objective numeric score is required for re-assessment following modifications, to determine their effectiveness'.

Lenton, (2004) carried out a comparative analysis of the results obtained from the NIOSH lifting equation and REBA using lifting postures adopted by front line A&E crews. She carried out a Friedman's test on the ranked scores which found no significant difference between the results produced by the two methods. The results of this study may lack validity as the researcher could only compare 12 postures because few lifting activities were observed in the data collection. However, Pinder (2002) had similar findings in a comparison of five paper based postural analysis tools through benchmarking activities:

1) REBA
2) NIOSH lifting equation
3) OWAS
4) QEC
5) MAC

A Friedman's test was carried out using the ranked scores from each tool, identifying that the tools did not produce significantly different action categories, therefore validating REBA against the other tools.

Pinder (2002) argued that REBA was flawed because it created overall scores from a mix of risk factors specific to the upper limb and lower back. However, the creators (Hignett and McAtamney, 2000) intended to include the different sections of the body to account for all individual risk factors. In this study the tools compared were developed to measure different types of risk, therefore the comparison strategy was potentially flawed. The tools range between general risk assessment tools, to lifting tools and so should not be compared within each other. The REBA scoring system was considered to be difficult due to the complex tables used to calculate the final score. This study required Ergonomists to use the tools and benchmark MAC against the four other assessment tools. Conclusions about REBA may be unreliable because the Ergonomists assessing the tool may have been biased towards a particular tool.

Li and Buckle (1999) highlighted a number of limitations of using paper based postural analysis tools in their summary of techniques for assessing work-related musculoskeletal risks. The recording procedures for paper-based postural analysis lack precision, proving a problem for reliability. Little is known about the comparative importance of each risk factor, so it becomes difficult to weight each risk variable. There is little knowledge about safe exposure levels of postural risk so it is difficult to measure the overall risk posed by an individual task.

Covalla (2003) conducted a study to determine people's ability to visually estimate postural angles of the shoulder, trunk and wrist, to determine the effect of estimation error on risk analysis tools. Covalla reported that no validation studies had been carried out for REBA at the time of the study. However, inter-rater reliability assessments had been completed. Covalla reported that the inter-observer reliability was only moderate.

Chapter 4: Case Study 1

A comparative analysis of stretcher loading equipment

4.1 Introduction

The role of A&E staff in the UK ambulances service is to respond to emergency, urgent and routine calls delivering pre-hospital treatment. They undertake emergency driving and are required to lift and carry patients. This requires occasional or intense manual handling of patients (NHS employers, 2003). Manual handling in the ambulance service has decreased significantly in recent years due to advancements in equipment design and patient handling procedures (Boocock et al., 2002). Patients who are able to walk are now assisted to the ambulance on foot instead of being transported on a stretcher or carry chair (London Ambulance Service, LAS, accessed 06/12/2007; Welsh Ambulance Service, WAS, accessed 06/12/2007). Before the introduction of the Manual Handling Operations Regulations (HSE, 1998a) the York 4 stretcher was the primary stretcher used to transport patients (Figure 4.1). The York 4 was lifted into the ambulance by two paramedics or technicians, one either side of the stretcher (Hill, 06/06/2005, *Personal communication).*

Figure 4.1 York 4 stretcher source: www.spservices.co.uk/images/st004.gif

In 1992 Manual Handling Regulations (HSE, 1998a) were introduced, to be implemented in conjunction with the Health and Safety at Work Act 1974 (HSE, 2007) and Management of Health and Safety at Work 1992 (UCL, accessed on 02/02/04). Under this legislation manual handling operations should be avoided so far as is reasonably practicable and employers must ensure the health, safety and welfare of their employees.

The weight of the York 4 exceeded the guidelines in MHOR 1992 (MDA, 2003) so the ambulance service and manufacturers sought new loading methods to reduce manual handling in loading and unloading tasks. Although the York 4 is still used today on ramp vehicles, for the most part it has been replaced by more modern designs. The ambulance services made increased use of easyloader stretchers which rely on manually assisted, semi-automatic retraction or release of the legs when loading or unloading. In order to retract the legs staff manually operate lever controls. The legs unlock allowing the trolley to be pushed on to the ambulance, usually on to a receiving platform. This sequence is carried out in reverse to unload the stretcher, but a safety catch must be released to prevent the front legs collapsing prior to the release of the back legs (MDA, 2003). The weight of the stretcher is supported by the ambulance body reducing the weight carried by the crews.

The European Committee for Standardisation (CEN) introduced voluntary standards relating to ambulance design in 2000 (EN1865, 2000a; EN1789, 2000b and EN1789, 2007). Due to the importance of patient and paramedic safety, standard compliancy has become a purchasing requirement for new vehicles in the healthcare industry (Vehicle Certification Agency, VCA, accessed on 14/06/2006). EN 1865: 'Specifications for Stretchers and Other Patient Handling Equipment used in Road Ambulances' requires that during loading and unloading tasks, the maximum burden of any staff member is half of the total weight of the patient and stretcher, for the minimum time possible and in an optimal ergonomic position to minimise bending. The stretcher must therefore be designed to meet these criteria. The undercarriage must be suitable for loading and unloading at a maximum height of 750mm (2000a).

The easyloader stretcher did not comply with EN 1865 (2000a) and so since the arrival of the CEN compliancy, manufacturers and the ambulance services have had to consider new types of equipment which used new methods of loading and unloading. As a result many ambulance services opted to follow CEN guidance. This has led to a gradual phasing out of easyloader systems and the introduction of new mechanisms, such as the ramp and winch and the tail lift, which have reduced the level of manual handling carried out during the patient loading tasks.

A fully equipped ambulance costs in excess of £100,000, it was therefore not possible to replace all easyloader stretchers on the basis of non-compliance, so many ambulance services still have a number of easyloader stretchers in use. The stretchers are gradually being phased out of use but the equipment must reach the end of its life span before they can be replaced with more modern equipment (Farnsworth, 12/10/2007, *Personal communication*).

Clinical Governance was introduced to the NHS in 1998 (NHS, accessed on 14/11/2007) 'Clinical governance is a system through which NHS organisations are accountable for continuously improving the quality of their services and safeguarding high standards of care by creating an environment in which excellence in clinical care will flourish' (Scally and Donaldson, 1998). The clinical governance initiative demands a move towards evidence based medicine, considering that clinical decisions and health policy can no longer be based on opinion alone (Scally and Donaldson, 1998).

On reflection there seemed to be little information for fleet managers to base their purchasing decisions. Ambiguities in the CEN standards (Ferreira and Hignett, 2002) and the introduction of Clinical Governance prompted an ergonomic comparative evaluation of stretcher loading systems, to determine the preferred system for use by ambulance services.

Due to the nature of the emergency service the stretchers must be loaded quickly, but with care, to ensure a comfortable transfer. The loading system used is therefore of great importance. Although a number of stretcher loading systems have been analysed in the past (Boocock et al., 2002; Watt and Dickson, 1999) there has been no comparative evaluation of the three systems.

4.1.1 Aims and objectives

This project aimed to comparatively evaluate three stretcher loading systems to determine which was most suitable for use in a variety of environments (rural, urban and intermediate) and to make recommendations for improvements.

The specific objectives were to:

1. Carry out a detailed analysis of the tasks of loading and unloading stretchers with three stretcher loading systems, using three methods of analysis: CIT, Link Analysis and HTA
2. Investigate the exposure of ambulance staff to manual handling risks
3. Identify the key areas for improvement and rank in order of staff priority

4. Provide recommendations for improved stretcher loading systems that optimise safe systems of work for the tasks of loading and unloading patients with minimal risk of injury to staff and patients

4.1.2 Ethics

Ethical approval was provided by MREC (Multi-centre research Ethics Committee, ref no. 04/MREC09/3). All participants were provided with an information sheet (Appendix A) and health screening questionnaire (Appendix B) before participating. They were given the opportunity to ask questions and were asked to provide informed and photographic consent (Appendix C and D).

4.2 Method

4.2.1 Research approach

A realistic evaluation approach was adopted in this study (See Chapter 1, Section 1.3). A ground theory approach to data collection was adopted for the evaluation of stretcher loading equipment outlined in this chapter. Grounded theory takes a systematic approach towards discovering theory from data, grounded in observations from the real world (Robson, 2002). The data were collected in the field during a number of visits and analysed in the interim. Data collection ceased once the information obtained had reached saturation (Robson, 2002).

This study used quantitative and qualitative methodologies to make a detailed comparative analysis of the three ambulance stretcher loading systems. The mixed methods approach was used to draw on the benefits of both qualitative and quantitative methods and gain a thorough understanding of the research subject. The research was carried out in two phases, in phase one a field study was conducted to identify usability and manual handling issues experienced by A&E staff whilst loading and unloading patients during a shift. The issues identified during phase one were ranked in order of priority by ambulance service staff across the UK, in terms of future improvement. In phase two a simulation study was conducted whereby the tasks and scenarios observed in the field study were reconstructed in a controlled environment. Video data were collected allowing postural analysis to be carried out. Figure 4.2 shows the methods used and how they were integrated together. The rationale for each method is provided in the following section.

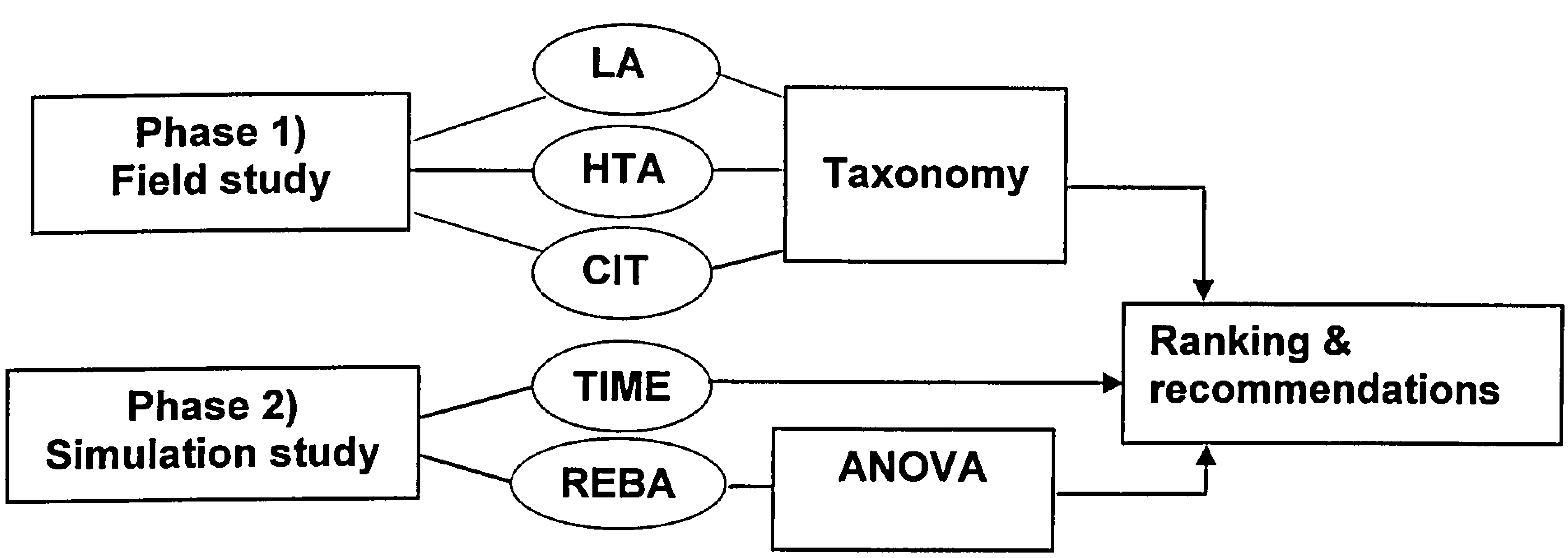


Figure 4.2 Protocol for stretcher loading study

4.2.2 Methods selected for phase 1 - Field study

To meet the aims and objectives of the study it was necessary to collect comparable data about each system when used in a variety of environments, covering a number of shift patterns, allowing variances such as the user, the call type, the road and environmental conditions, and weather conditions to be considered. The three loading systems work on very different principles and so data describing the operating task were needed. A field study was planned to evaluate the every day issues affecting equipment use.

4.2.2.1 Observation

The method of direct observation was selected to collect comparable data for each system. It was highly suited to data capture of a visual or audible nature and was a useful technique for recording physical task sequences (Kirwan and Ainsworth, 1992). Observation was considered the most appropriate method of identifying the problems experienced by staff in the real world setting. The period of observation allowed a rapport to be developed with participants, enabling other methods such as interviews to be carried out at the same time. This made the research process more efficient, generating a large amount of data for all three stretcher loading systems over a short period of time, and allowed more time for analysis. This provided real time and retrospective data. Direct observation was appropriate for observing the equipment used in a range of environments, shifts, job functions and weather conditions.

4.2.2.2 Link analysis

Link analysis was used to describe the physical interaction between the staff and equipment during loading and unloading tasks. It was selected because of its ability to highlight task complexity and inform about layout design (Hignett, 2005). Stretcher loading devices are complex systems consisting of many components and so the method was required to identify how the system components link together (Shepherd, 2001). Link analysis relies on observation of a task (Hignett, 2005). It has been used successfully in previous ambulance related research (Ferreira and Hignett, 2005) where it was applied to highlight task complexity and redefine the layout of the stretcher loading system so that the components could be located in the optimum position for efficiency and improved system performance.

4.2.2.3 Hierarchical Task Analysis

HTA was used to identify how ambulance staff interact with the stretcher loading equipment in the field to develop a detailed task procedure which identifies the errors and problems encountered during operation. HTA relies on observation or verbal protocol analysis (Stammers and Shepherd, 1990). It was selected because of its extensive use in analysing interface design, work organisation, training, human error (Kirwan and Ainsworth, 1992), allocation of function and workload assessment (Stanton, et al., 2005). The method has an acceptable level of validity (Stanton and Young, 1999). To improve reliability two analysts interpreted the data.

4.2.2.4 CIT and Semi-structured interviews

CIT was selected to collect data regarding the rare incidents which resulted in catastrophe or near misses. This method was chosen to support the observations and collect data about past events which could not be collected through real time observations. It was the most suitable method for collecting retrospective accounts of incidents which do not occur on a regular basis. Interviews were also carried out to identify more common occurrences which were not captured during the observations.

4.2.3 Methods selected for phase 2 - Simulation study

A simulation study was planned to assess the manual handling implications of stretcher loading and unloading activities. The work carried out by ambulance staff needed to be simulated to prevent the data collection process having an impact on the work carried out by ambulance staff in the field. Data were required to measure the postural risk posed by each system and to assess the time taken to load and unload the stretchers. In order to collect postural data video footage of the tasks needed to be captured. Photography was not permissible in the field due to ethical constraints, so the tasks were simulated under controlled conditions.

4.2.3.1 Postural analysis and REBA

Postural analysis was carried out rather than using other manual handling assessment tools such as force measurements, electromyography or Rate of Perceived Exertion (RPE). Participants were asked to simulate tasks usually conducted in the field, so the simulation exercise needed to be as realistic as possible. Invasive data collection techniques such as these impose on the task and were not deemed suitable. Postural analysis was considered to be the least invasive way of collecting data.

REBA was selected because it is the only postural analysis tool which assesses the entire body while accounting for the unpredictable postures which are adopted in the healthcare setting. The tool assesses risk relating to manual handling but also considers the hazards posed by the healthcare workers posture adopted during the manual handling task (Hignett and McAtamney, 2000).

It was important to assess risk factors beyond those associated with lifting. Tools such as MAC and the NIOSH lifting equation were rejected because they were designed specifically for assessment of lifting tasks and could not assess all the risks associated with stretcher loading and unloading tasks. Furthermore MAC was considered to be too general, giving an overall risk assessment instead of providing a risk rating. REBA was considered most suitable for this application because it considers a large number of variables in its analysis, including posture, force, repetition and coupling.

A parallel study was carried out by researchers at Sheffield University, assessing force and vibration effects of stretcher loading equipment operation (Cooper and Ghasemiah, 2007). It was not necessary to conduct further biomechanical analyses.

4.2.3.2 Mixed methods

Observation (HTA and LA) and interview (CIT) methods were triangulated in this study to address the limitations of each method. By using a mixed methods approach the validity and reliability of the data were increased. Furthermore, by using two task description methods (HTA and Link analysis) it was possible to account for the strengths and weaknesses of each, further increasing the validity of the results.

4.2.4 Field study data collection

4.2.4.1 Participating ambulance services

Three ambulance services collaborated in this study: East Midlands Ambulance Service NHS Trust (EMAS), East Anglian Ambulance NHS Trust (EAAT) and Two Shires Ambulance NHS Trust (TSAT). At the time of the study each ambulance service utilised at least one of the three loading systems (Figure 4.3). Collaboration with the three ambulance services allowed the full range of equipment to be evaluated in a number of different patient call situations and geographical locations.

EMAS – Hydraulic ramp and winch	EAAT – Modular tail lift	TSAT – Easyloader stretcher

Figure 4.3 Ambulance service loading equipment

In 1990 there were 46 ambulance services across the UK. In 2005 when Peter Bradley conducted the review of ambulance services in the 21st century the number had reduced to 31 (HSE, 2005). Since this research began, as a result of the Bradley report, in June 2006 the UK ambulance services merged across counties and there are now 13 (ASA accessed on 10/04/2007). EMAS merged with Lincolnshire Ambulance Service and the Northamptonshire side of Two Shires Ambulance NHS Trust (TSAT), while East Anglian Ambulance Service NHS Trust (EAAT) remained the same. The following section describes the collaborating ambulance services as they were at the time of the study.

East Midlands Ambulance Service

EMAS was formed in 1999 when the services in Derbyshire, Leicestershire and Nottinghamshire merged. EMAS served a population of over 2.9 million within an area of over 2700 square miles. The Trust operated from 38 ambulance stations and handled over 250,000 emergency calls at their control centre. Eight hundred and seventy four operational staff responded to these calls using over 200 vehicles (EMAS, accessed on 29/04/05). The service had a vehicle replacement strategy, aiming to replace the vehicles on a seven-year basis. Their 'make ready scheme' was piloted in 2003, whereby special crews prepare the vehicles for use, carrying out several checks including equipment replenishment, and checks for road worthiness (Commission for Health Improvement, CHI, 2003a). The service aimed to reduce the incidence of manual handling injury (EMAS, accessed on 29/04/05). In order to achieve this EMAS took a pro-active approach towards Health and Safety management, creating a Back Care Advisor position to organise and run moving and handling courses. A network of individuals were trained as Back care 'champions' to advise staff in the field (EMAS, 2006). At the time of this study EMAS was using the hydraulic ramp and winch.

East Anglian Ambulance Service

EAAT was formed in 1994 by the amalgamation of Cambridgeshire, Norfolk and Suffolk ambulance services. The service received over 150,000 emergency calls per year. EAAT's core activity is front line A&E response (EAAT, accessed on 29/04/05). CHI (2002) found that EAAT had improved manual handling training since recognising it as a high risk area, and work related injuries have decreased in number. Furthermore, between 2002 and 2003 EAAT introduced 10 new tail lift A&E vehicles in order to have a positive impact on manual handling figures (EAAT, 2003). At the time of this study EAAT were using tail lift vehicles.

Two Shires Ambulance Trust

Two Shires Ambulance NHS Trust (TSAT) was formed in 1993 when the Buckinghamshire and Northamptonshire services merged. The Trust employed 350 ambulance staff serving a population of 1.3 million. There were a total of 17 stations across the two counties (TSAT, accessed on 29/04/05). CHI found that TSAT had a good risk assessment system in place, whereby equipment was assessed prior to purchase. The ambulance trust aimed to provide equipment training to staff prior to use in the service. Some staff, however, were not satisfied with the training provided, feeling that it was not delivered in a timely way (CHI, 2003 b). The trust recognised that the biggest cause of injury amongst staff was manual handling, and therefore made an effort to reduce the imposed risk by acquiring additional patient movement devices (Ive, 2003). CHI (2003b) noted that TSAT formed a working group to carry out risk assessments of vehicles and equipment prior to purchase. TSAT were mostly using easyloaders at the time of this study, however they recently acquired a number of manual ramp systems. The manual ramp was not included in the field study because not many stations were using them. It was included in the interviews and the simulation study.

4.2.4.2 Conducting observations

Front line A&E crews were observed over 27 shifts. Over 324 hours of field data were collected and were analysed using Link Analysis and HTA. 37 participants were observed in their normal working environment, minimising constraints on the task or system. Participants were asked to carry out their usual daily tasks and these tasks were observed from a discrete distance. The task was not highly cognitive so did not require a cognitive walk through or verbal protocol. No medical procedures were observed for the purpose of the study due to ethical constraints.

Prior to the observations meetings were arranged with ambulance service staff (operators, fleet managers, operations managers, risk managers and occupational health officers) to set the scene and gain an understanding of the background to the vehicle design and equipment. Information was collected about how the equipment was designed to be operated and how it operated in ideal conditions.

Observations were conducted using the same shift patterns as the ambulance staff, covering 12 hour shifts for three days or three nights during the week and at weekends. This ensured that the full use of the system was observed. Some stations chose not to have an observer covering night shifts so the systems were observed more frequently during the day.

The parameters of the task were defined before collecting data; the observations started when the patient was outside the call scene and ended when they were inside the patient compartment of the vehicle. The observer did not interrupt the task during data collection to minimise observer bias. Staff were observed loading and unloading patients on and off the ambulance. The steps they took to carry out these tasks were observed and noted down for later analysis.

The stations were selected by geographical location ensuring that observations were made from rural, urban and intermediate stations within each ambulance service; nine sites were visited in total. The trusts were visited at different times throughout the year, to observe the systems in a range of environments and climates. Data were collected over nine months, allowing for seasonal variation in system operation (Table 4.1).

Station	Location	Month	Shift	Week/end
Chesterfield	Intermediate	June	Day	Week
Loughborough	Rural	July	Day	Week
Daventry	Rural	July	Night	Weekend
Ipswich	Urban	August	Day	Week
High Wycombe	Intermediate	September	Day	Week
Huntingdon	Intermediate	September	Day & late	Weekend
Nottingham	Urban	October	Day	Week
Milton Keynes	Urban	October	Day & night	Week
Downham Market	Rural	January	Day	Week

Table 4.1 Data collection schedule

4.2.4.3 Critical Incident Technique

CIT data were collected during the hours of observation. The CIT participants were recruited from the observation participants. The researcher rode out with the crews at each ambulance station for three days to develop a rapport before collecting the CIT data. Semi structured interviews were carried out with ambulance staff whereby crews were asked to give details about critical incidents resulting in catastrophe, or near misses they had experienced when using the stretcher loading equipment. The interviewee decided which incident was relevant to discuss and the data were collected about the event; how the incident happened; what the consequences were and what the final outcome was for those involved? On occasion group interviews were conducted because the participants were part of a crew.

In the event that the staff could not recall any catastrophic or near miss events the scoping interview was continued and data about problematic events and usability issues experienced with the equipment were collected.

Care was taken not to influence the participants' response and to ensure that no leading questions were asked. Where possible the interviews were recorded and later transcribed. Predominantly the interviews were recorded with written notes due to the emergency nature of ambulance work.

The CIT conducted was adapted for the nature of ambulance work. The detailed level of information elicitation described by Stanton et al., (2005) was not possible due to the time allocated to the interviews and the frequent interruptions during shift breaks. Essential incident information was gathered but not time lines.

4.2.4.4 Selecting participants for field study

A convenience sample of A&E staff participated in the field study. The following factors were identified prior to participant selection:

1. The equipment to be evaluated
2. The ambulance stations using the equipment
3. Geographic locations with correct environmental conditions for the evaluation
4. The shift patterns required to conduct evaluations

This information was given to each ambulance service along with the participant selection criteria; Staff observed were required to be operational frontline A&E staff, working on emergency ambulances. Those participating in the study were direct end users. Participants were randomly allocated from the front line A&E crews on shift rotation. 37 participants were observed in total. There were no restrictions placed on age range or gender. 36 Interviews were conducted with frontline A&E staff at the ambulance stations during shift breaks.

4.2.4.5 Pilot study for field study

A pilot was conducted for the field study with each stretcher loading system to test the methods of data collection. One day was spent with each crew, conducting observations and interviews. The crews were shadowed and observed from a distance, without interfering in the task. Questions and photographs were taken when the patient transfer was complete. The data were analysed using a different method for each system. The tail lift data were analysed using CIT; LA was used for the ramp and winch; and the easyloader data were analysed using HTA. This allowed all the techniques to be tested before the main data collection.

4.2.5 Simulation study data collection

In the simulation study operational staff simulated patient loading and unloading tasks, allowing the operations observed in the field to be reconstructed in a controlled environment and providing visual data. Participants were provided with task scenarios which were simulated in the same way as their usual working practice. These scenarios were developed during the field study. The task simulations were carried out at an ambulance station within the regional area of each of the three ambulance services. They were conducted in the station garages with video cameras set up to capture the data. The stations selected were Loughborough in EMAS, Kings Lynn in EAAT and Bletchley in TSAT. The selection criteria for location was based on garage size and the availability of a suitable vehicle. The time taken to load and unload the stretchers using each ambulance loading system was recorded to produce time calculation data.

4.2.5.1 Selecting participants for simulation study

Participants for the simulation study were recruited from operational staff within each service. Staff participation was dependent on availability on the day of data collection. Where possible front line A&E crews were used. However, due to operational constraints other crews were used on a number of occasions (e.g. A&E events crews or training staff). The staff had all been trained to use the equipment in the same way so this should not have introduced bias. Each participant was briefed about the study before carrying out the simulations. Information sheets were distributed to participants and written consent was obtained from each participant before taking part.

4.2.5.2 Scenarios for simulation study

Loading and unloading task scenarios were developed based on real situations observed during the field study. These scenarios were tested in the pilot study and altered slightly for accuracy.

Task	Task completed	Patient profile
To load patient on Stretcher	In ambulance secured on stretcher ready for transportation	Male aged 54, weighs approximately 20 stone. Angina patient complaining of chest pains.
To unload patient on stretcher	Stretcher is out of ambulance ready for transfer into hospital	

Table 4.2 Simulation scenarios

During the simulations participants were required to load and unload a stretcher bound patient using the loading equipment supplied by their ambulance service. On the ramp and winch vehicle the stretcher was loaded and unloaded twice, once without the winch and once with the aid of the winch. Participants carried out their own risk assessment prior to conducting the simulations.

4.2.5.3 Recording data for simulation study

The simulations were captured on video recorder, allowing the data to be viewed for the postural analysis. Three cameras were used to film the footage. One camera was fixed in position facing the back of the ambulance where the loading systems were situated, whilst the other two cameras were mobile, to be moved to positions which would best capture the data required.

4.2.5.4 Equipment used for task simulation

The three ambulance services each supplied a vehicle for use in the simulations. The stretchers were supplied with the vehicles.

	East Midlands	East Anglia	Two Shires 1	Two Shires 2
Loading system	Hydraulic ramp and winch	Tail lift	Manual ramp and winch	Easyloader
Stretcher	Ferno Falcon 6	Ferno Falcon 6	Ferno Falcon 6	Phoenix
Loading mechanism	Foot pedal	Foot pedal	Electric switch	Phoenix loading platform

Table 4.3 Simulation vehicle, loading equipment and stretcher used

4.2.5.5 Simulation pilot Study

Two pilot studies were conducted for the simulation study. The first pilot was to test the measuring devices to ensure that measurements could be seen on the video analysis software (siliconCOACH Ltd, accessed on 11/07/2007). To conduct the study a researcher captured the participant loading a petrol canister into a car boot.

The second pilot was to test the video footage to ensure the cameras were in the correct position to carry out postural analysis. This pilot was completed at Loughborough Ambulance Station with an A&E crew. The paramedics used an old vehicle with a manual ramp and completed the required tasks. The crew were also involved in developing the task sheet, providing simulation scenarios (See Table 4.2).

4.2.5.6 Triangulation

In this study methodological and data triangulation were applied to overcome the limitations of each method used. Methodological triangulation combines qualitative and quantitative approaches. Data Triangulation uses more than one data collection method. This can help to enhance the rigidity of the research and increase the validity (Robson, 2002). Different methods were used to meet the aims and objectives. Different issues were identified, dependent on the strengths of each method applied. The results were combined to increase the validity and reliability of the data. Critical incident technique identified potentially catastrophic incidents with the aim to highlight errors in design; link analysis identified problems with the working layout and highlighted complex areas of the task (task complication); HTA identified overall usability issues.

The triangulation identified usability and manual handling issues experienced with each stretcher loading system. A taxonomy was developed pin pointing which issue was identified through which method. It also highlighted the issues affecting each system, demonstrating the strengths and weakness of all equipment evaluated. By using a number of methods, drawing the findings together for a second level of analysis and highlighting the influence of each method, richness was added to the study (Hignett, 2001).

4.2.5.7 Ranking

The issues found in use of stretcher loading systems were ranked in order of priority using a ranking questionnaire. The questionnaires were distributed to ambulance services across the UK via a mail shot sent out by the ASA. The respondents placed each item or object in order, dependent on where their judgement stood (Aiken, 1996).

4.3 Analysis and results

The following section presents the analysis and results of the field and simulation studies carried out in this investigation.

4.3.1 Phase 1 – field study

4.3.1.1 Activity sampling

The frequency of loading and unloading tasks observed in the field and the time calculation data from the simulation study were combined, to identify the percentage of time per shift was spent on loading and unloading activities with each system (Table 4.4). Use of the winch was not observed during the field study, but using the data collected these results show the percentage of time used on shift if the winch had been used for every call.

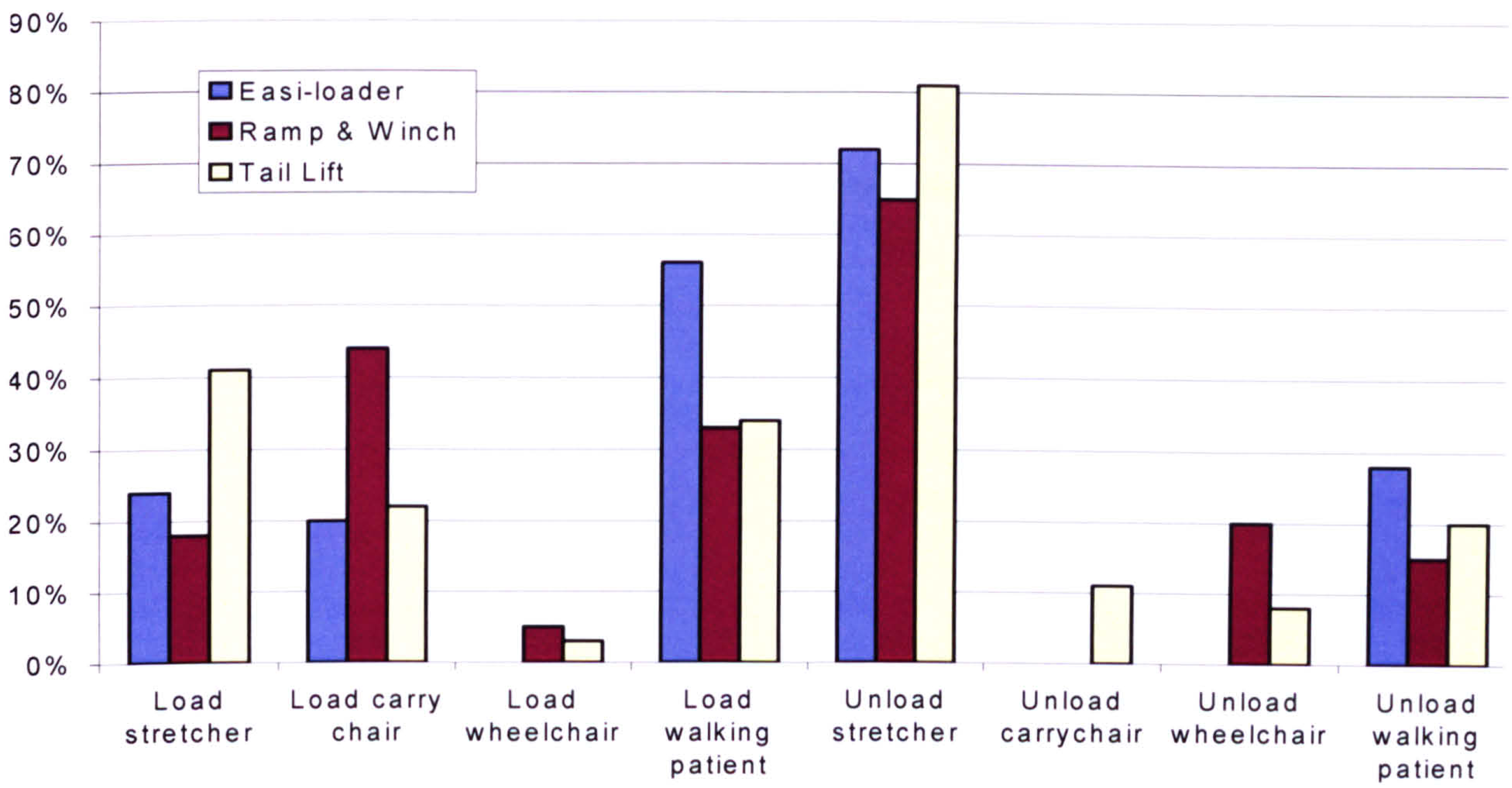
	Easyloader	Ramp	Ramp & Winch	Tail Lift
Total observed hours [shifts]	90 [7.5]	96 [9]	96 [9]	96 [8]
Ave. shift duration	*12 hours*	*10.67 hours*	*10.67 hours*	*12 hours*
Observed calls when patient travelled	25	40	40	32
No. of loading tasks	11	27	27	21
No. of unloading tasks	18	28	28	27
Ave. time to load (simulation)	26 secs	40 secs	82 secs	66 secs
[estimated total time for loading tasks per shift]	[4.8 mins]	[18 mins.]	[55 mins.]	[23.1 mins]
Ave. time to unload (simulation)	29 secs [8.7 mins]	35 secs [16.3 mins]	76 secs [35.5 mins.]	64 secs [28.8 mins]
Ave. total loading/unloading per shift [percentage of time on shift]	13.5 mins. [1.9%]	34.3 mins [5.4%]	90.5 mins [14.1%]	51.9 mins. [7.2%]

Table 4.4 Percentage of time spent on loading and unloading tasks per shift

The results show that the percentage of time using the easyloader on shift was less than using the other systems. This is because the time taken to load and unload patients with the easyloader stretcher was much lower. The ramp and winch system had the highest percentage of 14.1% because the time spent operating the equipment was much higher. However it should be considered that staff did not use the winch, opting not to, unless required in extreme circumstances.

The observation data were used to determine which mobility equipment was used to transfer the patients to and from the hospitals. This identified the equipment used most frequently with the loading equipment. No pattern was identified in terms of equipment used to transfer the patient to the vehicle. This was because there were so many variables in choice of equipment when in a patient's home. The factors affecting equipment choice included location of patient, accessibility in the home and terrain.

Graph 4.1 shows that regardless of which equipment was used to transfer the patient to the vehicle, the stretcher was the mobility device most frequently used to transfer the patient from the ambulance to the hospital. This may be because the hospital was a more controlled environment, and much more accessible for stretcher usage. The results show that the carry chair was used often to load patients but very rarely to unload a patient.



Graph 4.1 Equipment used to transfer patients to and from the vehicle

It is evident that the stretcher and the carry chair were the most frequently used mobility devices when conveying patients. Therefore it was important to consider both carry chair and stretcher loading in this study.

4.3.1.2 CIT

The recordings and notes obtained during the interviews were transcribed and analysed using NVivo 6; a qualitative data management tool (Bazeley and Richards, 2000). The data were coded in NVivo to determine the main themes and issues experienced by the staff.

36 interviews were conducted, 10 of which provided accounts of critical incidents. The interview analyses were therefore carried out in two parts, critical incident analysis and interview analysis.

The critical incident data were analysed using thematic analysis. This resulted in five primary codes, identified across the three systems:

1. System failure
2. Environment
3. Patient-related
4. Equipment
5. Coping strategies and adaptation.

Table 4.5 identifies which interviews provided accounts of critical incidents and provides a taxonomy identifying where the data were collected for each system.

Interview code	Critical Incident Technique (CIT)	Hydraulic ramp & winch	Manual ramp & winch	Easyloader	Tail Lift
EA1					✓
EA2	✓			✓	✓
EA3 (2 interviewees)	✓✓			✓	✓
EA4					✓
EA5				✓	✓
EA6 (2 interviewees)				✓	✓
EA7	✓				✓
EA8					✓
EA9 (2 interviewees)					✓
EA10					✓
EA11				✓	✓
EA12 (3 interviewees)	✓			✓	✓
TS1			✓	✓	
TS2 (3 interviewees)			✓	✓	
TS3			✓	✓	
TS4 (2 interviewees)			✓	✓	
TS5	✓			✓	
TS6			✓	✓	
TS7	✓		✓	✓	
TS8			✓	✓	
TS9				✓	
TS10				✓	
TS11	✓		✓	✓	
TS12			✓		
TS13			✓		
TS14 (2 interviewees)			✓	✓	
EM1		✓	✓		
EM2		✓			
EM3	✓	✓			
EM4		✓			
EM5 (2 interviewees)		✓	✓		
EM6	✓	✓			✓
EM7		✓			
EM8		✓			
EM9		✓			
EM10		✓	✓		

Table 4.5 Breakdown of CIT and interview data by system and participant

The 10 critical incidents are described below. The primary coding is represented using a colour key; system failure (A), environment (B), patient-related (C), equipment (D) and coping strategies and adaptation (E).

CIT1: Hydraulic ramp and winch

1. Loaded a male patient onto ramp and winch vehicle without any problem
2. Tried to raise air suspension for transfer to hospital
    2.1. Air suspension wouldn't raise
3. Drove vehicle very slowly to hospital, the call was not time critical
    3.1. Vehicle bumped against the ground all the way to hospital
4. Unloaded patient without any difficulty
5. Returned to vehicle to find air suspension had raised 20cm from ground
    5.1. Air suspension wouldn't lower again
    5.2. Had to lift empty trolley onto the ramp and stow it

CIT2: Hydraulic ramp and winch

1. Called to a stabbing incident
2. It was raining
3. Needed to get the patient loaded as quickly as possible
    3.1. Ramp was really slow
    3.2. So I just kicked it down
        3.2.1. We kick them down instead of waiting
        3.2.2. They end up breaking
        3.2.3. So it [*kicking them down*] does affect our job in the long run
4. Didn't affect the outcome of the patient because we didn't wait [*for the ramp to deploy*]

CIT3: Manual ramp and winch

1. Staff were called to attend to a very sick patient
2. The patient was heavy
3. Staff were tired after carrying the patient down 5 flights of stairs to get to vehicle
4. The shift was during a very hot day
5. The patient was loaded on a stretcher
    5.1. The stretcher was loaded onto the vehicle using the ramp and winch
    5.2. The winch was attached
6. The stretcher was not lined up correctly with the winch
    6.1. The winch slipped off the belt without the staff realising
    6.2. The winch jammed when the stretcher was drawn in
    6.3. The stretcher was part way up the ramp at an incline
7. The staff tried to salvage the situation
    7.1. The stretcher jammed so the staff couldn't load it

7.2. Staff tried to release the seatbelt coupling on the stretcher

7.2.1. The winch was too taut to be able to release the coupling

7.2.2. The manual override attempted by the crew didn't work

7.3. Another ambulance was called

8. It took ten minutes for the second vehicle to arrive
9. On arrival the patient was transferred from vehicle to vehicle using a carry chair
10. The patient was very sick and needed to get to hospital as soon as possible
11. The patient's family were not impressed with the delay and wanted to know what was happening

CIT4: Easyloader stretcher

1. Staff were unloading an easyloader stretcher

1.1. Unloading took place at a hospital where the unloading bay was set on a camber

2. The stretcher was pulled off the platform

2.1. The legs would not lock in place

2.2. Without the legs locking in position there was potential for trolley collapse

3. The attendant had to lift the trolley up above the unloading height
4. The legs then locked in place

CIT5: Easyloader stretcher

1. Staff were unloading a patient on an easyloader stretcher
2. The patient weighed 18 stone
3. Patient was on a long board which added weight
4. The stretcher was unloaded on a camber
5. The crewmate pulled the stretcher out

5.1. The crewmate didn't wait for the legs to be kicked into place

6. The stretcher was a new model, Rugged Stryker

6.1. The staff were accustomed to using the Ferno Phoenix which has a safety catch on it

7. The head end of the stretcher dropped down

7.1. The staff couldn't catch the trolley

7.2. The weight of the patient and the long board was too much

8. The staff were stood to the side of the trolley

8.1. It was difficult to hold the stretcher from that position

9. The patient was not injured

9.1. He was only on the long board as a precaution

CIT6: Easyloader stretcher

1. The crew was called to a patient who had been electrocuted
2. They had a vehicle with a Rugged Stryker easyloader stretcher
3. The platform that the stretcher loads onto got jammed
4. The crew couldn't load the stretcher because the bed was jammed
5. Another crew was called out to the scene
6. The second crew left with the patient

   6.1. The patient was stable
7. The stretcher was manually lifted onto the jammed platform to leave the scene

   7.1. They left the call scene
8. The patient's condition was not affected by this delay

CIT7: Tail Lift

1. The crew was called to a very heavy patient
2. The patient was aged 30 with a mental age of 7
3. The lady was in a lot of pain
4. She needed to be transferred to hospital
5. The crew needed to get the stretcher alongside the patients bed to transfer her

   5.1. The stretcher was too big to get into the house
6. Another vehicle was called for with an easyloader stretcher so that the patient could be transferred.

CIT8: Tail Lift

1. The crew was called to a cardiac arrest
2. The patient was a long way down a public footpath
3. The surface was awkward to get the trolley along
4. The crew was a technician team

   4.1. Paramedic backup was called for
5. The stretcher was loaded onto the vehicle
6. The platform was stowed

   6.1. The metal end plate got stuck

   6.2. The back door wouldn't shut

   6.3. The tail lift was jammed
7. The crew tried to solve the problem

7.1. The loading system couldn't be used to unload the patient

7.2. The vehicle couldn't be moved

7.3. The manual override system failed

7.4. The patient had to be scooped out of the back door

8. The patient was transferred to the paramedics vehicle
9. The patient was taken to hospital
10. The patient did not survive the cardiac arrest

CIT9: Tail Lift

1. The crew was called to a patient who had fallen from a ladder

1.1. The patient needed long boarding

2. The stretcher was moved as close as possible to the patient
3. The patient was strapped onto the long board
4. The long board was then rested on the stretcher
5. The technician went to pull the stretcher across gravel

5.1. The stretcher does not move easily over gravel

6. Pulling the stretcher the technician put her back out
7. The technician was off sick for three and a half weeks

CIT10: Tail Lift

1. The technician was on a night shift

1.1 The night shift was understaffed so they were single manning

2. A call came through to a patient with a serious head injury
3. The police officers tried to help get the stretcher off the vehicle

3.1 They did not understand the kit used

3.2 The stretcher was unloaded by a single operator

4. The technician experienced back pain
5. He / She carried on working through the pain but was careful not to aggravate it

4.3.1.3 Interviews

All 36 interviews were thematically analysed producing 53 primary codes. The nodes were grouped by category and analysed to see which issues were predominant across the three systems. A total of 53 codes were generated from the detailed thematic analysis. The five core codes generated through the critical incident technique were used as the framework and new codes emerged from the data. These codes are displayed in Table 4.6. An additional core code was added (Manual Handling) to reflect the large number of issues directly related to manual handling. These codes were separated into the three stretcher loading systems and coding examples from the interview data were provided.

Scope Items	~H~ Ramp	Tail lift	~M~ Ramp	Easy Loader
1) /System failure	-	-	-	-
(1 1) /System failure/Time	-	√	√	√
(1 2) /System failure/Injury	-	-	√	√
(1 4) /System failure/Organisation	-	√	√	√
(1 5) /System failure/Task complication	-	√	√	√
(1 6) /System failure/Electrical	√	-	√	-
(1 6 1) /System failure/Electrical/Air Suspension	√	√	√	√
(1 6 3) /System failure/Electrical/Tail lift	-	√	-	-
(1 7) /System failure/Mechanical	-	-	-	-
(1 7 1) /System failure/Mechanical/Tail lift	-	√	-	-
(1 7 2) /System failure/Mechanical/EL legs	-	-	-	√
(1 7 3) /System failure/Mechanical/steering stretcher	-	-	√	√
(1 7 4) /System failure/Mechanical/platform	-	-	-	√
(1 7 5) /System failure/Mechanical/winch	-	-	√	-
(1 8) /System failure/Security	-	√	-	-
(1 9) /System failure/Obstacles	√	√	√	-
(2) /Environment	-	-	-	-
(2 1) /Environment/Location	-	-	-	-
(2 1 1) /Environment/Location/Camber	-	-	√	√
(2 1 2) /Environment/Location/Clearance	-	√	√	√
(2 1 3) /Environment/Location/House access	-	√	√	√
(2 1 4) /Environment/Location/Ground surface	√	√	√	√
(2 2) /Environment/Weather	-	√	√	√
(3) /Patient	-	-	-	-
(3 1) /Patient/Safety	√	√	√	√
(3 2) /Patient/Characteristics	√	√	√	√
(3 3) /Patient/Infection control	-	-	√	√
(3 4) /Patient/Dignity	-	√	√	√
(4) /Equipment	-	-	-	-
(4 1) /Equipment/Other	-	√	-	√
(4 2) /Equipment/Wheelchair	-	√	-	-
(4 3) /Equipment/Winch	√	-	√	-
(4 4) /Equipment/Stretchers	-	√	-	√
(4 4 1) /Equipment/Stretchers/Ferno Falcon 6	-	√	-	√
(4 4 2) /Equipment/Stretchers/Ferno Phoenix	-	-	√	√
(4 4 3) /Equipment/Stretchers/Rugged Stryker	-	-	-	√
(4 4 4) /Equipment/Stretchers/Ferno 35a	-	-	-	√
(4 4 5) /Equipment/Stretchers/Design	√	√	√	√
(4 4 6) /Equipment/Stretchers/York 4	√	-	√	√
(4 5) /Equipment/Carry chairs	-	-	√	√
(4 6) /Equipment/Control location	-	-	√	√
(4 7) /Equipment/vehicle design	-	-	√	√
(4 8) /Equipment/Sensors	-	√	-	-
(5) /Coping strategies and adaptations	-	-	-	-
(5 1) /Coping strategies and adaptations/Carrying on anyway	-	√	√	√
(5 3) /Coping strategies and adaptations/Alternate methods	√	-	√	√
(5 4) /Coping strategies and adaptations/Second ambulance	-	√	√	√
(6) /Manual handling	√	√	√	√
(6 1) /Manual handling/entrapment	-	-	√	√

Table 4.6 Taxonomy from interview data

Ramp and Winch

Interview data were collected for the hydraulic and the manual ramp and winch. The data analyses for both system types are provided (Tables 4.7 & 4.8).

Code	
(1 6 1) /System failure/Electrical/Air Suspension	√
(1 6) /System failure/Electrical	√
(1 9) /System failure/Obstacles	√
(2 1 4) /Environment/Location/Ground surface	√
(3 1) /Patient/Safety	√
(3 2) /Patient/Characteristics	√
(4 3) /Equipment/Winch	√
(4 4 5) /Equipment/Stretchers/Design	√
(4 4 6) /Equipment/Stretchers/York 4	√
(5 3) /Coping strategies and adaptations/Alternate methods	√
(6) /Manual handling	√

Table 4.7 Node Assay report from NVivo: Ramp and Winch (Hydraulic)

Code	
(1) /System failure	√
(1 1) /System failure/Time	√
(1 2) /System failure/Injury	√
(1 4) /System failure/Organisation	√
(1 5) /System failure/Task complication	√
(1 7 3) /System failure/Mechanical/steering stretcher	√
(1 7 5) /System failure/Mechanical/winch	√
(1 8) /System failure/Security	√
(2 1) /Environment/Location	√
(2 1 2) /Environment/Location/Clearance	√
(2 1 4) /Environment/Location/Ground surface	√
(3) /Patient	√
(3 1) /Patient/Safety	√
(3 2) /Patient/Characteristics	√
(3 3) /Patient/Infection control	√
(3 4) /Patient/Dignity	√
(4) /Equipment	√
(4 2) /Equipment/Wheelchair	√
(4 3) /Equipment/Winch	√
(4 4 5) /Equipment/Stretchers/Design	√
(4 4 6) /Equipment/Stretchers/York 4	√
(4 5) /Equipment/Carry chairs	√
(4 6) /Equipment/Control location	√
(5) /Coping strategies and adaptations	√
(5 1) /Coping strategies and adaptations/Carrying on anyway	√
(5 3) /Coping strategies and adaptations/Alternate methods	√
(6) /Manual handling	√
(6 1) /Manual handling/entrapment	√

Table 4.8 Node Assay report from NVivo: Ramp and Winch (Manual)

The nodes were scrutinised for accuracy, consistency and duplication. This resulted in some nodes being combined in the taxonomy for the ramp and winch shown in Table 4.9.

Primary code	Secondary code	Tertiary code	Example from interview data
System Failure	Electrical	Air suspension	'The air suspension has a higher failure rate than the ramp' (EM5)
	Time		'The process of dropping the suspension, lowering the ramp, getting the winch out, attaching it, drawing it in, locking the stretcher in, putting the ramp back and raising the air suspension in a long winded process and we don't have the time in a time critical situation.' (TS8)
	Organisation		'One of the problems is moving between vehicles all the time, you are always changing equipment and it can get confusing, the staff operate the equipment wrongly.' (TS11)
	Mechanical	Steering stretcher	'The ramp trolley is awful, its heavy and the wheels go all over the place because they all move, it's not two wheel drive' (TS11)
	Mechanical	Winch	'I don't like the ramp and winch because they are a lot of hassle...too fiddly to use. The stretchers fixed in the side of the vehicle and you have to line it up with the ramp and winch before you can unload it....not practical.' (TS4) 'When unloading there are more problems because the winch becomes slack. The winch doesn't guide you in a straight line because its not taut.' (EM4)
	Obstacles		'The cow horn locking mechanism with the ramp and winch is awful' (TS11)
Environment	Location	Camber	'How well it works depends on the angle of the vehicle. If you park on the curb side and there is a camber on the road, one side of the ramp will touch before the other' (EM5)
	Location	Ground surface	'The ramp trolley is awful, it's heavy and the wheels go all over the place because they all move, it's not two wheel drive. If you are putting it on gravel it's impossible, you really have to tug' (TS11)
Patient	Safety		'Forgot about the yellow box being in the middle of the pathway so I didn't make any kind of leeway for it. The stretcher hit the box and the patient was jolted slightly onto the ramp so they were in a bit of discomfort.' (EM2)
	Characteristics		'The winch is good when you've got a heavy patient. Its not quick if you're in a hurry you can't use it. That's the only trouble really, in an emergency it's slower so you find that people tend not to use it.' (TS13)
	Infection control		'The locking mechanism is not sealed anywhere, so if you have any body fluid spillage you can't clean it at all. If we ever need to get into it to manually operate it there's all kinds of stuff in there' (TS14)

Equipment	Control location		'I don't like the ramp and winch because they are a lot of hassle...too fiddly to use. The stretchers fixed in the side of the vehicle and you have to line it up with the ramp and winch before you can unload it....not practical.' (TS1) 'The new ramp and winch system has the new stretcher locking mechanism with the yellow box and foot pedal. It operates differently. Instead of moving the stretcher out to the left at the foot end you have to move it forward slightly which brings it closer to the ramp, causing the stretcher to miss the ramp and come off the edge.' (EM5)
Manual handling	Manual handling	Entrapment	Yes, you could trap your fingers, if you did it the way they said it meant that the second one you did your fingers were in-between that and the first one so you jammed your fingers together. I think the problem with that is that you've still got to bend over haven't you, because it goes up the ramp to guide it, so probably a lift would be better.' (TS2)

Table 4.9 Taxonomy for Ramp and Winch System from interview data

Easyloader

Table 4.10 shows the NVivo codes for the easyloader stretcher loading system.

Code	
(1 1) /System failure/Time	√
(1 2) /System failure/Injury	√
(1 4) /System failure/Organisation	√
(1 5) /System failure/Task complication	√
(1 7) /System failure/Mechanical	√
(1 7 2) /System failure/Mechanical/EL legs	√
(1 7 3) /System failure/Mechanical/steering stretcher	√
(2) /Environment	√
(2 1) /Environment/Location	√
(2 1 1) /Environment/Location/Camber	√
(2 1 4) /Environment/Location/Ground surface	√
(2 2) /Environment/Weather	√
(3) /Patient	√
(3 1) /Patient/Safety	√
(3 2) /Patient/Characteristics	√
(3 3) /Patient/Infection control	√
(3 4) /Patient/Dignity	√
(4 1) /Equipment/Other	√
(4 4) /Equipment/Stretchers	√
(4 4 3) /Equipment/Stretchers/Rugged Stryker	√
(4 4 4) /Equipment/Stretchers/Ferno 35a	√
(4 6) /Equipment/Control location	√
(4 7) /Equipment/vehicle design	√
(5 1) /Coping strategies and adaptations/Carrying on anyway	√
(5 3) /Coping strategies and adaptations/Alternate methods	√
(5 4) /Coping strategies and adaptations/Second ambulance	√
(6) /Manual handling	√

Table 4.10 Node Assay report from NVivo: Easyloader

Primary code	Secondary code	Tertiary code	Example from interview data
System Failure	Time		*Does that [transferring from carry chair to easyloader stretcher] add on a lot more time to the process?* 'Yeah, it does add on a lot of time yeah, especially when, you're in a....a....a.. life threatening situation with a patient, yeah like a cardiac arrest or something like that but um.. if its a very heavy patient then you've got to get the stretcher out because its um... a lot of strain on your back' (TS2)
	Mechanical	EL legs	'You have to take the weight of the whole trolley and the patient when moving the stretcher in and out because otherwise the legs don't lock out, especially the back ones. You are supposed to rest the stretcher on the front legs so the back legs can lock out but in reality they don't do this. You have to lift the stretcher up and take the weight so that the back legs rotate through the full arc.' (TS10)
Environment	Location	Camber	'If you drive up too close to the accident and emergency department there is a bit of a slope and when you unload the trolley sometimes the legs don't go through their full arc so the back legs don't lock out. You then have to lift the trolley quite high so that you can compensate and make the legs lock in place' (TS9)
	Location	Ground surface	'When the easyloader is on the little wheels on rough ground they don't work. You can't get them across a football pitch, it is very unstable, the ground has to be firm for them to work properly.' (EM2)
	Weather		'Unless they're particularly heavy, and also like we said if its pouring with rain and you bring the stretcher out, the stretcher gets soaking wet, the patients wet anyway, your putting them onto a wet stretcher. But it does happen, people, we do, we do still lift them in and out.' (TS2)
Patient	Safety		'It is a good piece of kit. For the patients it is encouraging because the stretcher is.. as its name suggests really...rugged, so the patients feel secure.' (TS1)
	Infection control		'The locking mechanism is not sealed anywhere so if you have any body fluid spillage you can't clean it at all. If we ever need to get into it to manually operate it there's all kinds of stuff in there.' (TS14)
Equipment	Control location		'When unloading you have to reach over...you can't get close enough because the step protruding from the back of the vehicle.' (TS10)
	Vehicle design		'The narrower vehicle means you can get through traffic easier.' (TS10)
Coping strategies and adaptations	Carrying on anyway		'and some people, myself included, still lift the patient in the back with the carry chair. You weigh up the weight of the patient and whether you think that you're, you're sort of risk assessing yourself of whether you think you're capable of lifting that weight into the back, it can save you a lot of time and a lot of discomfort to the patient as well,

			depending on what their injuries are, if you've got them on the chair, I tend to try and keep them on the chair if I can and then transfer them in the vehicle.' (TS2)
	Alternative methods		'If there is a patient with long legs you have to ask them to bend their legs so they are not against your chest. If a patient has their leg in a splint they cant do that so you have to work around their feet, which makes it a little difficult.' (TS1)
	Second ambulance		'Had to call a second crew out with another trolley but we had to then manually lift the trolley which weighs about 9 stone so that we could leave the scene of the incident.' (TS11)
Manual handling	Manual handling		'There are problems with the easyloader if you are not tall, i.e. if shorter than six foot because you have to be tall to pull the stretcher out at the right height for the legs to operate correctly and lockout. If shorter than 6ft you bring them out at a lower level so they cant operate efficiently. This is why shorter people struggle and have to lift the stretcher more.' (TS3) 'You have to take the weight of the whole trolley and the patient when moving the stretcher in and out because otherwise the legs don't lock out, especially the back ones.' (TS10)
	Manual handling	Entrapment	'There's a lot of risk of entrapment. When loading a trolley one guy amputated the end of his finger. I am not sure which trolley but it was an easyloader, probably a phoenix.' (TS11)

Table 4.11 Taxonomy for Easyloader system from Interview data

Tail Lift

Table 4.12 shows the NVivo codes for the tail lift stretcher loading system.

Code	
(1 1) /System failure/Time	√
(1 5) /System failure/Task complication	√
(1 6) /System failure/Electrical	√
(1 6 1) /System failure/Electrical/Air Suspension	√
(1 6 3) /System failure/Electrical/Tail lift	√
(1 7 3) /System failure/Mechanical/steering stretcher	√
(1 9) /System failure/Obstacles	√
(2) /Environment	√
(2 1 2) /Environment/Location/Clearance	√
(2 1 3) /Environment/Location/House access	√
(2 1 4) /Environment/Location/Ground surface	√
(2 2) /Environment/Weather	√
(3 2) /Patient/Characteristics	√
(4 1) /Equipment/Other	√
(4 2) /Equipment/Wheelchair	√
(4 4) /Equipment/Stretchers	√
(4 4 1) /Equipment/Stretchers/Ferno Falcon 6	√
(4 6) /Equipment/Control location	√
(5 1) /Coping strategies and adaptations/Carrying on anyway	√

Table 4.12 Node Assay report from NVivo: Tail lift

Primary code	Secondary code	Tertiary code	Example from interview data
System Failure	Time		'I know its better for us, not lifting but it's a very slow system, the tail lift. Most jobs it doesn't matter, but when it does matter...' (EA6)
	Task complication		'The lever to release the end plate is really fiddly you cant do it with your feet, you have to do it with your fingers so you have to bend to release it.....You can't use your feet, you'd have to have your legs at different angles. You'd have your foot on the lever then have to pull the end plate down, so you don't have enough legs.' (EA6)
	Electrical	Air suspension	*'Do you always use the air suspension?* 'No..not really with the tail lift. We usually...tend to use the suspension on vehicles without the tail lift to lower it down.' (EA9)
	Electrical	Tail lift	' they're not safety proof and they're not made to what I would term as an industrial specification which is what they really need to be...too many things on them break too easily because of the continued use that they get.' (EA9)
	Mechanical	Platform	'The end plate is a good safety feature to stop the stretcher falling off but if the end plates not raised there have been a few incidents where it hasn't been and its got jammed. There needs to be a warning light on the control panel to remind you if its not up, really...but that's more electrical things to go wrong' (EA4)
	Obstacles		'The other problem with the stretcher is the locking mechanism. It is annoying because you have to lean into the vehicle to release them. Got blocks to secure which get in the way and when you move over them if you hit them the patient gets jolted.' (EA8)
Patient	Safety		'I've not heard of any cases of the general public tripping over them when its laid flat but I suppose it probably has happened. (EA9)
Equipment	Control location		'You can't use your feet, you'd have to have your legs at different angles. You'd have your foot on the lever then have to pull the end plate down, so you don't have enough legs.' (EA6)
Environment	Location	Clearance	'The biggest problem is, are we going to have space to drop it down. We end up blocking the roads' (EA2)
	Weather		'The weather has a bad effect on them because if its raining the rain comes in the vehicle and it soaks the lift. It takes a long time to operate so the patient has to wait in the rain to load them onto the vehicle. The door being open also means the patient compartment gets cold. Its better to be able to keep the vehicle warm for the patient' (EA4)

Table 4.13 Taxonomy for Tail lift system from Interview data

4.3.1.4 HTA

The HTA conducted in this study followed the protocol outlined by Stanton and Young (2005):

1. The task analysed was defined; loading and unloading a patient onto the ambulance using stretcher loading equipment
2. The purpose of conducting the task analysis was defined; to identify usability and manual handling problems experienced when using the equipment to load and unload a patient
3. The data were collected with specific regard to the task. Background interviews were held with fleet managers from the 3 services. Observational data were collected for each patient loading and unloading task, conducted by the participating crews on shift. Interviews were conducted with staff following the observations if any part of the task was not understood by the researcher
4. All HTA's produced were combined for each system in an overall HTA identifying all usability issues observed

A HTA was developed for each loading and unloading task observed. These were each combined into one generic task analysis per system which displayed events from all observations (Appendix F). This was analysed to determine the overall issues identified. A large number of issues were found in the generic diagrams which have been compiled into tables highlighting the issue and where in the task it occurred (Tables 4.16-4.18).

All three systems were observed at different sites. The hydraulic ramp and the manual ramp were observed but the participants did not use the manual ramp vehicle very often so more observations were made for the hydraulic ramp and winch.

HTA diagrams were developed for each patient loading and unloading observation, regardless of the mobility equipment used. 170 HTA's were developed in total. Table 4.14 provides a breakdown of the observations made showing the total number of diagrams developed for each system, dependent on mobility equipment used. The HTA data were then used to develop link diagrams.

The full data set of HTA's can be found in Jones and Hignett, 2005.

Mobility Device	Task	Ramp & Winch (Hydraulic)	Tail Lift	Easyloader
Carry chair	Load	11	7	6
Stretcher	Load	6	14	5
On foot	Load	12	11	11
Wheelchair	Load	3	0	0
Stretcher	Unload	17	26	17
On foot	Unload	9	4	7
Wheelchair	Unload	2	2	0
Total = 170		60	64	46

Table 4.14 Data sets for HTA and LA

HTA	Task
HTA1	Load stretcher using platform easyloader
HTA 2	Load carry chair using platform easyloader ambulance
HTA 3	Assist patient into platform easyloader ambulance on foot
HTA 4	Unload stretcher using platform easyloader
HTA 5	Assist patient off easyloader ambulance on foot
HTA 6	Load stretcher using hydraulic ramp
HTA 7	Load carry chair using hydraulic ramp
HTA 8	Assist patient into hydraulic ramp and winch ambulance on foot
HTA 9	Load wheelchair using hydraulic ramp
HTA 10	Unload stretcher using hydraulic ramp
HTA 11	Assist patient off hydraulic ramp ambulance on foot
HTA 12	Load stretcher with tail lift
HTA 13	Load carry chair with tail lift
HTA 14	Assist patient into tail lift ambulance on foot
HTA 15	Load wheelchair using tail lift
HTA 16	Unload stretcher using tail lift
HTA 17	Assist patient out of tail lift ambulance on foot
HTA 18	Unload wheelchair using tail lift
HTA 19	Unload wheelchair using manual ramp and winch
HTA 20	Load carry chair using manual ramp and winch
HTA 21	Assist patient into manual ramp and winch ambulance on foot
HTA 22	Unload stretcher using manual ramp and winch
HTA 23	Assist patient out of manual ramp and winch ambulance on foot

Table 4.15 HTA generic diagrams (appendix F)

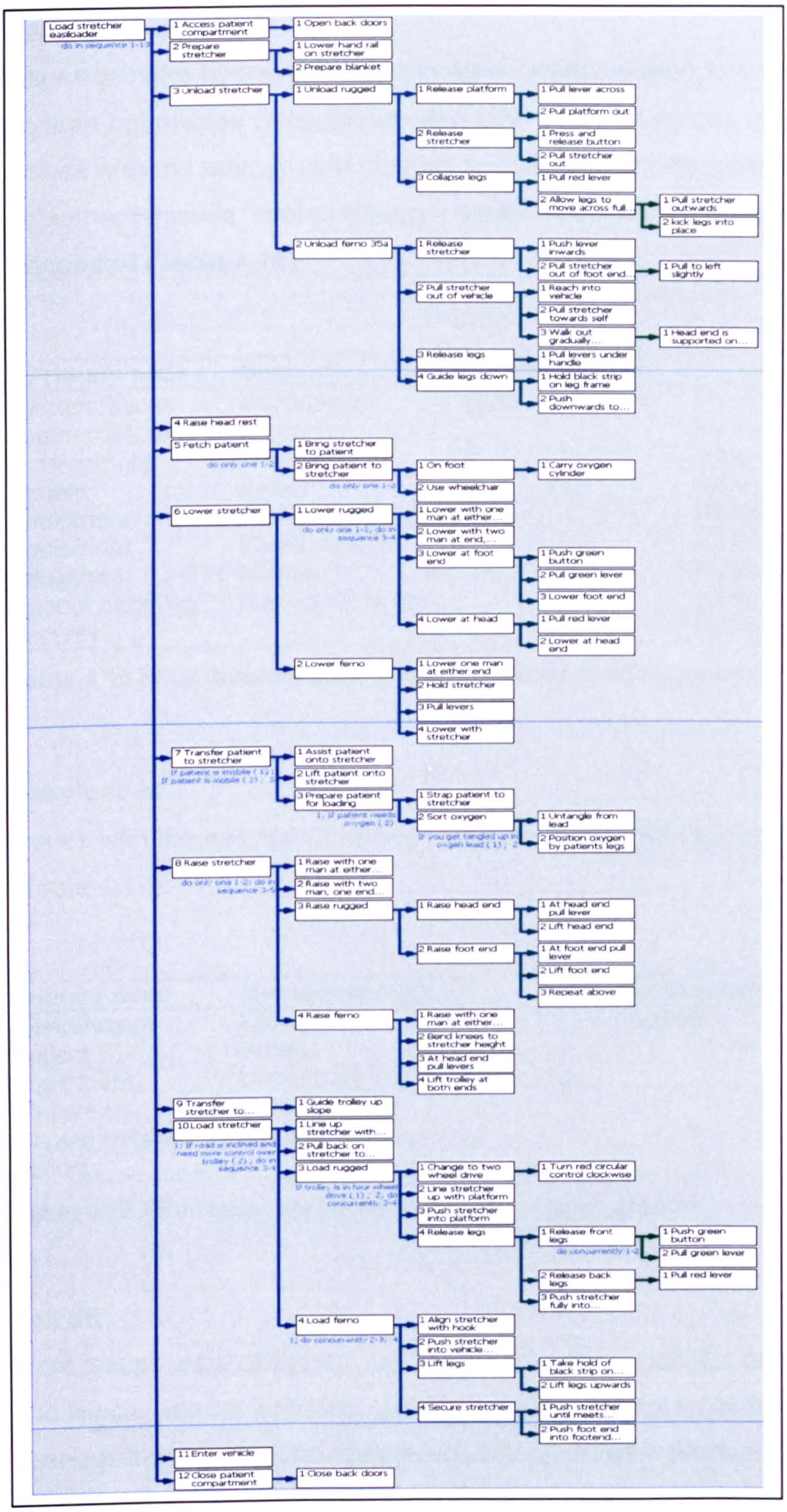


Figure 4.5 HTA diagram for loading a stretcher with platform easyloader (HTA 1)

Ramp and winch

Issues with the hydraulic ramp and winch mainly related to manual handling and posture but misuse of equipment and problems with vehicle layout were also observed. Issues with the manual ramp related to manual handling, posture, vehicle layout and equipment misuse, control location, equipment interface intolerance and patient discomfort (Table 4.16).

Primary code	Secondary code	Tertiary code	Data from HTA
System failure	Mechanical	Steering stretcher	HTA10 (7.2, 7.3)
System failure	Obstacles		HTA6 (11.4), HTA10 (7.2.2)
Environment	Weather		HTA7 (8.1), HTA9 (2.1)
Patient	Safety		HTA6 (14.2), HTA20 (9.4)
Equipment	Control location		HTA6 (2.3.4)
Equipment	Vehicle design		HTA10 (4.2)
Equipment	Misuse		HTA6 (10.1), HTA7 (9.2)
Manual handling	Manual handling		HTA6 (11.3)
Security			HTA10 (8.1), HTA22 (8)

Table 4.16 Final taxonomy for Ramp and Winch loading system

Easyloader

Issues with the easyloader were limited to manual handling, force exertion and posture (Table 4.17).

Primary code	Secondary code	Tertiary code	Data from HTA
Environment	Location	Camber	HTA1 (10.2)
Patient	Safety		HTA4 (6.1)
Equipment	Wheelchair / carry chair access		HTA2 (5.2, 5.3
Equipment	Vehicle design		HTA4 (3.2.1.2.1)
Manual handling	Manual handling		HTA1 (8.4.4)
Security			HTA4 (7)

Table 4.17 Final taxonomy for Easyloader loading system

Tail lift

More issues were observed with the tail lift vehicle than the easyloader and the ramp and winch. Issues identified included posture, control location, misuse of equipment, user equipment interface intolerance, and user error. Manual handling problems were not observed with the tail lift (Table 4.18).

Primary code	Secondary code	Tertiary code	Example from HTA data
System failure	Task complication		HTA12 (1-8)
System failure	Mechanical	Reliability	HTA13 (5.2.1.1)
System failure	Mechanical	Platform	HTA12 (8.4)
System failure	Obstacles		HTA12 (18.5), HTA16 (7.4.4)
Patient	Safety		HTA16 (7.2.2, 12.5)
Equipment	Control location		HTA12 (1.1-2.1), HTA16 (1.1, 1.2, 1.3)
Equipment	Sensors		HTA16 (4.1, 6.2)
Equipment	Misuse		HTA16 (7.1.1.2)
Environment	Location	Clearance	HTA13 (1.1), HTA15 (10.2.1)
Environment	Location	Camber	HTA12 (8.2)
Manual handling	Posture		HTA12 (5.1.1.2.1), HTA13 (1.5.2.1.1.1)
Security			HTA16 (13)

Table 4.18 Final taxonomy for Tail lift loading system

4.3.1.5 Link analysis

Link analysis was carried out using the HTA conducted from the observations made on shift. The researcher followed the procedure outlined by Stanton et al., (2005):

1. The task under analysis was defined as the task of loading and unloading a patient using the stretcher loading equipment under analysis. The analysis began when the patient was moved from the call scene, and ended when the patient was securely fastened in the vehicle
2. The purpose of conducting the task analysis was defined; to identify problems within the layout of the working area when using the equipment to load and unload a patient
3. Detailed plan drawings of the interior layout of each vehicle and stretcher loading system were developed for link diagrams during the pilot study in phase 1
4. Observation data were collected regarding the task outlined
5. The bottom level information from the HTA was used to conduct link analysis Link analysis diagrams and tables were developed using the HTA data

170 link analysis diagrams were developed from the HTA. The data sets were then summarised into 18 generic tasks, the link analysis diagrams for each of the 18 categories were combined to show the movement between system components for each loading system when assisting a patient into the vehicle and out of the vehicle on foot, on a carry chair and on a stretcher (Figure 4.6 – 4.8). The data were analysed to determine the average number of links per task. Table 4.19 shows the 18 link analysis task categories.

#	Task	Total # number of links	Average # of links per task
LA1	Load stretcher using platform easyloader	58	11.6
LA 2	Load carry chair using platform easyloader ambulance	25	4.2
LA 3	Assist patient into platform easyloader ambulance on foot	36	3.3
LA 4	Unload stretcher using platform easyloader	66	3.9
LA 5	Assist patient off easyloader ambulance on foot	19	2.7
LA 6	Load stretcher using hydraulic ramp	63	10.5
LA 7	Load carry chair using hydraulic ramp	96	8.7
LA 8	Assist patient into hydraulic ramp and winch ambulance on foot	41	3.4
LA 9	Load wheelchair using hydraulic ramp	13	4.3
LA 10	Unload stretcher using hydraulic ramp	126	7.4
LA 11	Assist patient off hydraulic ramp ambulance on foot	24	2.7
LA 12	Load stretcher with tail lift	270	19.3
LA 13	Load carry chair with tail lift	67	9.6
LA 14	Assist patient into tail lift ambulance on foot	31	2.8
LA 15	Load wheelchair using tail lift	13	?
LA 16	Unload stretcher using tail lift	251	9.7
LA 17	Assist patient off tail lift ambulance on foot	11	1.6
LA 18	Unload wheelchair using tail lift	12	6

Table 4.19 Link analysis generic diagram

Figures 4.6 to 4.8 give examples of link analysis task descriptions of loading a stretcher using each type of loading device. The full data set of LA diagrams can be found in Jones and Hignett (2005).

Ramp and winch

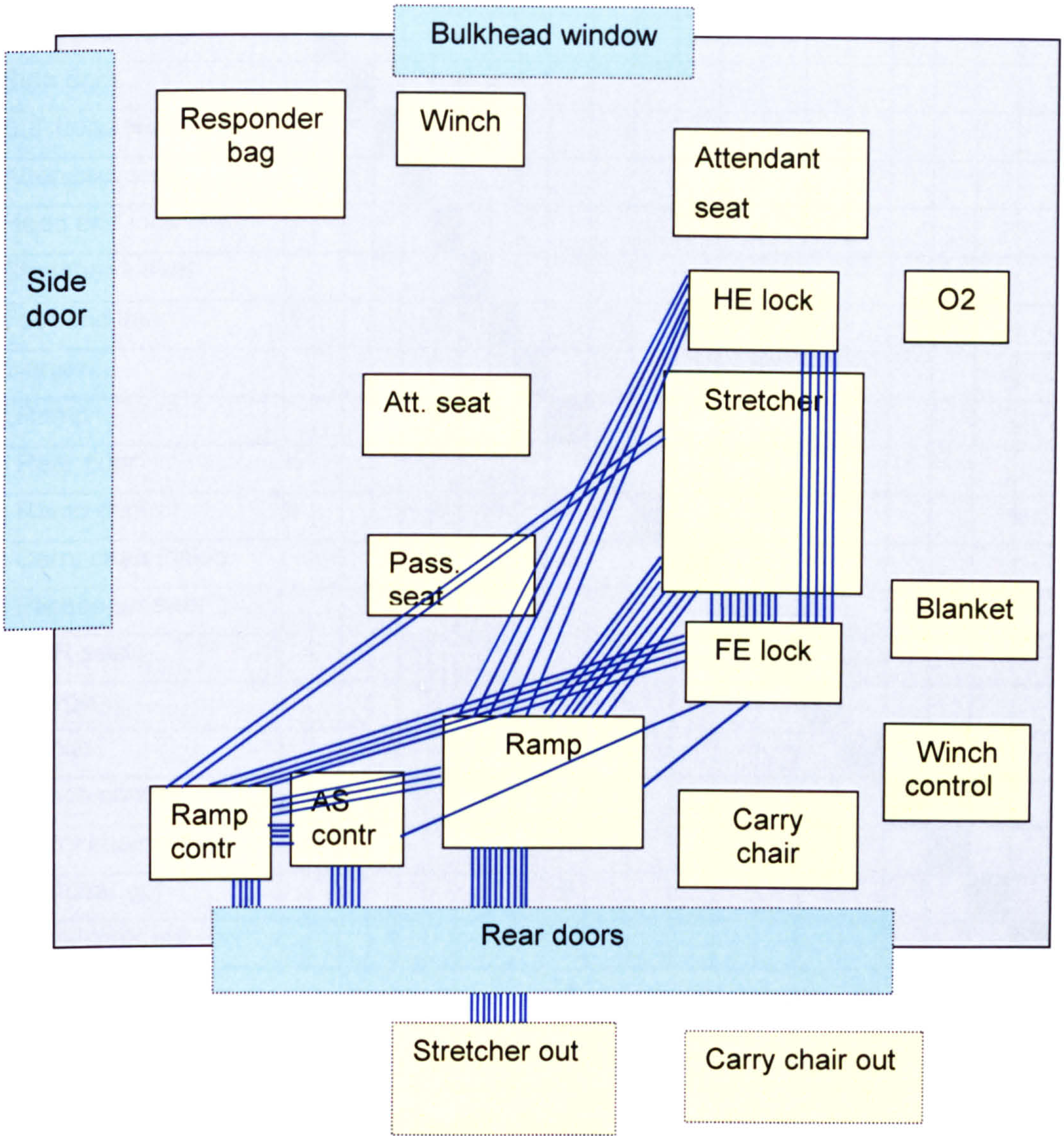


Figure 4.6 Generic link analysis representing all hydraulic R&W loading tasks

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1) Air suspension control																					
2) Responder bag																					
3) Side door																					
4) Bulkhead window																					
5) Attendant seat																					
6) Head end lock																					
7) Stretcher inside																					
8) Foot end lock	1					5	9														
9) Blanket																					
10) Ramp						5	7	1													
11) Rear door	5																				
12) Ramp control	6					2		4		3	5										
13) Carry chair inside																					
14) Passenger seat																					
15) CPR seat																					
16) Oxygen																					
17) Winch																					
18) Winch control																					
19) Carry chair out																					
20)Stretcher out										10											
21)Wheelchair out																					

Table 4.20 Generic link analysis table representing hydraulic R&W loading tasks

The ramp and winch link analysis results showed that the winch was not used during any stretcher loading activities. The vital system components, the ramp, stretcher and winch were not aligned meaning that the staff were working at angles to load the stretcher instead of manoeuvring it in a straight line. The staff were observed moving across a large surface area of the vehicle to carry out the task; the task was not concentrated in one area of the vehicle.

Easyloader

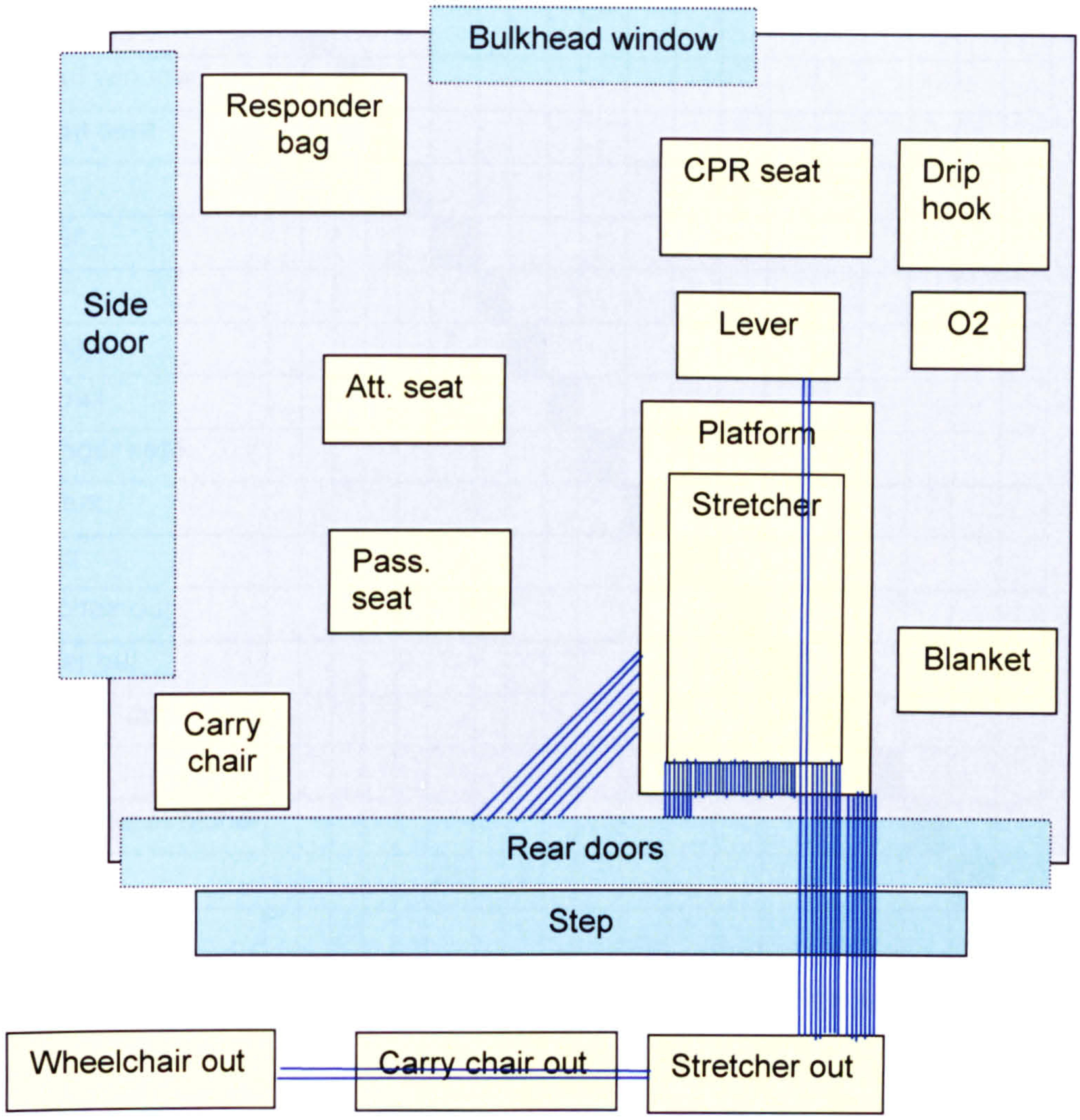


Figure 4.7 Generic link analysis representing all Easyloader loading tasks

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1) Responder bag																			
2) Side door																			
3) Bulkhead window																			
4) Attendant seat																			
5) Lever																			
6) Stretcher																			
7) Blanket																			
8) Rear doors						7													
9) Carry chair																			
10) Passenger seat																			
11) CPR seat																			
12) Oxygen																			
13) Carry chair out																			
14)Stretcher out					2	7													
15)Wheelchair out														2					
16)Step																			
17) Orthopaedic stretcher																			
18) Platform						26		7						7					
19) Drip hook																			

Table 4.21 Generic link analysis table representing Easyloader loading tasks

The easyloader link analysis results showed that during the loading activity all movement was concentrated around the back door area of the vehicle minimising movement by staff. The lever at the head end of the stretcher was away from the rest of the controls. However, this was not relevant to all easyloader models. The wheelchair patient had to be transferred to the stretcher to load because there was no wheelchair access. This would be the same for a patient conveyed on a carry chair.

Tail lift

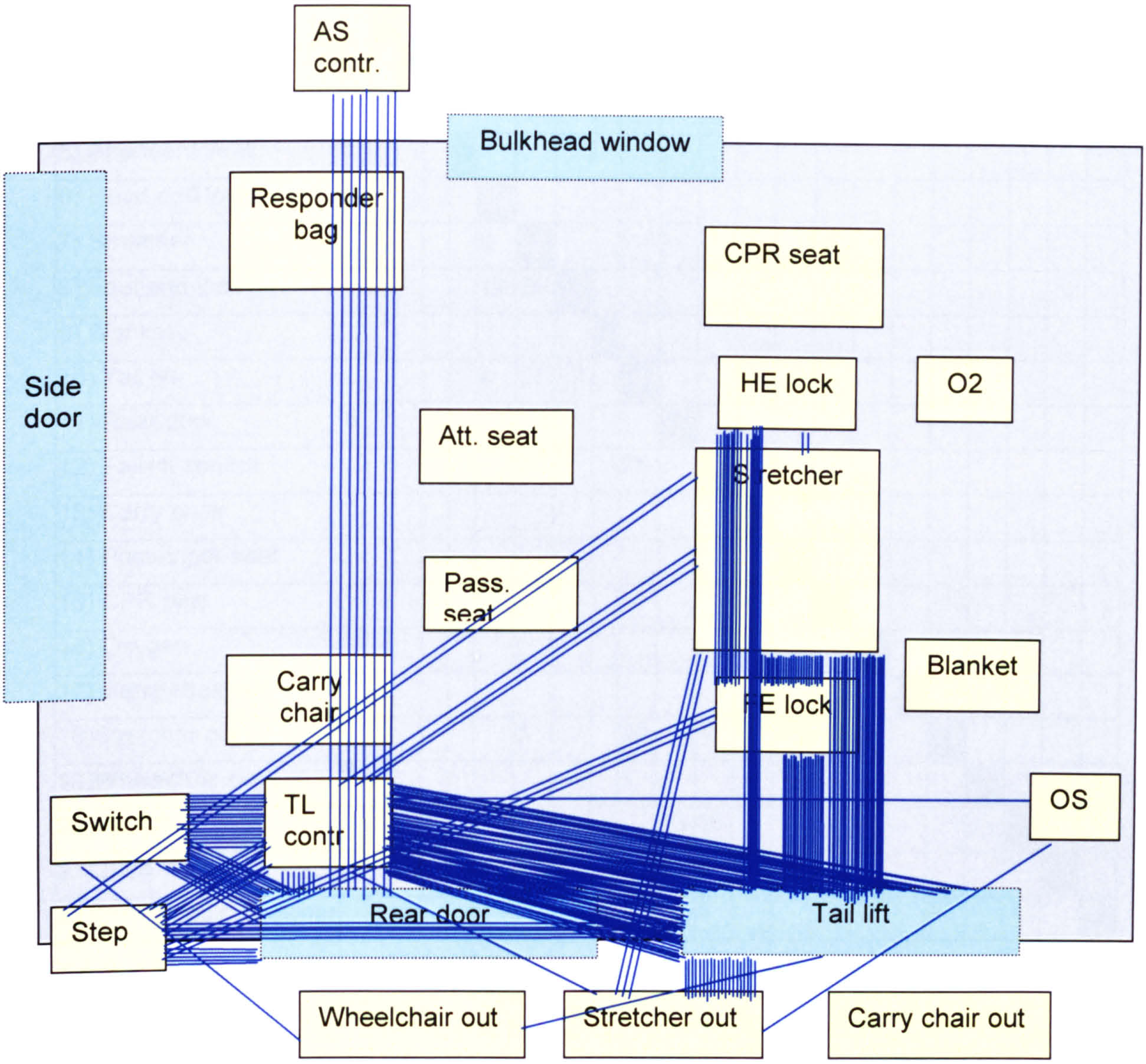


Figure 4.8 Generic link analysis representing all Tail Lift loading task

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1) Air suspension control																						
2) Responder bag																						
3) Side door																						
4) Bulkhead window																						
5) Attendant seat																						
6) Head end lock																						
7) Stretcher						2																
8) Foot end lock						12	25															
9) Blanket																						
10) Tail lift						8	27	17														
11) Rear door	8																					
12) Tail lift control							3			78	7											
13) Carry chair																						
14) Passenger seat																						
15) CPR seat																						
16) Oxygen																						
17) Carry chair out																						
18)Stretcher out							3			20		1										
19)Wheelchair out										1												
20) Switch											15	16							1			
21) Step							2	3		5	5	9										
22)Orthopaedic stretcher												1						1				

Table 4.22 Generic link analysis table representing Tail lift loading tasks

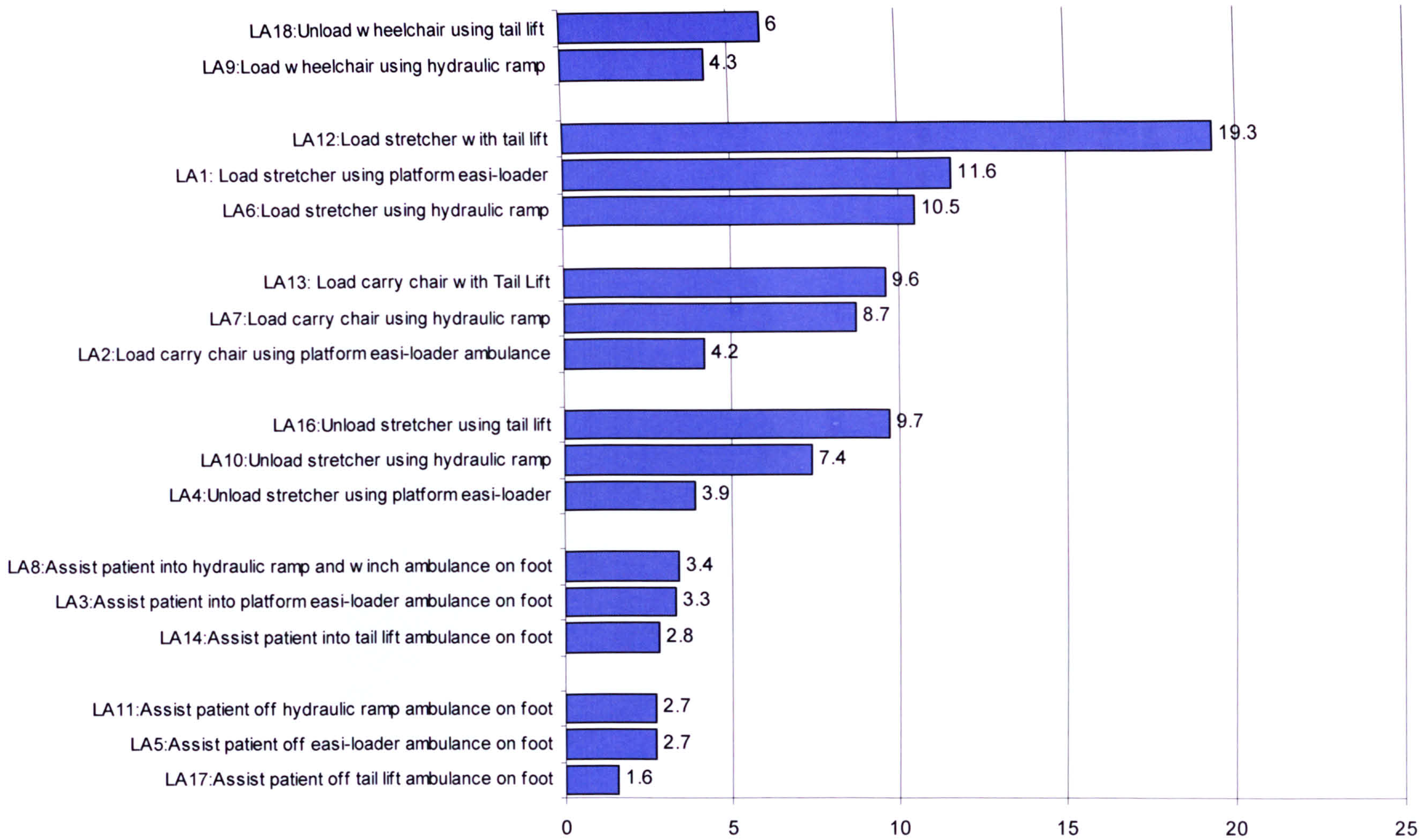
The tail lift link analysis results showed that there was a large amount of movement around the patient compartment when loading the stretcher. Movement was not concentrated in one area. There was a lot of movement between the controls and the platform, because of the safety precautions put in place prior to use. It may be beneficial to have the controls closer to the tail lift platform.

The air suspension control should be with the rest of the controls not on the dash board because participants were observed forgetting to press the button on the dash, increasing the movement between the front and the back of the vehicle.

Graph 4.2 shows the average links for each system for each task. The tail lift is seen to be a more complex task for both loading and unloading a stretcher. The average number of links required for loading was 19.3 compared to 11.6 for the easyloader and 10.5 for the hydraulic ramp respectively. The average number for unloading with the tail lift was 9.7 compared to 7.4 for the hydraulic ramp and 3.9 for the easyloader.

The link analysis data suggests that when loading a carry chair, the task is least complex when loading into an easyloader vehicle, but when referring back to the HTA data (HTA2) it was found that correct protocol for this system was not followed; the carry chair was lifted. TSAT's working practice dictated that the patient should have been transferred onto the easyloader stretcher outside the ambulance and then loaded on the stretcher.

Assisting a walking patient off an ambulance was easiest using the tail lift, with only 1.6 links compared with 2.7 for both of the other systems using the side step egress.



Graph 4.2 Average number of links per task per system showing task complexity (Accessed from Jones and Hignett, 2005)

4.3.1.6 Triangulation

Thorough analysis of the data was carried out by triangulating the observation and interview data to establish which methods identified similar results. The triangulation is represented in Figures 4.9 to 4.11. In the diagrams, the triangle represents the issues which were raised by all three methods, the circular segments represent data collected with only two of the methods used, and the boxes represent data collected with only one method.

Each method had limitations; link analysis looks at layout design and spatial features of a task, and so cannot account for issues such as time criticality. Therefore the issues seen in the diagram do not have any weighting attached to them, regardless of how many methods recognised them.

Ramp and winch

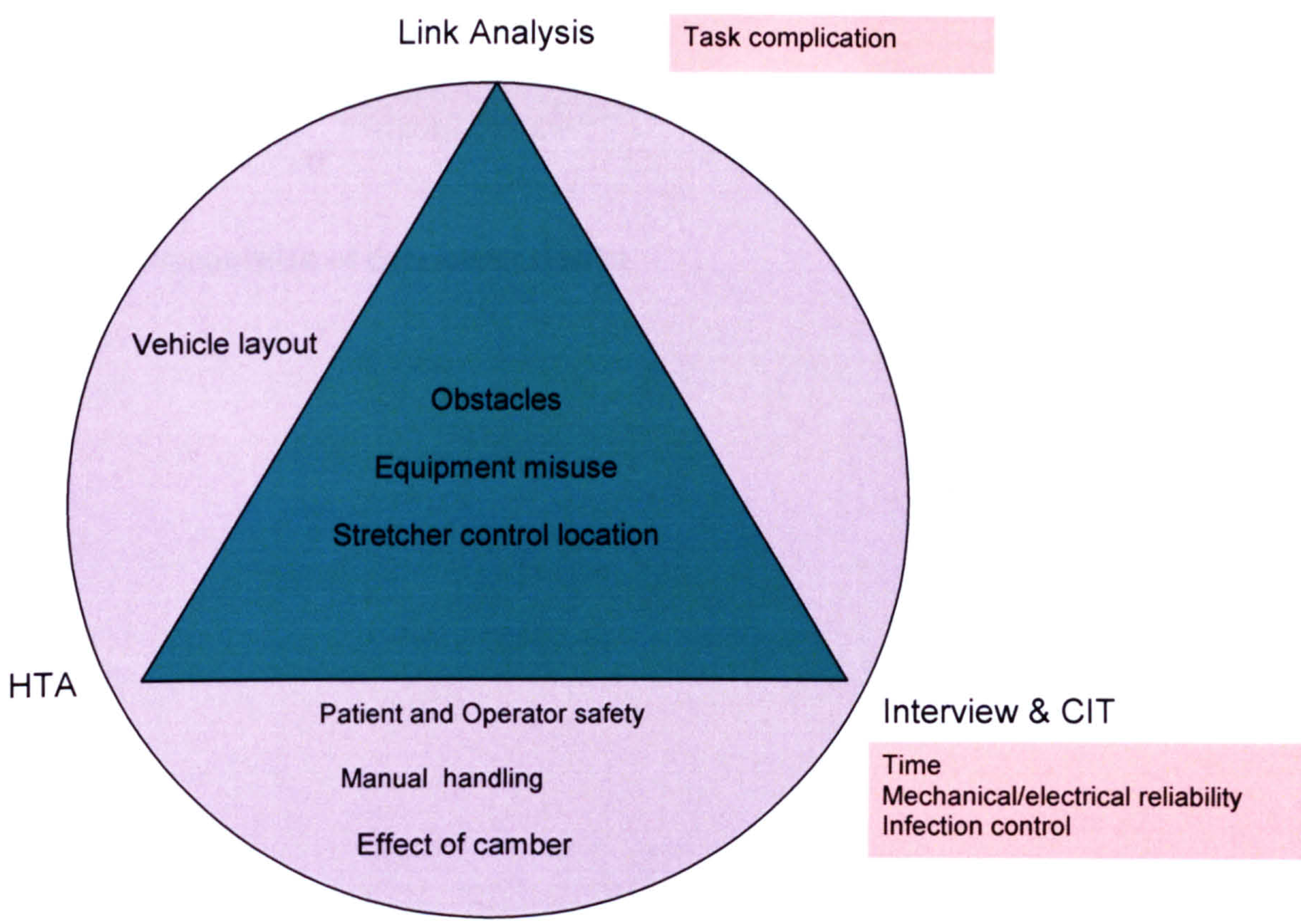


Figure 4.9 Triangulation of ramp and winch results

Easyloader

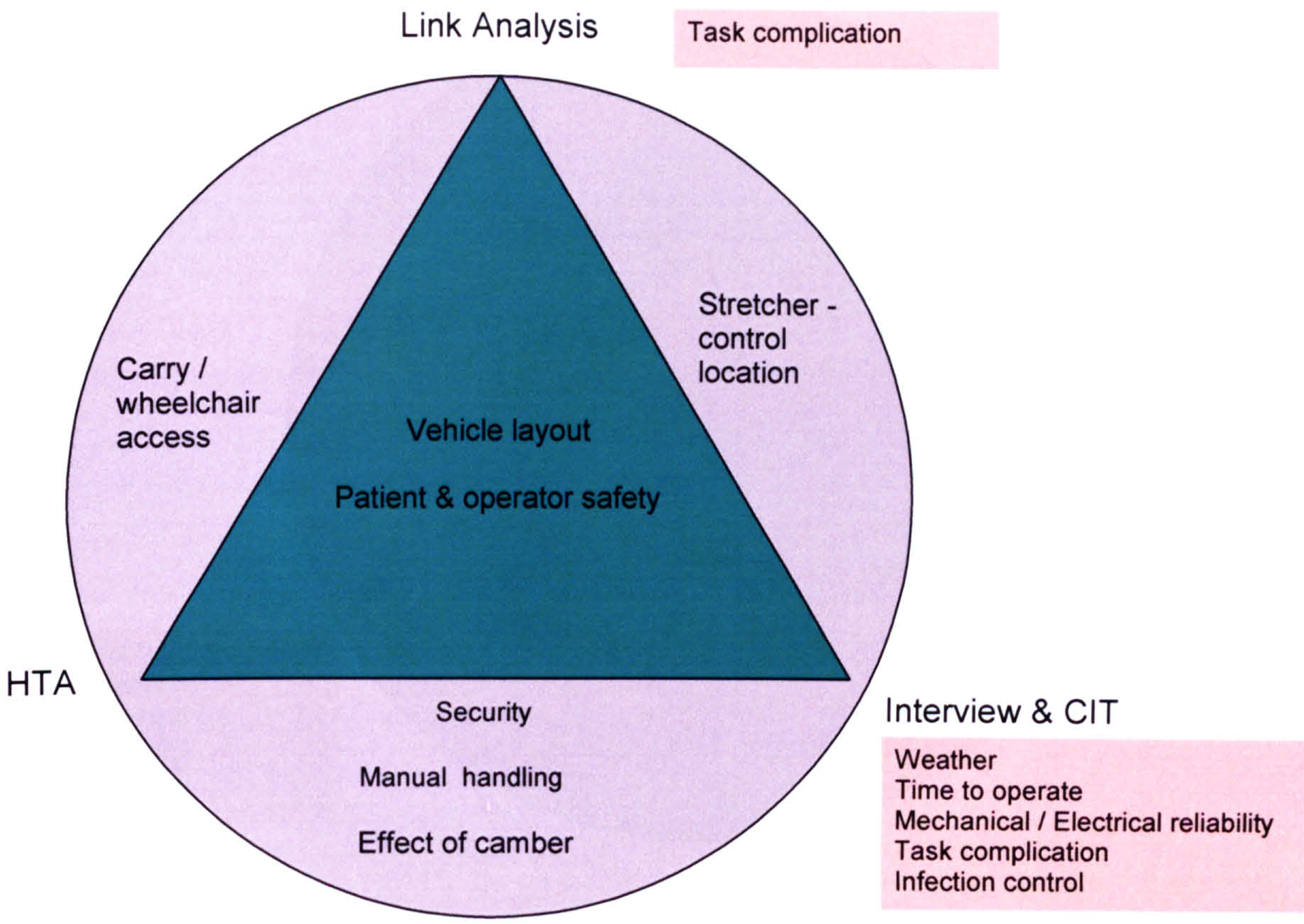


Figure 4.10 Triangulation of Easyloader results

Tail lift

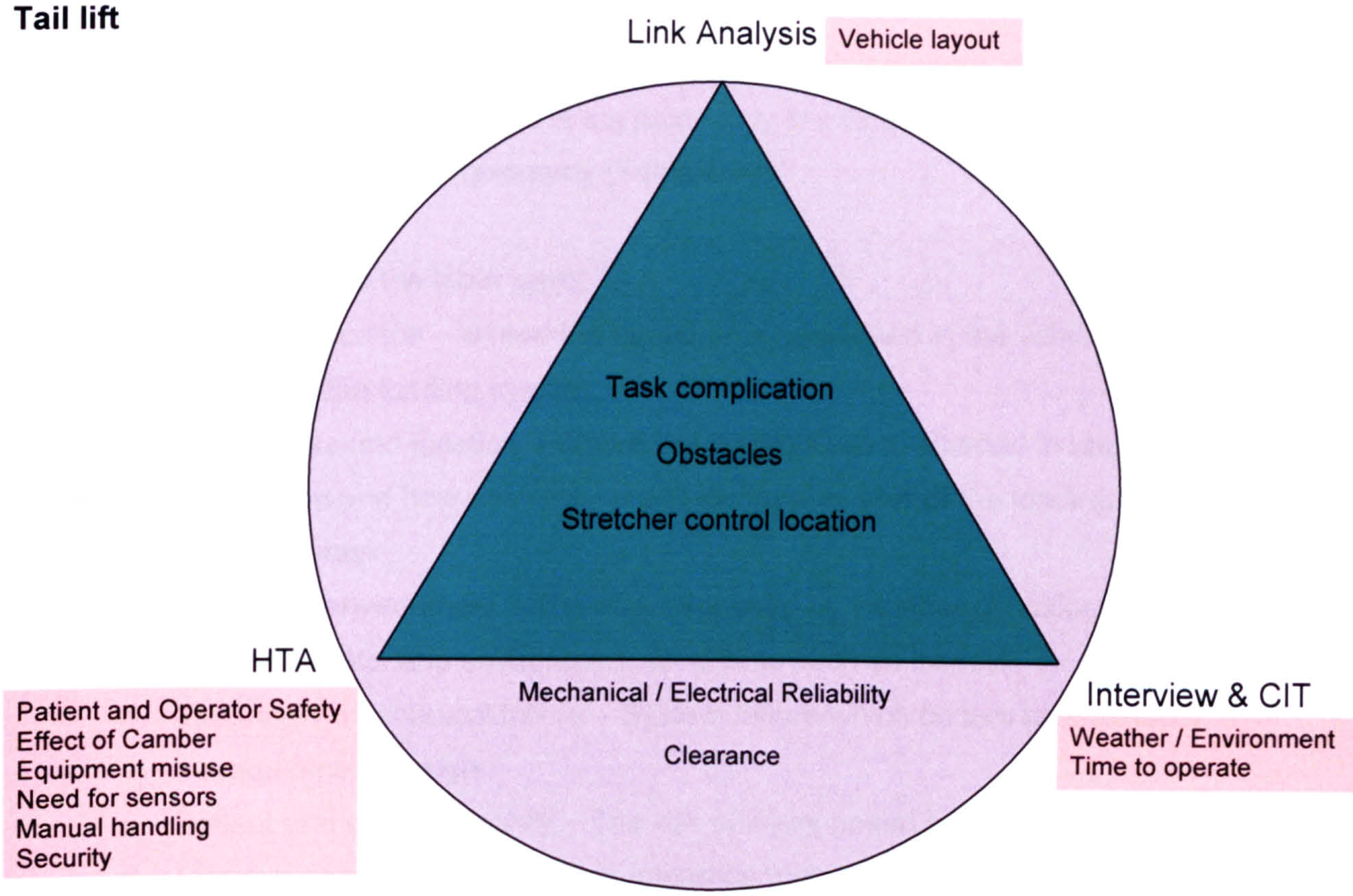


Figure 4.11 Triangulation of Tail lift results

4.3.1.7 Comparison of results

A taxonomy was developed identifying which method identified which issues for each system. The overall issues identified in the field study are listed and explained. Each issue was compiled in the final taxonomy (Table 4.23).

The issues compiled into the table were:

1. Stretcher location – Where the stretcher is positioned in the vehicle in relation to the loading system
2. Control use and location – Where the controls are positioned in relation to the system and how easy they are to operate as part of the loading and unloading task
3. Weather / environment – The effect imposed by weather conditions such as rain, snow, etc. and environment conditions such as insects.
4. Electrical / mechanical failure – System failure which occurs as a result of the equipment design
5. Patient and operator safety – The risk of injury posed by the system
6. Effect of camber – The systems tolerance towards cambers in the road
7. Task complication – The level of complication added to the task of loading and unloading patients by the stretcher loading system used
8. Security – The ease at which someone can access the patient compartment while the staff are with the patient
9. Time to operate – The potential for speedy loading and unloading
10. Equipment misuse – The potential for staff to misuse the equipment and take shortcuts
11. Need for sensors – The risk posed by moving parts, which are electronically controlled. The more mechanised a system has become the greater the need for sensors which stop the system operating in an emergency situation
12. Clearance - The amount of clearance that is needed at the back of the ambulance to load and unload a stretcher
13. Inappropriate loading of chair – The access provided for the loading and unloading of other mobility devices such as carry chairs and wheelchairs
14. Force – The amount of force required to remove the stretcher from the vehicle
15. Weight bearing and lifting – The level of manual handling needed to load and unload a stretcher
16. Very heavy patients – The ease of loading and unloading a very heavy patient

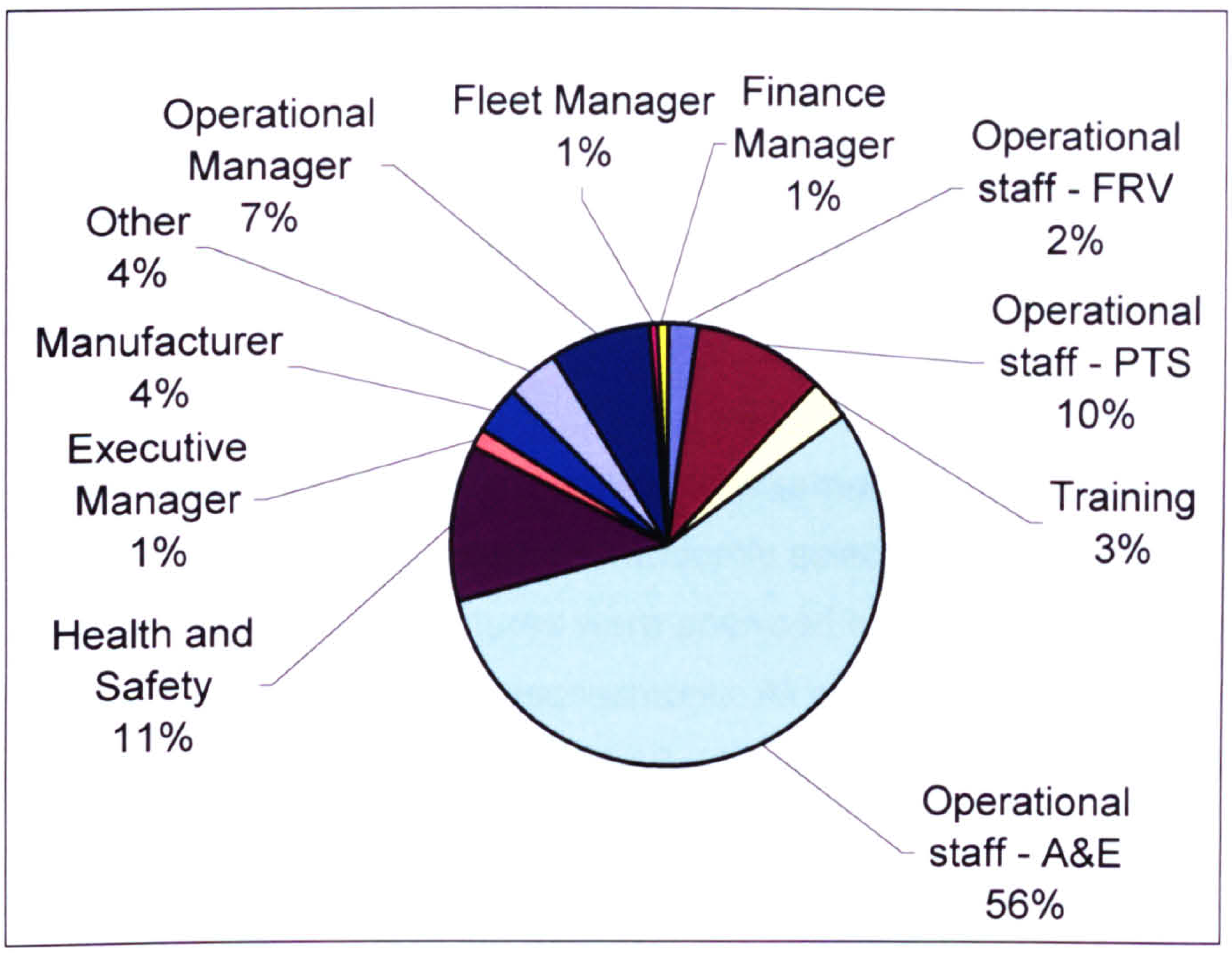
Table 4.23 shows which of the methods captured the issues identified for each system.

Issue	Ramp & winch	Easyloader	Tail lift
1. Stretcher control location	LA HTA INT	LA INT	LA HTA INT
2. Obstacles	LA HTA INT		LA HTA INT
3. Weather		INT	INT
4. Patient safety	HTA INT	LA HTA INT	HTA
5. Effect of camber	HTA INT	HTA INT	HTA
6. Task complication	LA	INT	LA HTA INT
7. Time to operate	INT	INT	INT
8. Equipment misuse	LA HTA INT		HTA
9. Need for sensors			HTA
10.Clearance			HTA INT
11.Carry/Wheelchair access		LA HTA	
12.Mechanical/electrical reliability	INT	INT	HTA INT
13.Infection control	INT	INT	
14.Manual handling	HTA INT	HTA INT	HTA
15.Security		HTA INT	HTA
16.Vehicle layout	LA HTA	LA HTA INT	LA

Table 4.23 Summary taxonomy for the three stretcher loading systems

4.3.1.8 Ranking

As you can see from Table 4.23, each system had strengths and weaknesses. In order to identify a preferred system for use by ambulance services, it was important to identify which problems needed reducing in terms of staff priorities. Therefore a ranking exercise was carried out to filter the information obtained in the field study and identify the preferred equipment for future use. A ranking questionnaire was distributed to ambulance services across the UK with the aid of the ASA. Two issues affecting stretcher design ('Obstacles' and 'Stretcher control location') were removed from the ranking exercise because they were related to stretcher design. This left 14 issues which affected the loading equipment design. 134 questionnaires were returned, 58% of respondents were operational staff. The distribution of respondents is shown in Graph 4.3. The results of the ranking questionnaire are shown in Table 4.24.



Graph 4.3 Distribution of respondents for ranking questionnaire

Factor	Average ranking	Ranking position
Patient and Operator Safety	1.7	1
Manual handling	3	2
Mechanical/electrical reliability	4.9	3
Time to operate	5.4	4=
Carry chair access	5.4	4=
Vehicle layout	5.7	6
Task complication	6.1	7
Weather/environment	8.0	8
Clearance	8.1	9
Effect of camber	8.3	10
Security	8.8	11=
Infection control	8.8	11=
Equipment misuse	9.0	13
Need for sensors	11.0	14

Table 4.24 Ranking questionnaire results

The highest ranking factors were patient and operator safety and manual handling. The results were used as a priority list and were compared against the taxonomy in Table 4.23, to identify which system met the needs of ambulance personnel.

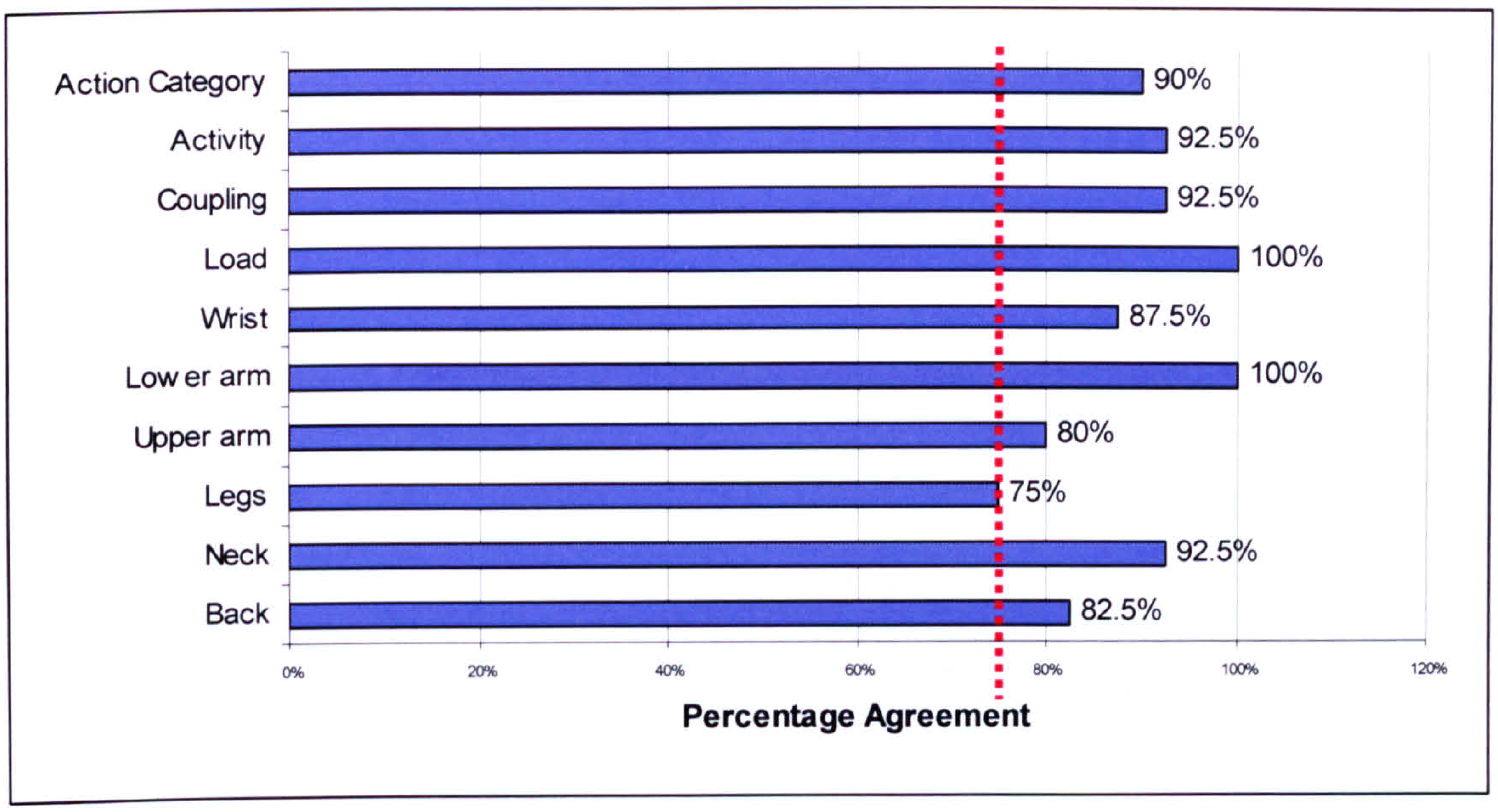
This comparison highlighted the tail lift as the most suitable equipment for purchase by ambulance services. This was because its automation virtually eliminated manual handling from the task of patient loading and unloading and the safety precautions which are implemented prior to its use increased the safety of both staff and patient.

4.3.2 Phase 2 – Simulation study

The video footage from each simulation was downloaded. Using Silicon Coach, a motion analysis software tool, the video footage was broken down into postural stills taken every 2 seconds of the loading and unloading tasks carried out by each crew member with each system.

4.3.2.1 REBA inter-rater reliability assessment

Of these data, 40 postures were randomly selected to carry out an inter-rater reliability assessment. The 40 postures were analysed by two researchers and the results were compared prior to the final assessment. All categories achieved at least 75% agreement, an acceptable level for field postural analysis tools (Heinsalmi, 1986).



Graph 4.4 Results of inter-rater reliability assessment

4.3.2.2 REBA

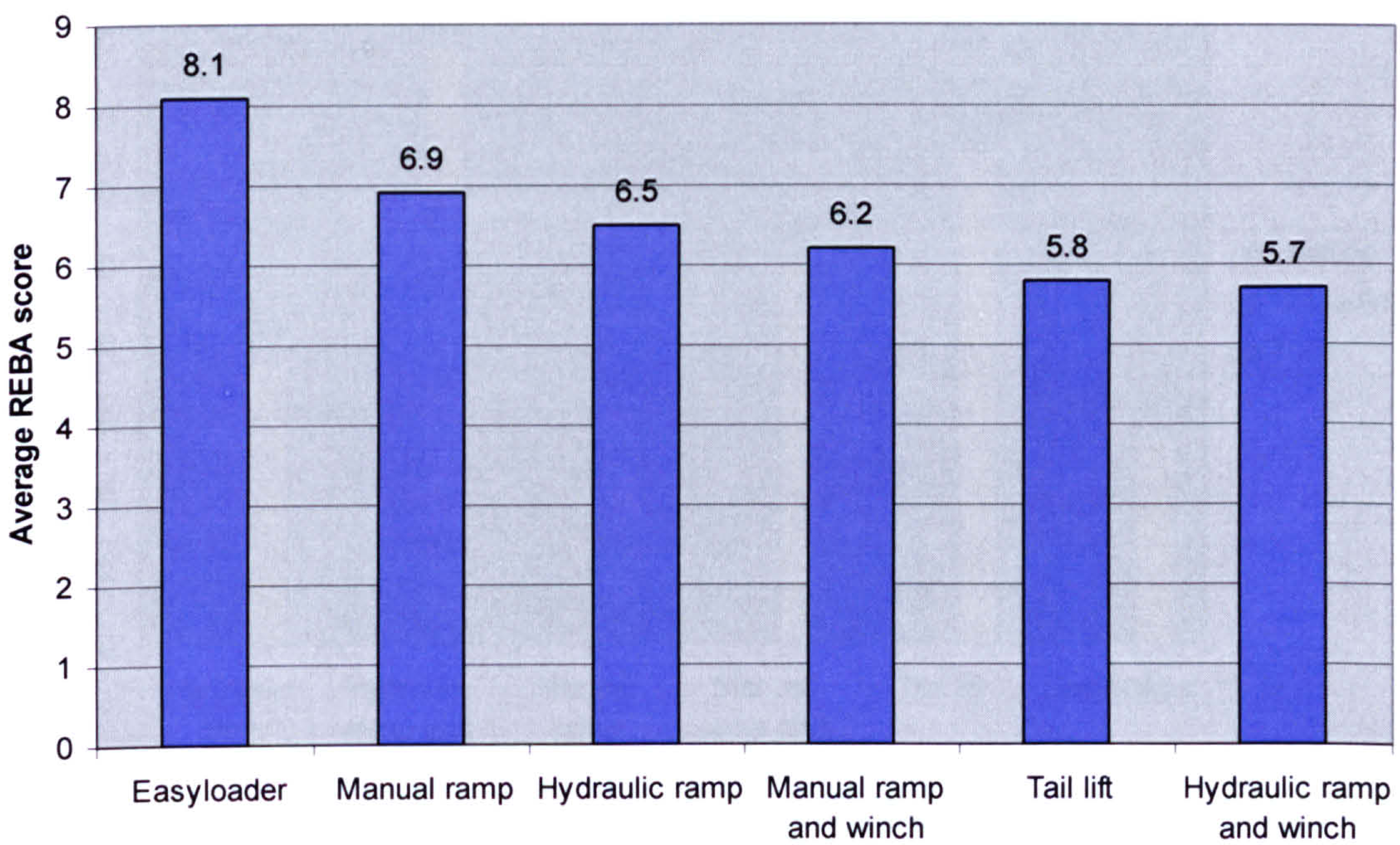
Once agreement was achieved the researcher analysed the main dataset of 662 postures. The breakdown of postures can be seen in Table 4.25. A REBA risk rating was calculated for each posture and the scores were grouped into loading and unloading tasks for each loading system. The mean REBA score for each loading system was calculated providing an average risk rating (Table 4.25; Graph 4.5).

	Easyloader	Manual ramp	Hydraulic ramp	Manual ramp & winch	Hydraulic ramp & winch	Tail Lift
Total no. of postures	76	69	93	114	135	175
Average REBA score	8.1	6.9	6.5	6.2	5.8	5.7

Table 4.25 Average REBA scores for all three loading systems

The easyloader stretcher had the highest REBA score (8.1), followed by the hydraulic ramp when used without the winch (6.5), the tail lift (5.8) and the hydraulic ramp and winch (5.7).

The easyloader posed a high risk to staff when loading and unloading patients, 'action is necessary as soon as possible' to reduce the risk of musculoskeletal injury. The ramp and winch and tail lift posed a medium risk to staff. The tail lift and the hydraulic ramp when used with the winch had the lowest REBA scores and posed the least risk to staff.

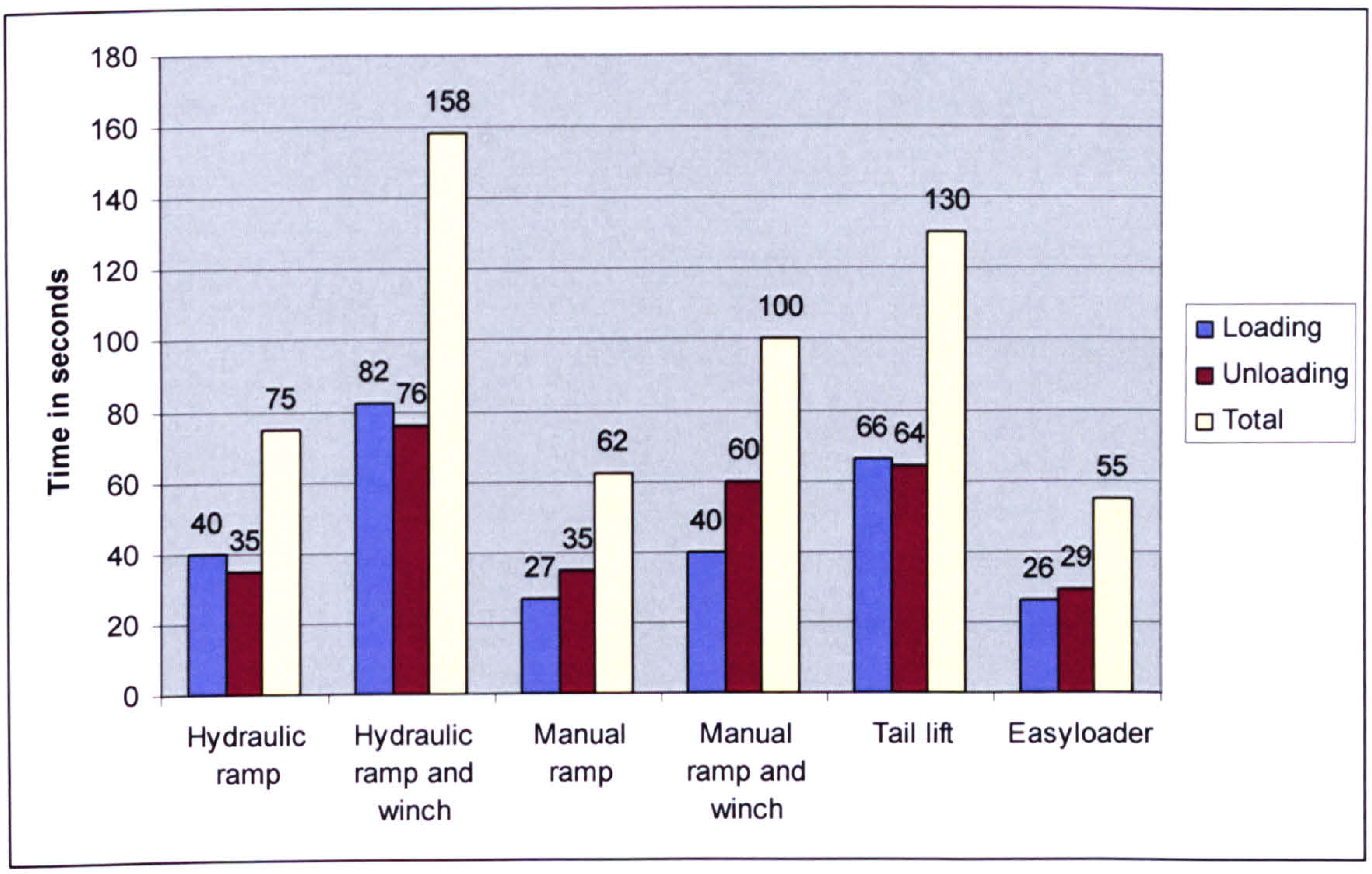


Graph 4.5 Average REBA scores for all loading systems

A One way Analysis of Variance (ANOVA) was carried out, which determined significant difference between the systems ($P<0.05$). The results indicated that there may have been a small amount of skew in the data. However, the one way ANOVA test worked well under small deviations from normality. Two post hoc tests were carried out to identify where the difference lay. These were Hochberg and Games-Howell. Hochberg was selected because it was good for testing data that includes unequal group sizes. Games-Howell was selected because it was good for testing data where the standard deviations were different. Both tests identified that the difference was between the Easyloader and the manual ramp and winch.

4.3.2.3 Time

The simulation footage was used to calculate the time taken to carry out loading and unloading tasks when using each system. As with the postural analysis, the ramp and winch was timed with and without the use of the winch. The results can be seen in Graph 4.6. The results show that the easyloader was the fastest system and the hydraulic ramp and winch was the slowest system to carry out the loading and unloading tasks.



Graph 4.6 Total time for loading and unloading tasks

4.3.2.4 Phase 1 and 2 results combined

The results of the field study and simulation study were compared for the final assessment and recommendation. Figure 4.12 shows the results of this comparison. Both the field study and the simulation study identified the tail lift as the preferred system for future purchase. The tail lift significantly reduced manual handling for loading and unloading activities, reducing the risk of musculoskeletal injury. It provided the option for all types of mobility device to be loaded and unloaded without any additional manual handling, and the vehicle itself was found to have a popular working layout.

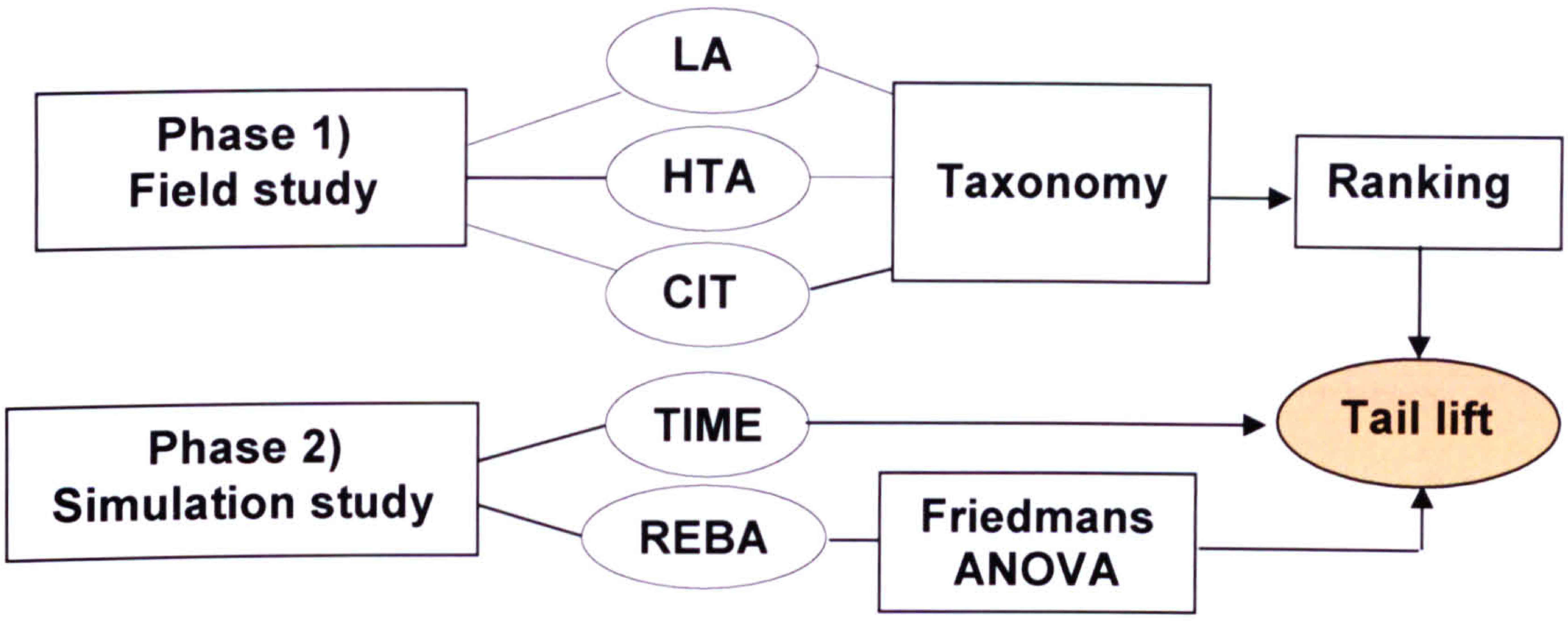


Figure 4.12 Summary of simulation study results

4.4 Discussion

This section discusses and contextualises the results identified in chapter 4, drawing on the findings of the field study, simulation study and the ranking exercise.

After considering the results, the factors ambulance staff considered important were ranked in order of priority. Patient and operator safety was the top priority, followed closely by manual handling. Other high ranking aspects included reliability, time to operate, carry chair access and vehicle layout. Each system was identified as having strengths and weaknesses relating to the 14 factors which were considered prior to identification of a preferred system.

Factor	Ranking position	Preferred system
Patient and Operator Safety	1	Tail lift
Manual handling	2	Tail lift
Mechanical/electrical reliability	3	No difference
Carry chair / wheelchair access	4=	Tail lift
Time to operate	4=	Easyloader
Vehicle layout	6	Tail lift
Task complication	7	Easyloader
Weather/environment	8	Ramp & winch / easyloader
Clearance	9	Ramp & winch
Effect of camber	10	No difference
Security	11=	Ramp & winch
Infection control	11=	Tail lift
Equipment misuse	13	Easyloader
Need for sensors	14	Easyloader

Table 4.26 Design factors ranked by importance

4.4.1 Issues identified

This section outlines and explains the issues identified with each system, highlighting their strengths and weaknesses.

4.4.1.1 Patient and operator safety

Tail lift

When a system becomes more automated, more safety features are incorporated to prevent patients or staff members becoming injured during operation of the equipment. The tail lift's safety features include hand rails, guide rails and a safety barrier at the end of the platform to prevent the stretcher or the patient falling off while the tail lift is raised or lowered. It has safety cut off points (sensors) which activate to stop the system functioning if the safety mechanisms are not put in place.

Ramp and winch

The ramp and winch is a semi automated system. Due to the simplicity of this system there have been few safety features incorporated in the design. There are no hand rails and no safety cut off points. The ramp does not have any guide rails to ensure the stretcher remains on the ramp during ascent and descent. Finger entrapment was identified as an issue in the interview data for the ramp and winch.

Easyloader

A number of easyloader stretchers have a safety mechanism (a catch) at the head end of the stretcher, preventing the stretcher from coming off the platform before the legs have locked in place. This stops accidents from occurring. If the legs do not lock in place properly, for reasons such as road camber, the trolley can collapse and the patient can fall. In 2003 the MDA received over 50 incident reports of trolley collapse. Potential safety risks posed when loading and unloading the easyloader include operator injury and limb entrapments, mechanism jamming and component failure (MDA, 2003).

The critical incident technique carried out in this study identified a trolley collapse and a near miss. Both incidents were due to the ambulance being parked on a camber, the patient was not injured in either account. The interviews carried out identified a risk of entrapment with the easyloader stretcher. One participant discussed a colleague who had a finger amputated when loading the trolley. The MDA (2003) report the risk of this happening, suggesting that, when a trolley collapses, if staff try to help the patient, they may sustain entrapment or musculoskeletal injuries.

4.4.1.2 Manual handling

Tail lift

The tail lift virtually eliminated manual handling from loading and unloading activities. During the loading and unloading process, there was no manual handling, the operator pressed a button and supervised the operation of the system, ensuring that the stretcher remained steady on the platform. If the system failed, it could be put into a manual over-ride mode. This required staff to manually raise or lower the platform using a hydraulic pump. However, this was a rare event which was not observed.

The critical incident technique carried out for the tail lift identified two occasions when staff members were injured. One of these incidents was experienced away from the vehicle and was related to the stretcher used with the tail lift vehicle, rather than the loading system itself (see Section 4.3.1.2; CIT 9). The other was related to working practice (see Section 4.3.1.2; CIT 10). An operator had to operate the equipment with no assistance from their crew mate. This caused the operator to experience back pain. Working practice should be considered to ensure that staff do not carry out two person loading activities alone.

Ramp and winch

The ramp and winch required manual handling. Staff, were observed pushing and pulling the stretcher up and down the ramp which had a gradient of 12 degrees. This required force to pull the stretcher up the ramp. The winch was provided as an aid for heavy patients. Some ambulance services recommend that staff use the winch with every loading or unloading task but staff considered this to be unfeasible due to time constraints. The winch reduced the level of manual handling; this was highlighted in the postural analysis results. However, staff chose only to use it for very heavy patients, so the benefit was often lost. The ramp and winch system has eliminated the lifting from the task of loading and unloading patients, and has reduced the level of manual handling required to load heavy patients.

Easyloader

The easyloader was first introduced to reduce manual handling; because prior to this stretchers were lifted into the vehicle. Manual handling was reduced by reducing the lifting and the amount of weight supported by the operator during loading and unloading activities. In order to load and unload the stretcher staff lifted the stretcher slightly to allow the legs to lock or unlock. This was found to be a particular problem for the shorter staff members and was reflected in the interview data. The easyloader was the only system which required an element of lifting. The postural analysis identified that the easyloader posed the greatest risk of musculoskeletal injury to staff. These results were supported by Cooper and Ghassemiah (2007) who carried out a kinematic assessment of the three stretcher loading systems in parallel to this study. The results showed that the easyloader required greater forces than the other two systems. The tail lift was identified as the preferred system in terms of manual handling.

4.4.1.3 Mechanical and electrical reliability

Tail lift

CIT8 identified an issue with the mechanical and electrical reliability of the tail lift. The safety mechanism jammed when stowing the tail lift, preventing the vehicle from being secured. This meant that a second vehicle was required which increased the time taken to get the patient to hospital. In this incident, a cardiac arrest victim, did not survive, but it was unknown whether the time incurred was a contributory factor.

The tail lift was an automated system with more electronic components, so there was a risk that the equipment would fail with catastrophic results. However, it was possible to manually override the tail lift system. In the event of a break down the tail lift could be mechanically raised and lowered. This would add time onto the call response and increase the level of manual handling involved in the task.

Ramp and winch

The hydraulic ramp and winch was also an automated system. It was used in conjunction with lowering air suspension to achieve an angle of 12 degrees. The air suspension and the automation of the ramp deployment and winch operation meant that there were a number of electronic components which could fail. Staff were observed getting impatient with the time taken to deploy the ramp, so they over-rode the mechanism by forcing the ramp down with their feet. This was identified in the HTA data. Misuse of the equipment increased the likelihood of the equipment failing. CIT1 reported that the air suspension had failed, increasing the travel time and forcing staff to lift the heavy stretcher in and out of the vehicle.

Easyloader

The easyloader system was not an automated system and so there was no risk of electrical failure. However, the mechanical failures reported with the easyloader stretchers may have put the patient and the staff at equal risk. A number of easyloader stretcher collapses reported were the result of the locking mechanism failing so the legs are not secured and the trolley collapses. This caused the trolley to collapse when away from the vehicle, leading to a patient fall scenario (MDA, 2003). This can be dangerous to the staff and patient.

While there was an increased risk of the tail lift and the hydraulic ramp failing due to electrical faults, there were a number of reported mechanical failures with easyloader stretchers leading to patient falls (MDA, 2003).

4.4.1.4 Carry chair / Wheelchair access

Patients were loaded onto the ambulances using a range of mobility equipment. The staff could convey patients to the vehicle on foot, using a carry chair, a wheelchair or a stretcher. The loading equipment used had to accommodate all these modes of transport. The activity sampling exercise found that the carry chair was most often used to convey the patient to the vehicle, where they were transferred onto a stretcher for travel. The stretcher was used more frequently to convey the patient into the hospital.

Tail lift

The tail lift accommodated all types of mobility equipment. A walking patient with reduced mobility could be assisted on to the platform on foot, and the tail lift raised to avoid the steps on the vehicle. A carry chair or wheelchair could be loaded using the tail lift in the same way as a stretcher. The stretcher was aligned with the tail lift when stowed in the vehicle, so when loading a carry chair or wheelchair the stretcher created a slight obstruction. There was virtually no manual handling involved when loading any type of mobility equipment on the tail lift.

Ramp and winch

The ramp and winch could be used to load stretchers, carry chairs and walking patients. Wheelchairs were pushed up the ramp but could not be transported onto the vehicle because the stretcher obstructed the path.

Easyloader

The receiving platform used with the easyloader would only accommodate a stretcher. Walking patients could be escorted on to the vehicle up the step at the back of the vehicle, but there was no provision for loading carry chairs or wheelchairs. In compliance with working practice, staff had to transfer the patient from a carry chair or wheelchair on to the stretcher before loading. This required extra time, and so staff displayed a reluctance to do this. During the field study participants were observed manually lifting patients on the carry chair into the back of the ambulance. This did not comply with the Manual Handling Operations Regulations 1992 (HSE, 1998a). Research carried out by Ferreira and Stanley (2005) found that lifting a chair from a low height exposed the foot end operator to a high risk of low back injury.

4.4.1.5 Time to operate

Easyloader

The time taken to operate each system was calculated during the simulation study. The easyloader was the quickest system to load and unload. However if participants followed correct loading procedures when loading carry chairs, the time taken to load would increase due to the time taken to transfer between mobility devices.

Ramp and winch

The ramp, when used with the winch, was found to be the slowest. This could be one of the reasons staff chose not to use the winch. Staff found ramp deployment and the lowering air suspension to be slow on the hydraulic ramp. There were ways of overriding the automation during emergencies, but this was to the detriment of the equipment itself.

Tail lift

The tail lift was found to be the compromise between the systems, although staff did report it to be slow to operate. Concerns were raised over a 30 second time delay for providing Cardio-pulmonary resuscitation (CPR) during loading which was also reported by Jones and Woollard (2003). There has been debate over whether this could have a detrimental effect on patients in a critical condition. Pell et al., (2001) argued that a shorter, 5 minute response time for 999 calls could almost double the survival rate for cardiac arrest patients. Shuster et al., (1995) conducted a study in Ontario, Canada, comparing the outcomes of patients with acute cardiac illness transported by ambulance, for whom pre-hospital care was provided by emergency medical technicians, paramedics or Emergency Medical Technicians trained in defibrillation. The study concluded that in an urban setting with short transport times the availability of pre-hospital paramedic care did not affect the occurrence of Myocardial Infarction (MI). Shuster et al., found little evidence to suggest that pre-hospital assisted life support care affects patient outcome, suggesting that the extra time to load the patient would have little effect.

4.4.1.6 Vehicle and control layout

The layout of the ambulance can pose a problem for staff. The desired loading system generally depicts which vehicle is purchased and if the staff dislike the vehicle, or its layout, they may take a dislike to the system. Control location was found to be an issue for each of the systems. For the most part because staff had to move between controls which do not have optimum positioning for ease of use.

The locking mechanism for the Ferno Falcon 6 stretcher used with the ramp and winch and the tail lift was found to create a trip hazard for staff because it was in the middle of the vehicle, but this was an issue of stretcher design rather than loading system.

Tail lift

No issues of vehicle layout were highlighted in the investigation for the tail lift vehicle. The controls to operate the tail lift were positioned on the inside of the left hand door at the back of the vehicle. The link analysis in Figure 4.8 shows much movement between the control panel and the platform, suggesting that the panel should be positioned closer to the platform, or hand held for flexibility.

Ramp and winch

The stretcher on the ramp and winch vehicle is secured to the right hand side of the ambulance. Therefore the primary system components (the ramp, stretcher and winch) are not aligned, making the staff twist and turn instead of manoeuvring the stretcher in a straight line. The winch control on both ramp and winch vehicles was at the opposite end of the patient compartment to the winch. This made it difficult to operate efficiently. The air suspension and ramp controls were also in a different position.

Easyloader

The control levers used to operate the easyloader were positioned underneath the foot end handles which encouraged the staff to bear the weight of the stretcher with their hands in a downward position taking the hand out of the neutral position.

4.4.1.7 Task complication

Tail lift

The link analysis showed that out of the three stretcher loading devices, the tail lift required the most amount of movement within the system. The average number of links (movement between two system components) identified per tail lift stretcher loading task was 19.3. Unloading tasks had a much lower average of 9.6. The task complexity was increased with the tail lift because of the number of safety precautions which must be put in place before operating.

Ramp and winch

The average number of links when using the hydraulic ramp to load a stretcher was 10.5. To unload a stretcher was 7.4. This would increase significantly however if the winch was used. Activities such as attaching the winch to the base of the stretcher and guiding the stretcher into the ambulance would increase task complexity.

Easyloader

Loading an easyloader stretcher had an average of 11.6 links, while unloading had an average of 3.9. It is therefore evident that full automation, when used to reduce manual handling, increased the complexity of the task. In terms of task complexity, the easyloader and the ramp when used without the winch would be the preferred systems. However, it is important to consider whether the benefits of reduced manual handling are worth the reduced simplicity of operation. The prioritisation of manual handling above task complication in the ranking task.

4.4.1.8 Weather and environment

All three systems were affected by the weather and the environment.

Tail lift

The tail lift platform was the back door to the modular ambulance. During observations it was identified that when attending to the patient the tail lift was deployed and lowered, allowing the staff to take the mobility equipment to the patient, ready to load on their return. During this time the ambulance was left open to the elements. In the interviews staff reported a number of problems associated with this, many of which were observed in the field study. When the tail lift was down the ambulance was open, allowing the heat to escape and the rain and snow to get into the vehicle. During night shifts the lights in the ambulance attracted moths and other insects, which shared the patient compartment. The platform also attracted dirt from the stretcher which was then seen on the inside of the ambulance when the patient was travelling to hospital. The patients were exposed to the rain for longer with the tail lift because of the time it took to raise and lower.

Ramp and winch

The ramp vehicle was not affected in the same way as the tail lift because the vehicle could be secured even when the ramp was deployed. The ramp had a non slip surface to prevent it from becoming slippery in the rain, but staff did report it becoming slippery in bad weather. Use of the winch was hindered in bad weather because the staff did not want patients waiting while the winch was set up and drawn in and out of the vehicle.

Easyloader

The weather was not a big factor for the easyloader stretcher because with usual operation the stretcher was very quick to load and unload so there was not enough time for patients to get wet. However, if the staff loaded carry chair patients into the vehicle following correct procedures, the weather could become a problem. During the time it took to pull the stretcher out, the patient and the stretcher were exposed to the rain. The wet patient would then be transferred to a wet stretcher and loaded. For this reason staff tended to lift the carry chair onto the vehicle instead of carrying out the transfer.

The tail lift was clearly most affected by weather and environment. However, in more recent years manufacturers recognised this and introduced vehicles with a secondary back door to secure the vehicle when the tail lift is down, solving the problems highlighted above.

4.4.1.9 Clearance

Clearance is the amount of open space required at the back of the vehicle in order to deploy the equipment and load and unload a stretcher. The tail lift requires approximately 3m space, the hydraulic ramp and winch needs 1.7m and the easyloader 1.5m.

In a busy street or hospital unloading bay the 3m clearance required for the tail lift, may not be possible. During observations the stretcher was seen to be almost lifted off the tail lift platform because there was not enough clearance space. Some manufacturers have addressed this by considering side loading tail lifts on future ambulances (Hill, 05/05/2006, *Personal communication*). London ambulance service, who have the busiest roads and biggest congestion problem in the UK, use tail lift vehicles, suggesting that clearance is not a substantial problem.

4.4.1.10 Effect of camber

The road surface can have a big impact on the use of the system, and for a number of ambulance services the regional environment and types of roads had a big impact on the purchasing decisions made.

Tail lift

The observations identified that, when the tail lift was parked on a camber, staff had to compensate for the incline by using slight force. However, this was no greater than using a ramp.

Ramp and winch

The interview data identified that the ramp does not lie flat against the ground if there is a camber in the road.

Easyloader

The camber did affect operation of the easyloader stretcher. It hindered the legs from moving around their full arc of rotation, preventing them from locking in place. If this was not noticed the easyloader would collapse. Staff were observed lifting the stretcher to compensate for the road camber, increasing the level of manual handling carried out.

4.4.1.11 Security

Security issues were greatest for the tail lift and the easyloader stretcher. When the staff took the stretcher to the patient the vehicles were left open and unsecured. This meant that members of the public could access the vehicle, increasing the potential for theft. It was possible to secure the ramp and winch vehicle when the ramp was deployed.

Ambulances are known for carrying expensive equipment and drugs which are otherwise unavailable to the public, which makes them vulnerable to theft. The study conducted by Alves and Bissell (2003) highlighted the vulnerability of ambulances when parked in hospital loading bays. They identified that 90.1% of ambulances across several states in the US were left unattended during their observations, 84.1% were left unlocked and 16.6% had visitors while the crews were away from the vehicles. This highlights the importance of vehicle security.

It is apparent that at the time of the field study there were security drawbacks with the tail lift vehicle. However, the advancements made in recent years, developing an additional back door to close when the tail lift is down, have increased the security of the vehicle.

4.4.1.12 Infection control

Infection control issues are bound to be experienced with any equipment used to carry or load patients. The ramp and winch and the tail lift were identified as being most at risk of infection control issues because of the locking mechanism used to lock the stretcher in place in the vehicle. The components were suggested to be so intricate, that blood and other bodily fluids could easily get into the mechanism and it would be difficult to clean sufficiently. However this was a problem for the stretcher manufacturer, not the vehicle manufacturer and so should not be used to identify a preferred system.

4.4.1.13 Equipment misuse

Both the ramp and winch and the tail lift systems were observed being misused on a number of occasions. This was because the automation slowed down the use, so in emergency situations staff chose not to follow recommended procedures.

Tail lift

When using the tail lift, participants were observed jumping in and out of the vehicle instead of raising and lowering the step. They were adopting poor postures to get in and out of the vehicle. However, it was possible that the postures adopted to raise and lower the step posed an equal risk to staff.

Both crew members were supposed to load and unload the stretcher whether there was a patient on board the stretcher or not. Operators were observed loading and unloading alone, while their crew mate attended to the patient. This was not recommended, and staff were advised to follow the appropriate procedures to reduce manual handling risks further.

Staff were also observed placing one foot on the tail lift platform and raising or lowering themselves with the tail lift. This was not considered safe and staff were advised by the service, not to do this.

Ramp and winch

Staff were observed forcing the ramp open by pulling it, instead of using the button to deploy. This was a manual handling risk and should not occur. Staff were also observed pushing their foot down on the ramp to force it down quicker. This could potentially cause the system to fail.

Easyloader

With the Easyloader stretcher Staff were observed ignoring procedure, misusing the equipment by loading the carry chair by lifting instead of transferring the patient to the stretcher.

4.4.1.14 Need for sensors

The tail lift and the ramp and winch were automated systems which needed to be supervised by the person operating them. Neither system currently has any sensors on the deployment platform to stop them operating in the event of someone getting in the way.

Tail lift

The tail lift would benefit from sensors on the platform, to stop operation if it makes contact with an object or person. This would prevent it from hitting a passer-by. The tail lift did have an emergency cut off system which prevented it working when the safety mechanisms were not put in place.

Ramp and winch

The ramp and winch could benefit from sensors on the underside of the ramp, to stop it deploying if the operator's foot got in the way. The heavy equipment could cause an injury.

Easyloader

The easyloader was not an automated system so there was no need for sensors.

Sensors were ranked at the bottom of the priority list by ambulance personnel. In hindsight this may be because the title of the ranked item was a little ambiguous, and could have been misinterpreted by respondents.

4.4.2 Meeting the aims of the investigation

The aims of this project were to use ergonomic methods to comparatively evaluate three stretcher loading systems, to determine which was most suitable for use in a variety of environments and to make recommendations for improvement. The study identified that the tail lift was the preferred model for future purchase, due to the rapidly reduced risk to operator and staff through automation of the task.

Certain aspects of usability may have suffered due to mechanisation of equipment, but when considering the priorities of ambulance staff (identified in the ranking activity) it was evident that the reduced risk in terms of operator and patient safety and manual handling, and the accommodation of all types of mobility equipment, compensate for the increased time to operate and task complication.

Both the field study and the simulation study identified that the tail lift reduced the manual handling and postural risks posed to staff, although it was evident through the postural analysis that the tail lift did pose a medium risk of musculoskeletal injury and so action should be taken to further reduce this risk.

4.4.3 Limitations

Due to the nature of ambulance work there were a number of limitations to the study. Problems were experienced as a result of collecting data in the field. The observer lacked control over the data collected because it was important not to impact on the work carried out by the ambulance crews. The researcher planned to observe the equipment being used in the full range of patient calls attended, day and night, in a variety of environments. However some station managers discouraged observers attending night shifts which meant that the equipment was observed more during the day than the night. More data were collected from urban stations than rural stations because the staff attended more calls in urban environments, providing more opportunity for observation. There was less information about use of the systems in rural environments. More data were collected over the summer months because the data collection period fell mainly over the summer period. This meant some of the equipment may not have been observed in its full range of use. Some issues affecting equipment usage in the night time, in winter and in rural environments may have been missed. This should have been accounted for in the interview and critical incident technique data but it should be noted that the recommendations in section 4.4.4 were based on the call scenarios observed.

Short interviews were conducted because staff were busy with patients and didn't have time to conduct tape recorded interviews. For this reason the interviews were semi structured and mostly recorded with notes. Longer interviews in more controlled environments may have provided more detailed responses leading to more detailed recommendations.

The participant selection criteria were limited. Convenience sampling was used because staff availability was limited. This meant that it was not possible to observe a sample which was fully representative of the population. Some ambulance workers who did not participate may have experienced issues which were not captured in the data collection.

The simulation study was conducted with one crew (two participants) per loading system evaluated. This was because the study duration was limited and did not allow for more data to be collected. The postures analysed were therefore limited. The postures adopted may have differed with other workers of different stature, so it should be recognised that the recommendations were based on limited data.

The participants who simulated the patient in phase 2 (Simulation study) varied for each loading system. This was because the access to ambulance service equipment and staff was limited to particular days, conflicting with the availability of participants to act as patients. Therefore the three loading systems were tested with different weights carried on the stretchers. This may have affected the results. However the weight carried on each stretcher was below the bariatric patient threshold and therefore should not have impacted significantly on equipment use.

4.4.4 Recommended further work

This research identified the Modular tail lift as the preferred system for use on UK ambulances. Although it was the preferred system it was not without its weaknesses in terms of usability. Further work could be carried out to comparatively evaluate a number of tail lifts to identify the preferred model, accounting for more modern improvements in terms of security and further automation.

The weaknesses of the tail lift should be further investigated. Further investigation into current working practice for tail lift operation could be carried out to identify where the task could be improved in terms of manual handling implications and usability issues.

Further investigation into tail lift use in urban and rural environments would be beneficial to fully understand the implications of its wide spread use.

4.5 Recommendations and conclusions

Figure 4.13 provides a summary of the field and simulation study findings, both identify the tail lift as the preferred stretcher loading system for use in the UK. The tail lift was found to eliminate lifting and radically reduce manual handling from the loading and unloading tasks, accommodating all types of mobility equipment including stretchers, wheelchairs, carry chairs. It allows patients to walk onto the vehicle.

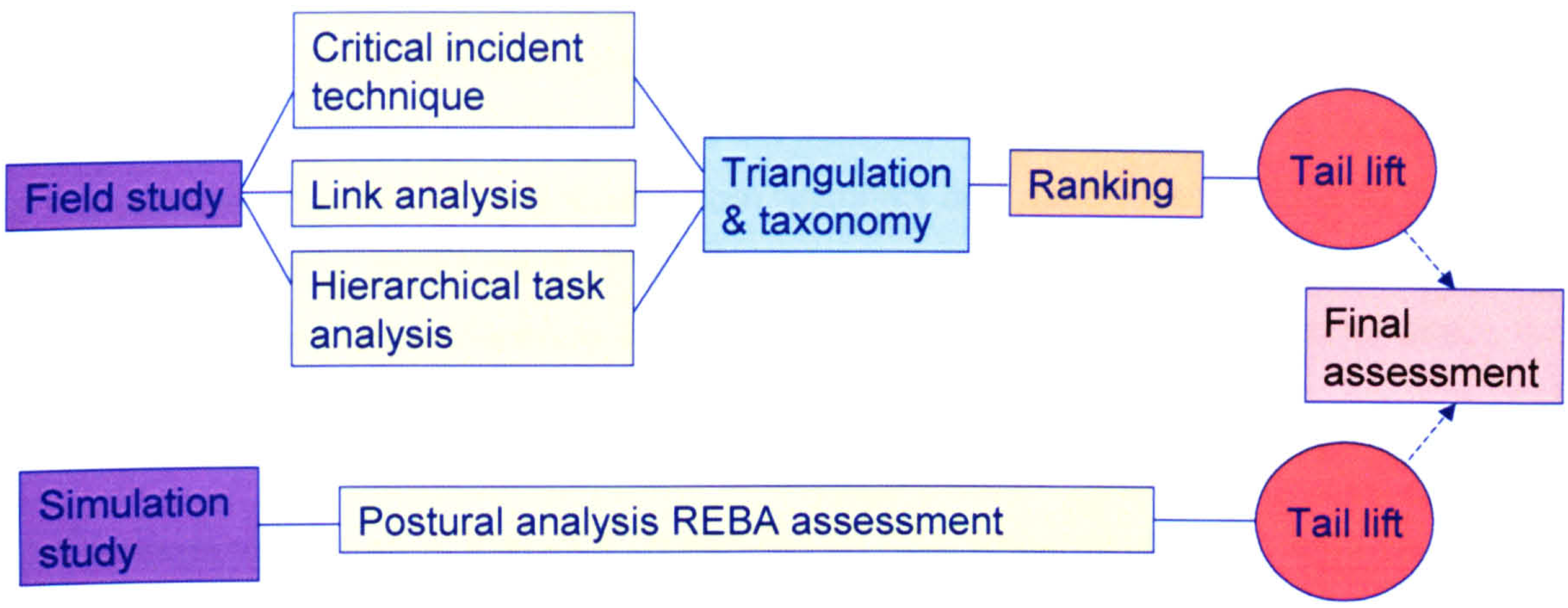


Figure 4.13 Summary of results for stretcher loading system evaluation

As a result of this study it was recommended that the subtasks which posed the greatest risk to staff should be further automated to prevent harmful postures being adopted. These tasks included raising and lowering the hand rails on the tail lift platform, and folding and unfolding the safety plate at the end of the platform. Opening out the step at the back of the vehicle was also identified as a high risk task. Alternative step design should be considered.

Since this study was conducted significant developments have been made in tail lift design. Subtasks such as those outlined above have been automated on certain models, meaning that many of the tail lifts weaknesses have been addressed and are no longer a problem on more modern designs. The issues manufacturers have resolved on more recent models include task complication, weather and environment, security, and need for sensors.

The findings from this study have been incorporated into the national emergency ambulance specification. Ambulances purchased on the national contract in future will all be fitted with a tail lift (Jones et al., 2007).

Chapter 5: Case Study 2

A comparative evaluation of mobility equipment

5.1 Introduction

A&E and Patient Transport Services (PTS) staff employed by the UK's emergency services carry out very different roles. The National Profile for Ambulances (NHS employers, 2003) states that the role of PTS staff is to collect patients and escort them to the vehicle, drive the vehicle to and from hospitals and escort the patients to the appropriate clinic or department. The role of A&E staff is to respond to emergency, urgent and routine calls delivering treatment. They are clinically trained, undertake emergency driving and are required to lift and carry patients.

The emergency nature of the work carried out on A&E requires staff to attend to patients in a number of different environments, ranging from inner city homes to rural suburbs, so their equipment must be adaptable. PTS however, have a planned programme of events for each shift and so are able to prepare themselves for each call. Whilst both crews transport patients from their homes to hospital, PTS also collect patients from hospital using wheel chairs and stretchers and return them home, often requiring the crews to carry patients upstairs. A&E crews transport patients from clinic to clinic when attending urgent calls but rarely, if ever, do they transport the patients to their homes (NHS Employers, 2007).

These two roles have very different responsibilities towards the patient, yet they are provided with the same stretchers and carry chairs to carry out manual handling tasks. A primary role of ambulance staff, be that A&E crews or PTS crews, is to transport patients to hospital (NHS Employers, 2007). In order to do this the patient must be conveyed to the ambulance. Methods of conveyance usually include a stretcher, carry chair or wheelchair, or if the patient is fully mobile the patient may walk with assistance to the vehicle (Ferreira and Stanley, 2005).

There are a number of factors which influence the choice of mobility devices used to transport the patient. These include the environment and accessibility, patient condition, patient mobility etc. On arrival at the scene the ambulance staff carry out a physical assessment, followed by a risk assessment of the environment to identify the best means of movement (Doherty, 29/12/05, *Personal Communication*).

The stretcher is used to transport immobile patients to the ambulance and is usually used to convey patients into hospitals (Jones & Hignett, 2005). The carry chair is used as the primary mode for conveying patients downstairs and into the ambulance (Ferreira & Stanley, 2005). The design of stretchers supplied on ambulances has improved in recent years, reducing the manual handling element of patient transfers through hydraulic raising and lowering mechanisms. There has been little change in the design of the carry chair used on ambulances over the past thirty years (Hill, 10/01/2006, *Personal communication*). Transporting them up and down stairs involves a lot of lifting.

The clinical governance initiative was introduced to the health service in 1998 (Scally and Donaldson, 1998). It is important that the ambulance services uphold this by ensuring the best possible equipment is purchased for their staff and patients. Thorough equipment evaluation processes offer a means of maintaining clinical governance within the ambulance service.

The mobility equipment supplied to ambulance staff by the ambulance services has varied very little over the past few decades. However as a result of current legislation such as the CEN standards (EN1865 2000a; EN1785 2000b and EN1785 2007) and Manual handling regulations (HSE, 1998a), manufacturers have concentrated their efforts on designing and producing equipment which provides mechanical assistance to staff, reducing the manual handling involved in transporting patients (Overton, 2001).

There is currently a large range of equipment available on the market, but little information to identify the most suitable. All new equipment supplied to the ambulance service must first be risk assessed prior to introducing it to staff (Smith, 15/02/2006, *Personal communication*). By conducting user trials it was possible to rank the equipment in terms of staff preferences, providing information to aid in the equipment selection process.

5.1.1 Knowledge transfer partnership

This study was carried out as part of a knowledge transfer partnership (KTP) funded by the Engineering and Physical Sciences Research Council (EPSRC). The researcher was seconded to EMAS for one year under the Research Assistant Industrial Secondment (RAIS) scheme to gain an understanding of industrial processes, whilst educating the ambulance service in terms of ergonomic practices and techniques. A number of challenges were met during the researcher's time with the ambulance services, who became involved in a number of projects evaluating equipment and tasks to identify potential risk and performance issues. The greatest legacy provided by the researcher at the end of the knowledge transfer scheme was a protocol for carrying out thorough ergonomic user trials. A number of training sessions were held with members of the risk and safety team demonstrating task analysis and postural analysis techniques. Pilot sessions for the user trials were held with the team, demonstrating how to carry out the trials with end users and a protocol tool was produced demonstrating the steps required to carry out all stages of the assessment.

The KTP put a number of restrictions on the study. The research was conducted in an industrial setting which meant that there were time pressures to consider and limited resources were available for the research.

5.1.2 Aims and objectives

The aims of this investigation were to:

1. Comparatively evaluate mobility equipment designed for the ambulance market
2. Identify preferred mobility equipment for A&E and PTS staff
3. Identify whether A&E and PTS staff should be provided with different equipment to meet the requirements of their individual roles

The objectives of this investigation were to:

1. Identify the types of equipment provided by suppliers, the environmental conditions affecting equipment use and the typical patient scenarios experienced in the field
2. Develop an evaluation protocol to assess manual handling and usability
3. Evaluate the equipment with input from end users
4. Analyse the data and recommend preferred equipment for use in each role

The purpose of this study was to identify the preferred equipment for use by A&E and PTS teams within the ambulance service. The intention was to take a number of products from the ambulance market and comparatively evaluate the products. In order to do this it was necessary to gain an insight into the usability and manual handling issues faced by staff with the equipment currently in use. This provided a list of tasks and conditions with which to trial equipment, and prioritised the testing criteria. The preliminary study incorporated observations and focus groups to capture the experiences and views of the end users, the ambulance staff. It was used to inform the user trial design and development process, identifying the important factors to simulate and evaluate.

5.1.3 Ethics

This research was covered by the Loughborough University ethical advisory committee criteria. All participants were provided with an information sheet before participating. They were given the opportunity to ask questions and were asked to provide informed consent and photographic consent.

5.2 Method

Figure 5.1 shows the methods used to conduct this investigation, and how they were integrated together. The rationale for each method is provided in section 5.2.2 and 5.2.3

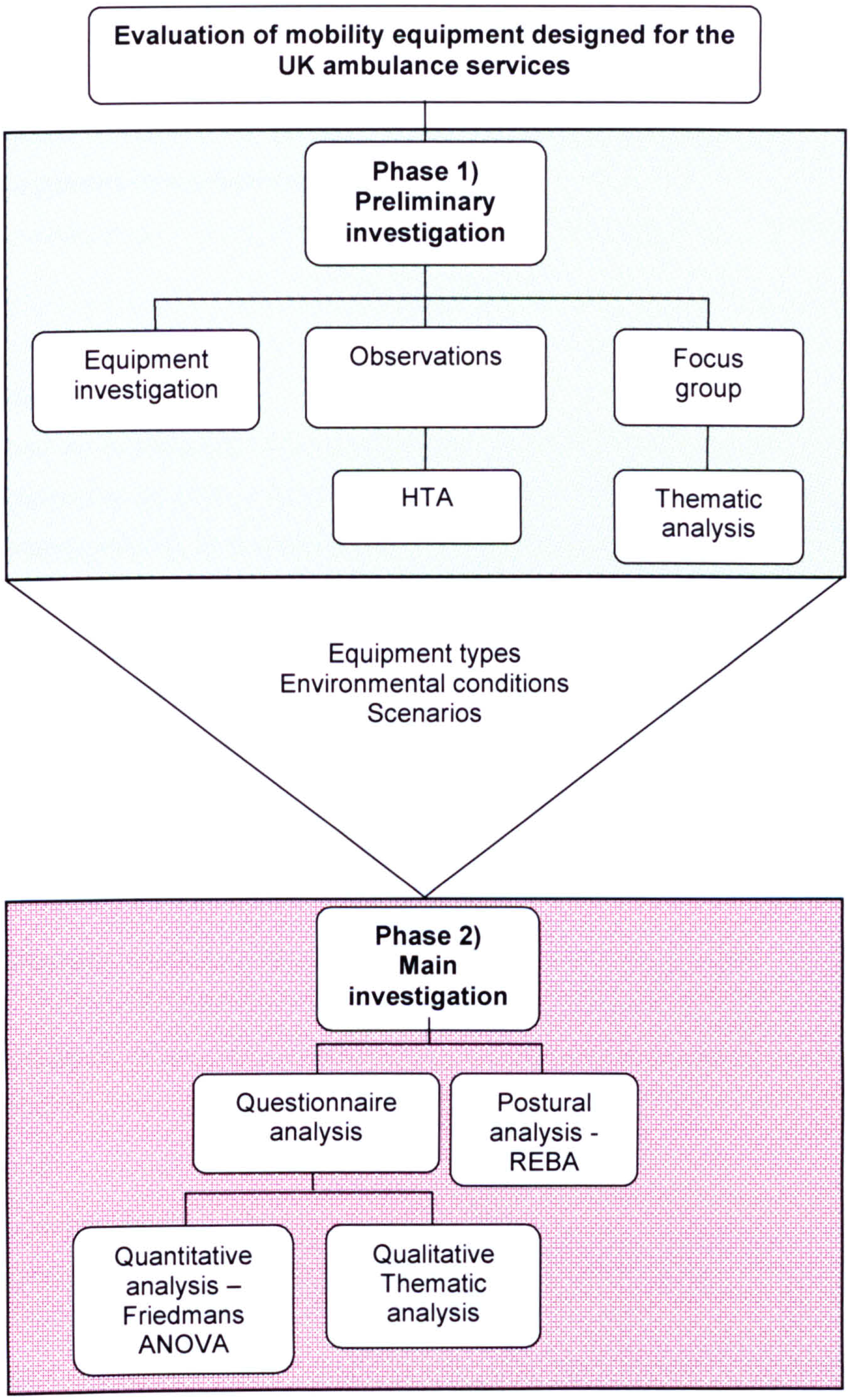


Figure 5.1 Protocol for mobility device evaluation

5.2.1 Research approach

A realistic evaluation approach was adopted in this study (See Chapter 1, Section 1.3). A grounded theory approach to data collection was adopted in the preliminary investigation, whereby data were collected in phases and the analysis was ongoing throughout the data collection process (Robson, 2002) (See Chapter 4, Section 4.2.1). In the main investigation all data were collected during the trials and analysis followed.

5.2.2. Method selected for phase 1- preliminary investigation

5.2.2.1 Equipment investigation

A market investigation was carried out to identify suitable equipment for the ambulance market.

5.2.2.2 Observations

Observations were selected as an exploratory method used to identify the usability issues experienced by staff in the field. They were chosen to support focus group data, increasing validity by compensating for the limitations of the method (Robson, 2002). Observations were carried out to identify the differences in the work carried out by the two roles of service (A&E and PTS), the types of environments and the use of equipment. The observations demonstrated constraints in the working environment experienced by ambulance staff whilst operating mobility equipment.

5.2.2.3 HTA

Task description methods were needed to analyse the observation data. HTA was selected because it allowed the researcher to break down the task and analyse it in fine detail. It is a core ergonomics approach which has been used for over 30 years in a number of applications (Stanton et al., 2005). The method has been used in a previous studies set in healthcare (Lane et al., 2006).

5.2.2.4 Focus groups

Focus groups were selected to support observation data for exploration and discovery (Morgan, 1998), to identify a range of constraints affecting ambulance workers when transferring patients using mobility equipment. Focus groups were considered the best way of gathering exploratory data from a large number of staff. Individual interviews would have been more time consuming and would lose the benefit of the group dynamic gained through focus groups (Bruseberg and Macdonagh-Philp 2002). In order to increase the validity of the data collected through the focus groups purposive sampling was used to select the participants from direct end users (Erlandson et al., 1993).

The use of observation and focus groups in the preliminary investigation drew on the strengths of both methods and compensated for their weaknesses.

5.2.3 Methods selected for phase 2 - main investigation

Methods were sought to collect comparable data regarding the usability and manual handling risks associated with a large range of equipment.

5.2.3.1 User trials

User trials were used to collect data because they are effective in conducting comparative analysis which is fair to all products (Butter and Dixon, 1998). Controlled simulations, incorporating constraints experienced in the field, were the most suitable method of evaluating the equipment to assess its fitness for purpose.

5.2.3.2 Questionnaires

Questionnaires were selected to collect qualitative and quantitative data during the user trials because they are effective in ascertaining user perceptions of products. They are effective in comparing the opinions of a number of people and in the same way can be used to comparatively assess equipment (Stanton et al., 2005). They ensured all participants compared the equipment under the same assessment criteria. Questionnaires were felt to be an effective tool to capture the user opinion without imposing on the task simulation. The tool has been successfully used in previous studies as a method of evaluation (Woods and Buckle, 2005)

5.2.3.3 Postural analysis

Postural analysis was carried out to identify the risk of work related injury when using the mobility equipment, and was selected because it is the most appropriate method of determining the limits of infrequent lifting of large heavy objects (Haslegrave & Corlett, 1990). Observational methods of postural analysis have been identified as the most appropriate tools for use by occupational safety and health practitioners, and those from related professions; this is due to cost, capacity, versatility, generality and exactness, and allows the establishment of priorities for intervention (David, 2005).

The main rationale for using REBA has been provided in Chapter 4. However to summarise, REBA was selected to analyse the risks posed to staff when using each product, to identify which product poses the least risk to staff when conducting the conveyance tasks. It was selected because it is the only postural analysis tool which assesses the entire body and accounts for the unpredictable postures which are adopted in the healthcare setting. The tool assesses risk relating to lifting but also considers the hazards posed by the healthcare workers posture adopted during the manual handling task (Hignett and McAtamney, 2000).

Biomechanical analyses, force measurements and electromyography were not conducted because the equipment and facilities required were not available and there was limited time to carry out a thorough analysis. It was also felt that these methods would impose on the task simulation exercise.

A mixed methods approach was used in the main investigation to increase validity.

5.3 Data collection

5.3.1 Preliminary investigation data collection

To plan the user trials a preliminary investigation was carried out using focus groups and observations to identify the types of constraints affecting equipment use.

5.3.1.1 Equipment investigation

An investigation was carried out to identify suitable equipment for the ambulance market. Managerial staff involved in equipment purchasing for UK ambulance services were contacted with the help of the ASA. Manufacturers and their products were researched and a range of equipment was identified. Manufacturers and distributors in the ambulance market were invited to collaborate in the study.

5.3.1.2 Observations

A five day observation period was carried out with the A&E crews from Nottingham Ambulance station and five days with PTS crews from Heath and Loughborough Ambulance stations. This was to identify the differences in the work carried out by the two roles, the types of environments and the use of equipment.

Participants were selected by convenience sampling. Observations were carried out with ambulance staff working shifts on allocated days.

5.3.1.3 Focus groups

Four focus groups were conducted; two with A&E staff and two with PTS staff, to identify issues experienced with the mobility equipment. Where possible, the focus groups were conducted in the training rooms at EMAS, providing a quiet environment for discussion. Each focus group had between four and six participants dependant on the availability of ambulance staff (See Table 5.1). Convenience sampling was used to recruit participants. The participants were required to be operational, with experience of using mobility equipment. Each focus group session took 45-60 minutes.

In order to trial the questions, venue and equipment a pilot focus group was held with seven members of the corporate services team within the ambulance service. This group included the Head of Risk and Safety, two Risk Advisors, the Back-care Advisor / Manual Handling Trainer, the Supplies Manager and an off-road Paramedic who had been given light duties.

Focus group	Participants	Venue
Pilot (corporate services team)	6	Headquarters meeting room
A&E1	4	Station coffee room
A&E2	4	Headquarters conference room
PTS1	6	Station meeting room
PTS2	4	Training centre meeting room

Table 5.1 Focus group description

The observations and focus group analysis resulted in a list of environmental factors to plan the equipment trials including a detailed list of tasks, environmental conditions and patient scenarios. Informed consent was collected from each participant before the data were collected (See Section 5.4).

5.3.2 Main study data collection

5.3.2.1 User trials – designing protocol

A combination of McClelland's (1990) key components for user trials, the procedures for conducting user trials (Stanton et al., 2005) and the findings of the preliminary study were used to develop a protocol for the user trials carried out in this study.

The protocol and design of the user trials for the evaluation of mobility equipment differed slightly to McClelland's and Stanton's protocols due to the complexity of equipment. Additional information regarding test conditions and secondary user / patient profiles were provided, as the equipment trialled was complex in nature and the task simulation features needed to be specified in much more detail.

The protocol applied to the user trials is illustrated in Figure 5.2, each phase is described in more detail in the following section.

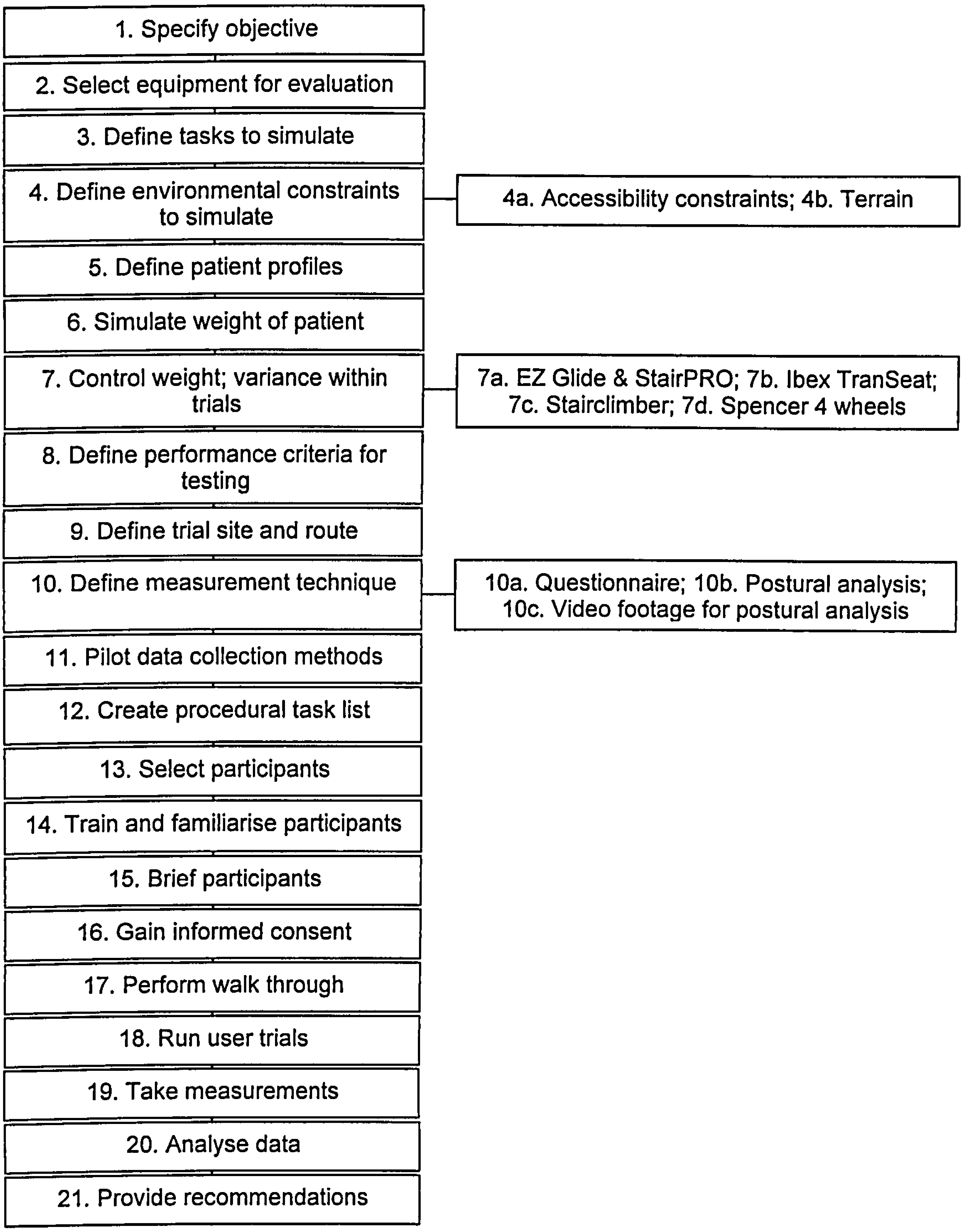


Figure 5.2 Protocol for user trials

Step 1: Specify objective

The objective was to conduct simulations of patient transfer equipment tasks using current mobility equipment, incorporating the environmental conditions experienced in the field. The purpose of this was to identify preferred equipment for A&E and PTS staff and to identify which products posed the least risk of musculoskeletal damage to staff.

Step 2: Select equipment for evaluation

A large selection of equipment was identified, ranging between standard chairs, mechanised chairs, assisted chairs and evacuation chairs, so that the most suitable equipment for use on UK ambulances could be identified.

Market research was carried out, identifying a number of manufacturers and suppliers within the ambulance market. Eleven companies were contacted and invited to collaborate in the research, five of which agreed to collaborate (Table 5.2).

Manufacturers / suppliers	Products	Collaboration
Alber	Mechanised chairs	X
Baronmead International	Mechanised chairs	X
Ferno	Chairs and stretchers	√
Galls Dynamed	Chairs and stretchers	X
Melber	Chairs and stretchers	X
ParAid (Pensi)	Chairs and stretchers	√
RTS Chapuis France	Chairs and stretchers	X
Sano UK	Mechanised chairs	X
Spencer Italia	Chairs and stretchers	√
Stryker	Chairs and stretchers	√
VW Company	Stretchers	√

Figure 5.2 Manufacturers and suppliers invited to collaborate

If manufacturers responded positively, products from their range were selected, based on the list of equipment identified from the focus groups (see Section 5.4). The selection criteria required that the equipment be designed for the ambulance market, be durable and robust, and suitable for use by two person crews. Managerial staff in the ambulance service approved all equipment evaluated ensuring that the equipment was suitable for use by EMAS staff and ethical considerations were maintained. Several products were considered inappropriate for UK working practices and were rejected prior to the trials. The products selected are shown in Tables 5.3, 5.4 and 5.5.

Manufacturer	Market	Device	Code	Model	Equipment code
Ferno	EU & US	Chair	(c) A	C-max	Mechanised chairs
Ferno	EU & US	Chair	(c) B	Compact 2	Standard carry chair
Ferno	EU & US	Chair	(c) C	Compact 3	6-wheel chair technology
Ferno	EU & US	Chair	(c) D	EZ Glide	Track evacuation
Ferno	EU & US	Chair	(c) H	Sirocco	6-wheel chair technology
ParAid	EU	Chair	(c) F	Pensi 41-10-20	Standard carry chair
ParAid	EU	Chair	(c) G	Pensi 41-11-20	Standard carry chair / wheelchair capacity
ParAid	EU	Chair	(c) E	Ibex TranSeat	Track Stairclimber
Spencer	EU	Chair	(c) I	Spencer 450	Standard carry chair
Spencer	EU	Chair	(c) J	Spencer 455/B	Standard carry chair / wheelchair capacity
Spencer	EU	Chair	(c) K	Spencer blue	Standard carry chair / wheelchair capacity
Stryker	EU & US	Chair	(c) L	StairPRO	Track evacuation
Ferno	EU & US	Stretcher	(s) A	Falcon 6	Hydraulic stretcher
Ferno	EU & US	Stretcher	(s) B	Pegasus	Hydraulic stretcher
ParAid	EU	Stretcher	(s) C	Parensi Easilite	Hydraulic stretcher
VwCompany	UK	Stretcher	(s) D	MedAssist	Hydraulic stretcher / Stretcher converting chair

Key	
C	Chair
S	Stretcher

Table 5.3 Equipment trialled

Chair	Image
C-max (Stairclimber)	 http://www.aat-online.de/img/rehatechnik/c-max_u2_gr.jpg
Compact 2	 http://www.spservices.co.uk/images/ch022.gif
Compact 3	 http://www.spservices.co.uk/images/ch023.gif
EZ Glide	 http://www.med-worldwide.com/media/59Tbig.jpg
Sirocco	 http://www.med-worldwide.com/media/sirocco-sm.jpg
Pensi 41-10-20 (2 Wheels)	 http://www.pensi.fi/e_tuotteet_kantotuoli.html
Pensi 41-11-20 (4 wheels)	 http://www.pensi.fi/e_tuotteet_kantotuoli.html

Ibex TranSeat	 http://www.paraid.co.uk/bulletin/ibexnews.gif
Spencer 450 (2 wheels)	 http://www.evacuationchair.net/english/trasporto.htm
Spencer 455/B (4 Wheels)	 http://spenser.medcom.ru/kres/prod13.jpg
Spencer 420 (Blue frame)	 http://spenser.medcom.ru/kres/prod22.jpg
StairPRO	 http://www.ambunet.com/admin/images/9/6252%20Stair%20Pro.gif

Table 5.4 Identification of chairs selected for evaluation

Stretcher	Image
Falcon 6	 http://www.spservices.co.uk/resize.php?image=images/ZZ2244.jpg&width=100
Pegasus	 http://www.stjohnsupplies.co.uk/common/suppliesImage.asp?ProductID=F61039
Parensi Easilite	 http://www.paraid.co.uk/parensi/easilite3.html
MedAssist	 http://www.vwcompany.com/data/images/prod_medassist.jpg

Table 5.5 Identification of stretchers selected for evaluation

The staff had previously used the Compact 2 carry chair and the Falcon 6 stretcher during their careers. Training was provided to all participants by an experienced manual handling trainer from EMAS.

The manufacturer names were not hidden during the trials because all equipment had been marketed and were distinct in design, therefore covering the brand name would not have maintained product anonymity.

The equipment was stored in a secure location in the Healthcare Ergonomics and Patient Safety Unit (HEPSU) laboratory and was insured under the university policy.

Step 3: Define tasks to simulate

The following frequently occurring tasks were highlighted in the preliminary investigation:

1. Carrying patients down stairs / steps
2. Carrying patients up stairs / steps
3. Manoeuvring through corridors
4. Manoeuvring in confined spaces
5. Lifting patients over kerbs / thresholds

The task selected for simulation was the conveyance of patients from the collection point to the delivery point using a stretcher or a carry chair. For an A&E crew this would require transporting a patient from the call scene to the ambulance. For a PTS patient this may require transporting a patient from the dispatch room on a hospital ward to the ambulance, or from the ambulance to their home. Both tasks involve patient manoeuvring and manual handling.

The trials were carried out twice with each chair, to allow the participants to evaluate each chair in the head end and the foot end position. The trials were carried out four times with each stretcher, so the stretchers were tested in the head end and foot end positions when lowered and elevated, covering the range of equipment usage.

Tasks relating to the vehicle such as storage on the vehicle and transferring patients within the vehicle were not considered in the trial. The evaluation focused on the transportation of the patient. Aspects relating to the vehicle were outside remit of the study.

Step 4: Defining environmental constraints to simulate

In the field, patient conveyance tasks are made difficult by constraints including confined spaces such as doorways, corridors and stairways, different terrain such as carpeted floors and access constraints such as kerbsides and steps. Guha, (1989); Stevenson et al., (1995); and Lavender et al., (2000a and 2000b) have all discussed the complex environments which add further complications to the task of manoeuvring patients out of buildings.

Step 4a: Accessibility

Every home is different. Until recently there has been no standard for threshold height. However revised building regulations state that newly built dwellings should only have thresholds in exceptional circumstances and should be no greater that 150mm in height (Office of the Deputy Prime Minister, 2000). However older buildings do not adhere to any standards. Some houses have small ridges over the doorway and other houses have steps up into the home. Some homes have slopes or ramps of differing gradients depending on the threshold heights. The layout inside the house will be unique to the home. Room layouts and the locations of soft furnishings will differ.

The lack of standardisation for old build thresholds, entranceways and home layouts makes it very difficult to simulate these constraints and obtain results relevant to the majority of environments. If these constraints were simulated the results would only be relevant to the specific height of the threshold tested, the specific room layout tested and the specific gradient of ramp.

Ambulance workers move obstacles within a patient's home wherever possible, to provide a clear route for the chair or stretcher. If obstacles had been simulated the participants would have moved them before carrying out the trials so it was considered unnecessary to include the constraint.

The equipment should be tested in the environments which the staff are most likely to encounter. Birtles and Boocock (2003) found that the most common environments encountered by ambulance staff when transporting seated patients, were kerbs (80%), stairs (50%) and steep slopes (50%). Due to the difficulties in standardising the angle of the ramp it was believed that incorporating a kerb and stairs into the trial route would be sufficient to evaluate the equipment.

Step 4b: Terrain

Birtles and Boocock (2003) found the most common floor surfaces encountered were carpet (68%) and smooth floors (52%). Gravel and grass were found to be more difficult but less common.

Thresholds, kerbs, steps, slopes and ramps were external access constraints identified in the preliminary study. Carry chairs and stretchers were conveyed over all of these constraints when entering and leaving buildings.

Problems with new build houses and nursing homes were identified through focus groups, relating to accessibility such as kerbs, steps up to the houses and thresholds. Ambulance staff attend calls at numerous homes with various designs of threshold. It is difficult to simulate external constraints such as rain and ice. Internal constraints allow for controlled conditions. Outdoor constraints could not be simulated due to weather conditions and the need for video footage. In order to control the environment all imposed constraints needed to be internal. Therefore two types of terrain were simulated, smooth flooring as found in nursing homes and hospitals, and carpeted flooring, as found in patient's homes. Lifting and carrying activities were simulated using a stairway and a kerb.

It was not possible to identify a standard threshold to test the equipment so a threshold was not simulated. Kerb heights in the UK range between 12.5cm and 15cm. The standard kerb height in Nottinghamshire and Leicestershire is 12.5cm. Steps were simulated using a staircase within the department of human sciences.

Corridors, a small stairwell and a confined double doorway were simulated. The confined doorway used in the trial was a similar size to a hospital lift and therefore not necessary to trial separately. A pilot was carried out to test the chairs on a spiral staircase, but only the standard carry chairs could be carried up and down these stairs. This made the trial inappropriate for any other chair. This information was recorded and considered when making the recommendations, but in the user trials an alternative staircase was used to test the manual handling element of the task.

Ideally all the constraints experienced in the field would be simulated in the trials. However it was not possible to account for all variables. There would be difficulty simulating some constraints including, thresholds, obstacles in patients' homes, and ramps / slopes, weather and terrain including grass, gravel, ice / water and pathways.

Step 5: Defining patient profiles

To further define the tasks, patient profiles (Table 5.6) were developed with members of the risk and safety team at EMAS. The profiles were used to standardise the experimental tasks.

Patient	Profile
A&E carry chair patient profile	Female, 60 years old, fractured neck of femur (Hip bone thins and breaks), non-weight bearing
A&E stretcher patient profile	Male, 57 years old, experiencing CVA (Stroke), patient is unable to communicate with the crew. Patient has history of hypertension, which he currently takes medication for. Patient cannot assist himself
PTS carry chair patient profile	Female, 64 years old, diabetic amputee, suffering with kidney failure. Patient returning home after dialysis
PTS stretcher patient profile	Male, 64 years old, suffering long term with bowel cancer, attending hospital for chemotherapy. Patient is bedridden

Table 5.6 Patient profiles for simulation

Simulate weight of patient

A patient conveyed by ambulance staff could range between a baby to an adult weighing 25 stone (158.8kg). When a patient is over 25 stone (158.8kg) with a body mass index over 40 they are classified as bariatric (Doherty, 12/10/2007, *Personal communication*). Previous studies have used mannequins to simulate a realistic patient weight of 75kg (Stanley and Ferreira, 2005).

A verbal risk assessment was carried out by EMAS risk and safety advisors to determine whether participants would be placed at risk during the trials. The team advised that staff would not be at risk if a mannequin weighing 17kg was used to simulate a patient. However, participants would be at risk if a person weighing ≥ 50Kg was used to simulate the patient.

The weight of a mannequin was tested during the pilot session with eight participants. Those participants identified that it was not sufficient to trial the chairs as 17kg did not provide sufficient weight for the tracked evacuation chairs to function correctly. The lack of weight provided poor traction so the tracks would not rotate as intended by the design. The above findings all suggested that additional weight was necessary. Therefore 13Kg of weight was added using props (sand bags), providing a total weight of 30Kg. The risk advisor recommended carrying the 17kg mannequin, adding the 13kg sand bags at the point of contact with the stairs for the tracked chairs only. This was not an appropriate solution, because all the chairs needed to be compared under the same weight conditions and the participants felt that additional weight should be added for realism. There was a conflict between participant ethics and collecting valid, reliable and unbiased data, so the design of the trials was reconsidered to allow for the additional weight without putting staff at risk:

1. The combined weight of the mannequin and props weighed a maximum of 30kg
2. The sequence order was randomised to allow a mixture of stretchers and chairs being evaluated during each day, ensuring that all 12 chairs were not evaluated on one day. This ensured the weight carried during each day was reduced.
3. A rest period was provided after each trial to allow participants to recuperate before carrying out the next trial. EMAS Director of Operations suggested that the level of manual handling carried out would not be a problem providing the crews were given ample rest periods (Whiting, 02/02/2006, *Personal communication*)
4. A maximum of 60 minutes lunch period was provided for participants to recuperate
5. Staff were advised to request prolonged rest periods where necessary
6. The weight required to assess the chairs was discussed with participants to account for differences in physical abilities prior to starting the trials. Any staff concerned about carrying the full 30Kg would be able to carry the 17kg mannequin without additional weight.
7. Staff were asked to carry out an individual manual handling risk assessment of the task before each trial and decide whether it was safe to continue with the evaluations. If staff felt at any risk when carrying 30kg they would be asked to only carry the 17kg mannequin. If they felt at risk conducting the trials with only 17kg they would be asked to inform the researcher and the trials would end.
8. The EMAS back-care advisor was present on the first day of the trials and was asked to advise if he felt the staff were put at risk.

Crew	Participants	Weight conditions
Crew 1 (A&E)	2 male	30kg load
Crew 2 (A&E)	2 male	30kg load
Crew 3 (A&E)	2 male	30kg load
Crew 4 (A&E)	1 male, 1 female	17kg load
Crew 5 (PTS)	2 female	17kg load
Crew 6 (PTS)	2 male	30kg load
Crew 7 (PTS)	2 male	30kg load
Crew 8 (PTS)	2 male	30kg load

Table 5.7 Weight carried

Step 7: Controlling weight; variance within trials

Two of the eight crews (crew 4 - A&E and crew 5-PTS) found that 17Kg was adequate to trial the equipment and chose not to add the additional 13Kg. It was felt that this was a suitable solution as long as each participant was trialling each chair under the same weight.

However, following the individual manual handling risk assessments carried out by participants during the trials, a number of participants opted not to carry additional weight on certain chairs due to the cumulative manual handling experienced during the trial. Five chairs were trialled by some participants with a varying weight (The Ibex TranSeat, the EZ Glide, the StairPRO, the Spencer 455/B 4 wheels and the Stairclimber chair).

Step 7a: EZ Glide and StairPRO

Crew 4 and 5 evaluated the EZ glide and StairPRO with 17kg until they reached the top of the stairway, where they added an additional 13kg to descend the stairs. The additional 13kg was maintained on the carpeted floor rather than disrupting the trial further by removing the weight at the bottom of the stairs.

Step 7b: Ibex TranSeat

The Ibex was found to require additional weight for the tracks to function correctly and so crew 4 and 5 needed to add the additional 13kg load during the evaluation of the Ibex. These crews were asked to carry out a risk assessment before using the additional 13kg and to decide when it was necessary to add this weight. The weight was needed on stair ascent and stair descent for the chair to function as the manufacturers intended. Crew 4 added the weight at the start of each trial carried out with the Ibex and so had additional weight all the way through the trials. Crew 5 added the weight at the base of the stairs, so had additional weight on stair ascent, descent and on the carpeted floor.

Step 7c: Stairclimber

When making their individual manual handling risk assessments crew 2 and crew 7 carried a load of 30kg on all chairs except the Stairclimber on which they carried 17kg. This is not believed to have impacted on the results because the Stairclimber is an automated chair, so the weight would have been supported by the chair, not the participant, so the amount of weight carried would not have much significance on the evaluation.

Step 7d: Spencer 455/B (4 wheel carry chair)

When operating the Spencer 4 wheel chair, crew 1 carried a load of 17kg during the first evaluation and 30kg during the second evaluation. This was considered to be the result of their individual manual handling risk assessment. After the first evaluation they may have felt rested enough to carry the extra weight in the following evaluation.

Weight issues

Weight carried on the chairs was found to be a big problem in the user trials. In hindsight, the option of carrying additional weight was not ideal because of the loss of consistency in weight between trials. There were difficulties controlling the amount of weight carried on each chair because the participants did not understand the importance of the controlled comparisons. It was not possible to explain the importance of controlled weight because it may have been interpreted as coercion. In hindsight the solution may have been to conduct the trials over a longer period, for example three days, and add discrete weight to the mannequin itself, fixing it in position so that there was no way of participants using different weights on the equipment. Participants would be informed of the weight before the trials and would agree or disagree to participate based on the weight carried. Participants would carry out their risk assessments prior to the trial and either opt in or out of each trial.

A further solution to this problem would have been to collect data and evaluate the equipment over a longer period so the weight carried in one day would have been reduced. However because the participants worked for the Ambulance Service their availability was limited.

Participants needed the option not to carry the extra load, because it would have been unethical to insist they carry loads which they were not physically capable of. This obviously impacted on the researchers' ability to control the weight of the patient so it could be argued that these results should be excluded. For the purpose of the evaluation it was felt that it was important to include these results, highlighting the variance in the protocol.

Step 8: Define performance criteria for testing

The focus groups indicated a number of criteria which were tested in the user trials, through task simulations and data collection and analysis. The criteria tested were:

1. Lifting and carrying
2. Bending / posture
3. Flexibility of equipment
4. Stability

The individual features of the equipment were not evaluated due to the distinct differences between products. Features were not standardised across the chairs evaluated. For example, not all chairs had arm rests, foot rests or brakes. Table 10.6 shows the distribution of features per chair and Table 10.7 shows the distribution of features per stretcher. The equipment features were too different to conduct a statistical comparative analysis. Comparatively evaluating equipment features with such inherent differences would have introduced bias. Each chair was designed to aid the same task, conveying a patient from the home. Therefore, they were compared in terms of the performance during this task. To compare the features of the chairs they would have to be broken down into specific categories and each feature weighted in terms of their importance.

Feature	(c)A	(c)B	(c)C	(c)D	(c)E	(c)F	(c)G	(c)H	(c)I	(c)J	(c)K	(c)L
Number of wheels	4	2	8	2	8	2	4	2	2	4	4	2
Brakes	√		√	√			√			√	√	√
Tracks				√				√			√	√
Head rest	√				√							√
Drug storage	√			√								
Arm rest	√			√		√	√		√	√		√
Foot rest	√	√	√	√	√	√	√	√	√	√	√	√
Lifting handle				√		√	√		√	√	√	√
Flexible HE handles	√		√	√	√			√				√
Flexible FE handles				√		√	√		√	√	√	√

Key:

Label	Product
(c) A	Cmax
(c) B	Compact 2
(c) C	Compact 3
(c) D	EZ Glide
(c) E	Sirocco
(c) F	Pensi 41-10-20 (2 Wheels)
(c) G	Pensi 41-11-20 (4 wheels)
(c) H	Ibex Transeat
(c) I	Spencer 450 (2 wheels)
(c) J	Spencer 420 Blue
(c) K	Spencer 455/B (4 Wheels)
(c) L	StairPRO

Table 5.8 Chair features checklist

Feature	A	B	C	D
Brakes	2	4	4	2
Hydraulic lift assist	√	√	√	√
Head rest		√	√	
Arm rest	√	√	√	√
Direction lock for wheels				√
Chair conversion				√
O2 storage				√
Drip stand				√

Key:

Label	Stretcher
(s) A	Falcon 6
(s) B	Pegasus
(s) C	Parensi
(s) D	MedAssist

Table 5.9 Stretcher features checklist

The focus group results (See section 5.4.1.2) identified storage as an important aspect of transportation. Carrying oxygen and bags whilst trying to carry out the conveyance tasks was felt to be an issue relating to working practice rather than usability and manual handling issues. Therefore storage was not considered for evaluation. The trials did not evaluate the worst case scenario but looked instead at the most frequently occurring situations.

Step 9: Define a trial site and route

An experimental trial route was developed incorporating all internal constraints highlighted in the preliminary investigations (Table 5.10; Figure 5.3).

Obstacle number	Description
1 (Start of trial)	Confined spaces (manoeuvring through corridors on smooth flooring)
2	Manual handling (kerb negotiation)
3	Confined spaces (manoeuvring through confined doorways)
4	Prolonged manual handling (stair-way negotiation)
5 (End of trial)	Confined spaces (manoeuvring through corridors on carpeted flooring)

Table 5.10 Obstacles throughout trial route

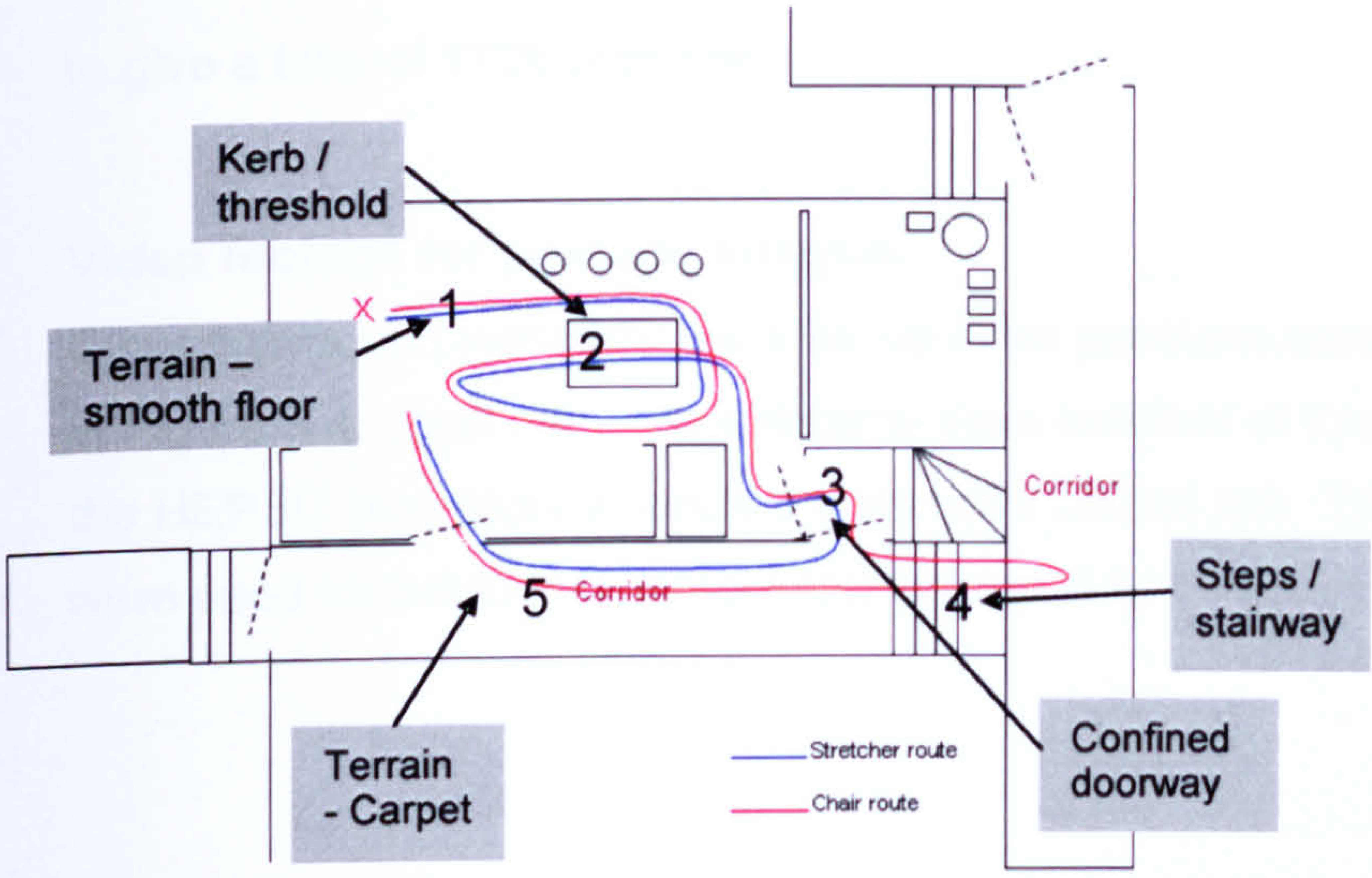


Figure 5.3 Trial route for carry chairs and stretchers

During the chair trials participants followed the red line outlined in Figure 5.3. This led the staff around a winding corridor (1), over a kerb (2), out through the confined double doorway (3) into the outside corridor. Participants transported the chairs up and down the staircase (4) and then over the carpeted flooring and through the second doorway (5).

During the stretcher trials the participants followed the blue route (Figure 5.3). This was a similar route to the chair trials but the stretchers were not transported up and down the staircase (4) because this task is not carried out with stretchers in the field.

Step 10: Define measurement technique

Questionnaire

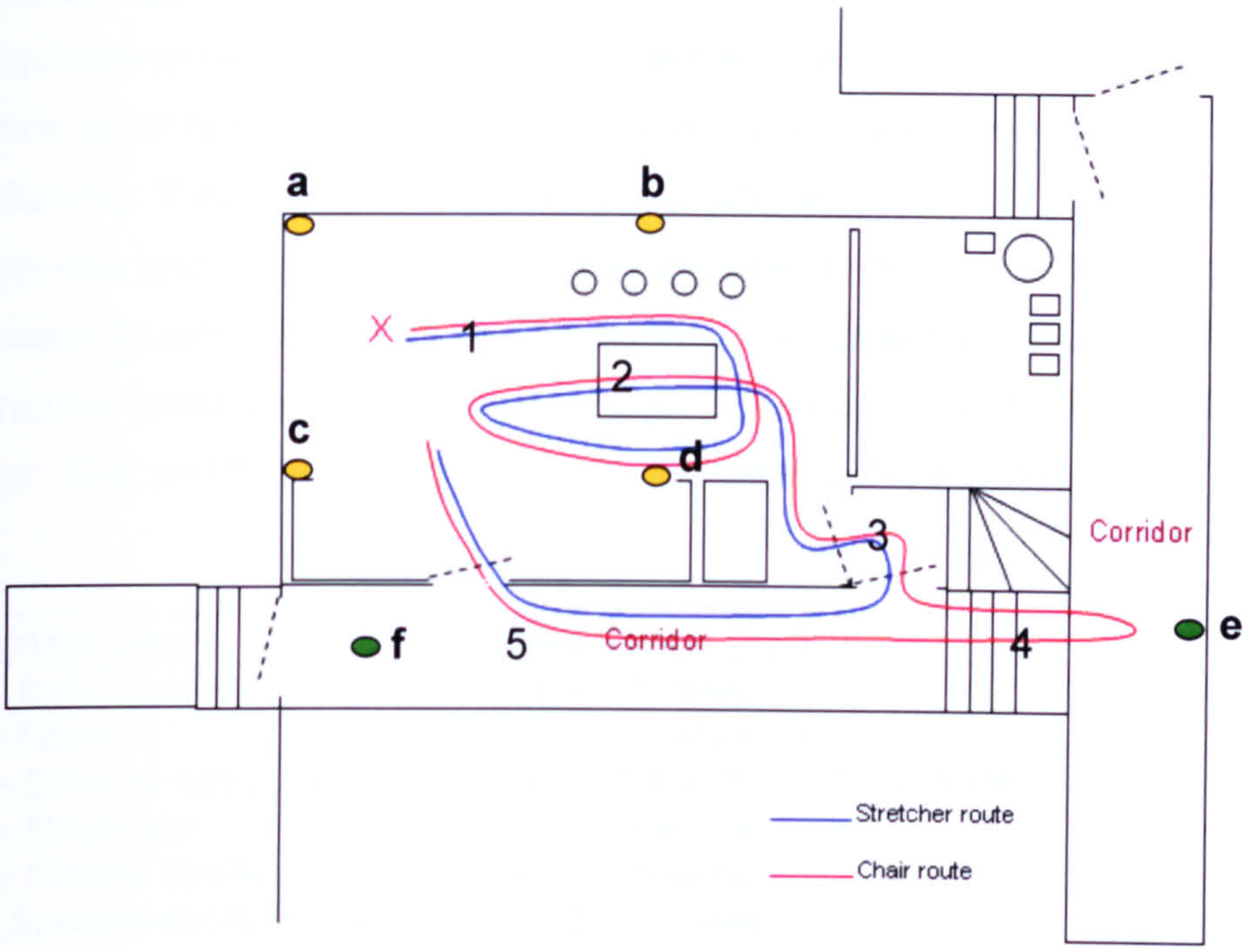
A questionnaire was developed to rate and identify usability issues experienced during each stage of the user trial. Measurement outcomes were ease of use, stability, coupling, posture and level of manual handling. Aspects of all the individual tasks were rated in terms of usability, and comment boxes were provided for any unprecedented events or issues experienced during each trial. All participants completed a questionnaire for each product after conducting each trial.

Postural analysis

The postural analysis data were collected from the video footage taken during the user trials. The worst case postures adopted during the manual handling tasks were analysed to identify which equipment posed the greatest risk to staff when carrying out the tasks. 1344 chair postures and 384 stretcher postures were analysed using REBA, to give a total of 1728 postures.

Video footage for postural analysis

Camcorders and webcams were set up in six positions around the trial route, as shown in Figure 5.4. Wall mounted webcams were installed at four fixed locations a,b,c & d in the HEPSU laboratory where the trials were carried out. Tripod mounted cameras were used for additional camera locations (e & f).



Key:

- Webcam locations
- Tripod mounted camera locations

Figure 5.4 Camera locations

The fixed webcams captured all activities which occurred inside the laboratory, including negotiation of the winding corridor, the kerb and the double doors. The tripod mounted cameras captured staff movements when manoeuvring the stretcher out through the outer double door, through the corridor and the second doorway.

Step 11: Pilot data collection methods

The questionnaire was piloted with academic staff and ambulance staff to ensure that the questions were easy to understand, could not be misinterpreted, and all the important factors for analysis had been incorporated. All valid suggestions were incorporated into the final questionnaire.

The pilot user trials were carried out with operational and ex-operational A&E and PTS staff from the risk and safety team. During this session the equipment, questionnaires and recording procedures were tested as well as the analysis procedures.

Step 12: Create procedural task list

Latin squares were generated to randomise the order of equipment trialled to eliminate sequence order bias. Latin squares are tables which have an equal number of rows and columns. Treatments or variables are positioned inside the table, each occurring once per row and once per column. They are used to control variation in an experiment (Washington State University, WSU, accessed 07/12/2007). In this case the variables used were the product names. Tables 5.11 and 5.12 show the product order for A&E and PTS participants produced using Latin squares.

A&E Trial 4 day 1	A&E Trial 4 day 2
(c) H - Ibex TranSeat	(s) B – Pegasus
(s) A - Falcon 6	(c) C – Compact 3
(c) K – Spencer 420 (blue)	(c) F– Pensi 41-10-20 (2 Wheels)
(s) D – MedAssist	(c) L - Stair-pro
(s) C – Parensi Easilite	(c) E – Sirocco
(c) J - Spencer 455/B (4 wheels)	(c) D - EZ Glide
(c) B - Compact 2	(c) A - Stairclimber
(c) G - Pensi 41-11-20 (4 wheels)	(c) I – Spencer 450 (2 wheels)

Key	
(c)	Chair
(s)	Stretcher

Table 5.11 Example of product sequence for an A&E crew generated with Latin squares

PTS Trial 6 day 1	PTS Trial 6 day 2
(c) F – Pensi 41-10-20 (2 wheels)	(c) I – Spencer 450 (2 wheels)
(c) E – Sirocco	(s) H – Ibex TranSeat
(c) K – Spencer 420 (blue)	(c) B – Compact 2
(c) L – StairPRO	(s) C - Parensi Easilite
(s) D – MedAssist	(c) G - Pensi 4 wheels
(s) B – Pegasus	(c) A - Stairclimber
(c) J – Spencer 455/B (4 wheels)	(s) A - Falcon 6
(c) C – Compact 3	(c) D - EZ Glide

Table 5.12 Example of product sequence for a PTS crew generated with Latin squares

Step 13: Select participants

8 A&E participants and 8 PTS participants were recruited for the user trials with the aid of the operational management teams. A convenience sample was used due to the difficulty of accessing ambulance staff. At the time of the study the ambulance service had initiated a drive to get all ambulance staff out on the road. This conflicted with the need to have ambulance personnel as the end users evaluating the equipment. Meetings were held with operations managers and staff were allocated to participate.

The criteria for selection were that participants had to be fit and physically capable of carrying out the manual handling tasks. They had to have experience of using the standard mobility equipment used on EMAS ambulances.

A&E staff and PTS staff have different jobs but the constraints they work under are very similar. During the trials the crews conducted the same tasks but considered their own role, within A&E or PTS when responding to the questionnaires.

Step 14: Train and familiarise participants

All participants were given training and equipment familiarisation to ensure each product was trialled under the same conditions. Training was provided by a Training Instructor (also employed as a Back-care Advisor) with over twenty years experience of providing manual handling training for EMAS. Each piece of equipment was demonstrated to the participants during the morning session. This involved demonstrations of all individual features and simulations of lifting, carrying and manoeuvring tasks. After the demonstrations staff were provided with an afternoon to practice using all the equipment and gain familiarity. The PTS staff and A&E staff were trained on separate days due to pressures of work and the need to keep numbers to a minimum to provide effective training.

On the day each crew were given a period of time to again familiarise themselves with the equipment before carrying out the tasks.

Step 15: Brief participants

Participants were briefed during the training and familiarisation phase and again on the first day of each crews trials. A run through of the trial route, the conditions for testing and the tasks to be carried out were provided to ensure that all participants thoroughly understood the purpose of the trials and the trial procedures. Information sheets were provided to all participants before beginning each session.

Step 16: Gain informed consent

After providing all participants with a thorough briefing, each participant was asked to provide their informed consent prior to conducting the user trials. Signed consent was provided and questionnaires regarding the participants health status were completed.

All participants were recruited through the ambulance service who had indicated the staff members ability to participate in the user trials. This was accepted as a sufficient health status check for participation.

Step 17: Perform walkthrough

A walkthrough of the trial was performed ensuring that staff understood the tasks to be performed. Any questions were addressed during this walkthrough.

Step 18: Run user trials

The user trials were carried out, following the procedure outlined in Figure 5.2. The equipment was loaned for trials between March and June 2006. During this period the pilot studies, equipment training and user trials were carried out.

Date	Questionnaire planning
March 2006	Equipment loan period begins
March – April 2006	Questionnaire planning based on equipment design
April 2006	A&E user trials held
May 2006	PTS user trials held

Table 5.13 Trial time scale

Step 19: Take measurements

The questionnaires were provided to staff to complete after each trial. They were collected and stored in secure files. Video footage was captured of each user trial using the six cameras set up across the trial route.

Step 20: Analyse data

The data were analysed as described in Section 5.4.

Step 21: Provide recommendations

Conclusions were drawn and recommendations were made to the ambulance service and manufacturers.

5.4 Analysis and results

The following section presents the analysis and results of the preliminary investigation and the main investigation carried out in this study.

5.4.1 Preliminary investigation

5.4.1.1 Observations

The observations were analysed using HTA. HTA diagrams were developed for all observations in identifying the constraints in the working environment whilst operating mobility equipment. The constraints were then listed in order to prioritise for the user trials.

The constraints and performance issues highlighted through A&E and PTS observations were coded. 17 HTA's were developed from A&E observations, and 36 were developed from PTS observations. 53 HTA's were developed in total. The greater number of PTS observations were due to the routine calls carried out by staff. A&E work is much more sporadic so fewer observations were made during these shifts (See Appendix J for the full data set of HTA's). Table 5.14 highlights the issues identified by the A&E observations.

Primary code	Secondary code	HTA
Manual handling	Lifting	(HTA7;6.1)(HTA7;6.1.3)(HTA7;7.6.2)(HTA7;8)(HTA8;5.3)(HTA8;5.3.3) (HTA8;5.4)(HTA10;3.3)(HTA10;3.3.3)(HTA10;3.5)(HTA12;2.6.3)(HTA13;3.1)
	Manual handling	(HTA5;3.1)(HTA5;3.2)(HTA7;6.2.3)(HTA8;5.1)(HTA8;7)(HTA12;2.6.1) (HTA13;3.2)(HTA13;3.3)(HTA13;3.3.1.2)(HTA16;2)(HTA16;2.2.2)
	Manoeuvring	(HTA6;6)(HTA10;3.2)(HTA15;5)
	One man	(HTA8;5.3)
	Bending	(HTA5;3.2.1)(HTA7;6.1.1)(HTA8;5.3.2)(HTA12;2.4)
Environmental constraints	Threshold	(HTA8;5.3)(HTA13;3.1)
	Kerb	(HTA8;7)(HTA12;2.6.1)(HTA13;3.3)
	Step	(HTA8;5.3.3)(HTA8;5.4)
	Terrain	(HTA13;3.2)
Patient	Patient positioning	(HTA13;3.3.1.3)
	Patient discomfort	(HTA8;7.3)
Performance	Stability	(HTA8;7.2)
Wheelchair use	Wheelchair use	(HTA13;1)

Table 5.14 A&E HTA observation analysis

The HTA for A&E observations identified five overall themes; manual handling, environmental constraints, the patient, performance and wheelchair use. Manual handling issues and environmental constraints were identified in a number of observations. The secondary codes for manual handling highlight that lifting, bending, manoeuvring and general manual handling are all factors which affect A&E staff on the road. Environmental constraints such as thresholds, kerbs, steps and terrain have also been identified in the HTA's.

Primary code	Secondary code	HTA
Manual handling	Manual handling	(HTA3;13.6)(HTA4;11)(HTA8;8)(HTA8;10.2)(HTA12;6.1)((HTA15;7)(HTA16;8.2)(HTA22;3.3)(HTA25;8.7.1.1.1)(HTA25;8.7.2.3)(HTA27;3)(HTA29;4)
	Lifting	(HTA1;5.3.1)(HTA2;8.2)(HTA4;9.2)(HTA10;6)(HTA17;5.3)(HTA21;11)(HTA21;13)(HTA21;15)(HTA23;6.1)(HTA24;7)(HTA28;3)(HTA29;7)(HTA34;7.6.1)(HTA34;9.2)(HTA34;11.1)(HTA34;14)
	One man operation	(HTA25;11)
	Posture	(HTA11;2.1)(HTA21;15.2)
	Force	(HTA15;9.1)(HTA15;12.1)(HTA31;4.1.1)
Terrain	Gravel	(HTA2;3.1)
	Course road surface	(HTA7;3)
	Road indentations	(HTA7;13.1)
	Grating	(HTA4;17.1.1)
	Paving	(HTA6;7.2)
	Sand	(HTA14;3.2)
	Loose slabs	(HTA14;3.2)
	Chipped driveway	(HTA16;2.1)
	Slabbing	(HTA17;5.3)
	Carpet	(HTA26;9.2)
	Flooring	(HTA24;12.1)
Environmental constraints	Accessibility	(HTA2;4)(HTA2;5.2)(HTA8;3)(HTA8;10.2.1)(HTA14;5.1)
	Confined doorway	(HTA2;5)(HTA3;6.1)(HTA8;11.1.1)(HTA9;5.1)
	Manoeuvring around corners	(HTA35;2.1)(HTA35;2.2)
	Obstacles	(HTA2;10.1)(HTA14;3.3)(HTA27;2)(HTA34;13)
	Ramp	(HTA2;10.2)(HTA8;2.2)(HTA8;10.2.1)(HTA14;7.1)
	Gateway	(HTA6;7.3)
	Pathway	(HTA21;12)
	Threshold	(HTA10;6.1)(HTA17;5.3)(HTA21;13)(HTA21;15)(HTA27;3.2)(HTA29;7)(HTA34;9)
	Doorway	(HTA4;17.2)(HTA5;6.1)(HTA7;11)(HTA9;2.1)(HTA20;7.3)
	Kerb	(HTA4;17.3)(HTA5;7)(HTA6;7.1)(HTA7;13)(HTA21;11.2)(HTA25;4.1)(HTA29;4)(HTA33;6)
	Weather	(HTA25;4.2)
	Confined space	(HTA8;7.2)(HTA34;13)(HTA35;2.1)
	Lift	(HTA12;5.1)(HTA14;5.1)(HTA24;12.2)(HTA35;3.3)
Component design	Wheel alignment	(HTA20;7.4)
	Shock absorption	(HTA24;12.1.1)(HTA26;9.2.1)
	Malfunction	(HTA25;8.4.1)
	Obstruction	(HTA26;8)
	Component design	(HTA4;17.1.1)(HTA16;12.1.2.1)
Patient	Patient positioning	(HTA25;5.1)
	Patient possessions	(HTA8;1.1)(HTA9;3)(HTA12;2.3)(HTA24;11.1)
	Dignity	(HTA8;7.1)
	Patient condition	(HTA34;8.1)
Storage	Drug store	(HTA12;2.2)
	Oxygen storage	(HTA12;2.1)(HTA12;5.1)
Damage to property	Damage to property	(HTA8;11.2)
Trapping		(HTA24;9.6.1)

Table 5.15 PTS HTA observation analysis

The PTS observations identified 8 primary themes: Manual handling; Terrain; Environmental constraints; Component design; Patient; Storage; Damage to property and Trapping (Table 5.15). The most frequently occurring themes were Manual handling; Terrain and Environmental Constraints. Manual handling factors included lifting, posture, force and general manual handling. Environmental constraints identified in the HTA's included confined doorways, corners, obstacles, gateways, pathways, thresholds, kerbs, weather, confined spaces and lifts. Terrain included gravel, course road surfaces, road indentations, grating, paving, sand, loose slabs, chipped driveways, slabs, carpet and flooring. Other problems identified related to the equipment design and storage.

5.4.1.2 Focus groups

The focus group analysis identified 11 primary themes relating to mobility equipment and its use in the ambulance service. These themes were manual handling, environmental constraints, marketing, nationalisation, hygiene, working practice and issues affecting equipment, stretchers, chairs, the ambulance, and the patient. Primary, secondary and tertiary themes (codes) are identified in Table 5.16.

Primary code	Secondary Code	Tertiary Code	Pilot	A&E	PTS
Manual Handling	Carrying	Foot space carrying chairs on stairs	0	0	1
	Carrying	Carrying patients downstairs	3	1	0
	Carrying	Carrying patients upstairs	1	0	2
	Carrying	Lifting & carrying	2	9	3
	Working practice	Encouraging patient to walk	1	0	0
	Working practice	Emergency nature overrides safety	1	1	0
	Manual handling		1	2	1
	Potential for injury		3	2	0
	Transferring patients within the vehicle		0	0	1
	Educating the public		1	0	0
	'Brought in dead' patients		1	0	0
	Back-care		1	0	0
	Bending or posture		1	6	1
	Bariatric / obese patients		0	1	0
	Restrictions due to patient condition		0	1	0
	Sliding down instead of carrying		0	1	0
	Risk		0	2	0
	Mechanical aid		0	2	0
Environment constraints	Confined space		2	3	3
	Property	Accessibility	5	5	1
	Property	House boats	1	0	0
	Property	New build houses	0	2	0
	Property	Nursing homes	0	3	1
	Property	Bathrooms	0	1	0
	Property	Box rooms	0	1	0
	Indoor constraints	Lifts and elevators	0	3	0
	Indoor constraints	Corridors	0	2	0
	Indoor constraints	Obstacles in patients homes	0	0	1
	Terrain		3	3	2
	Terrain	Ice	1	0	0
	Terrain	Grass	0	3	0
	Outdoor constraints	Thresholds/kerbs	2	1	2
	Outdoor constraints	Uneven paths	0	1	0
	Outdoor constraints	Weather	0	0	2
	Vertical space	Slopes and ramps	0	3	1
	Vertical space	Stairs	3	8	1
	Vertical space	Spiral staircases	2	1	0
	Vertical space	Steps	3	3	0
Chair	Design	6-wheel chair technology	0	0	1
	Design	Tracks	1	1	0
	Design	Weight of chair	0	0	4
	Design	Wheelchair size	0	1	1

	Design	Wheelchair use on A&E	1	1	0
	Design	Biggest problem with equipment	0	1	0
	Design	Poor quality	0	2	0
	Equipment selection	Wheelchair use over carry chair use	0	0	2
	Mechanically assisted chair		0	2	0
Stretcher	Design	Weight of stretcher to pull	0	0	2
	Design	Hydraulics on stretcher	0	1	3
	Design	ITU and other hosp stretchers	0	2	0
	Design	Stretcher brakes	0	0	1
	Design	Stretcher dimensions	0	0	1
	Design	Storage of equipment on stretcher	0	3	0
	Design	Pulling position	0	2	0
	Manual handling	Lifting stretchers	1	0	2
	Confined spaces	Shortening stretcher frame	0	0	2
	Confined spaces	Stretcher convert into chair	1	0	2
	Number of stretchers on vehicle		0	1	0
	Constraints	Accessibility for stretchers	0	1	0
Equipment			0	2	0
	Weigh limits / capacity		0	2	0
	Not having right equipment		0	1	0
	Working practice	Speed of use	2	1	0
	Design	Trap hazards	0	0	1
	Design	Oxygen storage	0	0	1
	Design	Stability	3	0	4
	Design	Mechanised chairs	2	0	1
	Selection of equipment for a call		0	2	3
	Old models		1	1	1
	Research	Market awareness	1	1	2
	Use in environments	Flexibility	5	0	2
	Training		0	1	2
	Evaluation		0	1	0
	Technology		0	1	0
	Technology	Levitation	0	1	0
	Technology	Hoist	0	1	0
	Technology	Mangar Elk	0	1	0
Patient	Transfer		0	1	0
	Transfer	Supporting patients casts	0	0	1
	Larger patients		0	2	4
	Patient condition		0	3	0
	Patient positioning		0	1	2
	Patient safety		3	3	3
	Patients state of		2	2	0

	mind				
	Patient comfort		0	1	0
Marketing	Ambulance service need to direct market		1	0	0
	Manufacturer drives market		1	0	0
	People in procurement		1	0	0
Nationalisation	Legislation		1	3	0
	National contract		1	0	0
	Standardisation		1	0	0
Ambulance	Design		0	2	0
	Design	Storage of equipment on vehicle	2	3	2
	Design	Vehicle layout	0	2	0
	Design	Accommodating 2 stretchers	0	1	0
Hygiene	Infection control		0	2	0
	Cleaning procedures		0	2	0
Working Practice	Heat of the moment		1	1	0

Table 5.16 Thematic analysis of focus groups

Equipment types

The focus groups identified types of equipment familiar to the participants. The equipment investigation carried out in the preliminary phase found similar models on the market:

1. 6-wheel chair technology (Manually assisted stair-climber chairs)
2. Tracks (Evacuation chairs)
3. Wheelchair
4. Mechanised chairs (Automated stair-climber chairs)
5. Hydraulic stretcher (Lift-assist stretchers)
6. Stretcher which converts into a chair

5.4.1.3 Triangulation

The observation and focus group results were triangulated to identify the equipment, tasks and conditions required for evaluation in the user trials. The HTA data from the observations and the focus group data were coded drawing out similar themes. Where possible these themes were grouped to provide key equipment types, environmental variables, and tasks to include in the user trials. The two methods were combined to compensate for the limitations within each, for example, observations can only provide data regarding the equipment currently used on the ambulances, whereas the focus groups could capture experiences with other equipment types. The triangulated data from the preliminary investigation identified a number of constraints affecting equipment. These are listed in Table 5.17.

Accessibility outside and inside property	Terrain	Confined space	Manual handling
Threshold	Grass	Corridors	Lifting
Kerb	Gravel	Lifts / elevators	Carrying
Steps	Carpet	Doorway	Manoeuvring
Stairs	Flooring		
Slopes and ramps	Ice / water		
New build houses	Pathways		
Nursing homes			
Obstacles in peoples houses			

Table 5.17 Variables highlighted through preliminary analysis

Four main themes were drawn from the preliminary study for inclusion in the user trials: accessibility in and out of properties, terrain, confined spaces and manual handling. The results were used to develop the protocol for the user trials.

5.4.2 Main investigation - user trials

5.4.2.1 Chair evaluation

Quantitative questionnaire results

The results of the simulation questionnaire were analysed by ranking the sum of each participants ratings, followed by a sum of ranks. This allowed the variation in participants responses to be taken into account. The ranking for A&E and PTS crews for the chair trial are shown in Tables 5.18 and 5.19. The Stairclimber was ranked highest by both A&E and PTS.

A Friedman's ANOVA was carried out to determine the statistical significance of the results and to test the hypothesis that the Stairclimber was the preferred chair for both teams. The Friedman's test was used because it takes account of individual participant rankings when the same participants are used for each condition.

A&E

Product	Model	Type of chair	Final ranking
(C) A	Stairclimber	Mechanised chair	1
(C) E	Sirocco	3 wheel assisted chair	2
(C) D	EZ Glide	Tracked evacuation chair	3
(C) L	StairPRO	Tracked evacuation chair	4
(C) H	Ibex TranSeat	Tracked assisted chair	5
(C) B	Compact 2	Standard carry chair	5
(C) G	Pensi 41-11-20 (4 wheels)	Standard carry chair with 4 wheels	7
(C) J	Spencer 420 Blue	Standard carry chair with 4 wheels	8
(C) F	Pensi 41-10-20 (2 Wheels)	Standard carry chair	9
(C) K	Spencer 455/B (4 Wheels)	Standard carry chair	10
(C) C	Compact 3	3 wheel assisted chair	11
(C) I	Spencer 450 (2 wheels)	Standard carry chair	12

Table 5.18 A&E quantitative analysis ranking

The Friedman's ANOVA identified a significant difference between the chairs rated by A&E (χ^2 (11) = 51.65, p < 0.001).

PTS

Product	Model	Type of chair	Final ranking
(C) A	Stairclimber	Mechanised chair	1
(C) G	Pensi 41-11-20 (4 wheels)	Standard carry chair with 4 wheels	2
(C) K	Spencer 455/B (4 Wheels)	Standard carry chair with 4 wheels	3
(C) L	StairPRO	Tracked evacuation chair	4
(C) D	EZ Glide	Tracked evacuation chair	4
(C) F	Pensi 41-10-20 (2 Wheels)	Standard carry chair	6
(C) H	Ibex TranSeat	Tracked assisted chair	7
(C) B	Compact 2	Standard carry chair	8
(C) I	Spencer 420 Blue	Standard carry chair	9
(C) E	Sirocco	3 wheel assisted chair	10
(C) C	Compact 3	3 wheel assisted chair	11
(C) J	Spencer 450 (2 wheels)	Standard carry chair	12

Table 5.19 PTS quantitative analysis ranking

The PTS crews ranked the Stairclimber highest. The other high ranking chairs were those with four wheels. The Friedman's ANOVA found a significant difference between the chairs (χ^2 (11) = 47.34, p < 0.001).

A Mann Whitney test was carried out to identify whether there was significant difference between the overall rankings by A&E and PTS. This was testing the hypothesis that the two teams require different chairs to carry out their roles. There was no statistically significant difference between the A&E and PTS overall ranking (U=71.500, $p > 0.05$).

A Mann Whitney test was also carried out for each chair independently to identify whether there was significant difference between the A&E and PTS rankings for individual chairs. This was to test the hypothesis outlined above and to add depth to the analysis. Table 11.7 shows the results of the Mann Whitney test for each chair.

Chair	Mann Whitney U	P	Significance
Stairclimber	24	0.144	Non significant
Compact 2	14	0.056	Non significant
Compact 3	24.5	0.422	Non significant
EZglide	30	0.83	Non significant
Ibex TranSeat	23.5	0.366	Non significant
Pensi 41-10-20 (2 Wheels)	15.5	0.78	Non significant
Pensi 41-11-20 (4 wheels)	5.5	0.005	Significant
Sirocco	8	0.001	Significant
Spencer 450 (2 wheels)	18.5	0.14	Non significant
Spencer 455/B (4 Wheels)	13	0.045	Significant
Spencer 420 Blue	25	0.457	Non significant
StairPRO	28.5	0.705	Non significant
Overall	71.5	0.977	Non significant

Table 5.20 Results of Mann Whitney U test

The Pensi 41-11-20 (4 wheels), Spencer 455/B (4 Wheels) and Sirocco were the only chairs which had significance difference between the two teams rankings.

The difference between the A&E and PTS rankings for the Compact 2 was close to significant. If a larger sample size was used it could have increased power making the difference significant.

Qualitative questionnaire results

The issues identified with each piece of equipment during the user trials were coded thematically. The themes were grouped into negative (Table 5.21) and positive impact codes (Table 5.22). For the negative group, ten primary codes and 38 secondary codes were generated from the detailed thematic analysis of the chair data. The negative primary codes were task complication, design, performance, flexibility, manual handling, patients, operator positioning, component design, environment and overall dislike. The negative aspects for each chair can be seen in Table 5.21.

Primary coding	Secondary coding	Example	A	B	C	D	E	F	G	H	I	J	K	L
Task complication	Training	Need more training on the equipment to be confident in its use	4	0	0	0	0	0	0	0	0	0	0	0
	Practice	The equipment needs more training or practice than manual equipment	8	0	0	1	0	0	0	0	0	0	0	0
	User confidence	The chair needs to be used to gain confidence to move a patient	2	0	0	0	0	0	0	0	0	0	0	0
	Task complication	Constantly having to position and think about next step	1	0	0	0	0	0	0	0	0	0	0	0
	Responsibility	More responsibility for this end [head end] of chair when coming down [stairs]	0	0	0	1	0	0	0	0	0	0	0	1
	Track tension	Bit fiddly deciding correct tension on tracks	0	0	0	0	0	0	0	1	0	0	0	0
Design	Equipment component positioning	Handles on back of chair seem high	1	2	3	8	5	6	3	0	6	13	4	5
	Superfluous component	Head end handles are superfluous	0	0	0	0	0	0	1	0	0	0	2	0
	Intrusion into patient space	Due to patient being hit on back of head by stomach and hands digging into shoulders	0	0	0	0	0	0	0	0	1	1	0	0
	Design	Patient headrest would improve manoeuvring chair	0	0	0	0	0	0	0	0	0	0	1	0
Performance	Chair motion	The chair jolts on every step when pulling to the stair riser before its next action	2	0	0	0	0	0	0	0	0	0	0	0
	Stability	Chair very unstable on the way up, jolts	2	1	7	1	0	1	0	0	4	4	0	0
	Mechanical reliability	Only problem would be motor or battery fault / failure	1	0	0	0	0	0	0	0	0	0	0	0
	Noise	It is noisy and bumpy	1	0	0	0	0	0	0	0	0	0	0	0
	Tactile feedback	When on front step felt as though I was wheeling on the ground, had to get really low	0	0	1	0	0	0	0	0	0	0	0	0
	Size	Chair too big in confined space	0	0	0	0	5	0	0	0	0	0	0	0
	Friction	Turning on two wheels more friction if on floor	0	0	0	0	2	0	0	0	0	0	0	0
	Balance	With only one set of wheels you were having to balance the patient	0	0	0	0	0	0	0	1	6	4	0	0
	Restricted view of operation	Difficult to judge the position of the legs when coming to a stop	1	4	0	0	0	0	0	8	0	0	0	0
	Safety	No real brakes assistance	0	0	0	0	1	0	0	0	0	0	0	0
	Control	Poor control at the bottom of the stairs	0	0	0	0	1	0	0	0	0	0	0	0

	Operator stability	Chair tends to pull you forwards	0	0	0	0	0	0	0	0	2	0	0	0
Flexibility	Access on stairs	No good for normal stairs, only straight staircases	1	0	1	0	2	0	0	0	0	0	0	0
Manual handling	Manoeuvrability	If the patient was heavier turning the chair would be more difficult	0	2	5	0	2	4	0	0	6	1	0	0
	Body under strain	Reversing up stairs at head end puts strain on lumbar area of back	0	7	0	0	0	1	0	1	2	0	0	0
	Manual handling	Heavy patients very difficult	0	4	2	2	1	4	1	1	1	9	1	3
	Posture	Continually bending to manoeuvre lower aspect of chair	0	1	0	0	4	0	4	4	6	9	0	2
Patient	Patient positioning	Patients head tend to fall back at time and is propped up by the head end operators abdomen	0	8	0	2	0	4	4	3	12	7	10	2
	Patient ease	Patient may feel a little unsafe	0	0	0	1	0	0	2	0	0	0	2	0
	Patient discomfort	Could dig into patients shoulder blade	0	0	0	0	1	0	0	1	0	0	0	0
	Patient ride quality	Jerkiness for patient may subside with user practice	1	0	0	0	0	0	0	6	0	0	0	0
Operator positioning		Had to bend over patient to actually lift all weight on forearms, patients head into stomach	0	6	1	1	2	1	1	3	12	7	0	0
Component design	Coupling	There are no handles as such on this particular carry chair	0	1	0	0	0	0	1	2	0	9	0	0
	Component size	Front wheels too small to get over small level differences	0	0	1	0	0	0	0	0	0	3	0	0
	Component design	Lower handles too fussy to keep altering. Awkward angle to steady chair if needed	0	0	0	0	2	5	2	1	2	1	1	1
	Restricted view of operators feet	The need to be close to the chair makes seeing where your feet are a big problem	0	0	0	0	0	0	0	0	0	0	0	0
	Component interface	If the head restraint is used the head end handle doesn't always lock into place	0	0	0	0	0	0	0	0	0	0	0	2
Environment	Environmental capabilities	Extra tug needed if surface gets rough	0	1	0	1	1	1	0	1	2	3	0	0
Overall dislike	Overall dislike	Do not like this chair and would not like to work with it	0	0	0	0	1	0	0	0	0	0	0	0

Key:

Label	Product
A	Stairclimber
B	Compact 2
C	Compact 3
D	EZ Glide
E	Sirocco
F	Pensi 41-10-20 (2 Wheels)
G	Pensi 41-11-20 (4 wheels)
H	Ibex Transeat
I	Spencer 450 (2 wheels)
J	Spencer 420 Blue
K	Spencer 455/B (4 Wheels)
L	StairPRO

Table 5.21 Taxonomy of chair negative qualitative questionnaire data

For the positive group, 7 primary codes and 18 secondary codes were generated. The positive primary codes were performance, manual handling, component design, task complication, pleasure and patients. The positive aspects of each chair are identified in Table 5.22.

Primary codes	Secondary codes	Example	A	B	C	D	E	F	G	H	I	J	K	L
Performance	Ease of operation	Very easy with user confidence	1	0	1	0	0	0	1	0	0	0	0	0
	Quality	Once again nice equipment after user practice	2	0	0	0	0	0	1	0	0	0	0	0
	Visibility	Clearance from patient enables you to see where your feet are going	0	0	0	0	0	1	0	1	0	0	0	0
	Clearance	Give you good clearance from patient	0	0	0	0	0	1	0	0	0	0	0	0
	Wheelchair capability	Easy for one person as rides like a wheelchair	0	0	0	0	1	0	0	0	0	0	0	0
	One person manoeuvrability	One person can do easily	0	0	0	0	4	0	3	0	0	0	3	0
	Assistance	Only a small amount of help was needed getting down stairs	1	0	0	0	0	0	0	0	0	0	0	1
Manual handling	Manual handling	Would become very easy with regular use. Makes it simple to take even a heavy patient up and down	3	0	0	0	2	0	0	0	0	0	0	1
	Posture	Using bottom handles my back and my posture were straight not bent	0	0	0	0	0	1	1	0	0	1	0	0
	Manoeuvrability	I found the chair easier to manoeuvre using just the two rear wheels	1	0	0	0	0	0	0	0	0	0	1	0
Component design	Coupling	The handles are useful when lifting you are away from patients head	0	0	0	0	0	0	0	0	1	0	0	0
	Equipment component design	Cow horn type handles excellent	0	0	0	0	0	1	2	1	0	0	0	0
	Design feature	Descending feature very good	0	0	0	1	0	0	0	0	0	1	0	1
Design	Equipment component positioning	Better with foot handles fully extended	0	0	0	2	0	0	0	0	0	0	1	1
	Weight	The chair is quite light when moving through doorways etc	0	0	0	0	0	0	0	0	0	0	1	0
Task complication	Practice	Practice will lead to smoother operating	4	0	0	1	0	0	0	0	0	0	0	1
Pleasure	Enjoyment	Really did enjoy using this chair	0	0	0	0	0	1	0	0	0	0	0	0
Patient	Patient ride quality	The slower the more comfortable it feels for the patient	0	0	0	1	0	0	0	0	0	0	0	0

Key:

Label	Product
A	Stairclimber
B	Compact 2
C	Compact 3
D	EZ Glide
E	Sirocco
F	Pensi 41-10-20 (2 Wheels)
G	Pensi 41-11-20 (4 wheels)
H	Ibex TranSeat
I	Spencer 450 (2 wheels)
J	Spencer 420 Blue
K	Spencer 455/B (4 Wheels)
L	StairPRO

Table 5.22 Taxonomy of chair positive qualitative questionnaire data

(C) A – Stairclimber

The qualitative data for the Stairclimber were separated into negative and positive factors and coded thematically. Table 5.23 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative Coding	Example
Restricted view of operation	Difficult to judge the position of the legs when coming to a stop
Equipment component positioning	Handles on back of chair seem high
Training	Need more training on the equipment to be confident in its use
Chair motion	The chair jolts on every step when pulling to the stair riser before its next action
Stability	Chair very unstable on the way up, jolts
Patient ride quality	Jerkiness for patient may subside with user practice
Practice	The equipment needs more training or practice than manual equipment
User confidence	The chair needs to be used to gain confidence to move a patient
Access on stairs	No good for normal stairs, only straight staircases
Task complication	Constantly having to position and think about next step
Mechanical reliability	Only problem would be motor or battery fault / failure
Noise	It is noisy and bumpy but it would save a lot of hard work
Positive coding	**Example**
Manoeuvrability	I found the chair easier to manoeuvre using just the two rear wheels
Ease of operation	Very easy with user confidence
Practice	Practice will lead to smoother operating
Manual handling	Would become very easy with regular use. Makes it simple to take even a heavy patient up and down
Patient ride quality	The slower the more comfortable it seems for the patient
One man operation	You would only need guidance from your crew mate when stair climbing
Assistance	Still feel second person at foot end reassuring to 'controller' and also the patient
Quality	Once again nice equipment after user practice

Table 5.23 Negative and positive coding taxonomy for product (C) A

(C) B – Compact 2

The qualitative data for the Compact 2 were coded thematically. Table 5.24 provides the negative codes and an example quote showing the type of information the code was applied to. No positive aspects of the Compact 2 were identified by participants in the qualitative assessment.

Negative coding	Example
Patient positioning	Patients head tend to fall back at time and is propped up by the head end operators abdomen
Manoeuvrability	If the patient was heavier turning the chair would be more difficult
Body under strain	Reversing up stairs at head end puts strain on lumbar area of back
Operator positioning	Had to bend over patient to actually lift all weight on forearms, patients head into stomach
Patient ride quality	With the wheels on this chair the carpet joiner created a jolt for the patient
Coupling	There are no handles as such on this particular carry chair
Manual handling	Heavy patients very difficult
Stability	Slight ruff in carpet caused weight to shift
Posture	Continually bending to manoeuvre lower aspect of chair
Equipment component positioning	Needed adjustable handles at bottom of chair
Restricted view of operators feet	The need to be close to the chair makes seeing where your feet are a big problem
Environmental capabilities	Extra tug needed if surface gets rough

Table 5.24 Negative coding taxonomy for product (C) B

(C) C – Compact 3

The qualitative data for the Compact 3 were separated into negative and positive factors and coded thematically. Table 5.25 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative coding	Example
Stability	Chair tends to tilt if cornering too fast
Manoeuvrability	With four wheels on the floor at the back it was difficult to turn
Manual handling	You needed to push and pull to turn the chair
Equipment component positioning	The handle is too low
Patient ride quality	On the last step to the floor there is a jolt this is where the wheels have to line up when on the flat surface
Operator positioning	Needed to stoop to get hold of handles
Component size	Front wheels too small to get over small level differences
Access on stairs	Ok on straight stairs but not for normal staircases
Tactile feedback	When on front step felt as though I was wheeling on the ground, had to get really low
Positive coding	**Example**
Ease of operation	Quite easy with one person, maybe different with some weight

Table 5.25 Negative and positive coding taxonomy for product (C) C

(C) D – EZ Glide

The qualitative data for the EZ Glide were separated into negative and positive factors and coded thematically. Table 5.26 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative coding	**Example**
Stability	Slightest bump or carpet rail will make it unstable
Manual handling	If the hinged handles were a bit longer it would have been a lot more easier to lift over
Equipment component positioning	The upper handles to adjust longer would have made it easier going up on the stairs
Patient positioning	Patient very upright.
Patient ease	Patient may feel a little unsafe
Responsibility	More responsible for moving patient when descending
Practice	Initially mechanism difficult but when tried a few times ok with it
Operator positioning	Bottom handles a problem on the bottom and lower stairs they put you too low down
Environmental capabilities	Slightest bump or carpet rail will make it unstable
Positive coding	**Example**
Design feature	Descending feature very good
Practice	Initially mechanism difficult but when tried a few times ok with it
One person manoeuvring	One person can do easily
Equipment component positioning	Better with foot handles fully extended
Patient ride quality	Nice flowing motion descending

Table 5.26 Negative and positive coding taxonomy for product (C) D

(C) E – Sirocco

The qualitative data for the Sirocco were separated into negative and positive factors and coded thematically. Table 5.27 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative coding	Example
Equipment component positioning	Have to alter handles to manoeuvre on flat and change to longer to go upstairs - bit too flimsy
Operator positioning	Being by the head end I felt I was too far away due to the design of the handles
Ride quality	When reaching last step to come on to the ground there was a jolt in the chair
Size	Chair too big in confined space
Friction	Turning on two wheels more friction if on floor
Manoeuvrability	Wheels will not roll properly as four in contact with floor
Manual handling	Quite a lot of effort involved as pulling the patient upwards even with the rolling wheels
Accessibility in stairways	Would be unable to use on spiral stairways as wheels would not roll and chair quite bulky
Safety	No real brakes assistance
Component design	Lower handles too fussy to keep altering. Awkward angle to steady chair if needed.
Overall dislike	Do not like this chair and would not like to work with it
Posture	Coming down kerb using lower handles means you have to bend down very low
Control	Poor control at the bottom of the stairs
Environmental capabilities	Would be unable to use on spiral stairways as wheels would not roll and chair quite bulky
Patient discomfort	Quite nasty jolt as the last wheel comes down onto flat which would not be very pleasant for patient
Positive coding	**Example**
Equipment component design	Cow horn type handles excellent
Visibility	When using the lower handles I could see the wheels and the stair steps very easily

Table 5.27 Negative and positive coding taxonomy for product (C) E

(C) F – Pensi 41-10-20 (2 wheels)

The qualitative data for the Pensi 41-10-20 (2 wheels) were separated into negative and positive factors and coded thematically. Table 5.28 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative coding	**Example**
Equipment component positioning	Back of chair too low for my height
Manoeuvrability	4 wheels would make manoeuvring much easier
Component design	Extendable handles - all or nothing
Manual handling	Still have to lift whole system
Stability	Chair not too stable on two wheels
Body under strain	Because chair is tilted back all the time when moving about it would cause a lot of strain of the lower back
Patient positioning	Patient position on chair very upright feels like they are tipping forward
Operator positioning	Only problem is tipping back causing patient to come into contact with yourself in stomach area
Environmental capability	May need to extend handles to manoeuvre on rougher ground to make chair handle easier
Positive coding	**Example**
Enjoyment	Really did enjoy using this chair
Visibility	Clearance from patient enables you to see where your feet are going
Clearance	Give you good clearance from patient
Posture	Using bottom handles my back and my posture were straight not bent
Component design	The handles are very useful on this chair when carrying up stairs

Table 5.28 Negative and positive coding taxonomy for product (C) F

(C) G – Pensi 41-11-20 (4 wheels)

The qualitative data for the Pensi 41-11-20 (4 wheels) were separated into negative and positive factors and coded thematically. Table 5.29 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative coding	Example
Superfluous component	Head end handles are superfluous
Component design	The top handle is good, the hinged handle can move if the chair is tilted too far back
Patient positioning	Coming down stairs the patient was leaning forward due to the upright position of backrest
Operator positioning	Patients head was digging into my belly on way up
Equipment component positioning	The rear wheels kept catching my feet. Because they were directly below the handles
Patient ease	The chair is in an upright position which causes the patient to feel like he or she is leaning forward
Manual handling	Still quite a lot of effort required for safe lifting
Posture	Still have to bend low to perform lift but extension poles make it less intrusive to patient
Coupling	The handles (foot end) become more awkward the higher up the stairs till elbows were at a < 90°
Positive coding	**Example**
Equipment component design	Frame handles are a good height and the extended ones are ok
Quality	Nice to have a decent carry chair
One man manoeuvring	Easily handled by one person when pushing on level surfaces
Posture	Extending handles always aid posture
Ease of use	Easy to role chair away from top of stairs after performing lift due to putting down onto four wheels

Table 5.29 Negative and positive coding taxonomy for product (C) G

(C) H – Ibex TranSeat

The qualitative data for the Ibex TranSeat were separated into negative and positive factors and coded thematically. Table 5.30 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative coding	Example
Equipment component positioning	When going up stairs I feel the head end handle would be better extended than the position for normal use
Patient ride quality	Very bumpy for patient
Manual handling	hard to pull up stairs, bad posture, pulling on back
Posture	Where the handles are, you are very close to participants feet, have to bend down quite a way to lift frame
Body under strain	Hard to pull up stairs, bad posture, pulling on back
Component size	Tracks seem too short, jerky on stairs
Balance	Pulled forward by chair, could over balance and fall
Patient positioning	The patients feet are obstructing the handles
Track tension	Bit fiddly deciding correct tension on tracks
Coupling	The handles are too low and awkward in shape
Operator positioning	Where the handles are, you are very close to participants feet, have to bend down quite a way to lift frame
Component design	Wings of back of chair too shaped, could dig into patients shoulder blades
Patient discomfort	Could dig into patients shoulder blades
Environmental capabilities	The wheels are not appropriate for muddy or uneven surface, wheel mechanism would get caked in soil
Positive coding	**Example**
Wheelchair capability	Easy for one person as rides like a wheelchair
One man manoeuvre	Easy for person on own at head end
Manual handling	With the adjustable handles at the top and the tracks there was no lifting involved (mostly pulling) and pushing

Table 5.30 Negative and positive coding taxonomy for product (C) H

(C) I – Spencer 450 (2 wheels)

The qualitative data for the Spencer 450 (2 wheels) were separated into negative and positive factors and coded thematically. Table 5.31 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative coding	Example
Operator stability	Chair tends to pull you forwards
Patient positioning	Patient too upright and head leaning into my chest for support
Operator positioning	Patients head right into my stomach causing myself to extend arms away from myself
Equipment component positioning	Back of the chair is so low the patient head was pushing into my chest, unsteadying me
Stability	Chair too low and very upright. Not stable tipped back on wheels
Body under strain	Leaning over patient pulling on lower back
Balance	With only one set of wheels you were having to balance the patient
Component design	Handles do not extend
Posture	Had to keep bending to give chair pull as does not roll freely on wheels
Environmental capabilities	It was difficult to get the chair over door strips
Intrusion into patient space	Due to patient being hit on back of head by stomach and hands digging into shoulders
Ride quality	With small wheels the carpet join creates a jolt
Manoeuvrability	Needs another person to help steer from bottom
Manual handling	Too much bending and lifting involved
Positive coding	**Example**
Coupling	The handles are useful when lifting you are away from patients head

Table 5.31 Negative and positive coding taxonomy for product (C) I

(C) J – Spencer 420 (Blue)

The qualitative data for the Spencer 420 (blue) were separated into negative and positive factors and coded thematically. Table 5.32 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative coding	Example
Equipment component positioning	Fixed handle too low for me
Superfluous component	No need for lower set of fold out handles
Patient positioning	The patient is leaning forward somewhat due to the straightness of the backrest
Design	Patient headrest would improve manoeuvring chair
Manual handling	Unable to use arms as long levers
Patient ease	A less able patient may feel a bit vulnerable because of the feeling of tipping forward
Component design	Handles at foot end do not lock in position and can move freely during use
Positive coding	**Example**
Manoeuvrability	The chair is quite light when moving through doorways etc
Equipment component positioning	Lifting handles at foot of chair are very low to the ground but are a good length
Weight	The chair is quite light when moving through doorways etc
One man manoeuvring	Easily moved by one person if patient sitting properly

Table 5.32 Negative and positive coding taxonomy for product (C) J

(C) K – Spencer 455/B (4 wheels)

The qualitative data for the Spencer 455/B (4 wheels) were separated into negative and positive factors and coded thematically. Table 5.33 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative coding	Example
Balance	Chair felt off balance
Manual handling	Had to use force to get over carpet ridge
Intrusion on patient space	Holding frame catches patients back
Equipment component positioning	The handles are too low
Posture	Bending very low
Patient positioning	Patients head was in contact with my body, the back rest could be higher
Operator positioning	Felt as though I was leaning over all the time, the grip was not enough. Heavier patients would have problems
Coupling	Again patient would have been on my stomach area and affecting my grip
Component size	Wheels too small
Environmental capabilities	Small wheels ok on smooth floor, not good over tarmac / concrete would reduce ride quality for patient
Stability	Would be necessary to keep helping move chair as not stable on rougher surface at all
Manoeuvrability	When manoeuvring I would need to help all the time as I felt I was not very secure or stable with the chair
Component design	Handle no lock, arms had to be raised on this way up the stairs, not safe
Ride quality	Concrete would reduce ride quality for patient
Positive coding	**Example**
Design feature	The handles are useful on this chair when lifting up and down kerbs
Posture	With the extending lower handles I am upright when carrying up and down stairs, good posture

Table 5.33 Negative and positive coding taxonomy for product (C) K

(C) L - StairPRO

The qualitative data for the StairPRO were separated into negative and positive factors and coded thematically. Table 5.34 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative coding	Example
Component interface	If the head restraint is used the head end handle doesn't always lock into place
Equipment component positioning	Frame handles too high
Manual handling	Manual lifting going up stairs
Patient positioning	The patient seemed to be tilted towards as the chair was carried up the stairs
Responsibility	More responsibility for this end of chair coming down
Component design	Foot end handles have no locking mechanism and tend to slide into the frame
Posture	I had to stoop quite low to get at handles
Positive coding	**Example**
Practice	If the chair was used on a regular basis this operation would get easier for the crew
Design feature	Mechanised track is a good feature
Equipment component positioning	Nice to have variety of handle options
Wheelchair capability	This chair is like pushing a wheelchair there is no need to use both handles
Manual handling	Not too much efforts required at foot end coming down
Assistance	Only a small amount of help was needed when getting the patient down the stairs

Table 5.34 Negative and positive coding taxonomy for product (C) L

5.4.2.2 Stretcher evaluation

Quantitative questionnaire results

Four questionnaires, per attendant, per stretcher were analysed:

1. Lowered position, head end attendant
2. Lowered position, foot end attendant
3. Elevated position, head end attendant
4. Elevated position, foot end attendant

The stretchers were ranked in the same ways as the chairs. The data were ranked to identify the preferred stretcher for each team (see Tables 5.35 and 5.36). A&E crews identified the Ferno Pegasus as the preferred stretcher for use on A&E vehicles. PTS ranked the Parensi Easilite as the preferred stretcher for use on PTS vehicles.

A&E

Stretcher	Final ranking
Pegasus	1
Falcon 6	2
Parensi Easilite	3
MedAssist	4

Table 5.35 A&E quantitative questionnaire analysis

A Friedman's test was carried out to test the hypothesis that the Pegasus was the preferred stretcher for A&E crews. Significant difference was found between the A&E stretcher ratings (χ^2 (3) = 27.2, $p < 0.001$).

PTS

Product	Final ranking
Parensi	1
Pegasus	2
MedAssist	3
Falcon 6	4

Table 5.36 PTS quantitative questionnaire analysis

A Friedmans test was carried out to test the hypothesis that the Parensi was the preferred stretcher for PTS. No significant difference was identified between the PTS stretcher rankings (χ^2 (3) = 2.55, $p > 0.05$).

A Mann Whitney U test was carried out to identify whether there was significant difference between the A&E and PTS rankings for the stretchers. This was carried out to test the hypothesis that the teams required different stretchers to carry out their roles. There was no statistically significant difference between the A&E and PTS overall ranking (U=8, $p > 0.05$).

In order to add depth to the analysis a Mann Whitney test was carried out for the rankings of each individual stretcher. Table 5.37 shows the results of the Mann Whitney test for each stretcher.

Stretcher	Mann Whitney U	P	Significance
Falcon 6	20.5	0.194	Not significant
Pegasus	30	0.826	Not significant
Parensi Easilite	12	0.038	Significant
MedAssist	30	0.826	Not significant
Overall	8	1	Not significant

Table 5.37 Results of Mann Whitney U test

There was statistically significant difference between the A&E and PTS rankings for the Parensi Easilite stretcher. There was no statistically significant difference between the rankings for the other stretchers.

Qualitative questionnaire results

The issues identified with each stretcher during the user trials were coded thematically. The themes were grouped into negative impact and positive impact codes as with the chairs. For the negative group 7 primary codes, and 11 secondary codes were generated from the detailed thematic analysis of the stretcher data. The negative primary codes were flexibility, patient, manual handling, component design, design, performance and working practice. The negative aspects for each stretcher can be seen in Table 5.38.

Primary code	Secondary code	A	B	C	D
Flexibility	Flexibility	0	0	3	0
Patient	Patient positioning	0	0	1	0
Manual handling	Manual handling	3	3	2	7
Manual handling	Injury potential	1	0	1	2
Manual handling	Posture	0	1	3	1
Manual handling	Restriction of use	0	0	0	1
Component design	Equipment component positioning	0	1	1	0
Component design	Coupling	2	3	10	6
Component design	Equipment component dimensions	1	1	4	2
Component design	Obstruction	0	1	0	0
Design	Design improvements	0	0	1	0
Performance	Quality	0	0	0	2
Performance	Stability	0	1	0	0
Working practice	Working practice	2	0	0	0

Key:

Label	Stretcher
(s) A	Falcon 6
(s) B	Pegasus
(s) C	Parensi
(s) D	MedAssist

Table 5.38 Negative coding taxonomy for all stretchers

For the positive group 3 primary codes, and 3 secondary codes were generated from the detailed thematic analysis of the stretcher data. The positive primary codes were manual handling, component design and overall design. These aspects for each stretcher be seen in Table 5.39.

Primary code	Secondary code	A	B	C	D
Manual handling	Posture	2	0	1	0
Manual handling	Manoeuvrability	0	1	0	0
Component design	Coupling	0	1	0	0
Overall design		0	1	0	0

Key:

Label	Stretcher
(s) A	Falcon 6
(s) B	Pegasus
(s) C	Parensi
(s) D	MedAssist

Table 5.39 Positive coding taxonomy for all stretchers

The negative and positive coding for each stretcher are displayed in Tables 5.40 to 5.44.

(S) A – Falcon 6

The qualitative data for the Falcon 6 were separated into negative and positive factors and coded thematically. Table 5.40 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative code	Example	Fr	A&E	PTS
Coupling	When manoeuvring the trolley from the head end it is easier to use the frame rather than the handle	2	2	0
Working practice	When going up the kerb it seemed better using the handles	2	2	0
Manual handling	Very heavy to lift	3	2	1
Injury potential	No easy way to lift this up and down kerb, it is too heavy and awkward and carries a high risk of injury to crew	1	0	1
Equipment component dimensions	Handles are only wide enough for 1 hand. To lift separate parts of the handles are used	1	1	0
Positive code	**Example**	**Fr**	**A&E**	**PTS**
Posture	Better on posture	2	2	0

Table 5.40 Negative and positive coding taxonomy for product (S) A

(S) B – Pegasus

The qualitative data for the Pegasus were separated into negative and positive factors and coded thematically. Table 5.41 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative Code	Example	Fr	A&E	PTS
Coupling	Handles could be better	3	2	0
Manual handling	Heavier than other stretchers	3	3	0
Equipment component positioning	Handles could be wider	1	0	1
Posture	Quite heavy weight to lift at a low level	1	0	1
Equipment component dimensions	Handles could be wider	1	1	0
Obstruction	With the head rest in position did cause me a problem because I could not elevate the handle properly	1	0	1
Stability	Used side on method due to most stable way of manoeuvring over kerb	1	0	1
Positive code	**Example**	**Fr**	**A&E**	**PTS**
Coupling	When using extended handles enables to reach doors and hold open, also enables you to manoeuvre through doors safely	1	0	1
Overall design	Excellent	3	1	2

Table 5.41 Negative and positive coding taxonomy for product (S) B

(S) C – Parensi Easilite

The qualitative data for the Parensi-easilite were separated into negative and positive factors and coded thematically. Table 5.42 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative code	Example	Fr	A&E	PTS
Coupling	When using extended handle folded nothing to grip on to	10	5	5
Flexibility	Could do with a little more flexibility in the handles	3	0	3
Patient positioning	Difficult to lift stretcher over the kerb if patient is in the upright position	1	1	0
Manual handling	Stretcher very heavy to lift up and down kerb	2	1	1
Injury potential	High risk of injury	1	1	0
Equipment component positioning	Possibly foot end another few inches would have been useful in manoeuvring foot end	1	0	1
Design improvements	Rubber pedals might help	1	1	0
Posture	When using frame you are still bent over when lifting over kerb	3	1	2
Equipment component dimensions	Handle is a bit too low to push with when stretcher in lowered position	4	4	1
Positive code	**Example**	**Fr**	**A&E**	**PTS**
Posture	Felt more comfortable manoeuvring stretcher on flat surface. Posture improved	1	1	0

Table 5.42 Negative and positive coding taxonomy for product (S) C

(S) D – MedAssist

The qualitative data for the MedAssist were separated into negative and positive factors and coded thematically. Table 5.43 provides the negative and positive codes and an example quote showing the type of information the code was applied to.

Negative Code	Example	Fr	A&E	PTS
Coupling	I had to change from the extendable handles to the frame half way through a manoeuvre as I felt the handles were too long	6	0	6
Manual handling	This will hurt peoples backs	7	4	3
Posture	I seemed to be bent over if I were to use the frame coming down the kerb	1	0	1
Equipment component dimensions	Again handle a bit too long needs more adjustment	2	1	1
Quality	Extending handles are flimsy	2	1	0
Potential Injury	Back breaking manoeuvre	2	2	0
Restriction of use	No way to lift stretcher up kerb when patient is in upright position – no handles	1	1	0
Positive Code	**Example**	**Fr**	**A&E**	**PTS**
Manoeuvrability	Very smooth, easy to manoeuvre	1	1	0

Table 5.43 Negative and positive coding taxonomy for product (S) D

5.4.3 Main investigation – Postural analysis

5.4.3.1 Chair analysis and results

A postural analysis was conducted with the audio-visual footage using REBA (Hignett & McAtamney, 2000). The footage was downloaded and still photographs were captured showing the operators postures when manoeuvring or lifting the chairs. The postures sampled for analysis were in accordance with recommended selection criteria (Hignett, 2005) and were those:

1. Most frequently occurring
2. Requiring the most muscle activity and greatest forces
3. Most extreme, unstable and awkward, especially where force is exerted
4. Known to cause discomfort
5. Most likely to be improved by intervention

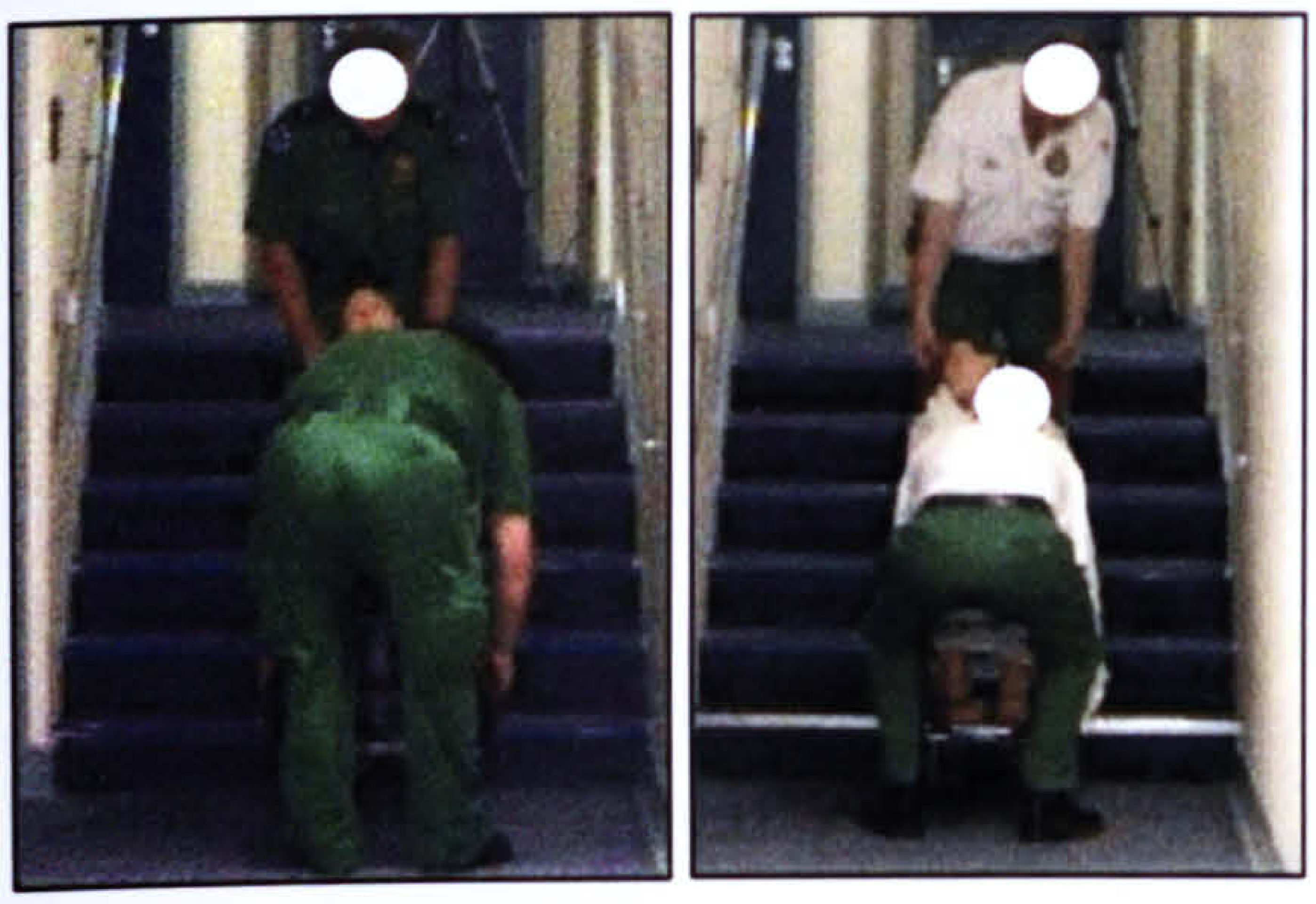


Figure 5.5 Photographic stills for chair analysis, postures 1 and 2 for A&E and PTS

Seven postures were selected per participant, these were:

1. Posture adopted when lifting the chair at the head end of the patient
2. Posture adopted when lifting the chair at the foot end of the patient
3. Posture adopted partway up the stairs at the head end of the patient
4. Posture adopted partway up the stairs at the foot end of the patient
5. Posture adopted partway down the stairs at the head end of the patient
6. Posture adopted partway down the stairs at the foot end of the patient
7. Posture adopted when lowering chair to floor at the foot end of the patient

1344 postures adopted during chair use were analysed using REBA. The risk ratings for each chair were calculated for each individual participant on a worksheet. The sum of the REBA scores per participant was calculated for each piece of equipment. The chairs were then ranked for each participant identifying which chair posed the most and least risk to each participant according to the overall REBA scores. A sum of the ranks was calculated to identify the overall equipment ranking, taking participant individuality into account (i.e. natural postural differences between participants). This provided an overall ranking for the chairs and the stretchers (Table 5.44). A Friedman's test was carried out with the sum of ranks to test the hypothesis that the Stairclimber posed the least risk to the participants when carrying out the manual handling tasks.

Product	Model	Type of chair	Final ranking
(C) A	Stairclimber	Mechanised chair	1
(C) G	Pensi 41-11-20 (4 wheels)	Standard carry chair with 4 wheels	2
(C) K	Spencer 455/B (4 Wheels)	Standard carry chair with 4 wheels	3
(C) F	Pensi 41-10-20 (2 Wheels)	Standard carry chair	4
(C) J	Spencer 420 Blue	Standard carry chair	5
(C) I	Spencer 450 (2 wheels)	Standard carry chair	5
(C) D	EZ Glide	Tracked evacuation chair	7
(C) L	StairPRO	Tracked evacuation chair	8
(C) B	Compact 2	Standard carry chair	9
(C) E	Sirocco	3 wheel assisted chair	10
(C) H	Ibex TranSeat	Tracked Stairclimber chair	11
(C) C	Compact 3	3 wheel assisted chair	12

Key:

Label	Product
A	Stairclimber
B	Compact 2
C	Compact 3
D	EZ Glide
E	Sirocco
F	Pensi 41-10-20 (2 Wheels)
G	Pensi 41-11-20 (4 wheels)
H	Ibex TranSeat
I	Spencer 450 (2 wheels)
J	Spencer 420 Blue
K	Spencer 455/B (4 Wheels)
L	StairPRO

Table 5.44 Chair postural analysis ranking

Significant difference was found between the chair postural risk rankings proving the hypothesis (χ^2 (11) = 29.6, $p < 0.001$).

5.4.3.2 Stretcher analysis and results

Data collected from the video footage were reduced as per the chair evaluation. For the stretcher analysis, six postures were selected per participant per product:

1. Posture adopted lifting stretcher up a kerb at the head end
2. Posture adopted lifting stretcher up a kerb at the foot end
3. Posture adopted lowering stretcher down a kerb at the head end
4. Posture adopted lowering stretcher down a kerb at the foot end
5. Posture adopted when manoeuvring stretcher around a corner at the head end
6. Posture adopted when manoeuvring stretcher around a corner at the foot end (See Figure 5.6 for examples of postures analysed).

Figure 5.6 Photographic stills for stretcher analysis, postures 1 and 2 for A&E and PTS

All postures analysed were adopted whilst lifting and manoeuvring the stretcher in the lowered position. The elevated lifting positions were not analysed. This was because the task was more hazardous when using a lowered stretcher. Posture selection followed the format outlined by Hignett (2005). 384 postures adopted during stretcher use were analysed for comparison. A sum of ranks was calculated to identify the preferred stretcher in terms of reduced manual handling risk (Table 5.45).

Product	Sum of ranks	Final ranking
Parensi	25	1
MedAssist	34	2
Falcon 6	42	3
Pegasus	52	4

Table 5.45 Stretcher postural analysis ranking

A Friedman's test was carried out to test the hypothesis that the Parensi stretcher posed the least risk to A&E and PTS staff. No significant difference was found between the stretcher postural risk rankings (χ^2 (3) = -5.7, $p > 0.05$).

5.4.4 Main investigation triangulation

5.4.4.1 Chair results

Figure 5.7 shows the triangulation of the chair data and results. The quantitative and qualitative questionnaire data and the postural analysis rankings for each chair can be seen in the individual triangles. The top triangle displays the Stairclimber findings. This was placed as the most important in the hierarchy due it being the preferred chair in terms of reduced postural risk and for both A&E and PTS participants. The Stairclimber also had no manual handling issues identified by participants during the trials. Chapter 5 identified that ambulance staff consider the reduction of manual handling to be a priority.

Please note there is no hierarchy of results depicted in the diagram. The chairs in Figure 5.7 were organised by the postural rating scores from top down, and left to right, to present the overall data, not to reflect the participant preferences.

The triangulation allowed several conclusions to be drawn:

1. The Stairclimber is the overall best chair in every aspect
2. Only the mechanised chair has issues with task complication. As can be seen from this study and the previous study, automation adds complication to a task
3. The three 6 wheel-assisted chairs have issues of flexibility highlighted
4. All chairs were found to have design issues
5. The four wheeled standard carry chairs and the StairPRO were the only chairs not to have performance issues, this may be due to simplicity and ease of use
6. The Stairclimber was the only chair not to have manual handling issues and the previous study highlighted that the reduction of manual handling is a primary concern for ambulance staff
7. Problems were predicted for the patient for all chairs except the Stairclimber
8. Operator positioning was identified as a problem for all chairs except for the Stairclimber, the StairPRO and the Spencer 455/B, 4 wheeled chair
9. Component design was a problem for all chairs except the Stairclimber and the EZ Glide

10. The environment impacted on all chairs except the Stairclimber, the Pensi 41-11-20 4 wheeled chair and the Spencer 455/B 4 wheeled chair.

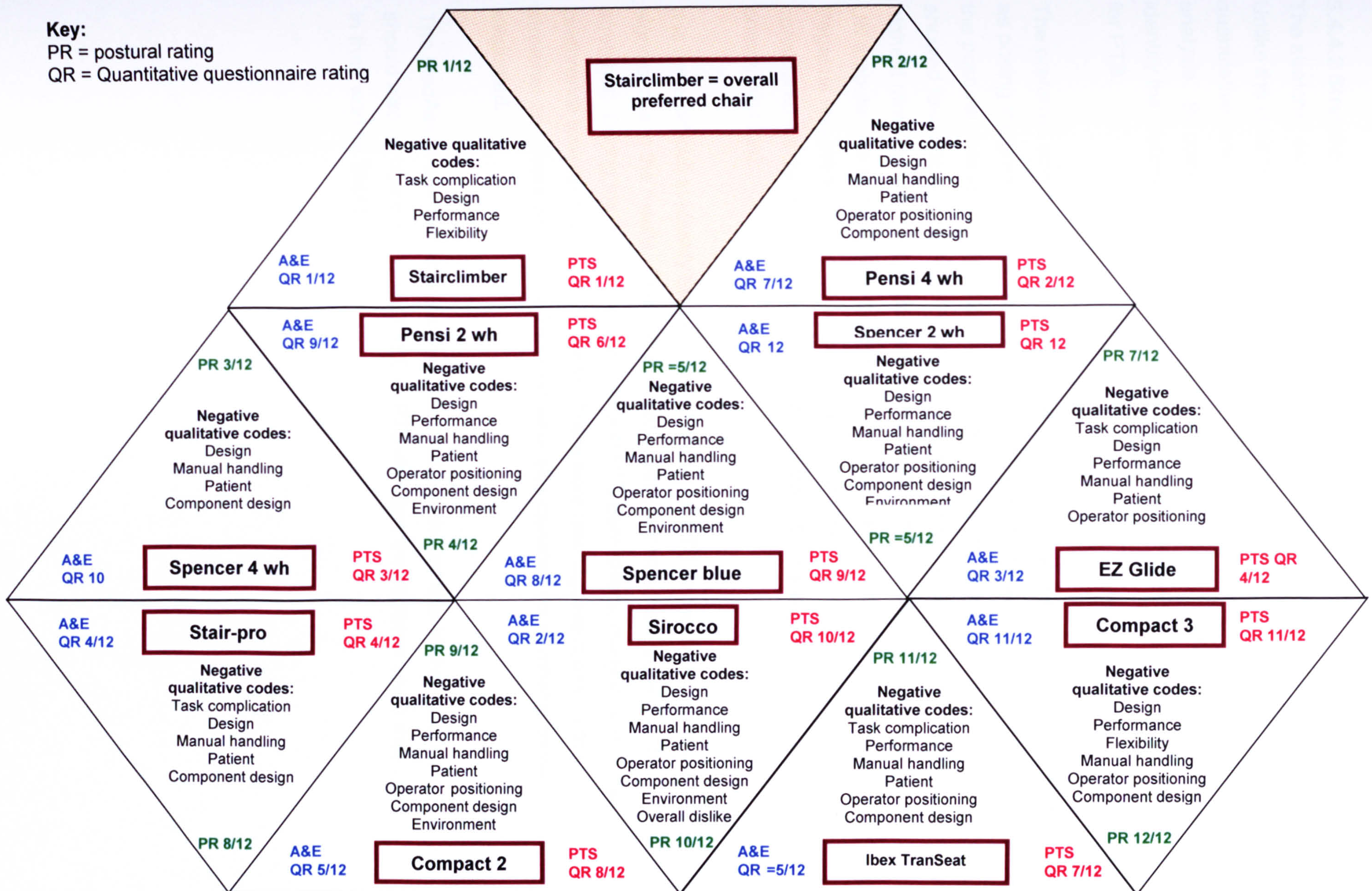


Figure 5.7 Triangulation of chair data

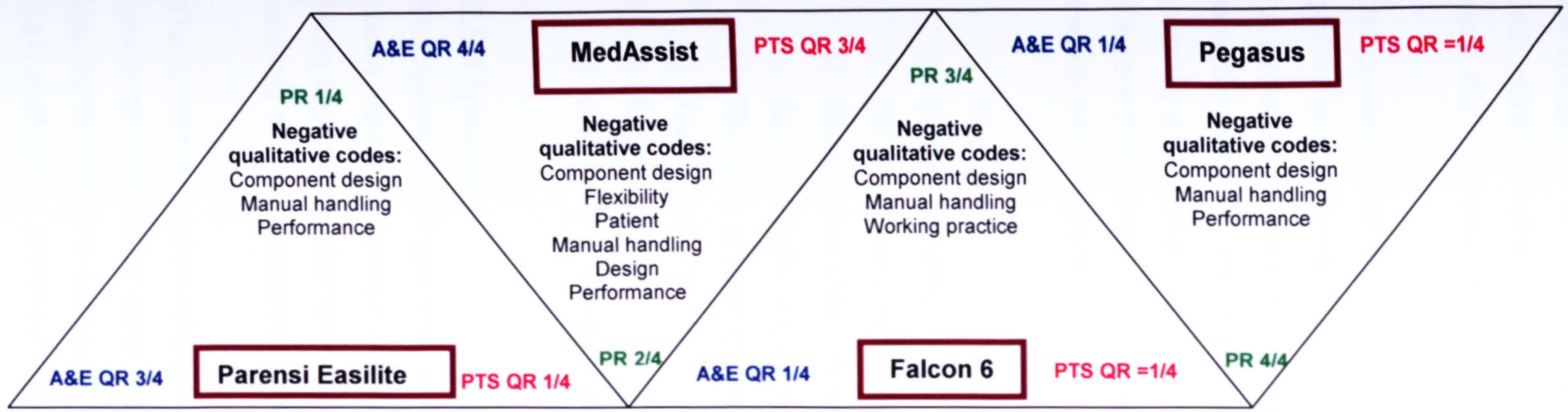
5.4.4.2 Stretcher results

The stretcher data were triangulated to provide a thorough analysis (Figure 5.8). Unlike the chair results, statistical tests showed no significant difference in the PTS quantitative rankings or the postural ranking. Significance was only found in the A&E analysis. By combining the ranking results with the qualitative results it was possible to identify the preferred stretcher for A&E participants and predict the preferred stretcher for PTS.

The preferred stretcher for A&E was the Pegasus. Although the Pegasus was ranked as posing the greatest risk to staff, no significant difference was found in the results, so the postural data for the stretchers can not be relied upon. The qualitative results showed few problems with the Pegasus during the manoeuvrability tasks. The second highest ranking stretcher for A&E was the Falcon 6. This stretcher was used on most UK ambulances at the time of this study and had similar features to the Pegasus. The Pegasus was introduced to the market after the Falcon 6, and the manufacturer considered it to be the improved version of the Falcon 6 (Jaques, 10/03/2006, *Personal communication*).

It is more difficult to identify the preferred stretcher for PTS because there was no significance in the results. The highest ranking stretcher was the Parensi Easilite stretcher. During the de-briefing sessions with PTS participants, many indicated their preference towards the Parensi Easilite. There were few negative codes for this stretcher and those which were identified were also identified for all other stretchers evaluated.

The MedAssist was highlighted to have the most issues and was ranked last by A&E. It should also be noted that neither A&E or PTS identified the stretcher which they used in their work at EMAS.



Key:
PR = postural rating
QR = Quantitative questionnaire rating

Figure 5.8 Triangulation of stretcher data

5.5 Discussion

The aims of this study were to comparatively evaluate mobility equipment designed for the ambulance market; identify preferred mobility equipment for A&E and PTS staff and; identify whether A&E and PTS staff should be provided with different equipment to meet the requirements of their individual roles.

Using observation and focus group methods the researcher was able to identify the problems experienced with use of mobility equipment in order to provide a full picture for evaluation. This enabled the researcher to carry out user trials and a postural analysis to identify the preferred equipment for A&E and PTS participants in terms of usability and manual handling. When combining the results of both methods used in the user trials, a number of patterns emerged for discussion. These are considered in the following sections:

1) Usability
2) Manual handling
3) Differences in preferences between A&E and PTS
4) Mechanised chair – automation in the ambulance service
5) Assisted technology does not mean lower risk to staff
6) Flexibility of assisted technology equipment
7) Tracked chairs
8) Adjustability
9) User trials in the purchasing process

5.5.1 Usability

The results of the user trials identified that at the time of this study, A&E and PTS crews were not provided with the most appropriate equipment in terms of usability. More appropriate alternatives were available on the market. Furthermore the results showed different equipment preferences for the two patient service sectors.

The stretcher used on A&E and PTS vehicles at the time of this study, was not the preferred stretcher for either group. However significance was only found in the A&E results, therefore no conclusion could be drawn for PTS from the quantitative analysis. A&E participants preferred the Pegasus stretcher to the equipment currently used; PTS preferred the Parensi Easi-lite stretcher. These findings were supported by the qualitative analysis.

Both A&E and PTS ranked the Stairclimber mechanised chair highest. The preceding high ranking chairs showed a difference between A&E and PTS preferences. A&E preferred the assisted chairs such as chairs with six wheels or tracked chairs and PTS preferred the chairs with four wheels which could be used in place of a wheelchair.

Each product demonstrated strengths and weaknesses during the user trials and although the analyses have identified preferred equipment, no single product was found to be ideal.

The study provided a number of findings:

1. The mobility equipment currently provided to A&E staff to transport patients to and from hospital was not the equipment preferred by participants
2. The mobility equipment currently provided to PTS staff was not the equipment preferred by participants
3. The equipment provided by the ambulance service was not the most appropriate in terms of reducing risks of MSD. At the time of this study alternative equipment was available which decreases the risk further
4. The Stairclimber, a mechanised chair, was the preferred equipment for use by both A&E and PTS
5. The Stairclimber was the preferred chair in terms of manual handling risks for both teams

5.5.2 Manual handling

The postural analysis identified no significant difference in the postural risk posed by the four stretchers evaluated. There was no difference in risk between the Falcon 6 stretcher used by the ambulance service and the other three stretchers evaluated.

However significant difference was found in the postural risk posed by the 12 chairs evaluated. The compact 2 used on A&E and PTS vehicles was ranked 9 out of 12, meaning that eight chairs posed less postural risk to participants. This suggests that at the time of this study the ambulance services were not using the most appropriate chair in terms of manual handling and there were more suitable products available for purchase. The chair which posed the least risk was the Stairclimber mechanised chair. The Stairclimber was operated by one staff member at the head end; the foot end operator provided guidance but there was no manual handling involved in the foot end task. This eliminated the harmful postures adopted at the foot end, reducing the risk of developing MSD's as a result of conveying patients up and down stairs. This was considered a more appropriate product in terms of manual handling.

5.5.3 Differences in preferences between A&E and PTS

An aim of this research was to identify whether the A&E and PTS teams should be provided with different equipment to each other. The results showed some similarities in how the teams ranked the equipment but there were some differences identified. Table 5.48 shows the results for each chair by team.

Chair	A&E ranking	PTS ranking
Stairclimber	1	1
Compact 2	5	8
Compact 3	11	11
EZglide	3	4
Ibex TranSeat	5	7
Pensi 41-10-20 (2 Wheels)	9	6
Pensi 41-11-20 (4 wheels)	7	2
Sirocco	2	10
Spencer 450 (2 wheels)	12	12
Spencer 455/B (4 Wheels)	10	3
StairPRO	4	4

Table 5.46 Comparison of A&E and PTS chair rankings

Mann Whitney tests were carried out to establish whether there was a statistically significant difference between the rankings by A&E and PTS participants. Significance was found for the Pensi 41-11-20 (4 wheels), the Spencer 455/B (4 Wheels) and the Sirocco rankings.

The chairs ranked better by PTS crews were the four wheeled standard carry chairs. These chairs were conveyed like a wheelchair. The observation and focus group data showed that PTS crews could use wheelchairs more often than carry chairs and stretchers but wheelchairs were found to be cumbersome and heavy, making them more difficult to manoeuvre. A carry chair used in the same way as a wheelchair could replace the need to carry both pieces of equipment and reduces the load carried by staff. This may be seen as progressive by PTS staff. The NHS job profiles (NHS Employers, 2007) highlighted that PTS staff carry out limited manual handling activities, and therefore would not often transport patients up and down stairs. They would manoeuvre patients on level ground more frequently. The focus groups and observations also highlighted this. The four wheeled carry chairs would improve manoeuvrability of chair bound patients on level ground. A&E staff used the carry chair more as a manual handling aid, a method to transport patients down stairs, and so the four wheeled carry chairs could be seen more as a hindrance, with the upright position causing patients to become unstable when carried.

The chair ranked better by A&E staff was the Sirocco. This may have been preferred by A&E because it offered mechanical assistance when transporting patients up and down stairs. A&E crews engage in more manual handling activities than PTS staff which could explain their preference of this product. The Sirocco was rejected by this study as an option for A&E vehicles during the triangulation process which showed that the sirocco posed a higher postural risk to staff than 9 other chairs evaluated, and more issues were identified through the qualitative analysis than for any other chair.

The results highlighted a preference for different equipment determined by the role of the team. Although the overall rankings by A&E and PTS were not found to be significantly different, the difference between some chairs was significant. The variation in rankings may be attributed to the role of the participants. This is understandable when the individual job descriptions for the two teams are considered (NHS employers, 2006).

A vast amount of research has been carried out investigating the risks associated with tasks carried out by paramedics (Lavender et al., 2000a and b; Lavender et al., 2007a,b,c; Furber et al., 1997; Birtles and Boocock, 2003; Doormaal et al., 1995), however the role of PTS staff has been neglected in previous research. It is recommended that further research be carried out into the risks associated with the role of PTS staff.

5.5.4 Mechanised chairs

A mechanised chair which automates the task of taking a patient up and down stairs was preferred by both groups of participants. This chair also ranked best in the postural analysis, posing the lowest risk of developing MSD's.

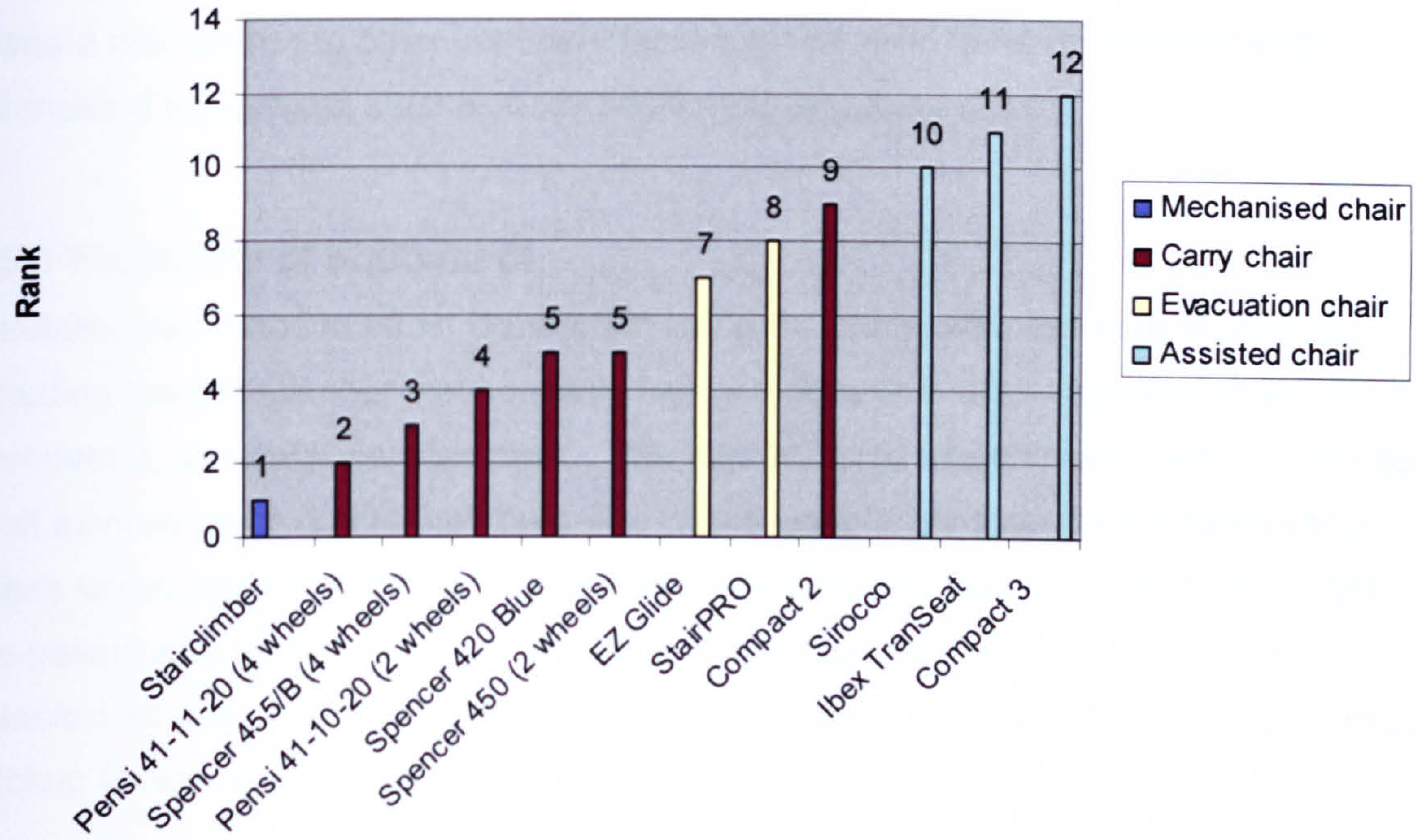
The mechanised chair was the best ranking chair in all aspects of the evaluation, highlighting that automation improves task performance, usability and posture. This was enforced by the findings of the stretcher loading study in chapter 4, which identified that automated stretcher loading systems reduce manual handling, eliminate lifting and pose less risk to staff (Jones and Hignett, 2007). Endsley (1996) highlighted that automation has changed the role of the person from that of performing a task, to monitoring the automated system. It reduces the need for manual handling (Dempsey, 1998). The role of the operator however is still vital, because although automation reduces or removes manual handling the increased complexity increases the risk of failure and when this happens it is the operator who will have to fix it.

Despite disadvantages such as system reliability and reduced speed, automated systems have a lot to offer manual handling tasks and therefore the development of automated equipment in the ambulance service would be beneficial. By incorporating the mechanised chair on vehicles the ambulance service could reduce the risk of employees experiencing MSD's and improve performance during the task of manoeuvring patients in a range of environments.

As a result of this study the mechanised chair was recommended to the ambulance service for future purchase. However, reduced manual handling there are a number of reasons this chair could not be solely utilised on ambulances. The chair would cost too much to supply on all vehicles, so would need to be used in a central pool, requesting it when it was needed instead of taking it to every call. The chair would not have suitable access in some confined spaces due to its size. During those rare emergencies when speed is of the essence, such as cardiac arrest, the speed of the chair is not suitable.

5.5.5 Assisted technology does not mean lower risk to staff

This study highlighted that the postural risks posed by the task are dependent on the individual chair and the position of chair components, as opposed to the type of chair used. A number of studies have identified that the physical demands and the risk of injury to ambulance staff are reduced with chairs that support the weight of the patient on the stairs (Ferreira and Stanley 2005; Stryker, 2006). The results of this study however dispute these findings. The postural analysis identified that the mechanised chair posed the least risk to staff, but the assisted chairs posed greater postural risk to staff than some manual lift chairs. This can be seen in Graph 5.1. The assisted chairs assessed differed to the chairs assessed by Ferreira and Stanley, who compared a track chair with the standard carry chair used on UK ambulances. However the assisted chairs evaluated do support the weight of the patient on the stairs.



Graph 5.1 Ranking of postural risk posed by chairs

So why are the results of these studies so different from the results of the mobility equipment evaluation study? Ferreira and Stanley only compared two chairs, and they compared these chairs using biomechanical analysis. This accounts for the forces adopted but not the postural risk posed to the participants. They concluded that there was more risk to the lower back when using the standard carry chair.

This evaluation used REBA to measure the risk posed for the entire body, when using each product, taking activity, load and coupling into account as well as the body part positions. The findings indicated that the chair which posed the least risk to staff was the mechanised chair because the load had been removed from the task, but also because the harmful foot end postures had also been virtually removed.

With the exception of the Stairclimber, the higher ranking chairs posing least risk to staff were the chairs designed to maintain the body's neutral position. For example the Pensi and the Spencer chairs were all designed with lifting handles which prevented the wrist from being twisted. They also encouraged the participants to adopt a neutral trunk position when ascending and descending stairs. The assisted chairs however had retractable handles at the head end which required the participant to adjust according to their height. If the handles were not positioned correctly the posture adopted by the participant was not ideal and posed higher risk of injury. Therefore this study highlighted that it was not only the load which was carried by the operator that poses a risk, there are other important factors which need to be considered when purchasing equipment, such as body positioning and ease of use.

5.5.6 Flexibility of equipment

Flexibility was found to be an issue when using the chairs with assistive technology, including the Stairclimber mechanised chair, the Sirocco 6 wheel assisted chair and the Compact 3, six wheel assisted chair. This was because these chairs could not be used in all environments due to their bulk. The chairs were larger than the standard carry chairs which had to be lifted by the operator and although they supported the weight of the patient and did not require lifting, they were not as flexible to use. Therefore if selected for use on ambulances, ambulance staff would need a standard carry chair as backup for use in the more extreme environments,

5.5.7 Tracked chairs

There were problems evaluating tracked chairs in this study because the pilot study highlighted that there was a minimal load of 30kg required. This was necessary for the tracks to function when descending the stairs with the EZ Glide and StairPRO, and ascend and descend with the Ibex. Because of this, additional weight was required to be carried by four participants, so that they did not evaluate all chairs under the same weight conditions. This means that the results for the three tracked chairs may be negatively biased. A number of studies have identified that evacuation and tracked chairs reduce the risks associated with transporting patients up or down stairs (Ferreira and Stanley 2005; Fredericks, 2002a and b; Stryker, 2006).

The postural analysis carried out for this study ranked the tracked evacuation chairs (EZ Glide and StairPRO) 7th and 8th out of 12, meaning that 6 chairs posed less risk to participants than the EZ Glide and seven chairs posed less risk than the StairPRO. The reason for the difference in the results could be a difference in type of evaluation. The three studies mentioned conducted a biomechanical analysis which considered the risk to the lower back. This study used postural analysis to identify the risk to the entire body, not only considering the load carried, but considering the positioning of each body part, together with the load, coupling and activity. Furthermore it should be noted that the study conducted by StairPRO considered the best case scenario when the equipment was used in ideal conditions.

5.5.8 Adjustability

The postural analysis results suggest that chairs with variable handle heights at the head end of the chair posed greater risk to staff than handles with fixed positions. Staff were unfamiliar with altering handle heights to suit their stature and so adopted worse postures than if they were using chairs with fixed handles. When using products with adjustable parts, thorough training should be provided demonstrating how to make the adjustments meet the anthropometric requirements of the user (NYC Health, 2007).

With one product, a manufacturer collaborating in this study demonstrated how to alter the chair handle height whilst the chair was midway up the stairs, to ensure the user adopted the most suitable posture. This was demonstrated during training sessions, but participants chose not to change the handle height during the task for the safety of their patients.

5.5.9 User trials in the procurement process

It has been identified that at the time of this study, more appropriate equipment was available on the market, than that supplied to A&E and PTS staff. This highlights a need for in-depth, robust, user evaluations to be carried out prior to equipment allocation. The difference in preferences between the two teams, suggests that the users need to be considered prior to equipment selection and purchase. The ambulance services selection criteria for procurement of mobility equipment should be further reviewed.

The UK ambulance services know which tasks pose the greatest risk to staff and which tasks could be improved with the aid of the right equipment. As the end users, ambulance staff should be at the forefront of purchasing decisions made by the ambulance services. See chapter 6 for more information about ergonomic evaluations in the procurement process.

5.5.10 Limitations of the study

A number of limitations were identified during the course of the study. It was not possible to simulate the tasks under the exact same conditions experienced in the field. Each piece of equipment needed to be tested under the same conditions for example, some staff in the field would carry a patients bag whilst pushing a carry chair, some would give the bags to the patient to hold and some would find somewhere on the chair frame to store the bags. Given that not all staff make the same decisions, it was felt that by trialling this, the researcher would be trialling the staff as opposed to the equipment.

Due to the number of products evaluated and the differences between models it was not possible to comparatively evaluate the equipment in terms of individual features. The recommendations were based on task performance and postural risk instead. Assessment of the individual product features may have provided different results. However because it was not possible to compare products in this way, it was not possible to meet the aims of this investigation through this type of evaluation. There were very few types of stretcher to evaluate, the complexity of the equipment made it difficult to comparatively evaluate the products in a controlled environment. Little significant difference was found between the stretchers, suggesting that they were too similar to comparatively evaluate.

It was difficult to incorporate environmental factors such as terrain and weather into the trial with the resources available. To test the equipment on a number of outdoor terrains would have involved outdoor data collection making it impossible to control for external factors like weather and working environment. The researcher therefore had to test the equipment indoors with constraints which could be controlled over a long period of time. The results may have been different if the products were tested in the field, rather than in a controlled environment, however it would not have been possible to collect comparable data in the field.

The load applied to the chairs varied between participants. This was due to the physical strength and ability of the participants. Two crews carried less weight on all chairs except for the evacuation chairs which needed additional weight to ensure the tracks would function correctly. There were other weight discrepancies on chairs when participants chose not to add the extra weight due to physical ability, these discrepancies may have impacted on the results. The researcher had limited control over the weight which was carried on the chairs. In an ideal study the researcher would have insisted on standardising the weight carried. However because the study was conducted as a KTP and because conflicting advice was provided by two members of the ambulance services risk and safety team and the participants a more pragmatic response to the decision making was more appropriate. This had the benefit of reintroducing realism to reflect different shapes, sizes and weights of patients.

Participants had prior experience of using the Ferno Compact 2 carry chair and the Ferno Falcon 6. Therefore they were more familiar with these products than the other equipment trialled. This may have created some bias in the results. However it was important to trial this equipment to identify whether the ambulance service were purchasing the preferred equipment for staff. To remove the chances of bias participants were given training in all equipment to ensure they had full working knowledge.

Due to the nature of the emergency services it was not possible to incorporate more than 8 participants from each of the two groups, A&E and PTS. Where possible staff were needed on the road tending to patients, so it was very difficult to secure participants for the trial period. More participants would have given the results more power.

5.5.11 Recommended further work

This research only considered stretcher and carry chair conveyance tasks. A&E and PTS crews have very different use of the equipment, for example A&E crews may need to carry out clinical tasks while conveying the patient to the ambulance or hospital. PTS however use the equipment for conveyance purposes only. Task analysis of the clinical activities carried out by A&E staff may be beneficial to identify preferred equipment for clinical needs.

Whilst research in the ambulance field is increasing, limited information is available about the role of PTS staff and the risks posed to staff whilst transporting patients. Further research regarding this role and the equipment used could help reduce worker injury and improve job design.

The ambulance service had a policy to test all equipment in a site trial (controlled evaluation) prior to using it in the field. Therefore all recommendations were based on laboratory testing. Further research could be carried out evaluating the recommended equipment in the field, observing the equipment being used with the patients. An intervention study could be carried out to assess impact of the recommendations made on the basis of this study.

At the time of this evaluation Stryker were developing a new stretcher which can be fitted onto the ambulance using the Ferno locking mechanism. There were marked differences between this stretcher and those evaluated. It had an electric lifting mechanism, to raise and lower the stretcher. The stretcher was not available in time for this evaluation but since its launch in June 2006, it may be beneficial to evaluate it for use on ambulances.

5.6 Recommendations and conclusions

A number of recommendations were made as a result of this study:

1. The Stairclimber was recommended for use by both teams but should be accompanied by a standard carry chair as a back up for use in confined spaces
2. The standard chair recommended for use by PTS staff was the Pensi 41-11-20, 4 wheel chair
3. The Pensi 41-11-20, 4 wheel chair, the StairPRO or the EZ Glide should be purchased for use on A&E vehicles. The Pensi chair would be more suitable for use in all environments because it was smaller in size
4. The Pegasus was the recommended stretcher for use on A&E
5. PTS could be provided with the Parensi Easilite but further consideration needs to be given to this because there was no significance found in the results
6. To aid the implementation of the Stairclimber a field study should be carried out to test the recommendations and to support the decision in terms of costing and transportation methods

This study successfully met the established aims and objectives. It identified that both A&E and PTS teams in the ambulance service require more appropriate equipment for conveying patients. The equipment used at the time of this study was not the preferred equipment for either team in terms of manual handling or usability. The individual roles of the two patient services should be considered prior to equipment allocation to ensure the teams are provided with the appropriate kit.

Chapter 6: General discussion

Up to this point this thesis has presented the process of conducting ergonomic evaluations in the ambulance service. The purpose of this chapter is to contextualise the findings of the two studies (Chapter 4 and 5) and to draw on what has been learned in the process of conducting this PhD. It will identify what information can be taken forward, and how the ambulance service can adapt their procedures to develop a procurement process which incorporates ergonomic input, to select patient movement and transfer equipment which reduce risk and are more user friendly.

6.1 The current evaluation and procurement process

In order to understand the changes that can be made for future procurement it is important to know how equipment is currently evaluated and purchased by the ambulance service. This information was obtained through discussions with the Purchasing and Supplies Manager and the Fleet Manager at EMAS between 2006 and 2007.

Ambulance equipment is currently evaluated by procurement teams within the services. Depending on the type of equipment purchased, staff representing different departments, form an equipment group who carry out product evaluations before making a purchasing decision. Different departments are responsible for purchasing certain types of equipment, for example, the Fleet department lead evaluations regarding vehicle purchasing (Farnsworth, 14/09/2006, *Personal communication*).

Two types of purchases are made in the ambulance service; revenue and capital. Revenue purchases (those made on a regular basis) are made by the purchasing and supplies department. Capital purchases (one off, purchases) are carried out following an evaluation process, and a bid is approved or declined by the team of directors. Figure 6.1 shows the departmental chain of responsibility for procurement within the ambulance service. Revenue or regular purchases include consumables, purchased for continuous stock on ambulances such as latex gloves, masks and bandages and office supplies, such as files, stationary and paper. Departments within the ambulance service are responsible for purchases related to their daily business. An equipment group represents the departments by putting forward a purchasing bid to the Board of Directors through a sponsor who would usually be a line manager. The sponsor is the person selected to lead the evaluation.

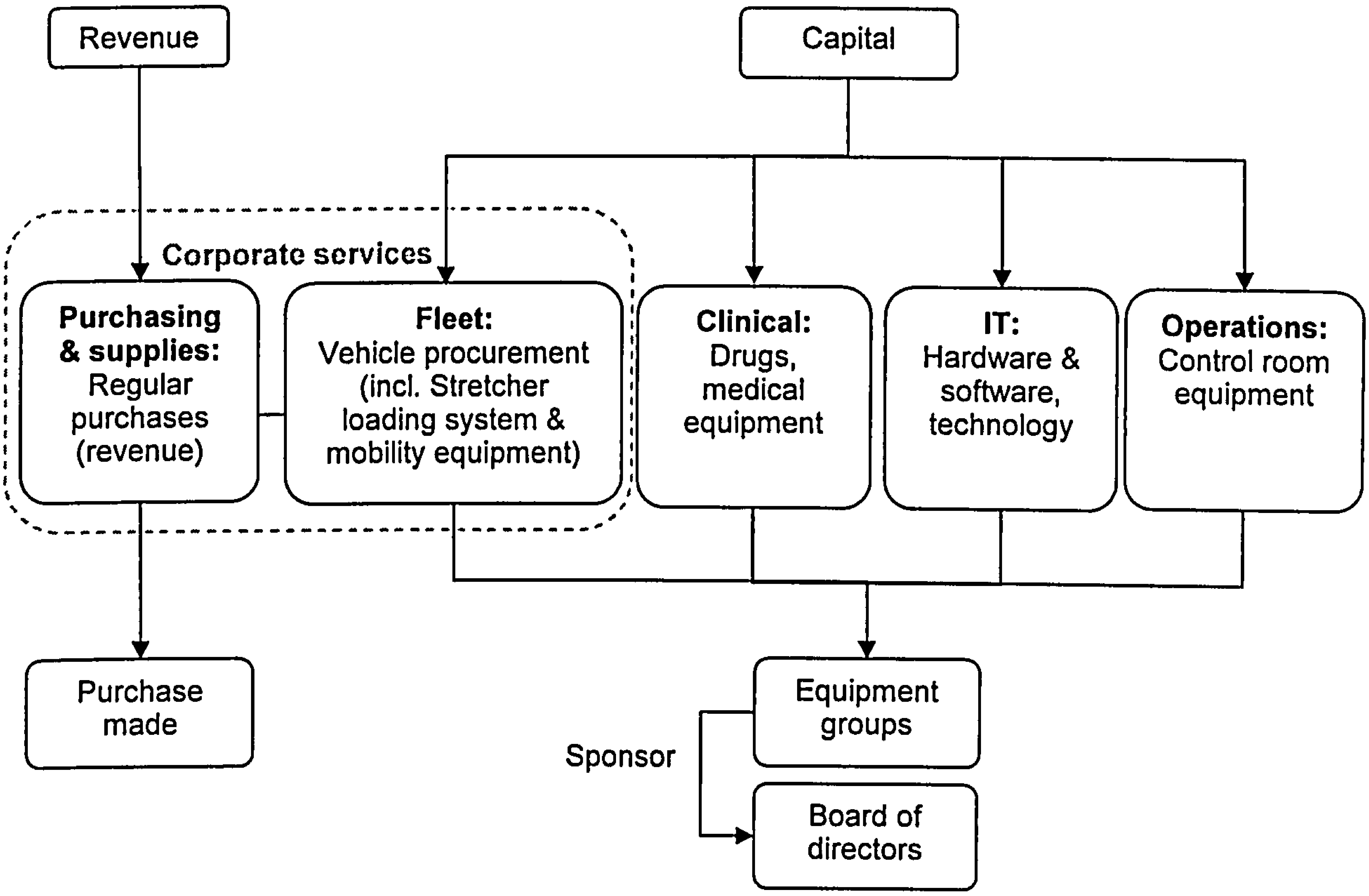


Figure 6.1 Departmental responsibilities towards procurement in EMAS

The flowchart in Figure 6.2 shows the evaluation process followed by EMAS when making revenue and capital purchases. The same procedures are followed irrespective of department. The flowchart shows the steps taken by the procurement teams identified in Figure 6.1. An equipment group starts the procurement process. A representative of this group is selected to take the lead on procurement of a given product, and is known as the sponsor. The group carries out market research, and an initial assessment narrows the purchasing options down to three products. These are then acquired and evaluated through site evaluations, field evaluations or both. Data are collected through evaluation forms which are assessed by the sponsor, and a final request is put forward to the Director of Finance and the Chief Executive Officer (CEO) in the form of a bid.

The main drawback to this process is that the sponsor is not trained in scientific data collection and analysis methods, and so the scope of the evaluation is limited. Time commitment is also limited because the sponsor has a number of other work commitments.

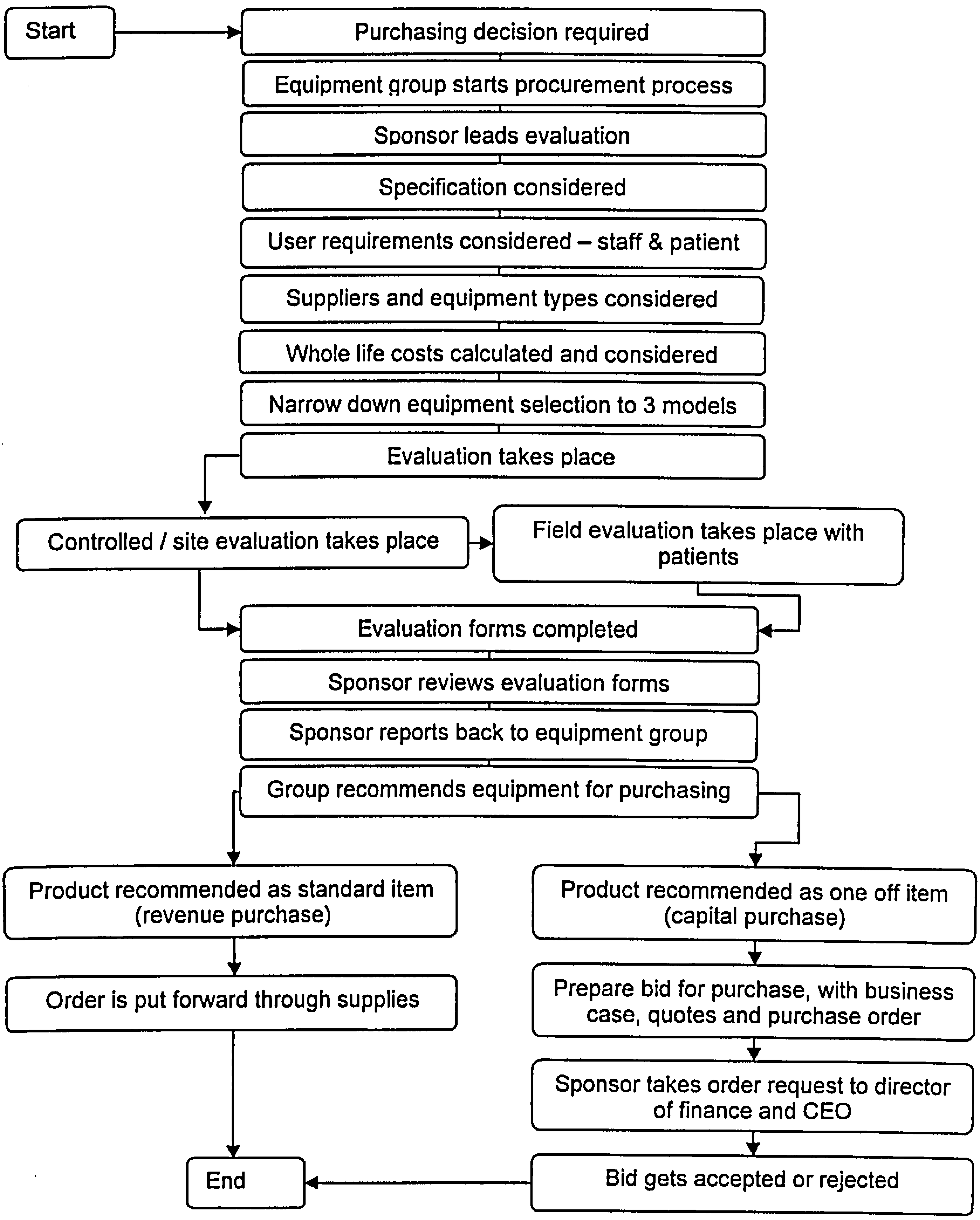


Figure 6.2 Current protocol for purchasing in EMAS

Before making a purchasing decision the ambulance services evaluate a small number of products (usually 3), over a short period of time (Lloyd, 11/10/2006, *Personal communication*). The field evaluations carried out by the ambulance services are short in duration and only have a small number of subjects, and limited environmental exposure. At the time of this investigation only two Ambulance Services employed a permanent full time Ergonomist; London Ambulance Service and Scottish Ambulance Service. It is therefore likely that little ergonomic input is provided with respect to equipment evaluations.

The methods used by EMAS to assess the equipment are limited, and used a basic evaluation form requiring a low level of analysis. These forms are a successful way of evaluating simple equipment or for narrowing down equipment choices; however the ergonomic evaluations carried out in this thesis used more complex and detailed scientific methods. By carrying out thorough evaluations of a number of products with higher participant numbers and a more detailed analysis, more appropriate equipment which meet the prioritised user requirements can be identified. With improved procurement processes for manual handling equipment, the ambulance service could benefit from a more informed and thorough decision making process.

It can be seen from the current model (Figure 6.2) that EMAS use a limited evaluation process in order to identify the most suitable product to suit their needs. The same process is used for capital purchases and revenue purchases, although the uses and equipment types are different. The purchase of patient movement and transfer equipment is considered as capital, because the purchases are made less frequently and the cost per quota is greater. Bulk purchases such as blankets and masks are considered revenue because the price per piece is much lower and regular supplies are required. When considering the function of these types of equipment it is apparent that a 'one size fits all' procurement strategy is not appropriate. Equipment which has a risk attached to it for staff and, or patients, should receive a higher level of assessment than a product with limited risk. The research undertaken in this thesis has led to a proposal for an alternative, ergonomic strategy for evaluating capital purchases, in particular, manual handling equipment, mobility equipment and vehicles.

6.2 Changes for an improved procurement in the future

In order to achieve an improved model for capital purchasing a number of changes must be made within the current system. The following section discusses the necessary changes for an improved system and identifies a new procurement strategy for the future. Figure 6.3 demonstrates how these changes form the model of the future:

1. Awareness of equipment on the market and informed choices
2. Improved collaboration between trust and manufacturer
3. Standardisation of equipment design based on scientific evidence
4. Automation and socio-technical systems
5. Supported implementation of change
6. Ergonomic intervention, CBA and WLC
7. Site and field evaluation procedures
8. Ergonomic protocol for future procurement

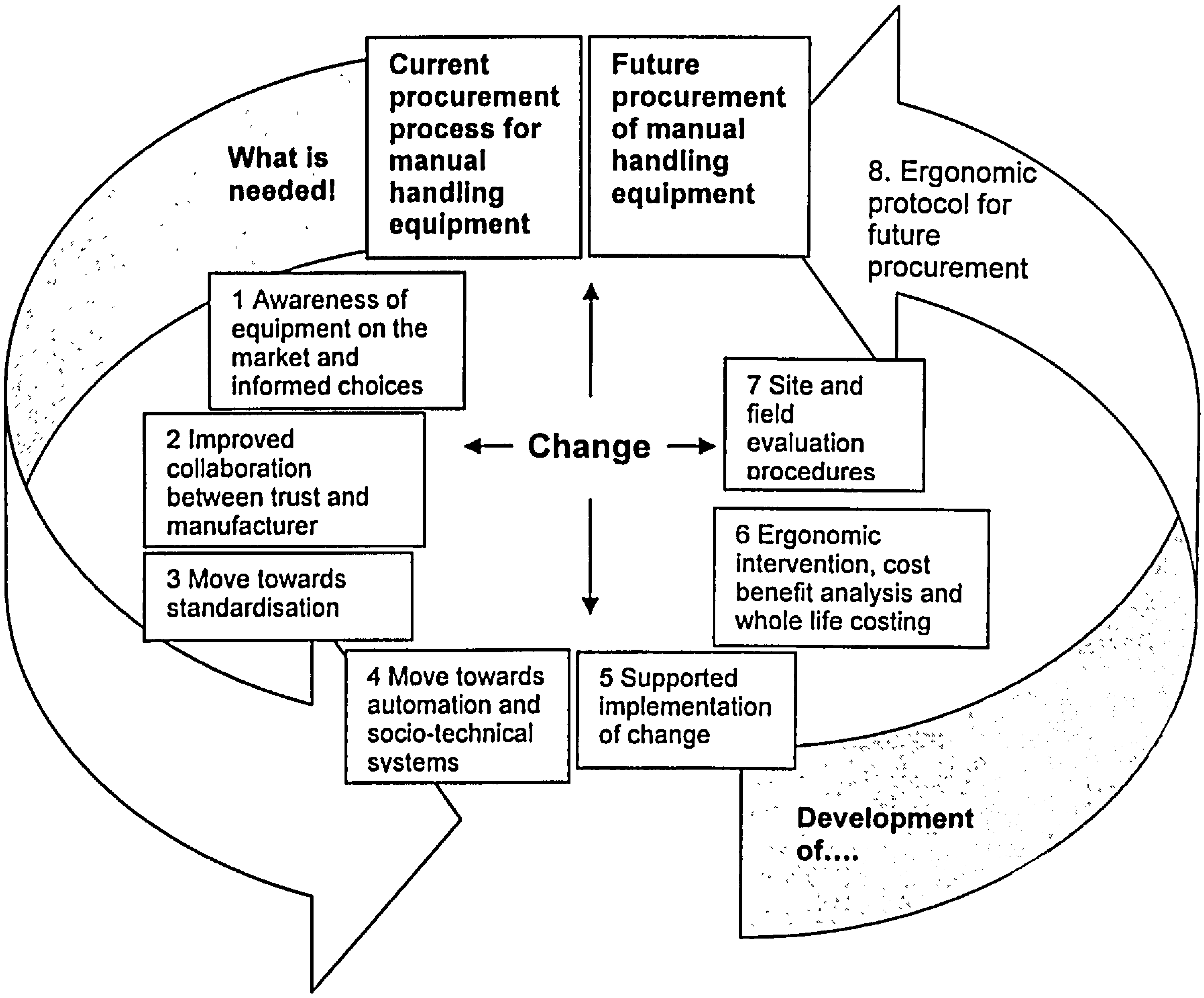


Figure 6.3 Changes needed in procurement model

6.2.1 Awareness of equipment on the market

A large range of mobility and manual handling equipment is available on the market and it is important for stakeholders to be aware of their choices. Currently ambulance services become aware of products on the market through conferences and word-of-mouth from colleagues in other services. The ASA hosts an annual exhibition and conference (Ambulance Service Association, accessed 27/07/07) gathering many manufacturers. This allows the ambulance services to view current and future products and is a good way of disseminating information, keeping staff up-to-date with their choices. It also gives staff from ambulance services across the UK and internationally the opportunity to liaise with each other and develop working relationships, promoting a learning environment where people can discuss positive and negative feedback regarding equipment purchase and use.

The ASA also acts as a portal of information for ambulance services. Risk and safety bulletins are distributed by the ASA regarding product recalls or bulletins issued by manufacturers. Departments across the ambulance services liaise with each other and share information, for example the Heads of Risk and Safety communicate closely regarding equipment risks (Smith, 12/08/2005, *Personal communication*).

These mechanisms are in place for information sharing but they do not give a complete picture about equipment procurement. The conference exhibition is set up for manufacturers to sell their products in a positive light, while the bulletins provided by the ASA are risk and safety alerts or product recall information. There is limited middle ground to look at the positive and negative aspects of equipment in operational use and there is currently no dedicated role for market research. During the KTP (Chapter 5) an investigation was conducted into the equipment available at an international level, and this information was shared with the corporate services team at EMAS. The benefit of having a role dedicated to scoping the market for potential products became evident and it was commented that this would be beneficial in the future (Dagley, 05/07/2006, *Personal communication*).

It would be beneficial for the ambulance services to be given informed choices by a neutral person who works independently of the manufacturers and the ambulance service, for example, consumer evaluations by 'Which good housekeeping' (Which, accessed on 23/08/2007). Ambulance services should have selection criteria for inclusion and exclusion of equipment based on robust scientific research. This information should be fed through all levels within the ambulance service so that the operational staff can have more input into purchasing. They have the most knowledge about their operational equipment needs, so should be more involved in the product selection process. This has begun with the equipment design groups but staff representation on these groups should be greater.

6.2.2 Improved collaboration between services and manufacturers

Ambulance services currently have varying levels of collaboration with manufacturers. Their involvement in the development of equipment is dependant on their business relationship with the manufacturer. It is evident from the work carried out for this thesis that a better liaison would be beneficial for equipment design. One way of doing this would be to have manufacturer representation on 'equipment design groups', or close liaison between an existing group member and the manufacturers, feeding back the 'wants' and 'needs' of the end users. Many staff within the ambulance service feel they have little influence over the design decisions made by manufacturers; feeling that the equipment purchased is market-driven rather than customer-led. The services can only purchase what the manufacturers make available to them (Hill, 10/01/2006, *Personal communication*). This was evident during the pilot focus group carried out with the corporate services team in EMAS for Chapter 5 of this thesis. Strong feelings about a lack of influence in design were reported in this focus group.

In some cases manufacturers have a small and limited market, making change very difficult. This was the case with stretcher purchases because the ambulance body builders install a standard Ferno stretcher to all modular build vehicles, with a standard locking mechanism. This locking mechanism fits all Ferno stretchers including the incubation stretchers used for neonatal transfers and other hospital stretchers. This makes it difficult to purchase from another stretcher manufacturers because they are used across the healthcare service and any hospital transfer requires the standard Ferno stretcher to be accommodated in the ambulance. It should be noted that in recent years Ferno have been working with other stretcher manufacturers, in particular Stryker to allow other stretchers, such as the Stryker PowerPro (Stryker, accessed 27/07/2007) to lock into the Ferno mechanism, therefore allowing ambulance services more choices in the future.

There have been cases where ambulance services and manufacturers worked together to influence the market. Mark Lloyd (11/10/2006, *Personal communication*) provided a case study (Figure 6.4) where the ambulance service were able to identify a user need and found a manufacturer who were willing to modify their designs to meet these needs.

Case Study:

Between 2002 and 2003 EMAS found a problem with their adult resuscitation masks. The paediatric masks, had a valve that would block off the air passing through the mask in the event of a blockage in the patient's lungs. The adult mask however did not have such a valve and EMAS considered this an important feature. On inspection of the market it was found that no manufacturer provided this option, but the EMAS clinical department decided that as a safety device, all resuscitators should have a blow off valve to vent any excess air rather than trying to force air into a patients lungs. The procurement team liaised with their current supplier to see if they could adapt the product to the EMAS specification. They refused to do this, so the team contacted other manufacturers and one agreed to produce the required adaptation. EMAS moved to that device immediately and after liaising with other ambulance services, many other services followed. Now almost every manufacturer offers this item. (Lloyd, 11/10/2006, *Personal communication*)

Figure 6.4 Case study: purchase of resuscitation masks

This is an example of how an ambulance service managed to influence manufacturers through liaison and developing business relationships. By developing stronger relationships, it may be possible to have more influence. It may be more difficult to influence capital purchases which are purchased in fewer quantities, giving manufacturers less incentive to make changes, for example the stretcher industry in the UK is currently led by two very large companies. This limits the competition but also gives very little negotiating power to the ambulance services. However in recent years these manufacturers have collaborated in ergonomic studies (Jones, 2007; Lavender et al., 2007a) whereby they take the needs of the users into account so the relationship with manufacturers does seem to be more positive where ambulance services have greater input into design.

Lingard (date unknown) wrote from the manufacturers' perspective of working with ambulance services in the development of new ideas, refuting the claim that the lack of change in patient handling equipment over past 50 years was due to manufacturers.

He suggested that the lack of innovation in ambulance equipment design was due to the unwillingness within the service to accept change. Lingard claimed this resistance was preventing manufacturers taking a risk and investing in the production of more innovative designs. By working with the manufacturers, designers and engineers, Lingard believed that the ambulance services could help develop new ideas to promote safer working practices.

In recent studies researchers have gone some way to bridging the gap between manufacturers and the ambulance services (Coleman, 2007). Coleman (2007) collaborated with HEPSU (Loughborough University), the NPSA and the ASA to conduct a study looking at A&E ambulance vehicle design with a view to standardising design across the UK. The researchers held stakeholder workshops to consult with representatives from NHS agencies, the ASA, UK ambulance trusts, Acute and Primary trusts, advisory agencies, patients, policy makers and UK manufacturers. The workshops led to proposals for the co-ordinated evolution of ambulance fleets, demonstrating the benefits of bringing together the major stakeholders in the ambulance and healthcare sector to generate design ideas for the future.

Familiarisation interviews held at the start of this thesis suggested that many decision makers for equipment purchasing may have never travelled in an ambulance or have had little contact with crews, which could mean they fail to understand user requirements.

Purchasing decisions can be restricted by standards and regulations such as CEN standards (2000a; 2000b and 2007), The Provision and Use of Work Equipment Regulations 1998 (PUWER, HSE, 1998b), Lifting Operations and Lifting Equipment Regulations 1998 (LOLER, HSE, 1998c) and Manual handling Operations Regulations (MHOR, 1998a). There are also staff-side (union) requirements to be considered. All these considerations lead to trade-offs being made in the decision making process. It was evident from working in the ambulance service, that the procurement process would be aided if those decision makers made visits to an ambulance station and liaised with staff in their own environment to identify the issues which need to be addressed through new equipment purchases. Observations on ambulances could also provide a better insight into the wants and needs of the crews and patients. This may appear to be inappropriate use of management time but the potential benefits include knowledge elicitation and improved union and management relations. Manufacturers would also benefit from observing staff using the equipment with patients. They could then design equipment with a better understanding of the user requirements. Better liaison between the decision makers, manufacturers and staff could benefit all parties, creating a better working relationship, in turn improving the morale of the workers, giving them greater influence over the decisions made regarding their work (Suserud, 2005).

During the observations in Chapter 4 of this thesis, it was evident that ambulance staff have concerns about management observations, believing this to be an opportunity for management to monitor their actions. The staff discussed the role of the observer in a light-hearted manner, suggesting that they were conducting a 'time and motion' assessment; keeping an eye on the movements of staff between calls. Through shadowing the crews over a number of shifts, a good rapport was developed, and it was evident that staff became happy to work with an Ergonomist, understanding that the findings of the study could be beneficial. The staff considered this to be a good opportunity to state their point of view.

Better collaboration between the ambulance service management, staff and manufacturers could increase productivity, improve worker morale and build good working relationships which can continue into the future.

6.2.3 Standardisation based on scientific evidence

Prior to the merger in 2006 (ASA, accessed 09/08/2007) each of the 31 ambulance services had their own procurement strategies, purchasing different equipment for use in different environments. Following the merger, the newly formed ambulance services acquired equipment which was not standard to their fleet, creating training and other operational and maintenance issues for the services. Although staff received training with the most recent models of equipment purchased, they were not trained to operate all of the new trust equipment, putting them at risk of operating unfamiliar equipment and increasing the risk of manual handling injuries occurring. Standardisation of equipment at a national level (where environmental factors would not impose restrictions) would benefit both staff and management within the ambulance services. One aim of the stretcher loading study (Chapter 4) was to provide robust scientific evidence in support of one system to provide a criteria for future purchase.

Coleman's (2007) report on the 'Ambulance Design for Patient Safety Study' argues the case for standardisation of vehicles in the ambulance service. Coleman states that throughout the workshops conducted for this study, there was a strong consensus on the need for standardisation, and the development of an agreed national criterion on which to base vehicle and equipment purchasing decisions. The researchers established a design direction with the aims of standardising, modularising and innovating. Standardisation of equipment should be reached within a five year period and modularising equipment within ten years for service improvement, flexibility and adaptability for delivering healthcare in the community.

Standardisation of equipment could benefit emergency planning and crisis management in the UK. In the event of national incidents, such as the London bombings which occurred in July 2005 (BBC, 2005). Ambulance Services across the UK are put on red alert, to respond or to support the ambulance services local to the event. During the London bombings Ambulance services close to London were called on to support London Ambulance Service. Supporting staff would have used equipment which they may not have been familiar with, therefore slowing down the process of providing treatment and transporting the patients to hospital. With nationalised equipment all staff would be familiar with the same equipment, allowing them to assist other ambulance services without putting themselves and patients at risk.

6.2.4 Automation and socio-technical systems

One of the central themes from both studies described in this thesis is that automation is the way forward in terms of reducing manual handling activities and the risk of MSD's to ambulance staff. The preferred system identified in the stretcher loading study (Chapter 4) and the preferred chair in the evaluation of mobility equipment (Chapter 5) were automated, reducing the physical effort applied to each task. By automating manual handling equipment wherever practical manufacturers could further reduce the risk to staff (Watt and Dickson, 1999). However a number of issues, including task complexity were identified as a result of automation and should not be ignored. Macleod (2003) stated that the greater the complexity of a system, the greater the complexity of associated tasks. This was found with the tail lift system in the stretcher loading equipment evaluation. The increased safety precautions put in place to use the tail lift led to task complexity and increased movement around the system components (highlighted by the link analysis). It was believed that further automation of the system would reduce this complexity, for example automation of the safety rails on the tail lift platform would remove parts of the task and reduce movement around the system.

However the interaction between the operator and the machine should not be forgotten when introducing new technologies.

Automation does not remove the need for an operator; in this case it only removes the need for the operator to conduct manual handling activities in order to reach the task end goal and the operator takes on the role of supervisor or guide. The machine has no knowledge of the purpose of its inbuilt processes or of the reasons for supporting its performance goals; the ultimate management, control and direction of the machine reside with the trained human operators, supervisors or managers (Macleod, 2003).

Correct implementation of automated products in the ambulance service need to be carefully managed. Macleod (2003) highlights that if the operation of the automation is a mystery to the operator they are often ill equipped to deal with surprises such as system failure or the effects of uncontrolled operation. To overcome this, the ambulance service should provide full and thorough training of the products operated, the internal mechanisms and maintenance. All automated systems should have a manual over-ride which is easy to activate in the event of failure, especially for emergency work carried out by the ambulance service. A problem with automated systems is that due to the complexity of the mechanism the equipment often becomes a lot heavier and more difficult to operate in the manual mode. An example of this is the Stairclimber chair identified as the preferred chair in the mobility equipment evaluation (Chapter 5). This chair, if operated manually, would be very heavy to lift or manoeuvre up and down stairs and for this reason is usually operated using the automation with and without a patient on board.

Problems have also been identified with the tail lift loading system when used in manual mode; it requires the operation of a pumping mechanism to raise the platform to the level of the ambulance, needing a lot of effort and taking a lot of time. It also puts the operators in a dangerous position at the road side, facing on coming traffic. This is something which should be considered in the future in terms of automating products. More thought should be given to operating the equipment in the manual mode so that in emergency situations, it is simple to operate and does not cause further unnecessary delay.

6.2.5 Supporting implementation of change

Some recommendations made from the ergonomic studies may require assisted implementation by the Ergonomist. While the evaluations in this thesis were scientific and thorough, the process ended at identification of the preferred equipment. The stretcher loading equipment evaluation provided a comparative analysis of equipment which was already used by the ambulance services. The information was disseminated at conferences, recommending that ambulance services consider the tail lift for future vehicles, but no implementation process was necessary as the product was familiar to most ambulance services. As a result of the study many UK ambulance services have purchased tail lifts. An implementation service could have been offered to services requiring the tail lift, training staff in the correct use of the equipment, and demonstrating how to reduce postural risk.

The evaluation of mobility equipment carried out in Chapter 5 was more complex. The higher number of products evaluated meant that the evaluation could not be as detailed as that in Chapter 4. The purpose of the evaluation was to limit the options available on the market and identify the preferences of equipment types for each patient service provider, in terms of usability and manual handling. Preferred equipment was identified but due to the duration of the knowledge transfer project it was not possible to assist in the implementation of the recommendations.

An example of how a product can fail or excel depending on its implementation was given by EMAS, when they purchased the Stairclimber a number of years ago (Figure 6.5).

The CMAX (known in this study as the Stairclimber) was purchased to aid manual handling activities in 2004. It was given to an ambulance station in Leicestershire and some staff were provided with training. The staff found it difficult to use and couldn't see the benefit and so the chair was taken off the vehicle and locked away in the garage (Smith, 15/07/2005, *Personal Communication*). In 2006 EMAS introduced a back-care initiative whereby they employed a back-care advisor, who recruited a number of back-care leads across the service to promote careful working with regard to manual handling. In his new role, the back-care advisor was approached by PTS staff who had to regularly transport a bariatric [defined by EMAS as over 25Kg] patient up and down three flights of stairs to a top floor flat. The Stairclimber, which had been previously purchased was relocated and staff at this particular station were provided with thorough training over a 1 day period. These staff were part of a focus group conducted for part 1 of this study and indicated that they were thoroughly impressed with the equipment (Carr, 10/11/2005, *Personal communication*).

Figure 6.5 Case study: products success or failure due to implementation procedures

This outcome could be the result of a number of factors. The more recent staff that used the equipment could have received more thorough training and felt more comfortable using the equipment, therefore suggesting that the implementation of its use was better managed. However it could also have been a result of the comparison with their previous experience of carrying the patient up and down stairs. This case study supports the recommendation from this thesis that ambulance services should provide more powered Stairclimber chairs as a manual handling aid.

6.2.6 Ergonomic intervention, cost benefit analysis & whole life cost

The HSE (2003) reported that ambulance crews were among the most likely of the public services to experience injury through lifting and handling activities, or as a result of aggression and violence. Interventions to reduce these injuries could be beneficial to both the service and the workers. This thesis describes evaluations of equipment, which have identified preferred equipment, to decrease the level of manual handling carried out by ambulance staff, in turn reducing the postural risk associated with the manual handling tasks. If use of these products is implemented correctly the long term financial benefits of reduced manual handling could outweigh the higher acquisition costs.

Ergonomic methods have been used with increasing frequency in the pre-hospital and the healthcare sectors to improve issues relating to manual handling activities and the resultant musculoskeletal problems affecting staff (Lavender et al., 2000b; Ferreira and Hignett, 2005; Jones and Hignett, 2007; Kluth and Strasser, 2005; Owen, 2000; Smedley et al., 2003). These studies have used different ergonomic techniques to measure, change or raise awareness of the physical demands of the job (Owen, 2000). Ferreira and Hignett (2005) and Jones and Hignett (2007) combined qualitative methodology with postural analysis techniques to identify performance issues and the risk of developing MSD's as a result of work related tasks. As a result of these studies ambulance services were given robust scientific evidence to inform their future procurement decisions. Kluth and Strasser (2005) conducted an ergonomic evaluation of ambulance cots, simulating carrying tasks. The study identified a number of changes to stretcher design in order to reduce the high strain on paramedics.

Lavender et al., (2000a and 2000b) conducted biomechanical analysis and postural analysis of frequently occurring strenuous work tasks. The studies identified a number of tasks which put ambulance workers at most risk. This work was taken forward by Lavender et al., (2007a and b) in their evaluations of transferring patients downstairs and evaluation of lateral transfer tasks. These studies identified a number of interventions which reduced the strain on the workers, one of these being a single rod rolled in the bed sheet which changed the bed transfer from a lifting task to a pulling task. These are some examples of successful ergonomic studies which have either informed or intervened where manual handling problems occur in the healthcare service. Shearn (2003) identified the direct and indirect benefits of carrying out occupational health and safety interventions (Table 6.1).

Direct benefits	Indirect benefits
Reduced insurance premiums	Reduced absenteeism
Reduced litigation costs	Reduced staff turnover
Reduced sick pay costs	Improved corporate image
Improved production / productivity rates	Improved chances of winning contracts
Lower accident costs / production delays	Improved job satisfaction / morale
Reduced product and material damage	

Table 6.1 Benefits of ergonomics interventions

Some studies have taken this further, identifying the financial benefits of conducting ergonomic and health and safety interventions through Cost Benefit Analysis (CBA) (Village, 2003; Shi, 1993). CBA is a method used to determine whether a change is worth making by estimating the value of the benefits and deducting the associated costs (Mindtools, 2007). CBA can aid the decision maker by giving financial values to the costs and benefits of an implemented change, allowing a thorough comparison to be made (Oxenburgh and Marlow, 2006). Sophisticated approaches to CBA attempt to put financial value on intangible costs and benefits (Mindtools, 2007).

Village (2007) conducted an ergonomic intervention study at two hospital laundries and a control laundry to evaluate changes in injuries, self reported pain and psychosocial factors as a result of the intervention. While both uncontrolled laundries saw a reduction in musculoskeletal injuries, Laundry B saw a reduction in self-reported pain and significant improvements in psychosocial factors. The only change identified in the controlled laundry was an increase in self-reported pain. Village conducted a CBA of the intervention and found that the ergonomic improvements would pay for themselves within one year or less. The benefits identified in Village's study were increased productivity, savings in overtime, turnover and return to work costs. This highlights the benefits of ergonomic intervention in manual handling industries and also identifies how CBA can prove beneficial in making the decision to carry out an intervention of this kind.

Shi (1993) also conducted a CBA, of a back injury prevention programme. The results showed a slight overall decline in back pain and substantial improvement in satisfaction and reduction in risky behaviours. The CBA of the programme identified an overall benefit of $161,108 with the investment return reaching 179%. The studies described identify how ergonomic and health and safety interventions can increase productivity, benefiting both the management and the workforce, whilst also highlighting the wealth of information the CBA method can provide to the decision maker (Village, 2003; Shi, 1993).

The Chartered Institute of Purchasing and Supplies (CIPS, accessed 17/04/2007) believe Whole Life Costing (WLC) to be a best practice tool for evaluating procurement options. In terms of equipment purchasing, WLC is defined as the total cost of purchasing and owning, operating, maintaining and managing the acquired product over the products life time, including end of life costs such as de-commissioning or disposal. The argument for WLC is based on the promise that if the procurement team only consider the acquisition costs of each product, they are not considering the full picture. A product may cost less in the short term but if the quality is lower than another product, the long term costs such as maintenance or replacement may be higher. It is CIPS (accessed 17/04/2007) recommendation that the WLC be calculated before making a purchasing decision, however they emphasise that purchasing decisions should not be based on price alone. WLC accounts for costs such as training, however it does do not consider the long term financial benefits of ergonomic intervention products such as patient movement and transfer equipment. While it is an accurate way of estimating costs, it only goes part of the way to estimating the products financial benefits and detriments. Used in conjunction with whole life costing in the early stages of equipment evaluation, CBA could greatly benefit the procurement process.

By considering the case studies in this chapter it is evident that WLC only gives part of the story. By combining it with CBA, it is possible to see a bigger picture and make an informed decision about a particular course of action. When evaluating equipment prior to purchase ambulance services should consider cost as one of the factors. Equipment purchased to carry out manual handling tasks should be evaluated in terms of the risk posed when using the equipment to carry out the task. If the manual handling risk is low, the whole life costs will decrease. Cost should be balanced with quality, too often only cost is considered. The quality of a product can balance out the cost and reduce it in the long term. Quality should be twinned with the end users needs (Lloyd, 11/10/2006, *Personal communication*).

6.2.7 Site and field evaluations

This thesis reports two main types of evaluation; site evaluation and field evaluation. Both proved successful methods but each were carried out under different conditions. All equipment should be trialled in the field before it is finally purchased. There is no way of accounting for all environmental constraints and situations experienced by ambulance staff in the field, without trialling the equipment on the road for a considerable length of time (approx 100 hours, as experienced in the stretcher loading study) as it is not possible to fully identify a products strengths and weaknesses. Understandably, ambulance risk and safety departments are reluctant to put any equipment on an ambulance which has not been initially tested in a controlled site evaluation (Smith, 09/12/2005, *Personal communication*) which is why site evaluations are usually conducted first (see procurement process flowchart, Figure 6.2). Field evaluations therefore should only be carried out if the equipment has been previously tested on site or were used for a number of years on vehicles prior to the study, as with the stretcher loading evaluation (Chapter 4).

Other factors preventing field evaluations include the number of products being assessed and ethical issues relating to the patient. The stretcher loading study discussed in Chapter 4 was in two parts, the field study and the simulation (site evaluation) study. Although the equipment evaluated had been used for a number of years a site evaluation was needed to collect video footage of the manual handling tasks to conduct the postural analysis. Due to ethical constraints, the researcher was unable to film patients and therefore the tasks had to be simulated without a real patient. To carry out a comparative analysis of the postural risk posed by each system, the tasks needed to be controlled, testing each system under the same conditions, (for example the road surface had to be the same for each simulation exercise). A field evaluation would not have achieved these conditions.

For the mobility equipment evaluation (Chapter 5) lab trials were carried out to comparatively assess 16 products. It would have taken a considerable length of time to put all 12 chairs and 4 stretchers on an ambulance and trial them in the field. Also the ambulances used by EMAS did not have the appropriate fixtures and fittings to safely transport the equipment. It would have been difficult to collect data for 16 pieces of equipment in different geographic locations; and finally the quality of data would have been difficult to control. Instead the products were tested in a lab trial and recommendations were provided for products to be evaluated by the ambulance service in a field trial.

Products should not be procured in large quantities until they have been subjected to field trialling, because there may be problems in the environment which have not been accounted for in lab trials. The simulations carried out for Chapter 5 were a compromise between a lab trial and a field investigation. Difficult environments were identified prior to trialling and simulated in the controlled environment. It would be good practice to carry out a lab trial and a field trial but the lab trial should be completed first. In certain circumstances it is plausible to conduct a field trial alone. In order to identify what type of evaluation is needed there are four decision steps to follow (Figure 6.6).

Step 1) What type of evaluation is needed?
Step 2) Is the equipment new to the market?
Step 3) Are there a large number of products to be evaluated?
Step 4) Is a manual handling assessment needed?

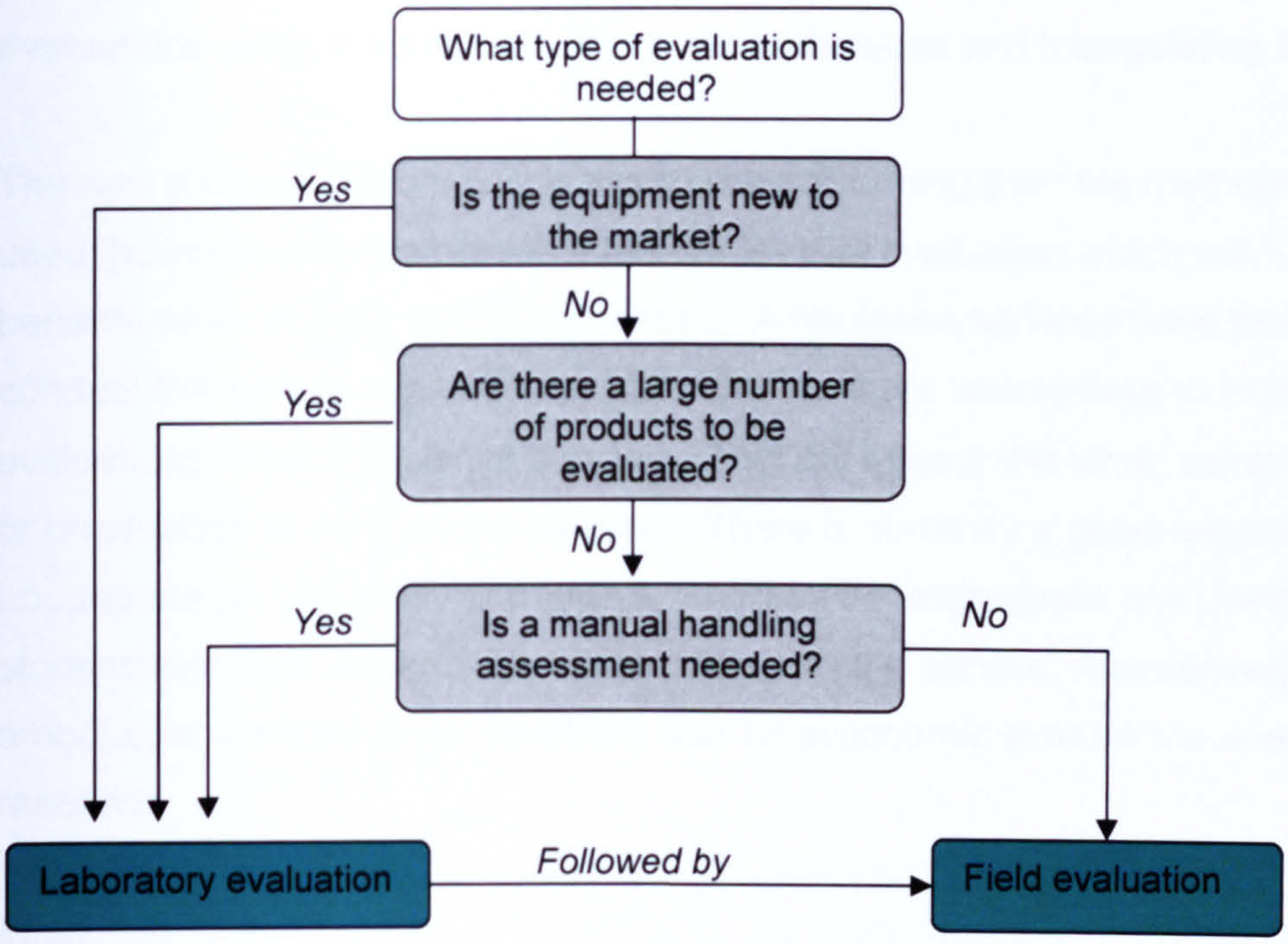


Figure 6.6 Flow diagram to select the type of evaluation to conduct

6.2.8 Ergonomic protocol for future procurement

Figure 6.7 shows the procurement process recommended as a result of this. It is evident from Figure 6.2 that the ambulance service do evaluate equipment, but are their evaluations thorough enough? The new approach to procurement and evaluation of capital purchases described in this section provides a much more thorough and rigorous evaluation offering an informed basis on which to make purchasing decisions about movement and transfer equipment. This thesis concludes that by using ergonomic methods, preferably using mixed methodology, it is possible to comparatively assess equipment on a scientific basis, and provide statistical evidence of the risk posed by this equipment. The HSE (2003b) claimed that manual handling tasks pose a great risk to ambulance workers, so identifying the equipment which poses the least risk and is the most user friendly, through evaluation would be beneficial. A more thorough evaluation protocol for purchasing movement and transfer equipment has been developed.

The flowchart in Figure 6.7 indicates all the necessary steps to carry out a thorough evaluation of equipment, prior to selection and purchase. This was taken from the original procedures followed by EMAS (Figure 6.2) and enhanced as a result of the findings in this thesis. It shows the importance of carrying out thorough site and field evaluations using a number of ergonomic techniques and triangulating the findings.

The new protocol (Figure 6.7) is more time consuming than the methods currently used, however it encompasses a greater level of evaluation which will have many benefits when making capital purchases. Ambulance services have limited time to conduct this type of evaluation process but there are alternatives to individual evaluations. The ambulance services could out-source the work, using consultancies or universities to conduct the research. There is currently a good relationship between Loughborough University and EMAS, whereby undergraduate and postgraduate students conduct research in collaboration with the service. Alternatively the ambulance services could develop a role for ergonomic evaluations and market research.

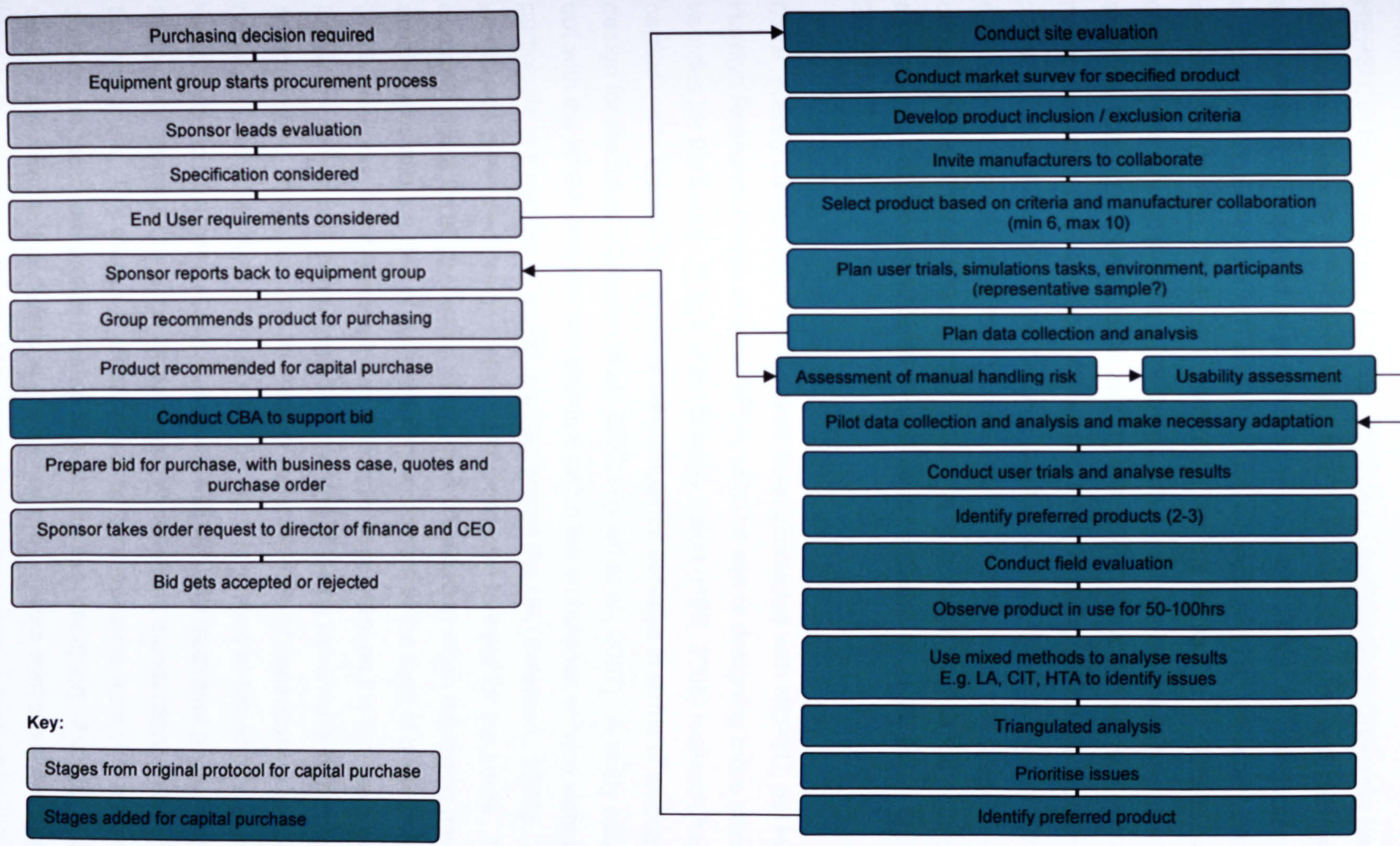


Figure 6.7 Procurement protocol for purchase of manual / patient handling equipment in the future

6.3 Previous and future research

HEPSU, in the Department of Human Sciences, Loughborough University have been conducting research in the ambulance sector for over four years, with studies including an evaluation of responder bags (Redden and Hignett, 2003), an assessment of the clinical working environment (Ferreira, 2002), an evaluation of non-emergency ambulances (Hunter, 2004), an investigation into the extrication of patients from confined and difficult situations (Yeomans, 2004), a comparative assessment of stretcher loading systems (Jones and Hignett, 2005; Jones and Hignett, 2007), moving patients through vertical space (Stevenson, 2005; Ponting, 2005), transporting bariatric patients (Grimshaw, 2003), the bariatric patient pathway (Hignett, et al., 2007b) and an evaluation of mobility equipment (Jones, 2007). This research has predominantly centred on activities or tasks carried out by the ambulance staff, ambulance design as a whole has not been considered up until recently (Coleman et al., 2007; Hignett et al., 2007).

More recently collaborative studies have been conducted with HEPSU, the Helen Hamlyn Research Centre and the NPSA, with the aim of designing more standardised vehicles for the future. In light of the Bradley report (HSE, 2005) research has been carried out to identify the needs of the ambulance services in terms of ambulance design for the future (Coleman et al., 2007; Hignett et al., 2007). A study was carried out with the NPSA whereby stakeholders within the ambulance service were invited to participate in a number of workshops held across the UK (Coleman., 2007). These workshops generated design ideas and ideas to take forward for the future. The main outcome was a list of key factors which need considering when designing new ambulances and the idea of standardising equipment in the form of a standard module which transports individual treatment packages dependent on the service provided. A follow on study is now being carried out looking at taking healthcare to the community (Hignett et al., 2007), with the intention of reducing 40% of unnecessary patient visits to hospital (Dale et al., 1995; DH, 2005). The study is looking at providing a standard vehicle pod to Emergency Care Practitioners (ECP) with treatment pods determined by the type of treatment required for each patient condition, standardisation being one of the end goals. This study will combine groups of researchers from very different domains to tackle the problem with a multi-disciplinary approach. Aspects of vehicle design and treatment packages will be looked at by a team comprised of Ergonomists, Vehicle Designers, Healthcare Management and Procurement specialists, a Sociologist and a Clinician. By using multi-discipline research teams researchers can provide a much more detailed analysis and package of recommendations can be provided to the ambulance service, looking not only at equipment design but helping to improve existing care and facilitate the delivery of new services to the patient.

Chapter 7: Conclusion

A number of conclusions have been drawn from this research. The automation of patient handling equipment is the way forward for reducing the risk posed to ambulance workers whilst conducting manual handling tasks including loading and unloading patients from the ambulance and transferring patients up and down stairs.

The ambulance services need to incorporate a more comprehensive evaluation procedure for manual handling equipment than that currently used. Evaluations of capital purchases should not be carried out using the same strategy as revenue purchases.

In order to adopt a more ergonomic approach to equipment procurement ambulance services need to adapt their procurement culture. This should include:

1. Developing a greater awareness of equipment on the market and informed choices
2. Improving the collaboration between trusts and manufacturers
3. Standardising equipment based on scientific evidence
4. Automating manual handling equipment wherever possible
5. Recruiting ergonomic support for correct implementation of change
6. Conducting ergonomic interventions which include cost benefit analysis, site and field evaluation procedures
7. Following the ergonomic protocol developed for future procurement

References

Aiken, L.R., 1996, *Rating Scales and Checklists; Evaluating Behaviour, Personality and Attitudes.* (New York: Wiley and Sons Inc).

Alves, D.W., Bissell, R.A. 2002, Ambulance snatching: how vulnerable are we? *The journal of Emergency Medicine*, 25, 211-214.

Annett, J. 2005. Hierarchical Task Analysis (HTA). In N Stanton., A Hedge., K Brookwillis., E Salas., H Hendrick (Eds.) *Handbook of human factors and ergonomics methods.* (London: CRC Press). 33.1-33.7.

ASA. 2007, *Ambex 2007.* http://www.ambex.net/ accessed 27th July 2007. [online]

ASA. 2007, *Ambulance Service.* http://www.asa.uk.net/editorial.asp?page_id=84 accessed on 16th November 2007. [online]

Aveyard, H., Woolliams, M. 2006, In whose best interests? Nurses' experiences of the administration of sedation in general medical wards in England: An application of the critical incident technique. *International Journal of Nursing Studies*, 43, 929-939.

Bainbridge, L., Penelope, S. 2005, Verbal Protocol Analyis. Chapter 7. In JR Wilson, ER Corlett (Eds.) *Evaluation of Human Work. A practical ergonomics methodology.* 3rd Ed. (FL: CRC Press). 159-184.

Barnekow-Bergvist, M., Aasa, U., Angquist,K.A., Johansson, H. 2004, Prediction of development of fatigue during a simulated ambulance work from physical performance tests, *Ergonomics.* 47, 1238-1250.

Bazeley, P., Richard, L. 2000, *The NVivo Qualitative Project Book.* (London: Sage Publications).

BBC. 2005, *London bombings toll rises to 37.* http://news.bbc.co.uk/1/hi/uk/4661059.stm. Accessed 9th August 2007. [online]

Bentley, L. 1995, *Derbyshire Ambulance Service Task Analysis and Recommendations.* EMAS. Internal document

Birtles, M., Boocock, M.G. 2003, An ergonomics evaluation of the manual handling operations of UK ambulance staff, with particular emphasis on the risks associated with the use of carry chairs, *Health and Safety Laboratory.* Internal report.

Boocock, M., Smith, C. and Morris, L. (2002) An Ergonomic Evaluation of loading operations using the Ferno 35A trolley cot. Internal Report. Health and Safety Executive.

Brodie, D.A. (1996). Matching the Staff to the Tasks; An Executive Report for Derbyshire Ambulance Service from the University of Liverpool. EMAS. Internal document.

Bruseberg, A., McDonagh-Philp. 2002, Focus groups to support the industrial / product designer: a review based on current literature and designers' feedback. *Applied Ergonomics.* 33, 27-38.

BSI. 2002, Safety of Machinery – Human Physical Performance – Part 3. Recommended Limits for Machinery Operation. BSI BS EN 1005-3:2001. London: British Standards Institution.

Buckle, P. 1997, Upper Limb Disorders and Work: The Importance of Physical and Psychosocial Factors. *Journal of Psychosomatic Research.* 43, 17-25.

Butters, L.M., Dixon, R.T. 1998, Ergonomics in consumer product evaluation: an evolving process. *Applied Ergonomics.* 29, 55-58.

Calland, V. 2005, Extrication of the seriously injured road crash victim. *Emergency Medical Journal.* 22, 817-821.

CEN. 2000a, Specifications for Stretchers and Other Patient Handling Equipment Used on Road Ambulance. BSI BS EN 1865:1999. London: British Standards Institution.

CEN. 2000b, Medical Vehicles and their Equipment – Road Ambulances. BSI BS EN 1789:1999. London: British Standards Institution.

CEN. 2007, Medical Vehicles and their Equipment – Road Ambulances. BSI BS EN 1789:1999. London: British Standards Institution.

Chell, E. 1998, Critical Incident Technique. Chapter 4. In G Symon., C Cassell (Ed.) *Qualitative methods and analysis in organizational research: a practical guide.* (London: Sage Publications). 51-72.

CHI. 2002, *Clinical Governance Review – East Anglian Ambulance NHS Trust.* http://www.eastanglianambulance.com/library/documents/other/chi/east_anglian_ambreport.pdf. Accessed 4th April 2005. [online]

CHI, 2003a. *Clinical Governance Review – East Midlands Ambulance Service NHS Trust.* http://www.healthcarecommission.org.uk/assettRoot/04/00/26/13/04002613.pdf. Accessed 4th April 2005. [online]

CHI (2003b). *Clinical Governance Review – Two Shires Ambulance NHS Trust and Thames Valley and Northamptonshire NHS Direct.* http://www.healthcarecommission.org.uk/assetRoot/04/00/33/44/04003344.pdf. Accessed 4th April 2005. [online]

CIPS. 2007, *Whole life costing (WLC) – The CIPS position, and what the buyer needs to know.* http://www.adm.monash.edu.au/procserv/purchasing/cips-whole-of-life-costing.pdf. Accessed 17th April 2007. [online]

Clayton, M. 1997. Delphi: a technique to harness expert opinion for critical decision-making tasks in education. *Educational Psychology.* 17, 373-386.

Coleman, R. 2007, *Safer ambulances by design: putting theory into practice.* http://www.saferhealthcare.org.uk/IHI/Topics/AnalysisandTheory/Features/9506_Safer+ambulances+by+design.htm. Accessed 13th July 2007. [online]

Coleman, R., Harrow, D., Evans,O., Kunur, M., Halls, S., Kafka, D., Jones, A., Crumpton, E., Hignett, S. (2007) Design for Patient Safety: Future Ambulances. National Patient Safety Agency/Helen Hamlyn Trust. www.npsa.nhs.uk/media/documents/2757_Ambulance_design_FULL.pdf. Accessed 2nd July 2007. [online]

Collins, B. 1994, Objective Manual Material Handling Assessments in the Ambulance Service Using the Lumbar Monitor Industrial Package. *Ambulance.* 10-14.

Cooper, G., Ghassemieh, E. 2007, Risk assessment of patient handling with ambulance stretcher systems (ramp/winch, easy-loader, tail-lift) using biomechanical failure criteria. *Medical Engineering & Physics.* 29, 775-787.

County Air Ambulance. *Homepage.* http://www.airambulance.co.uk/pages/about.htm. Accessed 11th April 2007. [online]

Covalla, E. 2003, *Visual Postures Observation Error and Training.* North Carolina State University, US. Unpublished MSc thesis.

Coyle, A. 2005, Comparison of the Rapid Entire Body Assessment and the New Zealand Manual Handling 'Hazard Control Record', for assessment of manual handling hazards in the supermarket industry. *Work.* 24, 111-116.

Dale J., Green J., Reid F., Glucksman E. 1995, Primary care in the accident and emergency department: Prospective identification of patients. *BMJ.* 311, 423-426.

Dalkey, N. Helmer, O. 1963, An Experimental Application of The Delphi Method to the Use of Experts. *Management Science.* 9, 458-467.

David, G., Woods, V., Buckle, P. Stubbs, D. 2003, Further Development of The Quick Exposure Check (QEC). http://www.geocities.com/qecuk/References/FurtherDevelopmentOfQEC-IEA2003.pdf. Accessed 14th November 2007. [online]

David G.C. 2005, Ergonomic methods for assessing exposure to risk factors for work-related musculoskeletal disorders. *Occupational medicine.* 55, 190-199.

David, G., Woods, V., Li, G., Buckle, P. 2008, The development of the Quick Exposure Check (QEC) for assessing exposure to risk factors for work-related musculoskeletal disorders. *Applied Ergonomics.* 39, 57-69.

Demetriades, D., Chan, L., Cornwell, E., Belzberg, H., Berne, T.V., Asensio, J., Chan, D., Eckstein, M., Alo, K. 1996, Paramedic V's private transportation of trauma patients, Archives of surgery, 131, 131-133.

Dempsey, P.G. 1998, A critical review of biomechanical, epidemiological, physiological and psychophysical criteria for designing manual materials handling tasks. *Ergonomics*, 41, 73-88.

DH. 2000, *999 calls to ambulance services double over last decade*, http://www.dh.gov.uk/en/Publicationsandstatistics/Pressreleases/DH_4004887. Accessed 11th September 2006. [online]

DH. 2003, *Ambulance improvement checklist.* http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4085178. Accessed 10th April 2007. [online]

DH. 2005, *Taking Healthcare to the Patient. Transforming NHS Ambulance Services.* http://www.dh.gov.uk/assetRoot/04/11/42/70/04114270.pdf. Accessed 2nd September 2005. [online]

DH. 2007, *Attendances at accident & emergency departments and minor injury units, NHS organisations in England, 2006-07* http://www.performance.doh.gov.uk/hospitalactivity/data_requests/a_and_e_attendances.htm. Accessed 9th August 2007. [online]

DH. 2007, *Ambulances.* http://www.dh.gov.uk/en/Policyandguidance/Organisationpolicy/Emergencycare/Modernisingemergencycare/DH_4063824. Accessed 16th November 2007. [online]

Doormaal, M.T.A.J., Driessen, A.P.A., Landeweerd, J.A., Drost, M.R. 1995, Physical Workload of Ambulance Assistants. *Ergonomics*. 38, 361-378.

Drury, 1990. Methods for direct observation of performance. In JR Wilson, EN Corlett (Eds.) *Evaluation of Human Work – A practical ergonomics methodology*. 2nd Ed. (London: Taylor and Francis). 45-68.

EAAT. 2003, *The road ahead – summary service plan 2003-2004.* http://www.eastanglianambulance.com/library/documents/other/summaryServicePlan2003-2004.pdf. Accessed 4th May 2005. [online]

EMAS. 2004, *Homepage.* http://www.emas.nhs.uk. Accessed 29th April 2005.

EMAS. 2006, Interim Report 1 April – 30 June 2006. EMAS. Internal document.

Endsley, M.R. 1996, Automation and situation awareness. Chapter 8. In R. Parasuraman., M Mouloula (Eds.) *Automation and human performance: Theory and applications.* (NJ: Lawrence Erlbaum). 163-181.

Erlandson, D.A., Harris, E.L., Skipper, B.L. and Allen, S.D. 1993, *Doing Naturalistic Inquiry: A guide to Methods.* (London: Sage).

FDA. 2005, *MAUDE.* http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfMAUDE/search.cfm. Accessed 10th April 2005. [online]

Ferreira, J.J. 2002, Ergonomic Investigation of Ambulance Design: Paramedics and Technicians Working in the Patient Compartment. Loughborough University UK. Unpublished MSc thesis.

Ferreira, J. and Hignett, S. 2005, Reviewing ambulance design for clinical efficiency and paramedic safety. *Applied Ergonomics.* 36, 97-105.

Ferreira, J.J. and Stanley, L. 2005, *Evaluation of manual handling tasks involving the use of carry chairs by UK ambulance personnel.* http://www.hse.gov.uk/research/rrpdf/rr314.pdf. Accessed 6th January 2006.

Flowers, J., Hinxman, L. 2001. *Controls assurance: best practice implementation strategies.* http://www.emeraldinsight.com/Insight/ViewContentServlet?Filename=Published/EmeraldFullTextArticle/Articles/0690191306.html. Accessed 10th August 2007. [online]

Fredericks, T.K., Choi, S.D., Butt, S.E., Kumar, A.R. 2002a, Postural Analyses of Paramedics Using Stairchairs. In *The Proceeding of the XVI Annual International Occupational Ergonomics and Safety Conference.* Toronto, Ontario, Canada, 10-13 June 2002. 71

Fredericks, T.K., Choi, S.D., Butt, S.E., and Kumar, A.R. 2002b, Biomechanical Analyses of Paramedics Using Stairchairs. In *The Proceeding of the XVI Annual International Occupational Ergonomics and Safety Conference*. Toronto, Ontario, Canada, 10-13 June 2002.

Furber S., Moore, H., Williamson, M., Barry. J. 1997, Injuries to Ambulance Officers Caused by Patient Handling Tasks. *Journal of Occupational Health and Safety – Aust/NZ.* 13, 265-269.

Gershon, R.R., Vlahov, D., Kelen, G., Conrad, B., Murphy, L. 1995, *Prehospital and Disaster Medicine*, 10, 14-18.

Glendon, I. and Coles, F. 2001, Stress in ambulance staff. Chapter 1.6. In: P Hancock (Ed.) *Stress, workload and fatigue.* (Laurence Earlbaum Associates). 167-199.

Great North Air Ambulance. 2007, *Homepage,* http://www.greatnorthairambulance.co.uk/story.php. Accessed 11th April 2007. [online]

Guha, S.K. 1989, A new stretcher design for easy manoeuvrability on narrow staircases and rough ground for developing countries. *Journal of Engineering in Medicine*. 203, 55-60.

Haslegrave, C.M., Corlett, E.N. 1990, Evaluating work conditions and risk of injury – techniques for field surveys. In JR Wilson., EN Corlett (Eds.) *Evaluation of Human Work – A practical ergonomics methodology.* 2nd Ed. (London: Taylor and Francis). 892-920.

Hassan, T.B., Barnett, D.B. 2002, Delphi type methodology to develop consensus on the future design of EMS systems in the United Kingdom. *Emergency Medical Journal*, 19, 155-159.

Heinsalmi, P. 1986, Methods to measure working posture loads at working sites. Chapter 10. In EN Corlett, JR Wilson, I Manenica (Eds.) *The Ergonomics of Working Postures.* (London: Taylor and Francis). 100-104.

Hignett, S. 2001, Using Qualitative Methodology in Ergonomics: theoretical background and practical examples. Ph.D. thesis, University of Nottingham.

Hignett, S. 2005, Qualitative methodology for Ergonomics. Chapter 5. In JR Wilson, EN Corlett (Eds.) *Evaluation of Human Work. A practical ergonomics methodology.* 3rd Ed. (FL: CRC Press). 113-128.

Hignett, S., Jones, A., Crumpton, E., Harrow, D., Evans,O., Kunur, M., Halls, S., Kafka, D., Coleman, R. (2007) Designing future ambulance transport for patient safety: research undertaken. National Patient Safety Agency/Helen Hamlyn Trust. www.npsa.nhs.uk/media/documents/2758_Ambulance_design_research.pdf. Accessed 2nd July 2007

Hignett, S., Griffiths, P., Chipchase, S., Tetley, A. 2007, The Bariatric Journey: An Integrated Systems Approach to Patient Handling. *In the Proceedings of the 7th Annual Safe Patient Handling and Movement Conference.* 12-16 March 2007. Orlando, Florida, USA.

Hignett, S., McAtmaney, L. 2000, Rapid Entire Body Assessment (REBA), *Applied Ergonomics.* 21, 201-205.

Hogya, P.T., Ellis, I. 1990, Evaluation of the injury profile of personnel in a busy urban EMS system. *The American Journal of Emergency Medicine*, 8, 308-311.

HSE. 1998a. Manual Handling Operations Regulations 1992. Guidance of Regulations. Http://www.hse.gov.uk/lau/lacs/56-1.htm. Accessed 2nd February 2004. [online]

HSE. 1998b, Safe use of work equipment. Provision and Use of Work Equipment. Provision and Use of Work Equipment Regulations (PUWER). Approved Code of Practice and Guidance L22 HSE Books.

HSE. 1998c, Safe use of lifting equipment. Lifting Operations and Lifting Equipment Regulations (LOLER). Approved Code of Practice and Guidance L22 HSE Books.

HSE. 2003a, *Manual handling assessment charts.* http://www.hse.gov.uk/pubns/indg383.pdf. Accessed 14th November 2007. [online]

HSE. 2003b, *Protecting Ambulance Staff.* http://www.hse.gov.uk/press/2003/e03245.htm. Accessed 30th May 2007. [online]

HSE. 2004, *Getting to grips with manual handling - A short guide.* http://www.hse.gov.uk/pubns/indg143.pdf Accessed on 11th November 2007. [online]

HSE. 2006, *Five steps to risk assessment.* http://www.hse.gov.uk/PUBNS/indg163.pdf. Accessed 10th August 2007 [online]

HSE. 2007, *Health and Safety at Work etc Act 1974.* Hse.gov.uk/legislation/hswa.htm. Accessed 14th November 2007. [online]

Ive, R. 2003, Risk Management Annual Report. Two Shires Ambulance Service NHS Trust. TSAT. Internal Report.

Janowitz, I.L., Gillen, M., Ryan, G., Rempel, D., Trupin, L., Swig, L., Mullen, K., Rugulies, R., Blanc, P.D. 2006, Measuring the physical demands of work in hospital settings: Design and implementation of an ergonomics assessment. *Applied Ergonomics.* 37, 641-658.

Jones, A. 2007. *Evaluation of mobility equipment in the ambulance service.* http://www.saferhealthcare.org.uk/IHI/Topics/ManagingChange/Features/9514_EvaluationOfMobilityEquipmentInTheAmbulanceService.htm. Accessed 12th November 2007. [online]

Jones. A., Hignett, S. 2005. Ambulance Loading Systems. Loughborough University. Internal report.

Jones, A., Hignett, S. 2007, Safe access/egress systems for emergency ambulances. *Emergency Medicine Journal.* 24, 200-205.

Jones, A., Hignett, S., Benger, J., Harrow, D., Coleman, R., Matthews, E., Caldwell, N., Petersen, A. 2007, Taking healthcare to the community in the 21st century. *Ambulance Today.* (In press)

Jones, T., Woollard, M. 2003, Paramedic accuracy in using a decision support algorithm when recognising adult death: a prospective cohort study. *Prehospital Care.* 20, 473-475.

Jordan, P.W. 1998, Human factors for pleasure in product use. *Applied Ergonomics.* 29, 25-33.

Kent, G., Wills, G., Faulkner, A., Parry, Whipp, M., Coleman, R. 1996, Patient reactions to met and unmet psychological need: A critical incident analysis, *Patient Education and Counselling*. 28, 187-190.

King. 1994, The qualitative research interview. Chapter 2. In C Cassell, G Symon (Eds.) *Qualitative Methods in Organizational Research.* (London: Sage). 14-36.

Kirwan, B., Ainsworth, L.K. 1992, *A Guide to Task Analysis.* (London: Taylor and Francis).

Kitzinger, J. 1995, Qualitative Research: Introducing focus groups. *British Medical Journal*, 311, 299-302.

Kluth, K., Strasser, H. 2006, Ergonomics in the rescue service – Ergonomic Evaluation of ambulance cots. *International Journal of Industrial Ergonomics.* 36, 247-256.

Knapik, J.J., Harper, W., Crowell, H.P. 1999, Physiological factors in stretcher carriage performance. *European journal of applied physiology*, 79, 409-413.

Landeweerd, J.A., Kant, I. 1996, Working postures and physical load of ambulance nurses. *Advances in Applied Ergonomics.* 941-4.

Lane, R., Stanton, N.A. Harrison, D. 2005, Applying hierarchical task analysis to medication administration errors. *Applied Ergonomics.* 37, 669-679.

LAS, 2003. Risk Management Strategy Summary, March. Internal document.

LAS. *Protocol for booking ambulance transport.* http://www.dvh.nhs.uk/downloads/documents/XUM0TNX4SS_Protocol_for_Booking_Ambulance_Transport.pdf. Accessed 6th December 2007. [online]

Lau, B.W.K. 1998, An appraisal of lay and medical concepts of illness. *Journal of the Royal Society of Health.* 108, 185-187.

Lavender, S.A., Conrad, K.M., Reichelt, P.A., Johson, P.W., Meyer, F.T. 2000a, Biomechanical Analysis of Paramedics Simulating Frequently Performed Strenuous Work Tasks. *Applied Ergonomics.* 31, 167-177.

Lavender, S.A., Conrad, K.M., Reichelt, P.A., Johnson, P.W., Meyer, F.T. 2000b, Postural analysis of paramedics simulating frequently performed strenuous work tasks. *Applied Ergonomics.* 31, 45-47.

Lavender, S.A., Conrad, K.M., Reichelt, P.A, Gacki-Smith, J., Kohok, A.K. 2007a. Designing ergonomic interventions for EMS workers, Part 1: Transporting patients down the stairs. *Applied Ergonomics.* 38, 71-81.

Lavender, S.A., Conrad, K.M., Reichelt, P.A., Kohok, A.K. and Gaki-Smith, J. 2007b. Designing ergonomic interventions for EMS workers – Part 2: Lateral transfers. *Applied Ergonomics.* 38, 227-236.

Lavender, S.A., Conrad, K.M., Reichelt, P.A., Kohok, A.K., Gaki-Smith, J. 2007c, Designing ergonomic interventions for emergency medical services workers – part 3: Bed to stairchair transfers. *Applied Ergonomics.* 38, 581-589.

Le Bon, C. and Forrester, C. 1997, An ergonomic evaluation of a patient handling device: the elevate and transfer vehicle. *Applied Ergonomics.* 28, 365-374.

Lenton, F. 2005, *A comparison of two postural analysis tools: Rapid Entire Body Assessment and The NIOSH Lifting Equation.* Unpublished B.Sc. dissertation. Dept of Human Sciences, Loughborough University.

Letendre, J. Robinson, D. 2000, Evaluation of Paramedics tasks and equipment to control the risk of musculoskeletal injury. For: Workers' Compensation Board Grant 99FS-14, Ambulance Paramedics of British Columbia, CUPE Local 873, Richmond, British Columbia, Canada, November, 2000, BCR Project No: 6-08-0793.

Leyshon, G.E., Francis, H.W.S. 1975, Lifting injuries in ambulance crews. *Public Health.* 89, 71-5.

Li, G., Buckle, P. 1998, A practical method for the assessment of work-related musculoskeletal risks – Quick Exposure Check (QEC). In *Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting – 1998.* 1351-1355.

Li, G., Buckle, P. 1999. Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. *Ergonomics.* 42, 674-695.

Liljergen, E. 2006, Usability in a medical technology context assessment of methods for usability evaluation of medical equipment. *International Journal of Industrial Ergonomics.* 36, 345-352.

Lingard (date unknown). Manual handling: The Partnership Approach to Problem Solving. *Risk Management.*19-20.

Massad, R., Gambin, C., Duval, L. 2000, The contribution of Ergonomics to the prevention of Musculoskeletal lesions among ambulance technicians. In *Proceedings of the IEA2000/HFES 2000 Congress.* The Human Factors and Ergonomics Society. Santa Monica, California. 4, 201-204.

MacLeod, I.S. 2003, Real-world effectiveness of Ergonomic methods. *Applied Ergonomics.* 34, 465-477.

McAtamney, L., Corlett, E.N. 1993, RULA—rapid upper limb assessment, *Applied. Ergonomics.* 24, 91–99.

McClelland, 1990. Product assessment and user trials, Chapter 10. In JR Wilson, EN Corlett (Eds.) *Evaluation of Human Work – A practical ergonomics methodology.* 2nd Ed. (London: Taylor and Francis) 249-284.

McDermott, P., Warwick J. 2002, Evaluation report on the JAKAB and MODULAR ambulances fitted with Tail-lifts. *For: London Ambulance Service.* Internal report.

McGill, S.M., Kavcic. 2005, Transfer of the horizontal patient: The effect of a friction reducing assistive device on low back mechanics. *Ergonomics.* 48, 915-929.

McGill, S.M., Potvin, J., Norman, R.W. 1990, Estimating low back demands in ambulance attendants using a hybrid anatomical model. In *Proceedings of the 23rd conference of the Human Factors Association of Canada.* Ottawa, Canada 26-26 Sept. The Association, Mississauga, Ontario. 191-195.

McGregor, J., Hanlon, N., Emmons, S., Voaklander, D., Kelly, K. 2005, If all ambulances could fly: putting provincial standards of emergency care access to the test in northern British Columbia. *Canadian Journal of Rural Medicine.* 10, 163-168.

Medical Devices Agency. 2003, *The Safe Use of Ambulance Stretcher Trolleys* http://www.medicaldevices.gov.uk/mda/mdawebsitev2.nsf/0/6f2565494ea642b480256cf0003ad107/$FILE/db2003(04).pdf. Accessed 4th April 2004. [online]

Mindtools. 2007, *Cost Benefit Analysis, Evaluating Quantitatively Whether to Follow a Course of Action.* http://www.mindtools.com/pages/article/newTED_08.htm. Accessed 30th May 2007. [online]

Mitterer, D. 1999, *Back injuries in EMS.* www.emsmagazine.com Accessed 21st March 2000. [online]

Morgan, D.L. 1998, *The Focus Group Guidebook.* (London: Sage Publications).

Nakata, M., Yoshizawa, M., Nishijima, Y., Kato, T., Boocock, M.G., Ishii, N., and Ängquist, K-A. (2006) Evaluation of muscular workload when handling ambulance stretchers. Proceedings of the 16th World Congress on Ergonomics, IEA2006 Congress (Edited by R N Pikaar, E.A.P Koningsveld, and P.J.M. Settels), 10th-14th July, Maastricht, Elsevier Ltd.

National Statistics. 2007, *Ambulance Services England 2006-2007.* http://www.ic.nhs.uk/webfiles/publications/ambulanceserv06/Final%20Ambulance%20Services%202006-07.pdf Accessed 9th August 2007. [online]

NHS. 2006, *NHS.* http://www.nhs.uk. Accessed 11th November 2006
NHS. 2007a, *How the NHS Works.* http://www.nhs.uk/aboutnhs/HowtheNHSworks/Pages/aboutthenhs.aspx Accessed 16th November 2007. [online]

NHS. 2007b, *NHS Authorities and Trusts.* http://www.nhs.uk/aboutnhs/HowtheNHSworks/authoritiesandtrusts/Pages/Authoritiesandtrusts.aspx. Accessed 16th November 2007. [online]

NHS Employers. 2007, *National Profiles for Ambulance Services.* http://www.nhsemployers.org/restricted/downloads/download.asp?ref=1741&hash=35f6ed2feca2ca8dbc648a199638f588&itemplate=e_aboutus_3col_aboutus-2028. Accessed on 16th November 2007. [online]

NHS Trent Region Procurement Consortium, East Midlands Ambulance Service NHS Trust and Lincolnshire Ambulance and Patient Transport Service NHS Trust. 2002, *Specification for Accident and Emergency BS EN 1789:2000 Type B Coachbuilt Ambulance Body Based upon Renault Master 3.9 Tonne GVW Cab Chassis.* NHS Trent Region Procurement Consortium. Internal Report

Norton, R., Wortman, E., Eastes, L., Daya, M., Hedges, J., Hoyt, J. 1996, Appropriate Helicopter Transport of Urban Trauma Patients. *Journal of Trauma Injury Infection and Critical Care.* 41, 886-891.

NPSA. 2007, *NRLS local database instruction for use.* http://www.npsa.nhs.uk/site/media/documents/572_NRLS_local_database_instructions_for_use_issue_2.pdf. Accessed 19th September 2007. [online]

NYC Health. 2007, *Office Ergonomics: The Chair.* http://www.nyc.gov/html/doh/html/eode/eode-ergonomics-chair.shtml. Accessed 12th August 2007. [online]

Office of the Deputy Prime Minister, 2000, *The Building Regulations 2000 Access to and use of buildings.* http://www.tauntondeane.gov.uk/Forms/AppDocM-Access.pdf. Accessed 16th November 2007. [online]

Öhman, U., Bylund, P.O., Bjornstig, U. 2002, Impairing Injuries Among Medical Personnel. *Western Journal of Nursing Research.* 24, 788-802.

Okunribido, O.O., Magnusson, M., Pope, M.H. 2006, Low back pain in drivers: The relative role of whole body vibration, posture and manual materials handling. *Journal of Sound and Vibration.* 298, 540-555.

Overton, J. 2001, Ambulance Design and Safety. *Journal of Pre-hospital and Disaster Medicine*. 16, 33.

Owen, B. 2000, Preventing Injuries Using an Ergonomic Approach. *AORN*. 72, 1031-1036.

Oxenburgh, M., Marlow, P. 2006, Cost, justification for Implementing Ergonomics Intervention. Chapter 4. In W Karworski, WS Marras (Eds.) The Occupational Ergonomics Handbook. 2nd Ed. (FL:CRC Press / London: Taylor and Francis). 4.7-4.13.

Pawson and Tilley. 1997, *Realistic evaluation*. (London: Sage).

Pell, J.P., Sirel, M., Marsden, A.K., Ford, I., Cobbe, S.M. 2001, Effect of reducing ambulance response times on deaths from out of hospital cardiac arrest: cohort study. *British Medical Journal*. 322, 1388-1388.

Pheasant, S., Stubbs, D. 1992, Back pain in nurses: epidemiology and risk assessment. *Applied Ergonomics*. 23, 226-232.

Pinder, A. 2002, *Benchmarking of manual handling assessment charts*. http://www.hse.gov.uk/research/hsl_pdf/2002/hsl02-31.pdf. Accessed 10th August 2006. [online]

Ponting, A. 2005, An Ergonomic Investigation of the Design of Emergency Carry Chairs Used by Ambulance Services. Loughborough University, UK. Unpublished MSc thesis.

Ray Smith Group. 2001, *Gentle Lifts into Ambulances*. http://www.rsg.co.uk/rsgnews/rsgnewsdetail.asp?ID=3. Accessed 8th February 2004.

Redden, D., Hignett, S. 2003, Evaluation of Paramedic Bag Systems. *Ambulance Today*. 3, 33-35.

Redelmeier, D., Blair, P.J., Collins, W.E. 1994, No Place to Unload: A Preliminary Analysis of the Prevalence Risk Factors and Consequences of Ambulance Diversion, *Annals of Emergency Medicine*. 23, 43.

Rennie, A.M. 1981, The application of ergonomics to consumer product evaluation. *Applied Ergonomics.* 12, 163-168.

Robson, C. 2002. *Real World Research - A Resource for Social Scientists and Practitioner-Researchers.* 2nd Ed. (Oxford: Blackwell Publishing).

Rodgers L. M. 1998, A five year study comparing early retirements on medical grounds in ambulance personnel with those in other groups of health service staff. Part II: Causes of retirement. *Occupational Medicine.* 48, 119-132.

RoSPA. 2000, *Safer People Handling; Preventing back pain and injury in the health and care sectors.* http://www.rospa.com/occupationalsafety/info/handling.pdf Accessed on 5th May 2005. [online]

Sarfas, H. 1993, Ill health retirement in health care workers. *Occupational Health.* 45, 101-103.

SAS. 1998, Mercedes Sprinter Accident and Emergency Unit with Electric Tail Ramp Risk Assessment. Scottish Ambulance Service Health and Safety Department. Internal report.

Scally, G., Donaldson, L.J. 1998, Clinical Governance and the Drive for Quality Improvement in the New NHS in England. *British Medical Journal.* 317, 61–65.

Schwartz, R.J., Benson, L., Jacobs, L.M. 1993, The prevalance of occupatrional injuries in EMTs in New England. *Prehospital and disaster medicine*, 8, 45-50.

Shadbolt, N. 2005, Eliciting Expertise. Chapter 8. In JR Wilson, EN Corlett (Eds.) *Evaluation of Human Work. A practical ergonomics methodology.* 3rd Ed. (FL: CRC Press). 185-218.

Shearn, 2003. Case Examples: Business Benefits Arising From Health & Safety Interventions. http://www.hse.gov.uk/research/hsl_pdf/2003/hsl03-13.pdf. Accessed on 12/09/2006. [online]

Shepherd, A. 2000, *Hierarchical task analysis.* (London: Taylor and Francis).

Shi. 1993, A Cost-Benefit Analysis of a California County's Back Injury Prevention Program. *Public Health Reports.* 106, 204-211.

Shuster, M., Keller, J., Shannon, H. 1995. Effects of Prehospital Care on Outcome in Patients With Cardiac Illness. *Annals of Emergency Medicine.* 26, 138-145.

Siemans. 2007, *Task analysis toolkit.* http://www.plm.automation.siemens.com/en_us/products/tecnomatix/human_performance/jack/task_analysis_toolkit.shtml. Accessed 14th November 2007. [online]

siliconCOACH Ltd. 2007, *Homepage.* http://www.siliconcoach.com/. Accessed 11th July 2007.

Simpson., R. Poirot, R., Baxter, M. 1999, Evaluation of the hephaestus smart wheelchair system. In *Proc. 6th Int. Conf. Rehabilitation Robotics* Stanford, 99-105.

Sinclair, M.A. 2005, Participative assessment. Chapter 4. In JR Wilson, EN Corlett (Eds.) *Evaluation of Human Work. A practical ergonomics methodology.* 3rd Ed. (FL: CRC Press. 83-111).

Smedley J, Egger P, Cooper C., Coggon, D. 1995, Manual handling activities and risk of low back pain in nurses. *Occupational and Environmental Medicine.* 52,160–163.

Smedley, J., Trevelyan, F., Inskip, H., Buckle, P., Cooper, C., Coggon, D. 2003, Impact of Ergonomic Intervention on Back Pain Among Nurses. *Scandinavian Journal of Environmental Health.* 29, 117-123.

Stammers, R.B., Shephard, A. 1990, Task Analysis. Chapter 6. In JR Wilson, EN Corlett (Eds.) *Evaluation of Human Work – A practical ergonomics methodology.* 2nd Ed. (London: Taylor and Francis). 144-168.

Stanton, N.A., Salmon, P.M., Walker, G.H., Baber, C., Jenkins, D.P. 2005, *Human Factors Methods A Practical Guide for Engineering and Design.* Aldershot: Ashgate publishing limited.

Stanton, N. A., Young, M.S. 1999, *A Guide to Methodology in Ergonomics: Designing for Human Use.* (London: Taylor & Francis).

Steen, E., Næss, A. C., Steen, P.A. 1997, Paramedics organizational culture and their care for relatives of cardiac arrest victims. *Resuscitation*, 34, 57-63.
Stevenson, M.G. 1995, Mechanics of Lifting Patients on Ambulance stretchers. Proceedings of the Ergonomics Society of Australia, Glenelg, Adelaide. 135-142.

Stillwell, J.A., Stillwell, P.J. 1994, Sickness Absence in an Ambulance Service. *Journal of Social Occupational Medicine*, 34, 96-99.

Stryker, 2006, *Ergonomic Analysis of Tracked Stair Chairs Show Stair-PRO's Ability to Alleviate the Risk of Operator Injury.* http://www.ems.stryker.com/media/pdf/ergo_2006.pdf. Accessed 12th September 2007. [online]

Suserud, B.O. 2001, How do ambulance personnel experience work at a disaster site? *Accident and Emergency Nursing.* 9, 56-66.

Suserud, B.O. 2005, Culture and Care in the Swedish Ambulance Services. *Emergency Nurse.* 13, 30-36.

Task Architect. 2005, *Homepage.* http://www.taskarchitect.com/. Accessed 12th June 2005.

The European Committee for Standardisation (CEN). 2007, *Title.* http://www.cen.eu/cenorm/homepage.htm. Accessed 7th December 2007. [online]

The NHS Confederation. 2004, *Pocket guide: The NHS in England 2004/05.* (London: The NHS Confederation).

Tortella, B.J., Lavery, R.F. 1994, Disabling job injuries among urban EMS providers. *Prehospital and Disaster Medicine.* 9, 210-213.

Turnbull, N., Dornant, J., Fletcher, B., Wilson, S. 1992, Prevalence of Spinal Pain Among the Staff of a District Health Authority. *Occupational Medicine.*143-148.

TSAT. 2003a, *Generic Risk Assessment Non-Patient Handling; Ferno electric foot end lock.* Internal document.

TSAT. 2003b, Generic Risk Assessment Non-Patient Handling; Ferno Pheonix 2400 Series Transporter. Internal document

TSAT. 2005, *Homepage.* http://www.twoshires.nhs.uk. Accessed 29th April 2005. [online]

UCL. 2004, *title.* http://www.ich.ucl.ac.uk/cmgs/hsregs.htm. Accessed 2nd February 2004. [online]

University of Surrey. 2007, *Quick exposure check.* http://www.surreyergonomics.org.uk/images/stories/Research/QEC/qec.pdf. Accessed 14th November 2007. [online]

Van der Ploeg, E., Kleber, R.J. 2003, Acute and chronic job stressors among ambulance personnel: predictors of health symptoms. *Occupational and Environmental Medicine.* 60, 40-46.

VCA. 2006, *Homepage.* http://www.vca.gov.uk/vehicle/ambul.shtm. Accessed 14th June 2006. [online]

Village. 2003, *Cost-Benefit Analysis of an Ergonomic Intervention in Two Hospital Laundries vs a Control Laundry, British Columbia Environmental & Occupational Health Research Network.* http://www.cher.ubc.ca/PDFs/laundryergonomics.pdf. Accessed 30th May 2007. [online]

Virzi, R. A. 1992, Refining the test phase of usability evaluation: How many subjects is enough? *Human Factors.* 34, 457-468.

Warwickshire and Northamptonshire Air Ambulance. 2007, *Homepage.* http://www.wnaa.co.uk/. Accessed 11th April 2007. [online]

Washington State University. 2007, *A field guide to experimental designs.* http://www.tfrec.wsu.edu/ANOVA/Latin.html. Accessed 7th December 2007. [online]

Watt, B., Dickson. 1999, The Scottish Ambulance Service Board Manual Handling Project; Evaluation of Ambulance Loading Systems – Update, *ASI International*, September 1999.

Welsh Ambulance Service. 2007, Welsh Ambulance Services NHS Trust. http://www.wales.nhs.uk/sites3/page.cfm?orgid=136&pid=864. Accessed 6th December 2007. [online]

Which?. date, *Homepage*. http://www.which.co.uk/. Accessed 23rd August 2007. [online]

Wichansky, A.M. 2000, Usability testing in 2000 and beyond. *Ergonomics*, 43, 998-1006.

Wiitavaara, B., Lundman, B., Barnekow-Bergkvist, M., Brulin, C. 2007, Striking a balance – health experiences of male ambulance personnel with musculoskeletal symptoms: A grounded theory. *International Journal of Nursing Studies.* 44, 770-779.

Wilson, J.R. 1990, A framework and a context for ergonomics methodology, Chapter 1. In JR Wilson, EN Corlett (Eds.) *Evaluation of Human Work – A practical ergonomics methodology.* 2nd Ed. (London: Taylor and Francis). 1-40.

Woods V., Buckle P. 2005, An investigation into the design and use of workplace cleaning equipment. *International journal of industrial ergonomics.* 35, 247-266.

Young, K.M., Cooper, C.L. 1997, Occupational stress in the ambulance service: a diagnostic study. *Health Manpower Management.* 23, 140-147.

Appendices

Appendix A: Ethics - Participant information sheet

Loughborough University

Dr Sue Hignett
Lecturer in Ergonomics
Dept. of Human Sciences
Loughborough University
Loughborough
LE11 3TU

S.M.Hignett@lboro.ac.uk

Ph: 01509 223003 Fax: 01509 223940

Design and Performance of Ambulance Stretcher Loading Systems

Invitation to participate

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Purpose of study

This research is comparing three different stretcher loading systems with the aim of producing a design recommendation based on robust scientific principles. We are collecting data from 4 Ambulance NHS Trusts in the UK (East Anglian, East Midlands, London and Two Shires).

Who is doing this research?

This research is funded by the Engineering and Physical Science Research Council. The ergonomics researchers are from Loughborough University (Sue Hignett and Anna Jones) and the mechanical engineers are from Sheffield University (Eli Ghassemieh and TBA).

Why have I been chosen?

Because you either work with or have been involved in the specification, design and/or manufacturing of one or more of the systems.

Do I have to take part?

No. Once you have read this information sheet, if you decide to take part you will be asked to sign a consent form. If you decide to take part you can still change your mind later, without giving a reason. You may withdraw at any time.

Sensitive personal data

If we are observing your work we will be asking you about your physical well-being as part of a self-screening process to help you to decide whether or not you want to take part.

What will happen to me if I agree to take part?

You will be asked to assist in data collection in your organisation, and will be kept informed of the project results.

What will happen if I decide to withdraw from the project?

There will be no affect on your employment status. The data already collected will be used for analysis unless you specifically request it to be withdrawn and destroyed.

What do I have to do?

There are several possible activities which we may ask you to be involved with.
1) We will watch your normal work activities so that we can look at how you use the different systems.
2) We will ask your opinion about the different stretcher loading systems and audio-tape your replies for analysis at a later date.
3) We will ask you to describe situations when you have had concerns about the stretcher loading systems – this may include either an actual incident or a near miss event. This would include audio-taping your replies for analysis at a later date.
4) We may ask you to take part in a simulation exercise so that we can make detailed data recordings. This would involve both audio- and video-tape recordings for analysis at a later date.

What are the possible advantages/disadvantages of taking part?

This research should produce a more scientific rationale for the design and specification of stretcher loading systems. It will give you an opportunity to put your viewpoint forward and to share your experiences of working with 1-2 different systems.

What happens if something goes wrong?

We will follow the incident reporting procedure at Loughborough University and your organisation concurrently. If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action but you may have to pay for it. Regardless of this, if you wish to complain about any aspect of the way you have been approached or treated during the course of this project the normal National Health Service (or University) mechanisms may be available to you.

Will my taking part in this study be kept confidential?

If you take part in the research all information collected about you and your organisation during the course of the research will be kept strictly confidential. All references to participants in the report and any subsequent publications/presentations will be anonymous. The information will be kept in a secure location, accessible only to the researchers. All of the data (video-tape, audio-tape, field notes etc.) will remain the property of Loughborough University and will be destroyed 5 years after publication.

What will happen to the results of the research study?

The results will be coded (for anonymity) and analysed by the research team before being reported. The results may also be presented in appropriate scientific journals and conferences. If you take part in this research, you can obtain copies of these publications from the research team. The data will be stored by the Chief Investigator (Sue Hignett, data controller) at Loughborough University under conditions specified by the Departmental Data Protection Advisor.

Who is funding this research?

This research is funded by the Engineering and Physical Science Research Council (EPSRC).

Who do I contact for more information?

You can ask: Dr Sue Hignett - S.M.Hignett@lboro.ac.uk, Tel. 01509 223003, Dr Eli Ghassemieh (E.Ghassemieh@sheffield.ac.uk) , Miss Anna Jones (A.L.Jones@lboro.ac.uk), Tel 01509 228479 and TBA (Mechanical Engineering)

What if I have any concerns?

If you have any concerns about this study or the way it has been carried out you should contact the investigators (Sue Hignett, Eli Ghassemieh and Anna Jones).

Thank you for taking part in this study

Appendix B: Ethics - Medical health questionnaire

Loughborough University

Dr Sue Hignett
Lecturer in Ergonomics
Dept. of Human Sciences
Loughborough University
Loughborough
LE11 3TU

S.M.Hignett@lboro.ac.uk

Ph: 01509 223003
Fax: 01509 223940

Pre-selection Medical Questionnaire

Loughborough University

Department of Human Sciences

Please read through this questionnaire, **BUT DO NOT ANSWER ANY OF THE QUESTIONS YET.**

When you have read right through, there may be questions you would prefer not to answer. Assistance will be provided if you require it to discuss any questions on this form. In this case please tick the box labelled **'I WISH TO WITHDRAW'** immediately below.

Also tick the box labelled **'I WISH TO WITHDRAW'** if there is any other reason for you not to take part.

	Tick appropriate box
I wish to withdraw	☐
I am happy to answer the questionnaire	☐

If you are happy to answer the questions below, please proceed. Your answers will be treated in the strictest confidence.

	Please delete as appropriate
1. Are you at present recovering from any illness or operation?	YES/NO
2. Are you suffering from, or have your suffered from or received medical treatment for any of the following conditions?	
• Heart or circulation condition	YES/NO
• High blood pressure	YES/NO
• Any orthopaedic problems	YES/NO
• Any muscular problems	YES/NO
• Asthma or bronchial complaints	YES/NO
• Epilepsy	YES/NO
• Diabetes	YES/NO
3. Are you currently taking any medication that may affect your participation	YES/NO

in the study?

4. Are you recovering from any injury? YES/NO
5. Are you allergic to sticking plasters? YES/NO
6. Do you have any other allergies? If YES please give details below YES/NO

7Are you aware of any other condition or complaint that may be affected by participation in this study? If YES please state below YES/NO

Appendix C: Ethics - Participant consent form

Loughborough University

S.M.Hignett@lboro.ac.uk

Ph: 01509 223003
Fax: 01509 223940

Dr Sue Hignett
Lecturer in Ergonomics
Dept. of Human Sciences
Loughborough University
Loughborough
LE11 3TU

Consent Form

Title:	**Design and Performance of Ambulance Stretcher Loading Systems**
Investigators:	Sue Hignett, Eli Ghassemieh, Anna Jones, Glen Cooper
Site:	**East Anglian Ambulance Service NHS Trust** **East Midlands Ambulance Service NHS Trust** **Two Shires Ambulance Service NHS Trust**

	Please cross out as necessary
Have you read and understood the information sheet?	YES/NO
Have you had opportunities to ask questions and discuss the study?	YES/NO
Have all your questions been answered satisfactorily?	YES/NO
Have you received enough information about this study?	YES/NO
Who have you spoken to? Dr/Mr/Ms...	
Do you understand that you are free to withdraw from this study	
• At any time?	YES/NO
• Without having to give a reason?	YES/NO
• Without affecting your employment?	YES/NO
Do you agree to take part in the study?	YES/NO
Do you understand that the data (including video recordings and stills) will not be available to you after the study?	YES/NO

Signature (Participant)... Date.........................

NAME (BLOCK CAPITALS)..

I have explained the study to the above participant and they have indicated their willingness to take part

Signature (Researcher)... Date.........................

NAME (BLOCK CAPITALS)..

Appendix D: Ethics Photographic consent form

Consent for the publication of medical photos

Researcher: ....
Department: ....
Date: ....

Surname: ....
First name: ....
Date of birth: ....
Address: ....
....
....

Copyright for all images remains with Loughborough University

Consent is given only for use in the publication(s) detailed below; images may not be used for any other purpose.

The photographs shown above this statement have been taken with my permission as part of my participation in the following project. I have also agreed that they may be used for teaching and professional staff.

Project title: Evaluation of stretcher loading systems

Following discussion / correspondence with the researcher (Name.................... Dept.........................) I understand that it may be helpful for these photographs to be published.

Publication media:

☐ Book
☐ Journal (print and electronic)
☐ Poster
☐ Other ....
☐ Patient information leaflet
☐ Hospital publication
☐ Electronic

Name of publication............................ Publisher.................................

Electronic publications may be available world wide on the internet. As a result, I understand that the material may be seen by the general public. My name and details will remain confidential but I understand that I might be recognised from the material so **full confidentiality is not guaranteed.**

In view of the explanations given to me by the researcher, I give consent for these pictures to be published in this form only. I have crossed through any pictures that I do not wish to be published and I accept the assurances given that these will not be used.

I understand that no pictures will be submitted for publication within the next 14 days and that during this time, this consent may be withdrawn by writing to the researcher. However should I wish to withdraw consent once photographs have been submitted for publication / published it may not be possible to withdraw them.

Signed:
....Participant..

Date:.....................................

Please complete x2 forms: Copies to (1) Publishers, (2) Principal Investigator (researcher)

Dept of Human Sciences, Loughborough University, Loughborough, Leics. LE11 3TU

Appendix E: Interview coding for Case study 1

NODE LISTING

NVivo revision 2.0.161 Licensee: Sue Hignett
Project: EPSRC1 User: Administrator Date: 19/08/2005 - 09:12:48

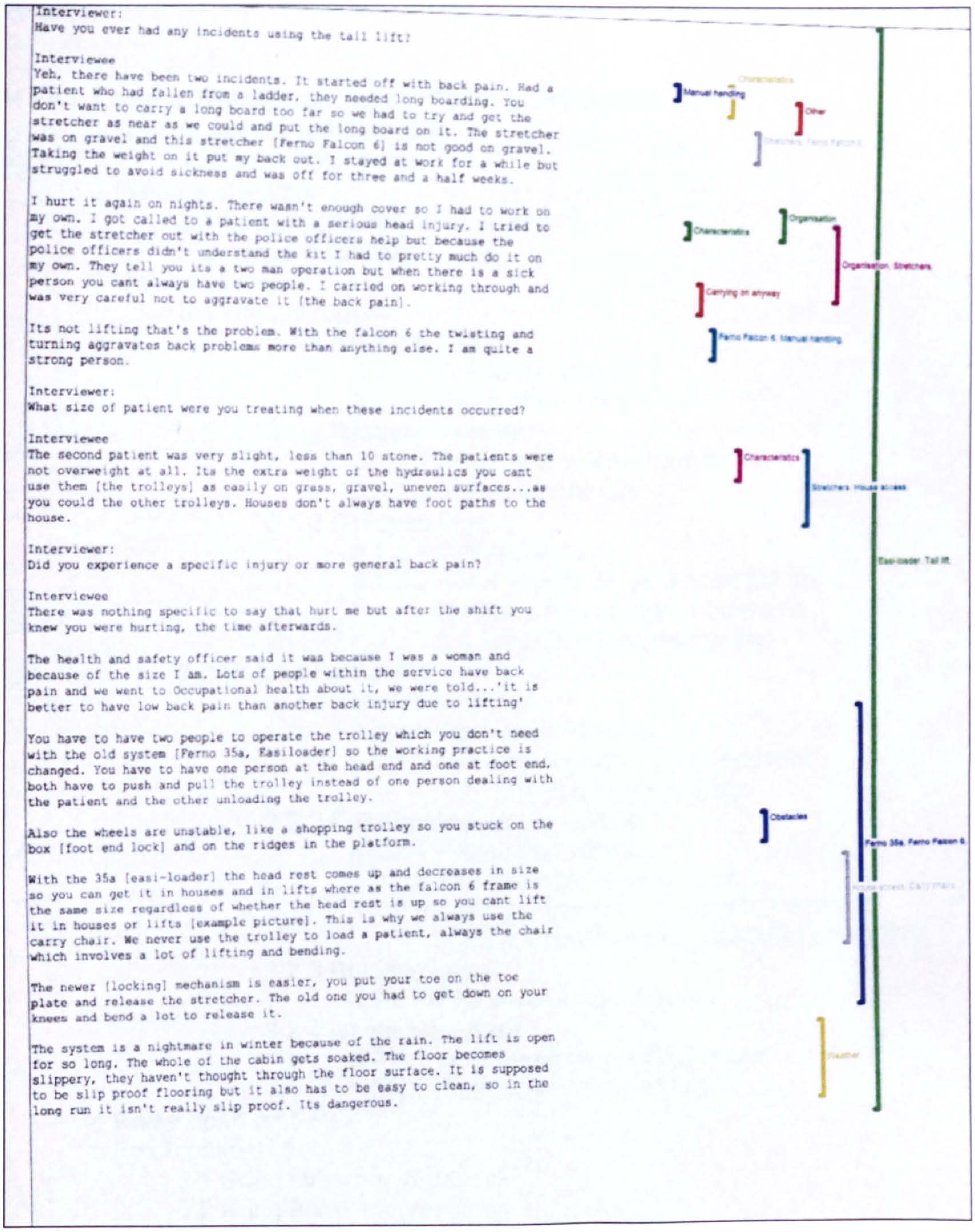
Nodes in Set: All Nodes
Created: 08/08/2005 - 14:54:06
Modified: 08/08/2005 - 14:54:06
Number of Nodes: 53

1 Easi-loader
2 Ramp & Winch ~M~
3 Ramp and winch ~H~
4 Tail lift
5 (1) /System failure
6 (1 1) /System failure/Time
7 (1 2) /System failure/Injury
8 (1 4) /System failure/Organisation
9 (1 5) /System failure/Task complication
10 (1 6) /System failure/Electrical
11 (1 6 1) /System failure/Electrical/Air Suspension
12 (1 6 3) /System failure/Electrical/Tail lift
13 (1 7) /System failure/Mechanical
14 (1 7 1) /System failure/Mechanical/Tail lift
15 (1 7 2) /System failure/Mechanical/EL legs
16 (1 7 3) /System failure/Mechanical/steering stretcher
17 (1 7 4) /System failure/Mechanical/platform
18 (1 7 5) /System failure/Mechanical/winch
19 (1 8) /System failure/Security
20 (1 9) /System failure/Obstacles
21 (2) /Environment
22 (2 1) /Environment/Location
23 (2 1 1) /Environment/Location/Camber
24 (2 1 2) /Environment/Location/Clearance
25 (2 1 3) /Environment/Location/House access
26 (2 1 4) /Environment/Location/Ground surface
27 (2 2) /Environment/Weather
28 (3) /Patient
29 (3 1) /Patient/Safety
30 (3 2) /Patient/Characteristics
31 (3 3) /Patient/Infection control
32 (3 4) /Patient/Dignity
33 (4) /Equipment
34 (4 1) /Equipment/Other
35 (4 2) /Equipment/Wheelchair
36 (4 3) /Equipment/Winch
37 (4 4) /Equipment/Stretchers
38 (4 4 1) /Equipment/Stretchers/Ferno Falcon 6
39 (4 4 2) /Equipment/Stretchers/ferno Phoenix
40 (4 4 3) /Equipment/Stretchers/Rugged Stryker
41 (4 4 4) /Equipment/Stretchers/Ferno 35a

42 (4 4 5) /Equipment/Stretchers/Design
43 (4 4 6) /Equipment/Stretchers/York 4
44 (4 5) /Equipment/Carry chairs
45 (4 6) /Equipment/Control location
46 (4 7) /Equipment/vehicle design
47 (4 8) /Equipment/Sensors
48 (5) /Coping strategies and adaptations
49 (5 1) /Coping strategies and adaptations/Carrying on anyway
50 (5 3) /Coping strategies and adaptations/Alternate methods
51 (5 4) /Coping strategies and adaptations/Second ambulance
52 (6) /Manual handling
53 (6 1) /Manual handling/entrapment

Best Copy Available

Interview EA3 showing coding stripes



Interviewer:
Have you ever had any incidents using the tall lift?

Interviewee
Yeh, there have been two incidents. It started off with back pain. Had a patient who had fallen from a ladder, they needed long boarding. You don't want to carry a long board too far so we had to try and get the stretcher as near as we could and put the long board on it. The stretcher was on gravel and this stretcher [Ferno Falcon 6] is not good on gravel. Taking the weight on it put my back out. I stayed at work for a while but struggled to avoid sickness and was off for three and a half weeks.

I hurt it again on nights. There wasn't enough cover so I had to work on my own. I got called to a patient with a serious head injury. I tried to get the stretcher out with the police officers help but because the police officers didn't understand the kit I had to pretty much do it on my own. They tell you its a two man operation but when there is a sick person you cant always have two people. I carried on working through and was very careful not to aggravate it [the back pain].

Its not lifting that's the problem. With the falcon 6 the twisting and turning aggravates back problems more than anything else. I am quite a strong person.

Interviewer:
What size of patient were you treating when these incidents occurred?

Interviewee
The second patient was very slight, less than 10 stone. The patients were not overweight at all. Its the extra weight of the hydraulics you cant use them [the trolleys] as easily on grass, gravel, uneven surfaces...as you could the other trolleys. Houses don't always have foot paths to the house.

Interviewer:
Did you experience a specific injury or more general back pain?

Interviewee
There was nothing specific to say that hurt me but after the shift you knew you were hurting, the time afterwards.

The health and safety officer said it was because I was a woman and because of the size I am. Lots of people within the service have back pain and we went to Occupational health about it, we were told...'it is better to have low back pain than another back injury due to lifting'

You have to have two people to operate the trolley which you don't need with the old system [Ferno 35a, Easiloader] so the working practice is changed. You have to have one person at the head end and one at foot end, both have to push and pull the trolley instead of one person dealing with the patient and the other unloading the trolley.

Also the wheels are unstable, like a shopping trolley so you stuck on the box [foot end lock] and on the ridges in the platform.

With the 35a [easi-loader] the head rest comes up and decreases in size so you can get it in houses and in lifts where as the falcon 6 frame is the same size regardless of whether the head rest is up so you cant lift it in houses or lifts [example picture]. This is why we always use the carry chair. We never use the trolley to load a patient, always the chair which involves a lot of lifting and bending.

The newer [locking] mechanism is easier, you put your toe on the toe plate and release the stretcher. The old one you had to get down on your knees and bend a lot to release it.

The system is a nightmare in winter because of the rain. The lift is open for so long. The whole of the cabin gets soaked. The floor becomes slippery, they haven't thought through the floor surface. It is supposed to be slip proof flooring but it also has to be easy to clean, so in the long run it isn't really slip proof. Its dangerous.

Appendix F: Example of generic HTA for Case study 1

All generic HTA's can be found in Jones and Hignett (2005).

HTA1 Load stretcher using platform easyloader

- 1 Access patient compartment
  - 1.1 Open back doors
- 2 Prepare stretcher
  - 2.1 Lower hand rail on stretcher
  - 2.2 Prepare blanket
- 3 Unload stretcher
  - 3.1 Unload rugged
    - 3.1.1 Release platform
      - 3.1.1.1 Pull lever across
      - 3.1.1.2 Pull platform out
    - 3.1.2 Release stretcher
      - 3.1.2.1 Press and release button
      - 3.1.2.2 Pull stretcher out
    - 3.1.3 Collapse legs
      - 3.1.3.1 Pull red lever
      - 3.1.3.2 Allow legs to move across full arc
        - 3.1.3.2.1 Pull stretcher outwards
        - 3.1.3.2.2 kick legs into place
  - 3.2 Unload Ferno 35a
    - 3.2.1 Release stretcher
      - 3.2.1.1 Push lever inwards
      - 3.2.1.2 Pull stretcher out of foot end lock
        - 3.2.1.2.1 Pull to left slightly
    - 3.2.2 Pull stretcher out of vehicle
      - 3.2.2.1 Reach into vehicle
      - 3.2.2.2 Pull stretcher towards self
      - 3.2.2.3 Walk out gradually supporting stretcher
        - 3.2.2.3.1 Head end is supported on vehicle
    - 3.2.3 Release legs
      - 3.2.3.1 Pull levers under handle
    - 3.2.4 Guide legs down
      - 3.2.4.1 Hold black strip on leg frame
      - 3.2.4.2 Push downwards to floor
- 4 Raise head rest
- 5 Fetch patient
  - 5.1 Bring stretcher to patient
  - 5.2 Bring patient to stretcher
    - 5.2.1 On foot
      - 5.2.1.1 Carry oxygen cylinder
    - 5.2.2 Use wheelchair
- 6 Lower stretcher
  - 6.1 Lower rugged
    - 6.1.1 Lower with one man at either end
    - 6.1.2 Lower with two man at end, one end at a time
    - 6.1.3 Lower at foot end
      - 6.1.3.1 Push green button
      - 6.1.3.2 Pull green lever

6.1.3.3 Lower foot end
6.1.4 Lower at head
6.1.4.1 Pull red lever
6.1.4.2 Lower at head end
6.2 Lower Ferno
6.2.1 Lower one man at either end
6.2.2 Hold stretcher
6.2.3 Pull levers
6.2.4 Lower with stretcher
7 Transfer patient to stretcher
7.1 Assist patient onto stretcher
7.2 Lift patient onto stretcher
7.3 Prepare patient for loading
7.3.1 Strap patient to stretcher
7.3.2 Sort oxygen
7.3.2.1 Untangle from lead
7.3.2.2 Position oxygen by patients legs
8 Raise stretcher
8.1 Raise with one man at either end
8.2 Raise with two man, one end at time
8.3 Raise rugged
8.3.1 Raise head end
8.3.1.1 At head end pull lever
8.3.1.2 Lift head end
8.3.2 Raise foot end
8.3.2.1 At foot end pull lever
8.3.2.2 Lift foot end
8.3.2.3 Repeat above
8.4 Raise Ferno
8.4.1 Raise with one man at either side
8.4.2 Bend knees to stretcher height
8.4.3 At head end pull levers
8.4.4 Lift trolley at both ends
9 Transfer stretcher to vehicle
9.1 Guide trolley up slope
10 Load stretcher
10.1 Line up stretcher with vehicle
10.2 Pull back on stretcher to compensate for downward incline
10.3 Load rugged
10.3.1 Change to two wheel drive
10.3.1.1 Turn red circular control clockwise
10.3.2 Line stretcher up with platform
10.3.3 Push stretcher into platform
10.3.4 Release legs
10.3.4.1 Release front legs
10.3.4.1.1 Push green button
10.3.4.1.2 Pull green lever
10.3.4.2 Release back legs
10.3.4.2.1 Pull red lever
10.3.4.3 Push stretcher fully into platform
10.4 Load Ferno
10.4.1 Align stretcher with hook
10.4.2 Push stretcher into vehicle slowly
10.4.3 Lift legs
10.4.3.1 Take hold of black strip on frame

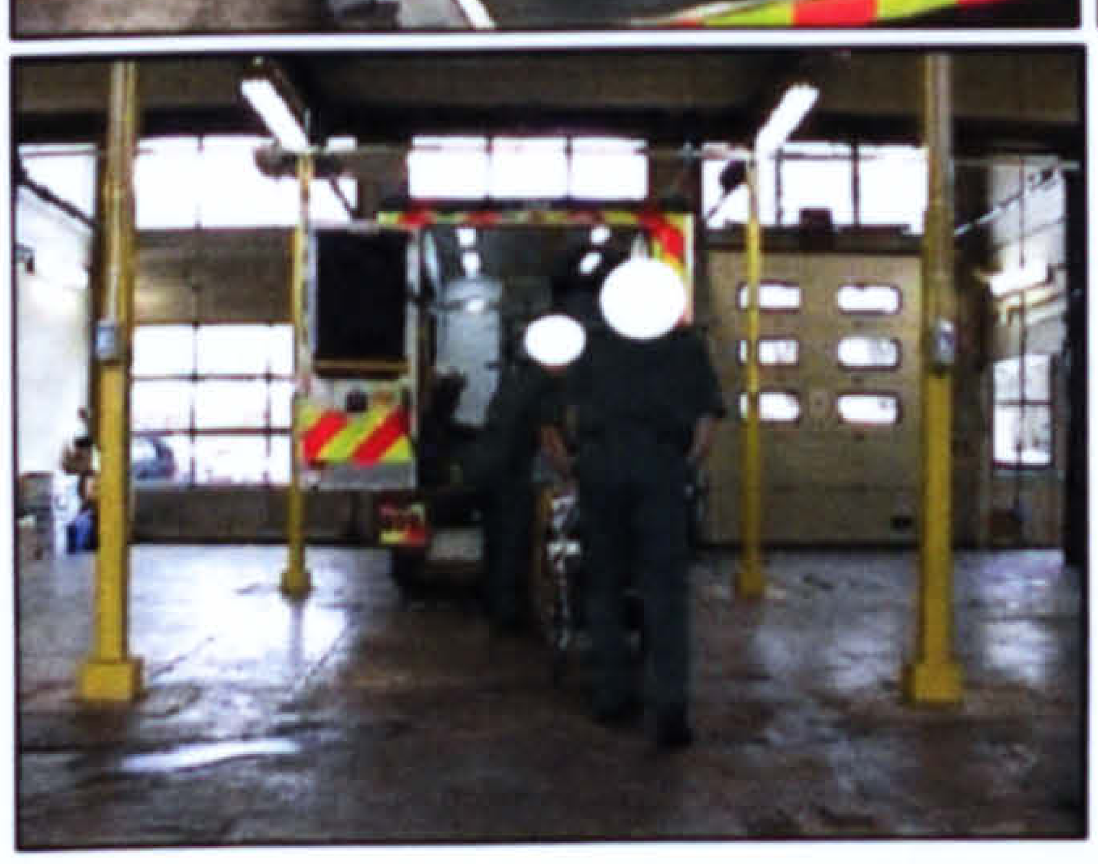
10.4.3.2 Lift legs upwards
10.4.4 Secure stretcher
10.4.4.1 Push stretcher until meets head end lock
10.4.4.2 Push foot end into foot end lock to right
11 Enter vehicle
12 Close patient compartment
12.1 Close back doors

Appendix G: Examples of postures analysed for Case study 1

Easyloader stretcher posture stills

Ramp and winch posture stills

Tail lift posture stills

Appendix H: Issue ranking questionnaire for Case study 1

HEPSU

Loughborough University

What is your interest in ambulance design? Please tick as appropriate. If other please specify

Role	Please tick
Paramedic	
Medical Technician	
Human Resources Manager	
Finance Manager	
Executive Manager	
Operational Manager	
Operational Staff ***	
Health and Safety	
Fleet Manager	
Vehicle designer / Manufacturer	
Support staff	
Other…………………………………………	

Which sector of the ambulance service do you work in?

Ambulance service	Please tick
NHS	
Voluntary	
Private	
International	
Other………………………………	

	Please tick
Accident and emergency Patient transport service Urgent / Delta / A&E Support Fast response Events	

Please rate the following issues affecting the task of loading / unloading a patient in order of importance for yourself.

Starting at (1) as the most important. Issues may have equal ranking.

Issue	Rating
Weather / environment	
Patient and operator safety	
Effect of camber	
Task complication	
Security	
Time to operate	
Equipment misuse	
Need for sensors	
Clearance	
Carry chair access	
Vehicle layout	
Mechanical / electrical reliability	
Infection control	
Manual handling	

Appendix I: Example focus group transcription for Case study 2

Int: Does the equipment supplied to you by EMAS meet the needs of the patient transfer tasks that you carry out on A&E?

p1. No.

p2. Severe manual handling, to get someone from an upstairs building downstairs using a carry chair that they've got, it causes unnecessary risk to staff and patients and has the potential of causing career threatening injuries as well.

P3. The technology to update, beyond what we've got has been in existence for a long time now, I've seen experimental equipment come in for evaluation five, six years ago and not proceed beyond the training department, never even being seen out on the road, even been evaluated in the workplace.

P4. The carry chair that we have got are really pretty poor aren't they, I've been on 26 years now and they've not changed really in any shape way or form really, have they, they're all basically the same. Definitely the carry chair.

P1. The principles the same isn't it. You still have to lift in a carry chair.

P4. Yeah you're still lifting, yeah.

P2 It's still called a carry chair. One of you still ends up bending more or less double to pick it up, one of you at one end can stay more or less upright, the other one has to bend to the floor, knees to floor practically to get yourself in the position where you can lift it. Severe risk of harm if you're bringing quite a heavy weight from the floor, from a very bad starting posture. The availability for the hoist is pretty poor really. I think the nearest one is about 17 miles away, which is obviously the urgent crew, so we don't have much access to that.

P1. There's not only that, they availability of the hoist, when they do bring the hoist to you there's certain people you cant lift with them like neck of femurs, you know, just one of the reasons, and it only goes up to a certain weight, and I hate to say this but we go out to people that go above that certain weight.

Int. How are the stretchers and carry chairs at dealing with the different weights of patients?

P1. I cant remember what the weight is on the carry chair.

P2. We've exceeded it more than once.

All: Agreement

P4. The stretchers, the Ferno 6, they're alright because they come, they're alright, they're better than the York 4 that we used to have to pick up, and there are ramps on the vehicle...

P3. With a winch if you...

P4. It's the carry chair that's more our problem and its something that we use day in day out at every job near enough isn't it.

P1. Its carrying the chair, the lifting from the floor to the chair that is the biggest problem.

P2. Or lifting from the floor to the stretcher, assuming you can get a stretcher in the house.

Int: What kind of problems do you have when you do that?

P1. Equipment problems really, on some of the urgent vehicles they have these manger elk cushions that we can put under and it actually lifts the patient for you.

P2. Oh yeah.

P3. Oh the compressor pump that compresses down to lift, yeah. I've seen them but I've never. Again they're urgent crews aren't they?

P2. Well we tried but the number of time you go, oh shall we try the elk, for that to be used you need more people really to.

P4. You've got to physically move the patient about to get it under the patient. Its ok if they're uninjured but if they are a large person, with an injury, you've got to start rolling them side to side, end to end, wiggling this thing under them, you've got the potential to do them harm.

P1. Its awkward places as well, bathrooms, little toilets.

P3. That's where most of our patients tend to get ill, in bathrooms, toilets or behind the door in a little box room.

P1. A little old ladies fallen, they come down the stairs.

Int: Do you have usability issues with the stretchers or chairs, actually not related to the patient, just when you are using it?

P3. Accessibility isn't it, with the stretcher. Some properties will not accept....

P2. And nursing homes. Especially the nursing homes, some nursing homes with 2 floors with a lift that's four foot by three foot, they're designed for two or three people so you can't even get a stretcher up stairs.

P3. Well the stretchers all right if it's a level ground that you're going in, but they're quite heavy themselves if you have to lift over a threshold or a couple of steps, even if it's a massive big hallway, some of these big bungalows and houses we've been to, you've still got to manually lift it up.

P4. It's a squeeze to get into some of the lifts with a carry chair never mind...

Int: What kind of external constraints hinder the patient transfers? Rain, weather terrain etc.

P4. Well that's it, terrain.

P2. Steps, uneven paths, grass

P4. If we rush a bit too much trying to get the poor bloke out the mess, and you're a bit too quick to stretch him off the floor without thinking about it properly, you haven't got time to get a carry sheet up for him or whatever, its just like under the arms and under the knees and its like up you go.

Int: So what kind of problems would you experience in these different constraints?

P4. Its just so varied, the patient can be obese, the patient injuries, the position of the patient, patient compliance, some of them, if they understand what you want them to do fine but some of them are away with the fairies, confused, disorientated, medical conditions making them combatative [confrontational] whatever, some of them are just bloody minded, they're fine until you start to move them and then they get scared, think they're going to fall over, start grabbing out or getting hold of you, pull you off balance, grab hold of the banister, all kinds of things, you're fine until the patient starts to panic and then you've got a serious situation where you're losing your balance, losing control of the patient.

Int: Can you think of any other problems you have with stretchers or carry chairs in everyday use?

P1. Pulling the stretchers up the corridors are quite a difficult, you're in the wrong position.

P3. One handed. Pulling it behind you.

P1. Yeah you've either got to be either holding it two hands, there's just never an easy way to do it, than using it one handed because you are slightly twisted and if you've got an extremely heavy patient on that trolley its difficult, it doesn't matter how much your colleague at the other end of the trolley pushes, because its difficult then to push as well. Its access to wheels I suppose but its difficult.

P4. It would be nice if you could have a clip on handle that went on the back that you could push on because you can push on the backrest but you always snag the handle and the backrest falls down.

P2. So we push the backrest.

P1. You know the other way would be to put something either side of the stretcher but then it would be difficult to store on the vehicles. But certainly pulling the stretcher up the corridors not good because you're not only are you twisted, you've got one arm behind the other.

P4. Especially when you get places like the DRI where you've got that ramp and things, going up a 30, 40 foot long ramp, it can get quite a strain. But everything's alright while you've got time to do it but...

P3. That's right but most of our jobs we haven't got time have we.

P4. If you've got a patient you need to get moving sometimes you don't when its serious emergencies you don't have the time to think well I should be using a draw sheet, whatever, I should be.... Its just we need to get on and get going.

P2. With ITU transfers and things, all their equipment, try to get around our trolleys and fastened on securely to the stretchers.

P1. At DRI they actually purchased an ITU trolley but of course its...

P4. Its obsolete isn't it.

P1. Its obsolete now, it doesn't fit in half the vehicles because....

P2. That's the same as the....yeah the incubator isn't it. And they're becoming elderly now.

P3. It's a York 4 Incubator, on the Marshalls.

P1. It was a Ferno that they purchased at ITU.

P2. It doesn't comply with the new regs [regulations] either about the stretcher being secured in the vehicle, nowadays you've got to be able to park the vehicle on the roof and the patient doesn't fall out.

P3. Even so there's no drip stands or anything is there.

P4.Turn it off and walk at the side.

P1. You still have to turn it off to move the patient.

P3. Like we said there's no equipment trays that flip over, so you are either carrying equipment or putting it on top of the patient.
P3. ITU have got a carrying tray haven't they? Its only in ITU.

P4. It doesn't carry everything though does it?

P3. It carries quite a bit of stuff doesn't it? I've seen these in other hospitals where they've got, one that carry's a defib [defibrillator] like the old....and other things but its just like syringe drivers, because most of our ITU's have got four or five syringe drivers haven't they and you put them on the end and they've got bits of Velcro and different configurations.

P3. I've taken patients up to CCU with the life pack 12 and you've got to carry it because there's nothing, and you cant not take it.

P1. We've never had any of them equipment on our trolleys.

P3. Like I say you're carrying a defib, push the trolley or pull the trolley at the same time, you're twisted.

P1. You should carry the red bag as well....and drugs.

Int: What's the most difficult patient transfer that you would do?

P4. A large person with a steep and narrow stair case. You know where you end up sat on your backside with the carry chair on your knees and you are literally sliding down the stairs stopping the chair falling and your mates underneath it with it up on his shoulder. If you're lucky there's room for two of you at the bottom, otherwise there's only room for one of you. You're literally just controlling the fall of the chair, you're not lifting it, you're not carrying it, you're just stopping it going uncontrolled down the stairs.

Int: Can you think of any equipment or any improvements that could be made to the equipment you use, which would make your job any easier?

P3. Well we've said one, a drip stand. An equipment tray. There's got to be some better carry chairs on the market than what we're using.

P1. Football grounds have these carry chairs that roll down the steps. They never use them; they're there for emergency use only. Why cant we have them on the vehicles that we use daily?

P2. How are they justifying avoiding the legislation that says you must use the safest system of work? If the same system exists and you have a serious risk legislation says you must employ that system or equipment. Cost is irrespective. If you have a high risk of serious injury as we do, we have a daily exposure to serious risk and injury using the carry chair why haven't we got these facilities, what is the justification for not complying with current legislation as I understand it? I've done health and safety training, got a general certificate in occupational health and safety and as I understood the legislation where you've got a high risk of serious injury you have to go out and find the best solution to over-coming that issue.
P1. Initially I was always told it was because these carry chairs don't fold, and its because of storage but I'm sure I've seen them that fold might only be slightly wider than the ones we use now.

P2. There are chairs on the market now that other services are using and have been using for quite some time so the problem with storage is really non-existent. If other services are using them and we're not thinking about them then there is obviously a problem.

Int: Are there any other problems that you can think about?

P3. That's about the main thing isn't it? Mainly stairs isn't it.

P4. It's the most used piece of equipment for patient movement.

P3. Yeah definitely.

P2. The stretcher and the carry chair. It's the most utilised piece of equipment that there is and we should have the best that there is.

P4. Safest.

P1. Safest all around.

P2. That reduces the risk of injuries.

P3. Save having some levitation equipment that can levitate them down the stairs.

Int: How do you make the choice between the stretcher and carry chair?

P2. Circumstances.

P4. Yeah well obviously you're not going to get a stretcher up the stairs. To get them from a bedroom or bathroom or wherever, downstairs to where your stretcher is you've got to use the carry chair, there's no other way.

P1. Or a scoop.

P4. Or yeah, well that's even worse then.

P1. That's the only piece of equipment we've got to get them down.

P3. If you've got a football injury and you cant take the stretcher on the field because it just ploughs it, its like ploughing a field. Its twice as difficult to pull it.

Int: Unless anyone can think of any other issues you have, that's everything.
P2. One of the newest problems is the new builds are quite often three stories so instead of having one flight of stairs to go down you have two.
Int: And what kind of staircases are they?

P2. Well because they are trying to maximise the space they use what they call winding stairs so like a triangle shape as you come round so one side is quite wide but the other side is very narrow. They use them a hell of a lot now because it minimises the amount of space that they need. And that causes a lot of problems.

P1. It's a bit like a spiral staircase isn't it.

P3. Yeah its like a spiral staircase.

P1. Only ever done it once, never want to do it again.

Int: A lot of ambulance services now are bringing wheelchairs onto A&E vehicles. How would you feel about using wheelchairs?

P3. Is that wheelchairs as a piece of equipment to use?

P.4 Well the problem with that is you still transfer the patient from the wheelchair to the stretcher. You've got to lift the patient over the arm.

P1. I still don't see how a wheelchair would be of any benefit because the carry chair does exactly the same job.

P3. Except for its on 2 wheels instead of 4.

P1. Yeah.

P4. Unless you've got facility for like a minor injury, leave them in the wheelchair and clamp the wheelchair in the back of the vehicle

P3. As they do in PTS.

P1. There's many a patient who say to us, I'm quite comfortable here on the carry chair, leave me on it.

P4. And we'd really like to but...

P1. Because we don't want to lift them again.
P4. But its storage again look.

P1. I mean years ago there used to be 2 stretchers on every vehicle. We are down to one and....

P2. Well to clamp them into these new rails we've got we'd have to take the stretcher out wouldn't we. The stretcher overhangs.

P4. We'd have difficulty manoeuvring a wheelchair up that ramp anyway with the trolley in. You cant really do it without taking a risk.

P3. Especially with the new ones.

P1. That's actually another point you know. When you're bringing the carry chair up the ramp you cant actually walk straight back because the stretchers in the way this is just in the back of the ambulance, you have to come up and remove the ramp.

P3. You've got to make sure the seats folded up.

Int: So do you have problems with the equipment inside the vehicle as well?

P1. Its placement of it really its not....

P3. There's a number of times you fold the seat up turn around a clunk, the seats gone down again.

P2. There's no carry belts, they've all been belts... we've not got any of them; there's no sliding boards, sliding sheets, banana boards.

P3. Yeah the equipment just disappears.

P1. It probably is when it gets soiled isn't it, because if it gets soiled you send it away for washing and it doesn't come back.

P2. Plastic stuffs fine you can give it a scrub in the sleuths, but the fabric stuff has to go away for re-ordering.

Int: Who's responsible for cleaning the carry chairs and stretchers when you use them?

P2. We are. I mean that can be a nightmare. The plastic bits aren't so bad but when the straps get contaminated and they're fabric, that can be awkward.

Int: So you're basically doing quite a few jobs in one.

P1. And the little nooks and crannies that you need to get into

P2. There are so many joints and the nuts and bolts.

Int: How do you, what's the protocol on that? If you do get blood inside?

P1. You mainly clean what you can see visually.
Int: So you can get taken off the road?

P4. You'd need to steam clean it with a steam cleaner so you are actually pressure washing through the joints. You're contaminating all the mechanical working parts then and somebody's got to sit down with a can of grease and somebody's got to start it all working again.

P2. Its not like it happens effectively all the time either because quite often you wash it over, you wipe it down, then you've got to go for another job, put it away, next time you get it out its been sat turned over dribbling a bit, and something else is covering it out, so you have to start washing again or you pick it up and you think oh yuck. Something goes squidge and you really wish it hadn't.

Appendix J: HTA's for case study 2

A&E

HTA 1 – Day 1 Patient 1, Transfer patient

1 Arrive at scene
2 Stand to side of patient
3 Ease patient back up into upright sitting position

HTA 2 – Day 1 Patient 2, Transfer patient

1 Assist patient to vehicle on foot
2 Open side door
3 Assist patient up step into vehicle
4 Assist patient onto stretcher
5 Strap patient onto stretcher
6 Transfer to hospital
7 Fetch wheelchair
8 Assist patient out of vehicle
  8.1 Assist patient down step
  8.2 Assist patient into wheelchair
9 Wheel chair into hospital
  9.1 Pull chair backwards
10 Wait
11 Assist patient from wheelchair to the hospital bed
12 Lift patients legs onto bed

HTA 3 – Day 1 Patient 3, Transfer patient from scene to vehicle

1 Arrive at scene
2 Open back doors
3 Pull down step
4 Assist patient into vehicle
5 Assist patient onto stretcher
6 Strap patient into stretcher
7 Travel to hospital and unload
8 Fetch wheel chair
9 Put patients arm in sling
10 Assist patient into wheelchair
11 Push wheelchair into hospital

HTA 4 – Day 1 Patient 4, Transfer patient

1 Remove carry chair from vehicle
  1.1 Lift it off the mounting
2 Take chair to patient
3 Assist patient on foot to vehicle
4 Open back doors to vehicle
5 Pull out step
6 Assist patient up step
7 Assist patient onto stretcher
8 Assess patient
9 Assist patient up off stretcher and out of vehicle

HTA 5 – Day 1 Patient 6, Transfer patient

1 Fetch carry chair
  1.1 Take carry chair to patient

2 Assist patient to vehicle on foot
3 Access patient compartment
    3.1 Open back doors
    3.2 Pull down step
4 Assist patient into vehicle up step
5 Assist patient onto the stretcher
6 Travel to hospital
7 Fetch wheelchair
8 Access patient compartment
    8.1 Open doors
    8.2 Pull down step
9 Assist patient off vehicle down step
10 Assist patient into wheelchair
11 Wheeled patient into hospital
12 Leave patient in wheelchair at hospital

HTA 6 – Day 2 Patient 1, Transfer patient

1 Prepare carry chair
    1.1 Fetch carry chair and blanket
    1.2 Take chair to patient
    1.3 Open out carry chair
    1.4 Put blanket over chair
2 Assist patient into the carry chair
    2.1 Wrap blanket around patient
    2.2 Fasten strapping
3 Wheel the chair out to vehicle
    3.1 Tilt chair back
        3.1.1 Warn patient of this
    3.2 Push chair forwards
        3.2.1 Bend to reach handles due to height
4 Access patient compartment
    4.1 Open back doors
    4.2 Open out the step
5 Undo carry chair strapping and remove blanket
6 Assist patient out of the carry chair
7 Assist patient up step into vehicle
8 Transfer patient to stretcher
9 Travel to hospital
10 Fetch wheelchair
11 Access patient compartment
    11.1 Open doors
    11.2 Pull down step
12 Assist patient down step
13 Assist patient into wheelchair
14 Wheel patient into hospital
    14.1 Hold doors open
    14.2 Wheel through corridors
    14.3 Wheel to ward
15 Transfer patient to hospital chair
    15.1 Take patients feet out of foot rest
    15.2 Raise foot rests
    15.3 Assist patient out of wheelchair
    15.4 Assist patient down into hospital chair

HTA 7 – Day 2 Patient 2, Transfer patient

- 1 Fetch carry chair
- 2 Open out carry chair
  - 2.1 clasp the seat
  - 2.2 hold the frame steady
  - 2.3 open out
- 3 Assist patient up off floor
- 4 Assist patient into carry chair
- 5 Fasten straps
- 6 Wheel carry chair to vehicle
- 7 Lift chair into vehicle
- 8 Assist patient from carry chair to stretcher
  - 8.1 Undo strapping
  - 8.2 Assist patient up onto feet
  - 8.3 Assist patient down onto stretcher
  - 8.4 Fasten straps
- 9 Travel to hospital
- 10 Unload stretcher at hospital
- 11 Transfer stretcher onto ward
  - 11.1 Hold doors open
- 12 Line stretcher up alongside hospital bed
- 13 Raise the stretcher
  - 13.1 Pull up on lever
  - 13.2 Pull stretcher upwards
- 14 Connect oxygen lead to the fixed oxygen supply
- 15 Prepare to transfer from stretcher to bed
  - 15.1 Put pat slide on bed
  - 15.2 Arrange sheets over the pat slide
  - 15.3 Pull sheets to pull patient over pat slide
  - 15.4 Remove the pat slide

HTA 8 – Day 2 Patient 4, Transfer patient

- 1 Fetch carry chair
  - 1.1 Open out carry chair
  - 1.2 Leave carry chair downstairs
- 2 Assist patient up to a sitting position
- 3 Wait for patient to compose herself
- 4 Assist patient down stairs slowly
- 5 Assist patient into carry chair
  - 5.1 Hold carry chair at head end
  - 5.2 Assist patient into chair from the front
  - 5.3 Wrap blanket around patient
  - 5.4 Fasten strapping
- 6 Wheel carry chair to vehicle
  - 6.1 Lift over threshold
    - 6.1.1 Bend at foot end to reach handles
    - 6.1.2 Hold chair at head end
    - 6.1.3 Lift chair
    - 6.1.4 Shuffle backwards / forwards with chair
  - 6.2 Lift down curb
    - 6.2.1 Bend at foot end
    - 6.2.2 Hold chair at head end
    - 6.2.3 Shuffle backwards / forwards with chair
- 7 Lift carry chair into vehicle

8 Line carry chair up with stretcher
9 Transfer patient to stretcher
    9.1 Shuffle patient across onto stretcher
10 Collapse carry chair
    10.1 Store carry chair in hold
11 Travel to hospital
12 Unload patient on stretcher
13 Transfer stretcher to hospital ward
14 Transfer patient to hospital bed
    14.1 Wheel alongside hospital bed
    14.2 Raise stretcher
        14.2.1 Pull lever
        14.2.2 Pull up stretcher
    14.3 Position pat slide on hospital bed
    14.4 Pull up sheets
    14.5 Roll patient towards attendants
    14.6 Position pat slide under patient
    14.7 Roll patient back onto slide
    14.8 Pull sheets across slide
    14.9 Remove pat slide

HTA 9 – Day 3 Patient 1, Transfer patient

Transfer patient
1 Fetch carry chair and oxygen
    1.1 Open out carry chair
    1.2 Position blanket on chair
2 Give patient oxygen
3 Assist patient into carry chair
    3.1 Wrap blanket around patient
    3.2 Ask patient
    3.3 Fastened straps
4 Rest oxygen on chairs crossbar
5 Wheel chair to vehicle
    5.1 Ease/tilt chair backwards
    5.2 Wheel to door
    5.3 Lift chair over threshold
        5.3.1 Face forward at head end
        5.3.2 Bend down at foot end
        5.3.3 Lift down step
        5.3.4 Turn chair 180 degrees
    5.4 Lift chair up 2 arc shaped steps
6 Prepare stretcher
7 Lower carry chair down curb single manned
    7.1 Wheel chair gradually down curb
    7.2 Correct the wheel footing as it bumps slightly to ground
    7.3 Patient moans
8 Transfer to hospital
9 Unload stretcher at hospital
10 Wheel stretcher into hospital
    10.1 Wheel over asphalt driveway
    10.2 Bump over floor surface
11 Transfer patient to hospital bed
    11.1 Wheel stretcher alongside hospital bed
    11.2 Raise stretcher
        11.2.1 Pull lever

11.2.2 Pull up stretcher
11.3 Ask patient to shuffle over onto stretcher

HTA 10 – Day 3 Patient 5, Transfer patient

1 Parent carries patient to vehicle
2 Access patient compartment
  2.1 Open back doors
  2.2 Open out step
3 Assist mother into vehicle
4 Transfer to hospital
5 Assist patient off vehicle
6 Walk into hospital

HTA 11 – Day 3 Patient, Transfer patient

1 Fetch carry chair
  1.1 Open out carry chair
  1.2 Place blanket on chair
2 Transfer patient from sofa to chair
  2.1 Assist patient up
    2.1.1 One attendant support patient from front
    2.1.2 One attendant support patient from behind
  2.2 Assist patient down into chair
    2.2.1 Wrap blanket around patient
    2.2.2 Fasten strap
3 Transfer chair to vehicle
  3.1 Ease / tilt chair backwards
  3.2 Wheel chair to door
  3.3 Lift chair over threshold
    3.3.1 Bend down at foot end
    3.3.2 Held chair at head end
    3.3.3 Lift
  3.4 Wheel to vehicle
  3.5 Lift chair into vehicle
  3.6 Assist patient from chair to stretcher
4 Travel to hospital
5 Fetch wheelchair
6 Access patient compartment
  6.1 Open back doors to vehicle
  6.2 Open out step
7 Assisted patient down step
8 Assisted patient into wheelchair
  8.1 Pull out foot rest
9 Wheel into hospital

HTA 12 – Day 4 Patient 1, Transfer patient

1 Assist patient into ambulance
  1.1 Open back doors
  1.2 Open out step
2 Assist patient into back of vehicle
3 Assist patient into seat
4 Fasten seat belt
5 Travel to hospital
6 Transfer patient to stretcher
7 Unload patient at hospital
8 Transfer patient to wheelchair

8.1 Fetch wheelchair
8.2 Wheel alongside stretcher
8.3 Ask patient to step up and onto wheelchair
8.4 Wheel patient to streaming

HTA 13 – Day 4 Patient 2, Transfer patient

1 Assist patient to vehicle on foot
2 Transfer patient to carry chair
2.1 Fetch carry chair
2.2 Open out carry chair
2.3 Ease patient down into chair
2.3.1 Attendant 1 guide from front
2.3.2 Attendant 2 guide from back
2.4 Bend to reach handles due to height
2.5 Fasten straps
2.6 Wheel chair forwards to vehicle
2.6.1 Ease chair over curb
2.6.2 Bend down to reach front handles
2.6.2.1 Guide carry chair from foot end
2.6.3 Lift chair into vehicle
3 Travel to hospital
4 Unload stretcher
5 Transfer stretcher to hospital
5.1 Tuck strapping under mattress
5.2 Wheel the patient to the ward
6 Transfer patient to hospital bed
6.1 Ask patient is she can stand
6.2 Lower stretcher
6.3 Wheel stretcher alongside bed
6.3.1 Apply the brakes
6.3.1.1 Press down on brake with foot
6.4 Assist patient to feet
6.5 Assist the patient to turn
6.6 Assist patient down onto the bed
6.7 Assist patient to put legs up
6.7.1 Support patients back
6.7.2 Move patients legs round onto bed

HTA 15 – Day 4 Patient 3, Transfer patient

1 Fetch wheelchair
2 Assist patient into wheelchair
3 Wheel chair to vehicle
3.1 Lift chair over threshold
3.2 Ease over the gap between the floor surfaces
3.3 Ease chair over curb edge
3.3.1 Raise front wheels to lower
3.3.1.1 Put foot down on wheelchair lever
3.3.1.2 Lower chair down
3.3.1.3 Struggle due to patients feet in way
4 Access patient compartment
4.1 Open doors
4.2 Open out step
5 Assist patient up step
6 Assist patient into static chair
7 Travel to hospital

8 Assist patient into wheelchair
9 Transfer patient to hospital ward
10 Wheel chair to bay alongside bed
11 Ask patient if he wants to sit in bed or chair
12 Assist patient onto feet
13 Assist patient into chair

HTA 16 – Day 5 Patient 1, Transfer patient

1 Assist patient on foot to vehicle
2 Assist patient into vehicle
3 Travel to hospital
4 Wheel stretcher into hospital
5 Wheel into bay alongside bed
6 Take down hand rail on stretcher
7 Ask patient to transfer themselves to bed

HTA 17 – Day 5 Patient 2, Transfer patient

1 Wheel stretcher to patient
2 Bend to ground where patient is lying
3 Push patients back up
4 Assist patient onto stretcher
    4.1 Hold patients leg out straight
    4.2 Ask patient to support self with good leg
5 Wheel stretcher to vehicle
6 Load stretcher
7 Travel to hospital
8 Unload stretcher
9 Wheel into hospital
10 Transfer from stretcher to wheelchair
    10.1 Ask patient to do all of work with good leg
    10.2 Hold bad leg
    10.3 Open out footrest
    10.4 Rest bad leg on foot rest
    10.5 Assist patient to shuffle herself into wheelchair
        10.5.1 Hold wheelchair to stop it moving
11 Transfer patient to streaming

PTS

HTA 1 - Day1 patient 3, transfer into home

1 Release stretcher
2 Wheel stretcher down ramp
    2.1 Open out the handles
    2.2 Manoeuvre down ramp
    2.3 Pull back at head end
3 Wheel stretcher to home
    3.1 Wheel over gravel driveway
        3.1.1 Stretcher bumps over terrain
4 Assess access into home
5 Squeeze stretcher through door to home
    5.1 Ease around corners, confined
    5.2 Restricted access into patients room due to confined space
        5.2.1 Attempt to get patient into room with stretcher
6 Fetch wheelchair to transfer patient

7 Wheel chair alongside wheelchair
8 Transfer patient to wheelchair
    8.1 Bunch up sheets around patient
    8.2 Lift patient into wheelchair
9 Wheel patient into room
10 Wheel stretcher to vehicle
    10.1 Squeeze stretcher past furniture
    10.2 Wheel down ramp
    10.3 Wheel over gravel driveway
    10.4 Load stretcher
        10.4.1 Wheel up ramp
        10.4.2 Stow stretcher

HTA 2 - Day1 patient 4, drop off at hospital

1 Transfer patient on stretcher
2 Unlock the stretcher
3 Wheel down ramp
4 Wheel stretcher into hospital
5 Open automatic doors
6 Wheel through automatic doors
    6.1 Sharp turn to get stretcher through door
7 Wheel stretcher onto the ward
8 Wheel stretcher into the room
    8.1 Wheel stretcher beyond the door
    8.2 Wheel the stretcher back through door
9 Undo straps
10 Raise stretcher
    10.1 Pull on handle
    10.2 Lift
11 Wheel the patient from the room
12 Move patient back into room
13 Transfer patient onto stretcher
    13.1 Fetch pat slide
    13.2 wheel stretcher alongside hospital trolley
    13.3 Put brake on stretcher
    13.4 Put pat slide under patient
    13.5 Pull sheets over pat slide
    13.6 Pull patient over onto bed
    13.7 Remove pat slide
    13.8 Put blanket on stretcher
14 Move stretcher to leave ward
    14.1 Drag stretcher due to brake still being on
15 Lower stretcher
    15.1 Pull handle up
        15.1.1 Struggle due to hands not being big enough
        15.1.2 Lower stretcher
            15.1.2.1 Stretcher lifts off ground slightly
16 Remove brake from stretcher
17 Wheel stretcher out to vehicle

HTA 3 - Day 1 patient 1 - dispatch from hospital

1 Pull stretcher off vehicle
2 Pull stretcher off ramp
3 wheel stretcher into hospital
    3.1 Hold door open with left hand

3.2 Wheel stretcher through door
3.3 Wheel stretcher to ward
4 Wheel stretcher up to hospital bed
5 Prepare stretcher for patient
5.1 Undo strapping on stretcher
5.2 Take the blanket off stretcher
5.3 Raise stretcher
5.3.1 Lift
6 Raise hospital trolley
7 Put pat slide on stretcher
8 Lift sheets on stretcher
9 Ask patient to roll onto side
10 Put pat slide under patient
11 Pull patient across
12 Prepare patient and stretcher for manoeuvring
12.1 Raise hand rails on stretcher
12.2 Fasten patient in strapping
12.3 Open out handles on stretcher
13 Wheel stretcher out to vehicle
14 Open hospital doors
14.1 Kick to open
15 Pull stretcher through doors
15.1 Manoeuvre quickly before doors close
16 Pull the stretcher out to vehicle
17 Pull the stretcher up ramp and load

HTA 4 - Day 1 patient 4, dispatch home from hospital

1 Take down ramp
2 Wheel out the stretcher
3 Wheel down ramp
4 Sort stretcher for patient
4.1 Arrange pillows
4.2 Arrange sheets
5 Wheel stretcher into hospital
5.1 Pull the door open wide
5.2 Wheel through door
5.3 Wheel through corridors
5.4 Wheel into lift
5.5 Wheel stretcher onto ward
6 Pull the bed out
7 Pull the table out of the way
8 Wheel stretcher alongside bed
9 Raise stretcher
9.1 Pull on handle
9.2 Lift upwards
10 Raise hospital bed
10.1 Pump up and down on foot pedal
11 Transfer patient
11.1 Pull out sheet and blankets on hospital bed
11.2 Put pat slide on stretcher
11.3 Pull sheets up
11.4 Push pat slide under patient
11.4.1 Roll patient towards nurse to get board under
11.5 Slide patient across onto stretcher
12 Pull handrails up on stretcher

13 Put blanket back over patient
14 Lower stretcher down
  14.1 Lift handle
  14.2 Hold trolley at both sides
  14.3 Lower slowly
15 Remove brake from stretcher wheels
16 Open out handles on stretcher
17 Wheel stretcher out to ambulance
  17.1 Wheel stretcher to lift
    17.1.1 Trolley bumped over grating on lift entrance
  17.2 kick and swing doors out
  17.3 Warn patient of bump as stretcher is wheeled over kerb
  17.4 Wheel stretcher onto ambulance

HTA 5 - Day 1 patient 5, dispatch from hospital

1 Wheel wheelchair to the ward
  1.1 Wheel chair backwards
2 Fetch patient
3 Wheel carefully through door
  3.1 Not much space
4 Wheel backwards to the lift
5 Pull wheelchair
6 Open doors
  6.1 Kick with foot
7 Wheel chair over kerb
  7.1 Warn patient of bump as go over kerb
8 pull out ramp on vehicle
9 Wheel chair up the ramp
10 Line chair up with static chair in vehicle
11 Push foot rest on the wheelchair in
12 Ask patient to hop across into the other seat
13 Attach Zimmer frame
14 Strap in place

HTA 6 - Day 1 patient 5, return home

1 Wheel chair into vehicle
2 Put brake on
  2.1 Pull lever back over the wheel
3 Assist the patient onto feet
4 Assist down into wheelchair
5 Remove brakes from the wheels
6 Wheel the chair backwards down ramp
7 Wheel the chair to patients home
  7.1 Raise the wheelchair over kerb
  7.2 Take care wheeling chair over paving slabs
  7.3 Open gate to pathway
  7.4 Push chair through gateway
8 Push chair up against step to house
9 Assist patient up out of chair
10 Assist patient into house

HTA 7 - Day 1 patient 6, dispatch to home address

1 Pull the stretcher out
2 Wheel down the ramp
3 Wheel over coarse road surface

3.1 Stretcher bumps over surface
4 Wheel the trolley onto the ward
5 Remove the straps for the stretcher
6 Remove the blanket
7 Get a rotunda to transfer patient
7.1 Push rotunda under patients feet
7.2 Assist the patient up onto their feet
7.3 Rotate the device so that patients bottom was inline with stretcher
7.4 Lower patient down onto stretcher
7.5 Raise patients feet
8 Cover patient with blanket
9 Wheel stretcher out into lift
10 Rest patients possessions on handles of stretcher
10.1 No other storage space
11 Open doors to hospital ward
11.1 Kick open doors
11.1.1 Unsteady on feet
12 Wheel stretcher out of hospital
12.1 Head towards ambulance
13 Manoeuvre down kerb
13.1 Wheel over dimpled road surface
13.1.1 Bumpy surface for patient and staff
13.1.2 Warn patient of potential discomfort
14 Load stretcher onto ambulance
14.1 Push stretcher at an angle to load

HTA 8 - Day 1 patient 6, Return home

1 Unload stretcher at patients home
1.1 Hold patients bags at foot end
1.2 Hold bags on frame at head end
2 Wheel stretcher to home
2.1 Wheel over shallow kerb
2.2 Manoeuvre up the ramp to driveway
2.3 Manoeuvre over chip and tar driveway
2.3.1 Stretcher bit shaky on this terrain
2.4 Manoeuvre up ramp to house
3 Assess whether stretcher can get into house
4 Wheel stretcher back down ramp
4.1 Stretcher wont get into house
5 Bring out patients electric chair from home
6 Apply stretcher brake
7 Assess where to carry out transfer to chair
7.1 Patients dignity and privacy is reduced conducting transfer outside
7.2 Not sufficient space in ambulance to carry out transfer
8 Transfer patient outside home
8.1 Assist patient into upright position
8.2 Balance patient from front
8.2.1 One staff member holds patients arms
8.3 Remove arm rests from wheelchair
8.4 Swing patient around onto chair
8.5 Count to three
8.6 Rock the patient up onto the wheelchair
9 Reattach foot brakes and arm rest
10 Wheel patient up ramp
10.1 Operate electric wheelchair

10.2 Struggle getting the chair onto ramp
10.2.1 Entrance to ramp is tight
11 Manoeuvre chair through door
11.1 Struggle to get chair through door
11.1.1 Doorway is confined
11.2 Edges of doors in house are chipped due to wheelchair manoeuvring
12 Make sure patient is safely settle in home
13 Wheel stretcher back to vehicle

HTA 9 - Day 1 patient 7, Stretcher transfer
1 Open the door of the home outwards
1.1 Pin open the doors
2 Wheel the patient in through the door
2.1 Hold the second door open while bringing the stretcher through
3 Rest the patients bags on the frame of the stretcher
4 Wheel the stretcher through the corridor
5 Wheel stretcher through door
5.1 Tight squeeze to get the stretcher through door
5.2 Rotate the stretcher at an angle
6 Line stretcher up with hospital bed
7 Assist the patient to sit up
8 Transfer the patient to the bed
9 Arrange the stretcher
10 Wheel stretcher out of the room
11 Wheel stretcher back to vehicle
11.1 Wheel stretcher through doors
11.2 Wheel stretcher through corridors

HTA 10 - Day 1 Patient 8, Taking patient out to house
1 Unclipped the strapping around the top of the chair
2 Draw out ramp
3 Remove the strapping at the back of the wheelchair
4 Wheel chair to the house
5 Wheel the chair backwards
6 Take the chair over the threshold
6.1 Move chair over ridge in the threshold
6.1.1 Tilt the chair backwards
7 Wheel into the living room
8 Remove the foot plates from the wheelchair
9 Prepare to transfer the patient into the chair
9.1 Put the banana board between the chair and the wheelchair
9.2 Patient slid herself across
9.3 Removed the banana board
10 Left the patient alone

HTA 11 - Day 1 patient 8, wheelchair transfer
1 Wheel chair to the ambulance
2 Wheel chair up the ramp
2.1 Stoop really low to push the wheelchair up the ramp
3 Fetch the fastenings for the wheelchair
4 Attach the wheelchair to the runners inside vehicle
4.1 Put the webbing into the runners
4.2 Secure to the frame of the chair

HTA 12 - Day 1 patient 9, Wheelchair transfer

- 1 Wheel chair into the ward
  - 1.1 Push chair forwards
- 2 Fetch patient
  - 2.1 Store oxygen on hook at side of patient
  - 2.2 Store patients drugs on hook at back of wheelchair
  - 2.3 Attendant carries patients personal possessions
- 3 Patient walked to the chair
  - 3.1 No need for assistance
- 4 Pushed chair into lift
- 5 Pulled chair out of lift
  - 5.1 Oxygen banged slightly on the lift door
- 6 Wheeled patient out to vehicle
  - 6.1 Struggle to wheel chair
- 7 Open the doors
- 8 Assist patient up steps to vehicle

HTA 13 - Day 1 Patient 11, Stretcher transfer

- 1 Wheel stretcher to ward
- 2 Swing open doors
- 3 Wheel stretcher into the ward
- 4 Prepare stretcher for patient
  - 4.1 Remove blanket
  - 4.2 Undo straps
  - 4.3 Put sheet on mattress
  - 4.4 Raise head rest
- 5 Transfer patient onto stretcher
  - 5.1 Assist patient up
  - 5.2 Turn patient onto the mattress
  - 5.3 Assist patients legs onto mattress
- 6 Adjust patients pillows for comfort
- 7 Put blanket over patient
- 8 Secure straps
- 9 Release brakes from stretcher wheels
- 10 Rest patient belongings on frame of stretcher
- 11 Open out handle
- 12 Wheel stretcher out of ward
- 13 Wheel stretcher into lift
  - 13.1 Kick the stretcher to aid movement
- 14 Wheel stretcher out of lift
- 15 Wheel stretcher out to ambulance

HTA 14 - Day 1 Patient 11, Transferring into the nursing home

- 1 Wheel stretcher out of holding bay
- 2 open out handles
- 3 Wheeled patient to home
  - 3.1 Transfer a little bumpy over sand
  - 3.2 Bump stretcher over loose slabs
  - 3.3 Manoeuvre around skip
    - 3.3.1 Tight squeeze, confined space
- 4 Wheel stretcher into home
- 5 Wheel stretcher into lift
  - 5.1 Stretcher does not fit in lift
  - 5.2 Lift is too small
  - 5.3 Transfer patient into wheelchair

5.3.1 Raise head rest of stretcher
5.3.2 Twist the patient around
5.3.3 Help him lower into the wheelchair
5.3.4 Place foot pedals under patients feet
6 Fasten straps on the stretcher
7 Wheel stretcher out to vehicle
7.1 Stretcher bumps against railings on ramp of home

HTA 15 - Day 2 Patient 2, Home to hospital

1 Prepare the stretcher with the sheet
2 Take off the straps
3 Put the pillows and sheets down
4 Take the stretcher into the house
4.1 Wheel over slabs with cracks in them
4.2 Wheel up ramp
4.3 Wheel into the house
5 Line up the wheelchair with the patients bed
5.1 Raise the stretcher
5.2 Bring up the hospital bed
6 Put the pat slide under the patient
7 Pull across the sheet over the slide onto the stretcher trolley
8 Pull the patient up on the stretcher
8.1 Wrap the sheet up around patient
8.2 Pull patient towards the head end of the stretcher
8.3 Adjust pillows
9 Raise the head end
9.1 Use force
9.2 2 Staff members involved
10 Raise stretcher one side at a time
11 Pull stretcher out of house
12 Pulled stretcher over makeshift ramp
12.1 Tug to get stretcher over ramp
13 Load the stretcher in vehicle

HTA 16 - Day 2 patient 2, Transfer into hospital

1 Wheel stretcher off vehicle
2 Wheel stretcher to hospital
2.1 Wheel over chipped driveway
3 Wheel stretcher into the hospital
4 Bring stretcher alongside hospital bed
5 Raise stretcher
5.1 Staff member at either side
6 Hospital staff raise hospital bed
7 Ambulance staff take off straps
8 Use pat slide to move patient
8.1 Put pat slide under patient
8.2 Pull the patient across the pat slide on the sheets
9 Fasten straps
10 Wheel the stretcher out
11 Take stretcher back to vehicle
12 Get stretcher ready for loading
12.1 Lower stretcher
12.1.1 Pull up handle
12.1.2 Cant lower
12.1.2.1 Attendants fingers too short to pull lever

12.1.3 Pick up stretcher off ground to lower
12.1.4 Shake stretcher a bit to lower
13 Load stretcher

HTA 17 - Day 2 patient 5, Transfer into home
1 Pull ramp out at patients home
2 Remove strapping from patients chair and tracking
3 Take patient off vehicle oxygen supply
4 Wheel the patient down ramp
5 Wheel patient to home
5.1 Wheel patient over slabs
5.2 Wheel up temporary ramp fitted to house
5.3 Raise chair over threshold
5.3.1 Put foot down on lever alongside wheel
5.4 Wheel over internal ramp to the conservatory
5.5 Wheel to the patio door
5.6 Move over threshold to patio
5.6.1 Put foot on lever
6 Wheel into living room
7 Wheel alongside patients chair
8 Patient assists herself onto chair in living room

HTA 18 - Day 2 patient 5, Wheelchair discharge
1 Transfer patient onto wheelchair
2 Assist patient into chair on foot
3 Take patient off oxygen supply
4 Give patient portable oxygen supply
5 Wheel chair out of home to ambulance
6 Load wheelchair
7 Strap patient into tracking
8 Attach patient to vehicle oxygen supply

HTA 19 - Day 2 Patient 6, ambulance to hospital
1 Take down the ramp on ambulance
2 Wheel stretcher down the ramp
3 Wheel trolley to ward
4 Swing open doors
5 Wheel through corridors
6 Wheel onto the ward
7 Leave the stretcher with the nursing staff
7.1 Wait for patient to become ready

HTA 20 - Day 2 Patient 6, from hospital to ambulance
1 Take off fixed oxygen supply
2 Put patient on portable supply
3 Assist patient onto stretcher
4 Fasten straps
5 Position blanket over patient
6 Raise head rest
7 Transport patient to ambulance
7.1 Rest patients drugs on stretcher
7.2 Wheel stretcher forward
7.2.1 Banging over ridges in the floor at the intersection
7.3 Kick doors open
7.4 Wheels move out of alignment

7.4.1 Kick wheel back into alignment
7.5 Wheel stretcher out of hospital
7.6 Load stretcher onto ambulance

HTA 21 - Day 2 Patient 6, transfer into home

1 Wheel chair into vehicle
2 Take oxygen supply off bed
3 lower hand rail on stretcher
4 Assist patient onto feet
5 Turn patient towards chair
6 Take brake off wheelchair
7 Assist patient into chair
8 Take oxygen in hand
9 Transfer patient out of vehicle
10 Transfer patient to hospital
11 Lift chair over kerb
11.1 Press on the lever
11.2 Raise chair up over kerb
12 Struggle past pathway
13 Lift up path threshold
14 Wheel over path
15 Lift up house threshold
15.1 Attendant on either side of chair
15.2 Bend down
15.3 Lift chair
15.4 Move back end first
15.5 Press on lever at back of chair next to wheel
16 Once inside assist patient into own home

HTA 22 - Day 2 Patient 7, Stretcher patient

1 Pull out ramp
2 Wheel chair up ramp
3 Take hand rail off the wheelchair
4 Spin patients legs round
5 Ask patient to stand up
6 Lift the patient up into chair
6.1 Top and tail
7 Put hand rails back on chair
8 Put foot rests down
9 Pull brake off
9.1 Pull lever up
10 wheel chair to home staff

HTA 23 - Day 2 Patient 7, Wheelchair patient

1 Take wheelchair to patient
2 Assist patient to feet
3 Swing her around into the wheelchair
3.1 Patient perched on the edge of the seat
3.2 Count to three
3.3 Move patient further backward
3.4 Turn foot pedals in
3.5 Place foot pedals under patients feet
4 Wheel chair out of ward to ambulance
5 Swing open the doors
6 Wheel out to the vehicle

7 Load wheelchair
8 Move wheelchair alongside the static chair
9 Lower the handle bar on the wheelchair
10 Lift / slide the patient across

HTA 24 - Day 3 Patient 1, Stretcher patient

- 1 Wheel stretcher to ward
- 2 Wheel stretcher alongside patient
- 3 Take handles down
- 4 Raise patient head rest
- 5 Unfasten straps
- 6 Put brakes on stretcher
- 7 Lift stretcher out of way to get to patient
    - 7.1 Patient waiting in seat
- 8 Hold onto the patients catheter
- 9 Assist patient onto stretcher
    - 9.1 Ask patient to stand up and sit on stretcher
    - 9.2 Assist patient onto feet
    - 9.3 Swivel patient round so her bottom is on stretcher
    - 9.4 Assist patient to lean back
    - 9.5 Assist patients legs onto stretcher
    - 9.6 Fasten straps
        - 9.6.1 Catch glove in strapping
            - 9.6.1.1 Unfasten strapping
            - 9.6.1.2 Struggle with strapping
- 10 Turn up patient hand rail
- 11 Rest patients possessions on frame
    - 11.1 2 bags rested on frame of trolley
    - 11.2 Notes rested under patients pillow
    - 11.3 Another bag carried by foot end attendant
- 12 Wheeled trolley out to vehicle
    - 12.1 Bumping over ridges in the floor
        - 12.1.1 No shock absorption on wheels of stretcher
    - 12.2 Bumped over entrance to lift
- 13 Wheeled stretcher up to vehicle
    - 13.1 Took patients belongings off the stretcher
    - 13.2 Moved stretcher into vehicle

HTA 25 - Day 3 patient 2, Stretcher transfer

- 1 Take down ramp
- 2 Fasten straps
- 3 Unload patients
- 4 Wheel stretcher to hospital
    - 4.1 Bump stretcher over low kerb
    - 4.2 Patient is getting wet in rain during transfer
- 5 Wheel stretcher into hospital
    - 5.1 Patients legs dangling over end of bed
    - 5.2 Patients legs kicking attendant
    - 5.3 Attendant asks patient to bend legs upward
- 6 Wheel stretcher into lift
- 7 Wheel stretcher out onto ward
- 8 Transfer from stretcher to hospital bed
    - 8.1 Prepare hospital bed
    - 8.2 Release brakes from stretcher
    - 8.3 Wheel stretcher to side of bed

8.4 Raise stretcher
    8.4.1 Stretcher lifted off ground as did this
8.5 Lined stretcher with hospital trolley
8.6 Put stretcher brakes back on
8.7 Arrange hospital trolley
    8.7.1 Ambulance stretcher remains in way
        8.7.1.1 Move ambulance stretcher
            8.7.1.1.1 Lift and push
    8.7.2 Transfer patient to hospital bed
        8.7.2.1 Grab sheets from both sides
        8.7.2.2 Count to three
        8.7.2.3 Drag patient across

9 Raise handles on stretcher
10 Fasten strapping
11 Lower the trolley one man
    11.1 Raise handle
    11.2 drop stretcher down
    11.3 Release brakes
        11.3.1 Kick brakes
    11.4 Pick up handles to wheel away
12 Wheel stretcher back to ambulance

HTA 26 - Day 3 Patient 2, Transfer from hospital

1 Wheel trolley to hospital bed
2 Put brakes on
    2.1 Press down on lever over wheel
3 Assist patient onto stretcher
4 Raised head rest
5 Strapped patient in
6 Release brakes
7 Manoeuvre trolley
8 Foot pedal for raising and lowering bashed against wall
    8.1 Kick lever due to sticking
9 Wheel stretcher out to vehicle
    9.1 Ask patients to keep arms in
    9.2 Bump stretcher over carpet join
        9.2.1 No shock absorption on wheels

HTA 27 - Day 3 Patient 3, Wheelchair transfer from home to vehicle

1 Wheel chair out backwards
2 Move mat away from door
3 Lower the chair slowly over threshold
    3.1 Move chair backwards
    3.2 Large step to threshold
4 wheel the chair down slope
    4.1 Wheel chair backwards to prevent patient falling out of chair
5 Transfer onto chair in vehicle
6 Assist patient into seat

HTA 28 - Day 3 patient 4, Transfer from ambulance to home

1 Wheel patient to house
2 Tip wheelchair back
3 Lift the chair back at either end of patient
    3.1 Head end and foot end
4 Lift up step to threshold

5 Lift over second step to threshold
6 Ask patient to keep hands in to prevent hitting wall
7 Take patient into house

HTA 29 - Day 3 patient 5, Transfer from ambulance into home

1 Remove webbing
2 Release brakes
3 Take wheelchair off ramp
4 Tip back the chair to get over kerb in forward position
5 Bring over path
6 Wheel into house
7 Lift over threshold
    7.1 Tip chair backwards
    7.2 Press down on lever to tilt
8 Settle patient

HTA 30 - Day 3 patient 5, Wheel chair transfer from hospital to ambulance

1 Transfer patient into wheelchair
2 Wheel chair through corridors of hospital
3 Wheel out to ambulance
4 Load wheelchair
5 Lock in wheelchair into locking mechanism

Appendix K: Chair user trial questionnaire for Case study 2

Researcher to complete	
Trial	____________
Trial date	____________
Equip	____________
Position	____________

2. Manoeuvring chair

2.1 Manoeuvring chair on smooth floor

1. How did you find manoeuvring the chair on the smooth floor?	Very easy	○ ○ ○ ○ ○	Not easy at all
2. How did you find turning the chair on the smooth floor?	Very easy	○ ○ ○ ○ ○	Not easy at all
3. How did you find the chair stability when manoeuvring on smooth floor?	Very stable	○ ○ ○ ○ ○	Not stable at all
4. Which handles did you use to manoeuvre chair?	Extendable handles ○		Frame ○
5. How did you find the handles for manoeuvring the chair?	Very appropriate	○ ○ ○ ○ ○	Not appropriate at all
6. How did you find your posture when manoeuvring chair?	Very good	○ ○ ○ ○ ○	Not good at all

Please comment if necessary....

2.2 Manoeuvring over the kerb

1. How did you find manoeuvring the chair over the kerb	Very easy	○ ○ ○ ○ ○	Not easy at all
2. Which handles did you use to manoeuvre chair?	Extendable handles ○		Frame ○
3. How did you find the handles for manoeuvring the chair?	Very appropriate	○ ○ ○ ○ ○	Not appropriate at all

4. How did you find your posture when manoeuvring the chair over the kerb	Very good	O O O O O	Not good at all
5. Please rate the level of manual handling when manoeuvring the chair over the kerb	Very low	O O O O O	Very high

Please comment if necessary....

2.3 Manoeuvring through doorways

1. How did you find manoeuvring the chair through the doorways	Very easy	O O O O O	Not easy at all
2. How did you find the chair for manoeuvring in a confined space	Very adequate	O O O O O	Not adequate at all
3. How did you find the wheels for manoeuvring chair through doorways	Very appropriate	O O O O O	Not appropriate at all
4. How did you find your posture when manoeuvring chair through doorways	Very good	O O O O O	Not good at all

Please comment if necessary....

2.5 Ascending stairs

1. How did you find manoeuvring the chair up the stairs?	Very easy	○ ○ ○ ○ ○	Not easy at all
2. How did you find the chair stability when manoeuvring the chair up stairs?	Very stable	○ ○ ○ ○ ○	Not stable at all
3. Which handles did you use to manoeuvre chair up stairs?	Extendable handles ○	Frame ○	
4. How did you find the handles for manoeuvring the chair up stairs?	Very appropriate	○ ○ ○ ○ ○	Not appropriate at all
5. How did you find the patients position on the chair when manoeuvring up stairs?	Very good	○ ○ ○ ○ ○	Not good at all
6. How did you find the ride quality for the patient	Very good	○ ○ ○ ○ ○	Not good at all
7. What level of skill was required to manoeuvre the chair up stairs	Very low	○ ○ ○ ○ ○	Very high
8. How did you find your posture when manoeuvring the chair up stairs?	Very good	○ ○ ○ ○ ○	Not good at all
9. What was the level of manual handling when manoeuvring the chair down stairs?	Very low	○ ○ ○ ○ ○	Very high

Please comment if necessary....

2.6 Descending stairway

1. How did you find manoeuvring the chair down the stairs?	Very easy	○ ○ ○ ○ ○	Not easy at all
2. How did you find the chair stability when manoeuvring the chair down stairs?	Very stable	○ ○ ○ ○ ○	Not stable at all
3. Which handles did you use to manoeuvre the chair down stairs?	Extendable handles ○	Frame ○	
4. How did you find the handles for manoeuvring the chair down stairs?	Very appropriate	○ ○ ○ ○ ○	Not appropriate at all

5. How did you find the patients position on the chair when manoeuvring down stairs?	Very good	O	O	O	O	O	Not good at all
6. How did you find the ride quality for the patient	Very good	O	O	O	O	O	Not good at all
7. What level of skill was required to manoeuvre the chair down stairs	Very low	O	O	O	O	O	Very high
8. How did you find your posture when manoeuvring the chair down stairs?	Very good	O	O	O	O	O	Not good at all
9. What level of manual handling when manoeuvring the chair down stairs?	Very low	O	O	O	O	O	Very high

Please comment if necessary....

3.7 Stair climbing / descending feature

1. How did you find preparing the stair climber to function on stairs?	Very easy	O	O	O	O	O	Not easy at all
2. How did you find operating the stair climbing chair?	Very easy	O	O	O	O	O	Not easy at all
3. How did you find controlling the stair climbing chair?	Very easy	O	O	O	O	O	Not easy at all

Please comment if necessary....

2.4 Manoeuvring chair on carpeted flooring

1. How did you find manoeuvring the chair on the smooth floor?	Very easy	O	O	O	O	O	Not easy at all
2. How did you find turning the chair on the smooth floor?	Very easy	O	O	O	O	O	Not easy at all
3. How did you find the chair stability when manoeuvring on smooth floor?	Very stable	O	O	O	O	O	Not stable at all
4. Which handles did you use to manoeuvre chair?	Extendable handles	O		Frame		O	
5. How did you find the handles for manoeuvring the chair?	Very appropriate	O	O	O	O	O	Not appropriate at all
6. How did you find your posture when manoeuvring chair?	Very good	O	O	O	O	O	Not good at all

Please comment if necessary....

Appendix L: Stretcher user trial questionnaire for case study 2

Researcher to complete	
Trial	______________
Trial date	______________
Equip	______________
Position	______________

3. Stretcher manoeuvring in lowered position

3.1 Manoeuvring stretcher

1. How did you find manoeuvring the stretcher on the smooth floor?	Very easy	O O O O O	Not easy at all
2. How did you find turning the stretcher on the smooth floor?	Very easy	O O O O O	Not easy at all
3. How did you find the stretcher stability when manoeuvring on smooth floor?	Very stable	O O O O O	Not stable at all
4. Which handles did you use to manoeuvre stretcher?	Extendable handles O	Frame O	
5. How did you find the handles for manoeuvring the stretcher?	Very appropriate	O O O O O	Not appropriate at all
6. How did you find your posture when manoeuvring stretcher?	Very good	O O O O O	Very poor

Please comment if necessary....

3.2 Manoeuvring over the kerb

1. How did you find manoeuvring the stretcher over the kerb	Very easy	O O O O O	Not easy at all
2. Which handles did you use to manoeuvre stretcher?	Extendable handles O	Frame O	

3. How did you find the handles for manoeuvring the stretcher?	Very appropriate	○ ○ ○ ○ ○	Not appropriate at all
4. How did you find your posture when manoeuvring the stretcher over the kerb	Very good	○ ○ ○ ○ ○	Not good at all
5. Please rate the level of manual handling when manoeuvring the stretcher over the kerb	Very low	○ ○ ○ ○ ○	Very high

Please comment if necessary....

3.3 Manoeuvring through doorways

1. How did you find manoeuvring the stretcher through the doorways	Very easy	○ ○ ○ ○ ○	Not easy at all
2. How did you find the stretcher for manoeuvring in a confined space	Very adequate	○ ○ ○ ○ ○	Not adequate at all
3. Would shortening the stretcher have impacted on this task?	Yes ○	No ○	

Please explain...

4. How did you find the wheels for manoeuvring stretcher through doorways	Very appropriate	○ ○ ○ ○ ○	Not appropriate at all
5. How did you find your posture when manoeuvring stretcher through doorways	Very good	○ ○ ○ ○ ○	Not good at all

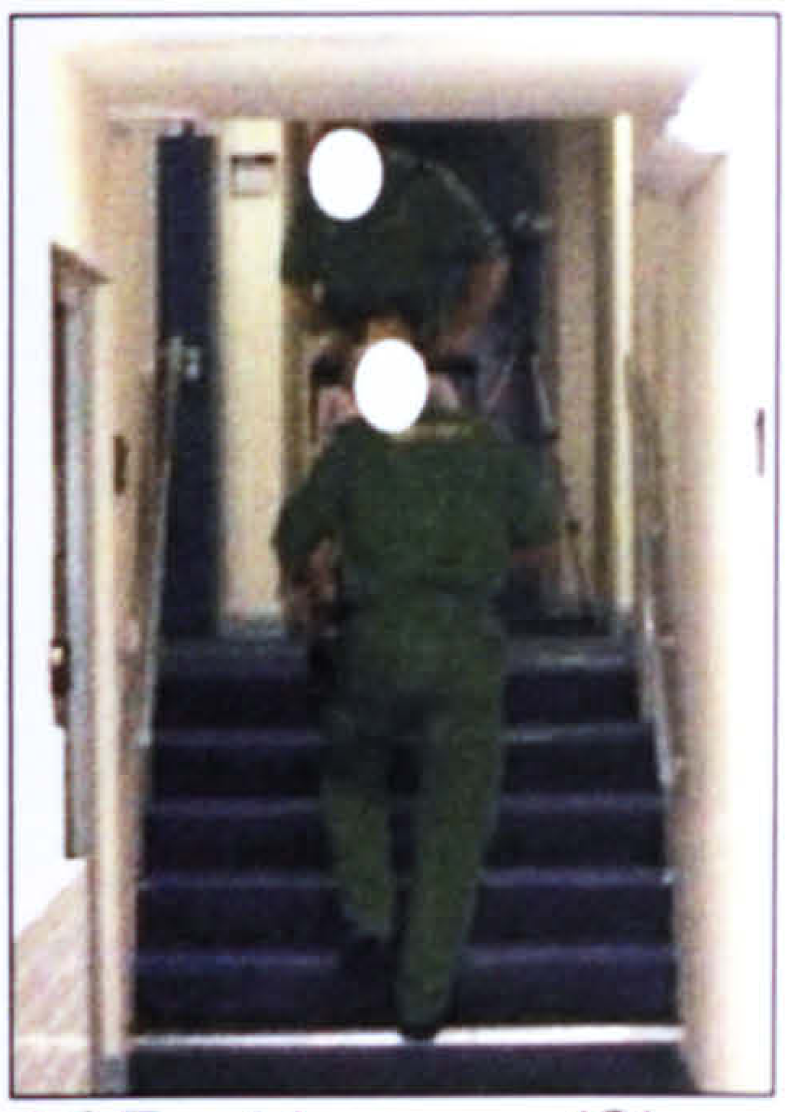
Please comment if necessary....

3.4 Manoeuvring stretcher on carpeted flooring

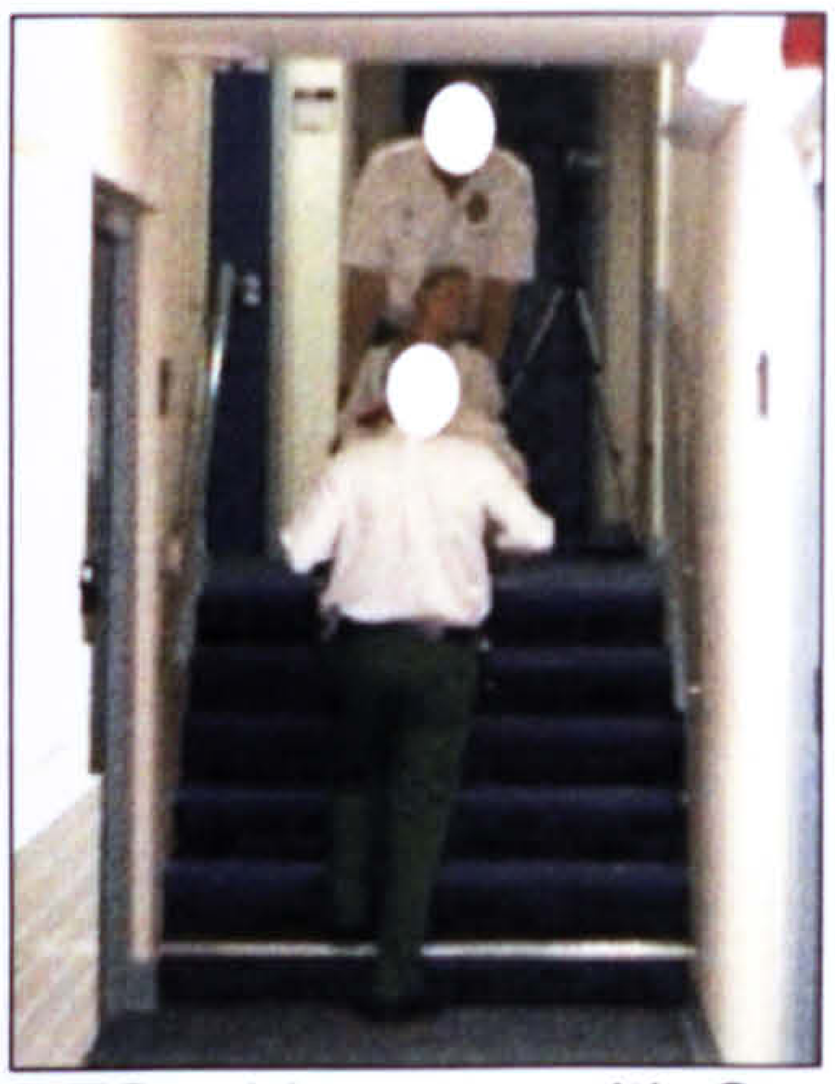
1. How did you find manoeuvring the stretcher on the smooth floor?	Very easy	O	O	O	O	O	Not easy at all
2. How did you find turning the stretcher on the smooth floor?	Very easy	O	O	O	O	O	Not easy at all
3. How did you find the stretcher stability when manoeuvring on smooth floor?	Very stable	O	O	O	O	O	Not stable at all
4. Which handles did you use to manoeuvre stretcher?	Extendable handles	O		Frame		O	
5. How did you find the handles for manoeuvring the stretcher?	Very appropriate	O	O	O	O	O	Not appropriate at all
6. How did you find the wheels for manoeuvrina stretcher?	Very appropriate	O	O	O	O	O	Not appropriate at all
7. How did you find your posture when manoeuvring stretcher?	Very good	O	O	O	O	O	Very poor

Please comment if necessary....

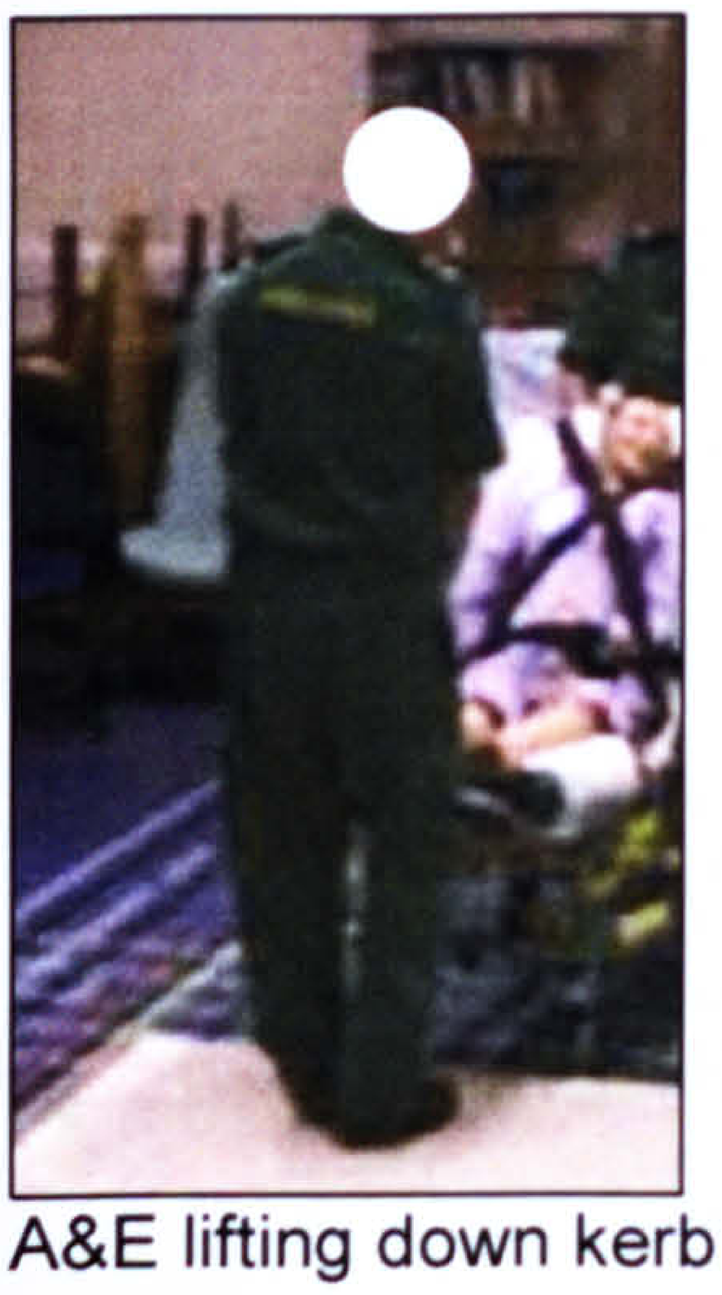
Appendix M: Examples of postures analysed for case study 2



A&E midway up (Sirocco)



PTS midway up with Spencer 2 wheels



A&E lifting down kerb at foot end of Parensi stretcher


PTS Lifting up kerb at foot end of Falcon 6 stretcher