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Usability of manual handling aids for transporting materials

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Manual transport aids (trucks and trolleys) are in widespread use throughout most industries, but their use does not always result in the anticipated reduction of workload or musculoskeletal stress. A survey of users has shown that many of the aids currently used are poorly designed or inappropriate for the tasks performed. The information gained during the survey has been analysed to identify the most important design features and to provide guidance for their selection and evaluation, in order to ensure that aids are suitable for the tasks for which they are used and that they are effective and safe. It is clear that the first stage in establishing design criteria and guidelines should be developing an understanding of the task requirements and environmental conditions under which materials have to be transported in industry.

Keywords: manual handling, handling aids, equipment design, usability

Manual materials handling is now widely recognised as a major source of injuries in industrial work. Reports from Stubbs and Nicholson (1979), and Davis and Sheppard (1980) showed that about 25% of all industrial accidents in Britain were associated with manual handling. Since then, this proportion has hardly changed and approximately half the resulting injuries are sprains or strains of the lower back (Health and Safety Executive, 1992). In Europe, the Directive 90/269/EEC on manual handling of loads (Council of European Communities, 1990) requires employers to assess the risk of injury for any manual materials handling tasks performed within their companies and to prevent, as far as practicable, the handling of heavy loads without mechanical assistance, and there is similar concern in many countries elsewhere.

When an assessment shows that there is a possibility of risk of injury, modifications are required to eliminate the risk or to reduce it so that the level of demand on the operators is acceptable. There are, of course, many possible solutions and companies are free to choose those which are most appropriate for their own circumstances – which could involve mechanisation or automation of the tasks, but in many situations can be achieved through less expensive improvements to the layout of the workplace or design of the task. The European legislation emphasises an ergonomic approach as the key to removing or reducing the risk of injury, with instruction and training as a complement to but not a substitute for a safe system of work (Health and Safety Executive, 1992).

Often the most immediate and attractive solution appears to be the use of manual handling aids, which can assist lifting or avoid the need for carrying loads over distances. This solution is relatively cheap, necessitating a minimum of modification to other equipment or plant, and few aids require much training for their users. Various case studies have shown that well-designed handling aids can help to reduce workload and the risk of injuries (Hansson and Nilsson, 1963; Datta *et al*, 1978; Drury *et al*, 1983; Winkel, 1983; Bobick *et al*, 1987; Chaffin *et al*, 1989).

However, despite the attractions of this solution in reducing the risks of manual handling and the widespread use of equipment such as trucks and trolleys in all types of industrial and commercial organisations, very little attention seems to have been paid to ergonomic aspects of their design. The risks that apply to direct lifting and carrying of loads can just as easily apply to the use of handling equipment, since this frequently involves the use of force, as when pushing trolleys or manoeuvring loads on hoists. There is, moreover, a danger that an aid purchased without proper attention to ergonomic factors may cause more problems than it was intended to solve, possibly introducing new stresses and risks for the operator (Berndsen, 1990; Nilsson and Dahlman, 1994).

The present study was undertaken to see whether handling aids are providing a successful solution to manual materials handling problems and, in addition, to determine which features are most important for their usability. Reference to brochures and catalogues supplied by equipment manufacturers quickly shows the vast range of handling aids which are available: hoists for lifting all types of materials, grippers for moving sheets of metal or glass, pallet tables for raising, lowering or rotating stacks of components or boxes, and trolleys and trucks for transporting goods (which may be packaged or in bulk solid, or liquid form), as well as much simpler devices such as crowbars or rollers. It was decided to focus this study on the use of transport aids (trucks and trolleys), since the need to move materials around a building or plant is common to almost every industry and every company.

Previous studies of manual transport aids

Despite the extensive literature on lifting and handling tasks, surprisingly few studies have been made of the design of trucks or trolleys, nor in the wider context has there been much discussion of design of manual handling equipment as a whole.

One of the most important features of transport aids is obviously the force required for pushing or pulling the loaded truck or trolley. Studies such as Hansson and Åstrand (1963), and Hansson and Johansson (1971), as reported in Strindberg and Petersson (1972), have shown that people are able to exert a pushing force on a four-wheeled trolley on a horizontal surface with approximately 80% of their body weight (which would be around 435 N for a man of 5th percentile weight). Winkel (1983), in a study of catering trolleys for civil aircraft, measured the maximum starting force which was acceptable to air stewardesses for repetitive exertions (either pushing or pulling) as 68 N and the maximum force for a single exertion as 270 N (group mean values), although these limits may well have been influenced by the surface friction of the carpeted floor, as well as by the subjects' capacities. Winkel suggested that the most important parameters which needed to be considered for improving the design of aircraft trolleys were: gross weight when loaded, wheelbase, wheel diameter, resistance to wheel swivelling, tyre pressure and type of handle(s).

Strindberg and Petersson (1972) performed a laboratory experiment to evaluate perceptions of load during the use of trolleys, measuring their subjects' responses by means of the psychophysical technique of magnitude estimation. Their trials involved the pushing of tall cage-type four-wheeled trolleys loaded with weights between 100 and 800 kg. The results of the trials revealed that for pushing forces up to a critical value of 130 N, the perceived force exertion was seen as being equal to the physical force involved in pushing the trolley. However, beyond 130 N, the pushing forces were perceived as greater than their actual values. Thus, a pushing force of 250 N was experienced as a force corresponding to 360 N. This suggests that the pushing of trolleys (at least of this type) is likely to be seen as heavy and stressful work when it requires forces greater than 130 N.

In an additional test, Strindberg and Petersson (1972) asked their subjects to compare the starting force needed to get the trolley into motion with their own maximal strength and found that tall subjects underestimated their strength, and small subjects overestimated theirs. The reasons for this are not clear but may be related to the handholds available on the trolley and the corresponding handling techniques used by the different subjects. The hand interface must be an important factor in perception of effort, as well as in the relationship between the load and the strength which the individual can exert.

Lee *et al* (1991) investigated the effects of both force and handle height on spinal loading in cart pushing and pulling, testing handle heights of 66, 109 and 152 cm, pushing forces of 98, 196 and 294 N, and walking speeds of 1.8 and 2.7 km/h. They found that, during pulling, the maximum compressive force on the lumbar spine increased linearly with the hand forces, but that the lumbar load changed little with handle height when pushing. Lumbar load increased with speed of pushing or pulling. When considering handle height, the heights of 109 cm for pushing and 152 cm for pulling produced the lowest loads on the spine. However, this height proved to be the worst for pushing, which emphasises the importance of considering task factors when optimising design parameters. These results were group averages and the handle heights quoted are unlikely to be optimum for tall or short people who might have to stoop more or reach up to the handles.

Experiments by Drury *et al* (1975), who were studying the manoeuvring of hospital trolleys, showed the importance of large diameter wheels in making four wheeled trolleys easier to handle. This was confirmed by a study reported by David and Nicholson (1985) who found that lumbar stress (indirectly assessed by intra-abdominal pressure) was lower when using larger wheels to manoeuvre a trolley on a carpeted floor. Drury *et al* (1975) had in fact found that carpeted floors tended to increase pushing forces by a factor of about two, which again emphasises the need for considering task and environmental factors, and testing under realistic conditions. They recommended that trolleys should have two of the castoring wheels lockable for movement (and preferably the front two wheels).

The studies discussed up to now have all concerned four-wheeled trolleys, but a few other studies have looked at the design of one-wheeled devices (such as barrows) and two-wheeled devices (which are often called trucks, although the terms used for handling aids are far from consistent). Their design parameters obviously differ from those of four-wheeled trolleys, most obviously because they require exertion of vertical forces to support the load in addition to the horizontal forces for movement. Relevant studies have been reported on the design of wheelbarrows used in the construction industry (Hansson and Nilsson, 1963), rickshaws and handcarts (Datta *et al*, 1978; 1983) and dustbin transporters (Jäger *et al*, 1984). These have clearly shown the importance for the users of optimising the design parameters, whether considering the physiological demands (energy expenditure), the biomechanical loadings or the factors related to ease of use. Hansson and Nilsson (1963) showed that an improved design of wheelbarrow could carry a 40% greater load without increasing the physiological demands. Datta *et al* (1978) demonstrated the advantage of balancing the weight distribution in a two-wheeled rickshaw, thus minimising the forces which have to be exerted in supporting the weight (which may have to be applied upwards or downwards depending on the configuration when loaded). The study by Jäger *et al* (1984) highlighted the compounding effects of the environment of use, showing the high biomechanical stresses on the lower back which can be imposed when manoeuvring two-wheeled bins over kerbstones or up flights of steps.

Most of the studies mentioned were directed at improvements in the design of particular types of aid with the objective of reducing the biomechanical or physiological demands during their use, but several of the design factors identified are common to many types of handling aid. Design factors affecting the force required or the posture adopted during force exertion are particularly important for reducing the risk of manual handling injuries. However, other factors may well have a considerable influence on the ease with which the aids can be used and ultimately on the performance in handling tasks they are intended to assist.

Design of survey of users of manual handling aids

A survey of users of handling aids was planned to look at both safety and usability, seeking opinions on the aids currently in use and on the factors which most affect perceptions of their usability. Twelve organisations (described in *Table 1*) participated in this survey, covering a cross-section of industry and service functions. The four hospital-based groups were in fact drawn from three separate hospitals. Several other companies had offered to help and provided some very useful discussions in the early stages of the study, but were excluded from the survey either because the preliminary discussions showed that the majority of their materials were handled in bulk with few manual handling aids in use or that manual handling aids were only needed occasionally. Two other companies had to be excluded because management changes or staff lay-offs made it too difficult to gather data.

Each company was approached through the Safety Manager, who then identified the employees who most frequently used manual handling aids during their work. These were interviewed individually at their work sites. In total 90 users of aids were interviewed, the largest group within an organisation being 17 users and the smallest three users. The details of these respondents are shown in *Table 1*. The hospital porters' work was far from confined to transferring patients between wards and theatres. They were found to be using a wide variety of handling aids, for collecting laundry and rubbish, and for delivering meals, pharmaceutical orders and mail.

Results

Usage and tasks performed

As shown in *Table 2*, the aids used most commonly were four-wheeled trolleys (which took many different forms, one of which is shown in *Figure 1*), followed by

Table 2 Types of handling aids used

		Number	% Sample
Four wheeled trolleys		142	65.7
Flat platform trolleys	20		
Mini-movers	12		
Bogies	9		
Box-sided trolleys	8		
Tall trolleys	21		
Deep trolleys	12		
Shelf/tier trolleys	19		
Hospital trolleys	27		
Canteen trolleys	5		
Other trolleys	9		
Two wheeled sack trucks		32	14.8
Cylinder trolleys		11	5.1
Hand pallet trucks		27	12.5
Other types of aid		4	1.9
Total		216	100.0

Table 1 Details of survey respondents

Type of organisation	Number of users of handling aids		
	Male	Female	Total
Textile manufacturer	7	5	12
Confectionary manufacturer	4	13	17
Industrial instruments manufacturer	5		5
Retail store	6		6
Retail products warehouse	9		9
Hospital stores	3	2	5
Hospital portering service (from three hospitals)	18	2	20
Laboratory technicians (from three units)	9	7	16
Total	61	29	90
Age			
Under 25 years	10	8	18
25–39 years	24	9	33
40–54 years	13	9	22
55 years and over	14	3	17
Stature			
Mean	1762	1633	1720
Standard deviation	74.9	84.6	98.5
Handedness			
Right-handed	56	27	83
Left-handed	5	2	7
Number of aids used			
Total	153	63	216
Mean per respondent	2.5	2.2	2.4

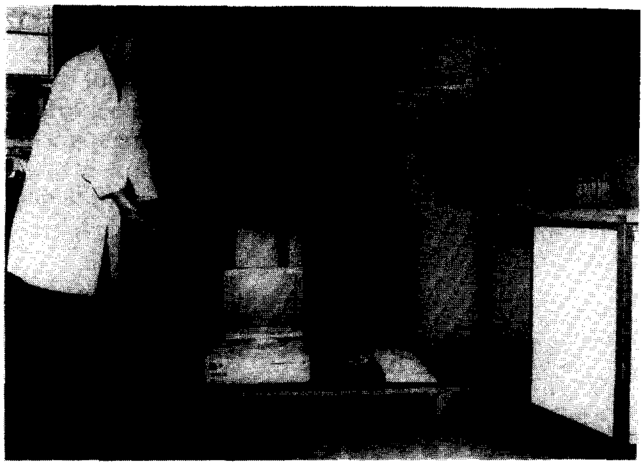

Figure 1 Flat platform trolley

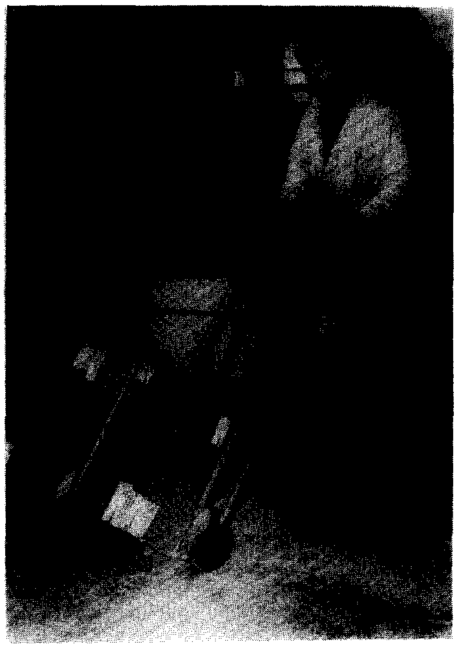

Figure 2 Sack truck

Table 3 Frequency of use

	Percentage of each type of aid used with a frequency of					
	>10 per day	**5–10 per day**	**1–4 per day**	**1 per week**	**<1 per week**	**Variable**
Four wheeled trolleys						
Flat platform trolleys	30	30	25	10	5	
Mini-movers	17	8	33	25		17
Bogies	67		22		11	
Box-sided trolleys		13	63	13		13
Tall trolleys	24	24	24	24		5
Deep trolleys	17	33	50			
Shelf/tier trolleys	42	16	21	16		5
Hospital trolleys	74	15	4	7		
Canteen trolleys			60	20		20
Other trolleys	33	11	44	11		
Two wheeled sack trucks	41	9	13	13	22	3
Cylinder trolleys		27	9	18	36	9
Hand pallet trucks	40	11	26	11		11
Other types of aid				50	50	

sack trucks (as illustrated in *Figure 2*) and hand pallet trucks, then cylinder trolleys. More than one type of aid was available within most companies, and at one company as many as seven types of trolley were found to be used by large numbers of the workforce. Most respondents used the aids frequently in their work, as can be seen in *Table 3*. Typical comments were "I use it hundreds of times throughout the day" from a hand pallet operator and "I use it all day" from a flat platform trolley user. However, a few of the aids were used only occasionally, perhaps once a fortnight or once a month, although this may have been influenced by usability factors as well as by need, since one cylinder trolley operator commented "I use it very rarely, only if I have to" and another sack truck user said "I don't use it too much – it's easier to carry, less bother".

Loads reported to be carried on any one trip varied from 2 kg on a flat platform trolley to 1500 kg on a hand pallet truck. The average distances travelled per trip ranged from 9 m ("not very far", "I only use it for short distances") to around half a kilometre ("for long journeys"). The aids were used both indoors and out of doors on a variety of surfaces, for example on linoleum, carpet, concrete and tarmac. Some of these surfaces were reported to be in poor repair.

Opinions on design factors

Interviews with the users provided a good understanding of the tasks for which manual handling aids were being used and identified the factors which their users believed to affect the usability of their equipment. The comments made by the respondents concerning problems experienced with each type of aid were then analysed and their main concerns are shown in *Table 4*. These included difficulties in controlling aids (especially when they were being moved on certain floor surfaces), instability of loads or of the aids themselves, restrictions to field of view while pushing or manoeuvring the aid, and overloading of aids. The effects of these problems on the users can best be appreciated by reading comments made during the interviews, many of which are recorded in *Table 5*. These are discussed in more detail in relation to the separate design factors.

It can be seen from *Table 4* that problems were experienced with all types of aid, the ones causing most problems being flat platform trolleys, cylinder trolleys and the hand pallet trucks. Many of the problems were compounded by environmental factors, the main ones being shown in *Table 6* and illustrated by comments quoted in *Table 7*. The condition of floor surfaces seemed to be a major problem. Sticky and carpeted floors increase the forces required to move the aid, while rough surfaces and bumps or steps not only increase the force, but make it difficult to move at all. Many sites seemed to have lifts which did not halt level with the floor, making it difficult to push aids over the crack or step when entering and leaving the lift.

Forces required

The difficulties in using poorly designed hand trucks can be appreciated from the comment of one sack truck user, who said "If I have a heavy weight on it,

Table 4 Factors affecting performance of each type of handling aid

	Percentage of users identifying each factor							
	Force required	Stability	Steerability	Interface	Starting or stopping	Field of view	Loading or unloading	Security of load
Four wheeled trolleys								
Flat platform trolleys	40.0	5.0	60.0	5.0	5.0	5.0	10.0	10.0
Mini-movers		8.3	16.7	66.7				8.3
Bogies	11.1		22.2	11.1				55.6
Box-sided trolleys	50.0		12.5		12.5			
Tall trolleys	52.4	9.5	23.8	4.5	19.1	23.8	4.8	4.8
Deep trolleys	25.0		41.7	8.3	25.0		8.3	
Shelf/tier trolleys	42.1	10.5	15.8	10.5	31.6	5.3		26.3
Hospital trolleys	48.2		29.6	11.1	11.1	3.7	22.2	
Canteen trolleys		20.0	20.0				20.0	60.0
Other trolleys		33.3			11.1		11.1	22.2
Sack trucks	46.9	25.0		15.6	6.3		15.6	28.1
Cylinder trolleys	72.7	63.6	9.1	18.2		9.1	18.2	36.4
Hand pallet trucks	48.2	11.1	11.1	7.4	25.9	7.4	40.7	18.5
Other types	75.0		25.0	25.0	25.0		25.0	25.0

someone else has to pull the base up while I pull the handles back."

From the data in *Table 4* and even more from the comments quoted in *Table 5*, it can be seen that many of the aids were thought to be heavy to operate, reports saying that they had problems with the forces needed in getting them into motion, controlling the aid and stopping it. These forces can be much higher than the forces required to push or pull an aid while it is moving. This is particularly serious since the main purpose of manual handling aids is to reduce the loads involved in lifting and carrying. The user may also have to be prepared to restrain the trolley if it starts to overbalance (while manoeuvring or on rough ground) or if it moves unexpectedly (perhaps when the load shifts). It is worth noting that Lee *et al* (1991) found from the 1985 accident statistics for the State of Ohio that 48% of injuries which involved carts and hand trucks were overexertion injuries.

There appear to be several reasons for the high forces in addition to mechanical design factors. In some cases, the aids were poorly maintained with dirt, fluff, pieces of fabric or string clogging up the wheels. The main reasons for lack of maintenance seemed to be staff shortages, shortage of time or simply that nobody had been assigned to the job. Small wheels were also a cause of high forces, especially on carpets and rough ground. This may not simply be due to poor design, but is sometimes the consequence of cost-saving policies because small, lightweight nylon or plastic castors are the cheapest option offered for many trolleys. In other cases, users were attempting to transport loads that were too heavy for the trolley or truck. From the evidence given by the interviewees, overloading of trucks and trolleys seems to be a common practice, and must significantly contribute to the complaints about the forces required in their use.

Stability

Stability was not a major problem for most types of four-wheeled trolleys, with the exception of canteen trolleys, although it was noted as a problem by some users of other taller trolleys and hand pallet trucks. The particular problems reported for canteen trolleys were largely related to the lack of security of their loaded trays.

Stability was a much more significant problem with two-wheeled devices and especially with cylinder trolleys (which also had consequences for the forces required when using them). Users had difficulty in finding a comfortable point of balance after they had tilted the trolley off the ground. Many reported that they had aching shoulders or back because the trolley was not adequately supporting the weight of the load. One type of cylinder trolley answers this problem by providing a third wheel at the rear, and a few users had in fact modified their own trolleys in this way. It is worth noting also that insecure loads can add to the problems of stability since their movement can change the centre of gravity and balance of a cylinder trolley. This is also true for two-wheeled trucks.

Steerability

Many users reported problems with steering and controlling trolleys. One user of a box-sided trolley said "It's hard to manoeuvre round corners; you have to take corners wide".

Castors which swivelled too freely made trolleys difficult to control and, moreover, this seemed to increase the force required to "make the aid do what you want it to". Users described this problem as "wheels go the wrong way when you push, they go all over the place" or "wheels lock, can't push it in a straight line". Wheel type and size, and also level of maintenance, were all factors affecting steering. Users added comments that they would prefer particular castoring systems, either with just the front two or just the rear two wheels swivelling. It was not clear whether their preferences related to particular tasks, although most respondents preferred the two fixed wheels to be at the rear of the trolley. This contrasts with the findings of Drury *et al* (1975), from the results of their study of equipment used in hospitals, that rear-wheel castoring gave a slight advantage in controlling a trolley, and is an aspect which needs further investigation, particularly in relation to different tasks and environments.

On some trolleys, mainly the tall cage types, small

Table 5 Respondents' comments related to performance factors

Performance factor	Comments	
Force required	Flat platform trolley –	"When you put a heavy load on it, it is useless, hard to push."
	Box-sided trolley –	"I'm not keen on it, sooner take the smaller trolley twice than this one. Harder to shove."
	Tall trolley –	"They don't push easily because of the weight; they only have small rubber wheels."
	Tall trolley –	"The nylon wheels were changed to rubber ones because they were breaking up the floor. More effort with rubber wheels."
	Shelf/tier trolley –	"Hard to push because wheels are dirty."
	Hospital trolley –	"I get pain in the shoulder pushing heavy trolleys. You really need two porters, one to push and one to guide."
	Sack truck –	"If I have a heavy weight on it, someone else has to pull the base up while I pull the handles back."
	Sack truck –	"I would like two extra wheels so I can use it to move filing cabinets. Weight will not be on the forearms."
	Cylinder trolley –	"The balancing should be looked at. Once you start moving, the weight pulls at you."
	Hand pallet truck –	"It's difficult to pull; got to give it a good hard pull to get it going."
Stability	Flat platform trolley –	"The castors fall off; they need to be continually tightened."
	Mini-mover –	"Have to be careful how you distribute the weight, it can tip over."
	Sack truck –	"I would like two extra wheels when I use it to move filing cabinets, so that the weight is not on my arm."
	Cylinder trolley –	"I would like an extra wheel for stability, a castor type of good quality, as it has to take a lot of weight."
	Cylinder trolley –	"It seems to have the wrong centre of balance. Needs large diameter wheels."
	Cylinder trolley –	"Pebbles and stones make it unstable; it seems to have the wrong centre of balance."
	Pallet truck –	"Going around corners it tends to tip."
Steerability	Flat platform trolley –	"It doesn't wheel very well outside; wheels go all over the place."
	Bogie –	"Wheels stick, they go in all directions. The wheels don't go where you push them."
	Box-sided trolley –	"It's hard to manoeuvre round corners; you have to take corners wide."
	Tall trolley –	"When I push it quickly, it tends to go off course a bit."
	Deep trolley –	"It's not very good, wheels too small and they go all over the place, go where they shouldn't go."
	Deep trolley –	"Too big and bulky. Heavy and hard to manoeuvre."
Interface	Mini-mover –	"I would like an adjustable height handle. If I use it a lot, it can be uncomfortable on the back."
	Mini-mover –	"I would like a higher handle. You have to stoop when fully loaded in order to push it."
	Shelf/tier trolley –	"If you pull rather than push, it catches on your heels. I push most often."
	Hospital trolley –	"It's a bit low; you have to bend down. I get a sore back with bending."
	Sack truck –	"Pains in the shoulder and back when I use the small type, but not with the larger one."
Starting/stopping	Shelf/tier trolley –	"Problems getting them mobile because of the small wheels."
	Hospital theatre trolley –	"If people get in the way you can't stop it in a hurry."
	Hospital trolley –	"Difficult to stop especially if floor has been polished; sliding all over the place."
	Sack truck –	"It is difficult to bring back onto its wheels, especially if it is a heavier load."
	Pallet truck –	"I can't stop it."
Field of view	Tall trolley –	"I push it, but pull if I can't see because of height of load."
	Hospital theatre trolley –	"With the head rest up, I can't see above it and can't see where I'm going."
	Cylinder trolley –	"I would like an extra one or two wheels to take the weight off me. I can't see over the top. You have to look left or right because the cylinder is in the way. If the angle you push it at gets too low, it pulls you down; your shoulders and arms ache."
	Pallet truck –	"I pull it, except if there are pedestrians; then I push so I know where I am going."
Loading/unloading	Deep trolley –	"Have to bend over to get the garments on the bottom."
	Sack truck –	"The shoe is so small that you can hardly get anything on at all; stuff falls off the shoe."
	Hand pallet truck –	"Difficult to get boards off the forks."
	Hand pallet truck –	"You need a lot of space to pump up the trolley, because the handle has to be pulled down far."
Security of load	Bogie –	"If I push too hard, the load falls off."
	Canteen trolley –	"Have to be careful, things fall off if you go around corners too fast."
	Canteen trolley –	"I would like something to stop the trays falling off."
	Sack truck –	"I have to put my hand on the goods when I stop in case they go forward."
	Sack truck –	"Things drop through the holes at the back."
	Cylinder trolley –	"It needs a better safety catch; it's a bit fiddly."

nylon wheels were fixed as standard and caused significant problems. These were reported to have the advantage of being hard-wearing, but were only effective on flat even surfaces. Any scrap on the floor (offcuts of plastic or wood, nuts and bolts or stones) could bring the trolleys to a complete halt and it could take considerable effort to free the trolley.

Handle interface

Mini-movers presented the most serious interface

Table 6 Environmental conditions affecting performance of each type of handling aid

	Percentage of users identifying conditions affecting performance				
	Floor surface	**Restricted space**	**Corners or turning**	**Steps or lift doors**	**Slopes/ramps**
Four wheeled trolleys					
Flat platform trolleys	30.0	5.0	5.0	5.0	
Mini-movers	8.3		8.3		
Bogies	66.7		11.1		
Box-sided trolleys			12.5	12.5	12.5
Tall trolleys	19.1	19.1	4.8	23.8	
Deep trolleys	33.3		8.3		
Shelf/tier trolleys	26.3	31.6		21.1	10.5
Hospital trolleys	37.0	14.8	18.5		7.4
Canteen trolleys	20.0		20.0		
Other trolleys	55.6	22.2	11.1		11.1
Sack trucks	21.9			3.1	3.1
Cylinder trolleys	27.3			18.2	18.2
Hand pallet trucks	40.7	14.8	14.8	3.7	7.4
Other types	25.0		25.0		25.0

Table 7 Respondents' comments related to environmental conditions

Environmental conditions	**Comments**
Floor surface (e.g. uneven, bumpy, wet, sticky, carpeted)	"It's difficult to steer if the ground is uneven." (Flat platform trolley) "Problems with uneven surfaces, items bounce off." (Bogie) "The carpets in the main entrance are more difficult to push across." (Hospital trolley) "Difficult to stop especially if floor has been polished, sliding all over the place." (Hospital theatre trolley) "Pebbles and stones make it unstable." (Cylinder trolley) "If it gets stuck in the cracks, I can't get it started; need help." (Pallet truck) "Stones and so on stop the wheels dead." (Pallet truck) "It gets stuck on the tiles, difficult to move out." (Pallet truck)
Restricted space	"I scraped my finger on the wall trying to squeeze through the door." (Flat platform trolley) "There is restricted space in the warehouse, it's difficult to manoeuvre." (Pallet truck)
Corners or turning	"You have to take a wider circle when you turn them." (Flat platform trolley) "Corners are a problem, it tends to tip." (Pallet truck)
Steps or lift doors	"The step to the incinerator is a problem, my shoulders ache a wee bit afterwards." (Box-sided trolley) "Unevenness of lifts causes problems, wheels get stuck." (Tall trolley) "Hurt back lifting it over a small step." (Double decker trolley)
Slopes/ramps	"I don't use it on slopes because it is too heavy." (Flat platform trolley) "Problem when going up a slope – I pull it up, hang on to a hand rail and work my way up." (Flat platform trolley) "It's hard to pull up the slope in the loading bay if it's heavy." (Pallet truck)

problem for the users. Typical mini-movers are small platforms with foldable handles around 800 mm high. They are seen as small, handy, multi-purpose aids, and are most suitable for occasional use in the movement of light loads. However, some interviewees were found to use them frequently and they complained that the handle height was too low, forcing them to stoop. This was a particular problem when pushing a heavy load.

Fewer comments were received about handle height or design on other four-wheeled trolleys. Some users indicated that handles were too low so that they had to stoop when pushing. This is certainly a factor which will affect the biomechanical loading and risk of injury when forces have to be exerted, and should be regarded as an important design factor even though many users do not seem to associate the problems with the handle itself.

Users of the two-wheeled sack trucks and cylinder trolleys were more critical about the interface design, which is interesting since handle height is less constraining on a two-wheeled device which can be tilted to give some degree of height adjustability. It may be that many two-wheeled devices have handles which are too short for many users or that the problems were related to other aspects of the interface. For example, many handles on sack trucks are nearly straight (vertical when parked) and some users commented that these were acceptable when pushing the truck, but not helpful in tilting the truck back when starting off. Handles with a horizontal bar running between and just below the handles were found to be more helpful. Three of the many handle designs currently available are illustrated in *Figure 3*.

One interface problem was specific to tall cage trolleys. When these are loaded, it can be very difficult for the person pushing the trolley to see where they are going. As a result, many users tend to pull the trolleys rather than push them. However, no adequate handholds are provided (whether for pushing or pulling) and pulling was reported to be particularly difficult, because

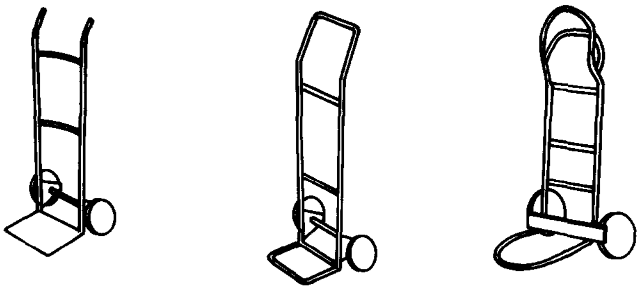

Figure 3 Three of the handle designs seen on sack trucks

the user was forced either to walk backwards or to walk in a twisted posture.

Starting and stopping

Many users complained of difficulties in starting and stopping. Starting seemed to be mainly a problem with heavy loads, and was usually worse if the aid had small wheels or was poorly maintained. In one company using oxygen cylinders (and where back injuries had occurred), the users suggested that the highest loads were experienced when they were trying to tilt the cylinder trolley in order to start pushing it.

Problems were encountered in stopping when loads had to be pushed down slopes or ramps. One hand pallet truck user unloading lorries in a delivery bay had frightening problems in holding the loaded pallet truck on the steep ramp placed at the back of the lorry. He admitted that he often let this run down by itself to be stopped by bouncing off the wall of the delivery bay! Stopping was also reported to be a problem when cornering or when pushing on wet or highly polished floors. Many respondents added that they would like to have brakes on their aids.

Loading and unloading

The greatest number of complaints about loading or unloading came from users of hand pallet trucks. The main reasons seemed to be that the space between the top and bottom of some pallet boards was too narrow for the pallet forks to pass through, and that some forks were shorter than the pallets being transported, so that the wheels at the front of the forks did not make contact with the floor and the load could not be raised. These problems arise from poor selection of the model purchased rather than from poor design of the pallet truck itself. If companies use several sizes of pallet, it could be an advantage to have adjustable pallet forks.

A somewhat similar problem occurs with the design of the load platform on two-wheeled trucks. In order to pick up the load, the shoe at the base of the truck needs to slip easily under the sack or other load. The shoe also needs to be long enough to support the load as it is picked up and moved.

Security of load

Security of load appears to be a major problem with bogies (simple wood or plastic surfaces mounted on four castors), canteen trolleys and cylinder trolleys. In some cases there was no means of securing the load and goods had a tendency to fall off in transit, especially around corners or over bumps (which was a common problem with hospital trolleys going into or out of lifts). Some users of cylinder trolleys felt that they had to hold the gas cylinder with one hand while pushing the trolley with the other. In other cases the securing devices were not adequate to stop the load wobbling while it was in motion, and in still others the mechanism was awkward or poorly maintained. Some users of cylinder trolleys said that they had injured fingers when cylinders moved and trapped them while the trolley was being pushed.

In the main, users of bogies did not secure their loads. Some however put pieces of underfelt or rubber on the surface to provide a little more grip. Sack trucks were often reported to present a problem because the rails across the back did not provide adequate support for the types of loads carried. *Figure 4* shows an example of a modification added by the user to help him in carrying small boxes and parcels.

Discussion

The survey results show that significant numbers (and with some types the large majority) of users are experiencing problems with their manual transport aids. Not only were many reported to be heavy to operate, but injuries had also been caused, such as the finger trapping already mentioned. In another company, where hand pallet trucks were used extensively to move crates of sweets, accident records showed that injuries (cuts and bruises to feet, ankles and legs) had been caused by the trucks running over people's feet. The other problems reported reflect aspects of usability which may well affect the efficiency of aids, slow the speed of work or lead the user to abandon the aid altogether.

Discussion of users' problems during the interviews gave some guidance on the reasons for the difficulties, as can be seen from the comments quoted in *Tables 5 and 7*: some were certainly due to poor design of the aids, but others appeared to occur because the aids used were inappropriate for the task being performed (including overloading of many types of aids), and finally many aids were being used under poor environmental conditions. Organisational factors were also important, and this was very clearly seen in the effects of lack of maintenance on many types of aid. In another survey, Mathisson *et al* (1994) found that time pressures on assembly lines led to handling aids not being used, even though the operators were well aware of the consequential risks of musculoskeletal injury. Use of the aids tended to be slower than simply moving the

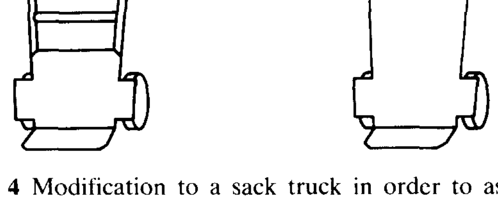

Figure 4 Modification to a sack truck in order to assist in carrying small packages. (a) As supplied, (b) As modified by user

components by hand and there was an additional task of stowing the aid after use.

Many users devise modifications for their aids. One reported moving the wheels of a shelf-tier trolley further apart to widen the wheelbase to stop it toppling over and another said that they had fitted a bar across the top of a tall cage-type trolley in order to stop the sides splaying out when fully loaded with fabric.

It would seem that improvements in usability need to be approached through at least two routes: greater attention to ergonomic aspects in their design, and clear guidance for selection of aids for particular tasks and environments. There are five main aspects which affect usability, determining whether an aid is suitable in a particular situation: the design characteristics (which comprise both mechanical considerations of structural design, efficiency and safety, and the ergonomics of the user interface), load characteristics, environmental considerations, operational conditions and user characteristics. The main parameters within each of these are indicated in *Figure 5*, which is based on information obtained during the survey, evidence from the literature, and generally accepted ergonomic principles.

Design of manual transport aids

The survey of users, together with evidence from the few studies which have been reported in the literature, indicate that the following features are particularly important in the design of two-wheeled and four-wheeled trucks/trolleys.

(1) The handle interface needs to be well placed and of the appropriate type, affecting both ease of steering and biomechanical stresses when exerting force. The height of the handle should allow the individual user to adopt a comfortable posture, although the optimum height of handle differs depending on whether the aid is being pushed, pulled or tilted prior to setting off. The height is most critical on four-wheeled trolleys since the handle height is usually fixed, whereas two-wheeled trolleys can often be tilted to a more comfortable height for the individual, provided that the handles are long enough for tall users. However, this has to be balanced against the fact that long (high) handles may be a disadvantage when the trolley is being tilted before starting off.

(2) Wheels and castoring greatly influence both the manoeuvrability of trolleys and the forces required to move them. The survey showed that purchasers of trolleys often neglect to consider these aspects: good wheel bearings account for a relatively high proportion of the cost of trolleys, but cost saving on this option can be counter-productive. Free movement of wheels is very important and regular maintenance can be crucial in ensuring that trolleys remain usable, especially in environments which are dusty or where the manufacturing process produces fluff or loose threads.

Small diameter wheels can be harder to push, pull or steer, although they may be helpful when manoeuvring in tight spaces. The most suitable

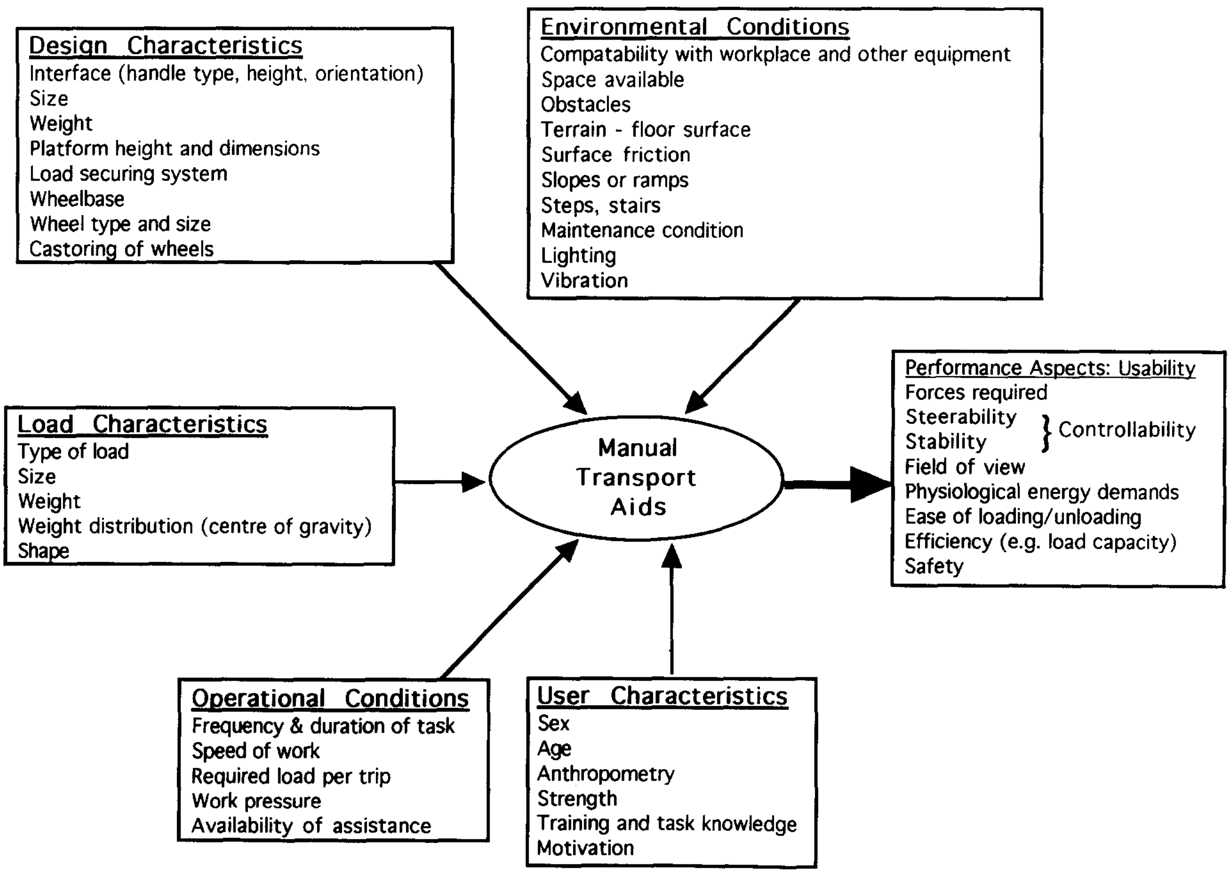

Figure 5 Factors which are important to the usability of manual transport aids

type of wheel and tyre pressure will depend upon the terrain over which the aid will be used. Large balloon tyres are helpful on rough ground, but will not be practical where space is restricted. Two-wheeled castoring appears to be better for steering and controlling a trolley, although four-wheeled castoring makes it highly manoeuvrable when it has to be parked in a very limited space.

(3) Ease of loading and unloading is very important. The height and surface of the load platform should be chosen with the particular load and workplace in mind.

(4) During the transport phase, ease of steering, manoeuvrability in tight spaces, and stability are all important, but these all interact and in fact also influence the forces required in using the aid.

(5) Details of a design may be very important to usability. For example, the size and angle of the shoe at the base of a two-wheeled truck is important for picking up large items and for their stability during transport. Attention to the design of the handle can help to overcome the differing requirements for pushing and tilting a two-wheeled truck. One of the possible solutions is seen in the sketch on the right side of *Figure 3*.

Given the nature of the tasks performed, design solutions will need to be assessed for posture and biomechanical loading during the forceful elements of the task, physiological demands if the work is performed at speed or for periods of time, and subjective views of the ease of use and acceptability of the aid for the particular task or tasks. The need for user trials is obvious, and these will help the designers to learn more about actual operating conditions which will affect the usability of the aids which they manufacture.

Selection of manual transport aids

The choice available to anyone requiring a manual transport aid is very wide, but selection of the right type of aid requires some initial analysis. In the light of the EC Directive on Manual Handling (Council of the

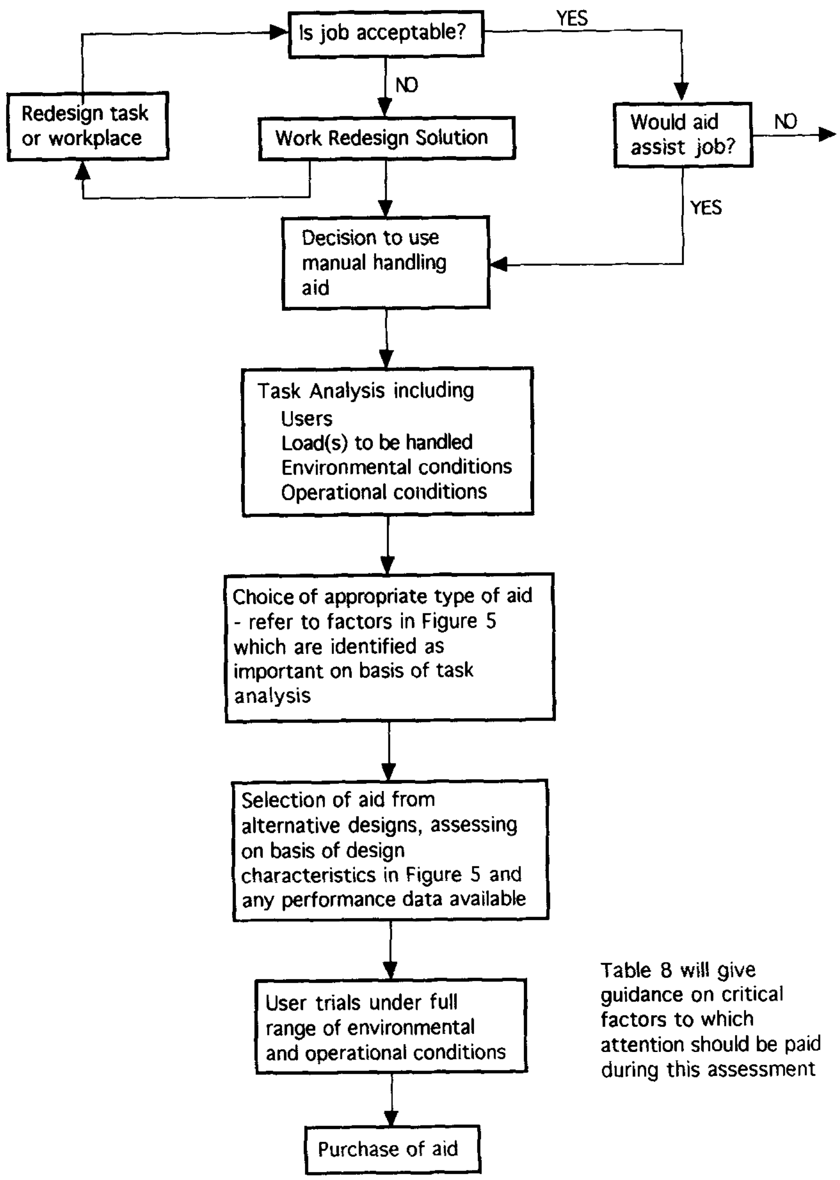

Figure 6 Selection process for a manual transport aid

Table 8 Most important performance factors to consider when assessing each type of heading aid

	Performance factors							
	Force required	**Stability**	**Steerability**	**Interface**	**Starting or stopping**	**Field of view**	**Loading/ unloading**	**Security of load**
Four wheeled trolleys								
Flat platform trolleys	★		★				○	○
Mini-movers			○	★				
Tall trolleys	★	○	○		○	○		
Deep trolleys	○		★		○			
Shelf/tier trolleys	★	○	○	○	★			○
Hospital trolleys	★		★	○	○		○	
Two wheeled trolleys								
Sack trucks	★	○		○			○	○
Cylinder trolleys	★	★		○			○	★
Hand pallet trucks	★	○	○		○		★	○

★Very important factor and a major problem reported (≥30% users in survey reported problems)
○Important factor (≥10% users in survey reported problems)

European Communities, 1990) it would seem reasonable to make sure first that the aid will reduce the level of risk identified in the task, and that it will not introduce any new stresses or risks into the handling operation. Once this has been ensured, performance aspects should be considered. The five most important ergonomic criteria related to performance are low force for operation, stability of both equipment and load, manoeuvrability, clear view whilst in motion, and 'usability' or fitness for purpose, but the full list can be seen in *Figure 5*. The concept of usability is the most difficult to define. To some extent it encompasses the user's perception of the first three criteria, but other factors are also involved, and are often related to the characteristics of the user and the details of the tasks to be performed.

A selection process which takes account of ergonomic factors is suggested in *Figure 6*. There are several stages in the selection of an appropriate aid, from the initial assessment of need and the choice of type of aid to the assessment of effectiveness and usability of alternative designs. The information in *Table 8* may be helpful in this later stage, since it shows the main performance characteristics which have, in practice, proved important to users of the most common transport aids.

It is impossible to assess transport aids in isolation from the work performed with them. Loading takes place within a workplace and the heights from which loads are lifted to be placed on the aid are an important factor in evaluating the biomechanical risks of injury. Narrow corridors, lift doorways or aisles through storage racks can exacerbate the difficulties of steering an aid. A trolley with small wheels can be quite adequate indoors on concrete floors, but impossible to use in the potholed delivery yard outside. During the visits to the companies participating in this study, many aids were seen lying in corners or unused in store cupboards because the operators found them difficult to use, even to the extent of carrying the loads by hand. User involvement and user trials are therefore essential to the selection process.

Conclusions

There is an increasing demand for manual handling aids, but the survey has shown that many of the aids currently in use are poorly designed from the user's point of view. Moreover, the provision of such aids has not guaranteed that stress levels on the body are reduced and some of the design faults identified can actually increase the risk of injury, defeating the primary objective for the introduction of the aid. If more attention was paid to ergonomic design factors by manufacturers and purchasers of aids, a significant improvement in efficiency and reduction in the number of injuries should be achievable. Given the range of design factors identified during the user survey, and the fact that these tend to interact and be affected by task factors, it will be important to address the usability of the aids through task analysis and user trials in order to identify the most important design features for the different types of aids and the different jobs for which they are used. The aim should be to make the handling of loads easier and safer, and in so doing reduce musculoskeletal stresses and the number of handling injuries.

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