Vehicle Manoeuvring Simulations and Performance Based Regulations: A Wheelchair Case Study

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Vehicle turn simulation programs are not only valuable design tools, but would also be excellent tools for performance-based regulatory compliance systems.

The programs, of which there are several commercially available, can be used for designing and analysing spaces for the manoeuvring of road vehicles, forklifts trucks, aircraft and other wheeled conveyances. However, there is another type of vehicle for which manoeuvring studies are equally applicable: wheelchairs[1].

An increasing number of countries have adopted or are moving towards adopting human rights based anti-disability-discrimination legislation. In Europe, the United Kingdom has revamped its Disability Discrimination Act, and the Council of Europe, the European Union's Parliament, and the European Commission have endorsed the establishment of such legislation. Amongst other matters, such legislation stipulates directly or indirectly that buildings and facilities be accessible to persons with a disability, including therefore people who rely upon wheelchairs for mobility. In other words, there must be sufficient space to and within premises for wheelchair travel and manoeuvring.

Regulatory codes for wheelchair access in premises typically express spatial requirements in terms of rectangles. However, as for road vehicles, the rotational nature of wheelchair manoeuvring results in manoeuvring spaces that have curvilinear boundaries, as has long been recognised in road design in the use of road vehicle turning templates. Rectangular prescriptions impose unwarranted design and building cost penalties because rectangular spaces that encompass manoeuvring paths are necessarily larger than curvilinear bounded manoeuvring path spaces, and because the redundant parts of rectangles are unavailable for other purposes within the design or usage of premises. Simplifications of curvilinear boundaries may of course be sensible in design for a variety of reasons, however the adoption of spatial simplifications that are larger than necessary for wheelchair manoeuvring should be left to the discretion of designers and their clients, not imposed by regulation.

The difference between rectangular prescriptions and actual manoeuvring paths can be easily demonstrated, and is done here using a wheelchair-manoeuvring simulation program developed for modeling the pivoting capabilities of wheelchairs[2]. Like the other vehicle turn programs, this wheelchair-manoeuvring program can accurately model the linear, rotational and helical motion of vehicles.

Figure 1 indicates the minimum spaces required in Australia for doorways of public buildings as approached from: the latch side of the doorway (A); the hinged side (B), and frontally (C)[3]. However, it can be seen in the manoeuvring plots for these doorways

[1] The programs discussed here are those that enable the driving "on-screen" of the plan outline of a vehicle, and which enable the wheel tracks and swept paths of vehicle bodies to be recorded. The programs discussed here do not refer to those that simulate the experience of driving. The term "wheelchairs" is used here to denote wheeled ride-on mobility aids, including three- and four-wheel scooters

[2] This program, developed by Hunarch Consulting in Australia, is suitable for plotting the manoeuvring of wheelchairs and scooters, and also road vehicles. Existing vehicle turn programs do not accommodate pivoting turns.

[3] The doorway layouts are from Australian Standard AS1428: Design for access and mobility.

(Figure 2) that in all cases, the actual area occupied by the travel path leaves parts of the rectangles redundant[4].

It is an arbitrary assumption that there will only be three approaches to doorways, and an assumption that precludes angled approaches, for example. This is evident in Figure 3, which shows 45º angled approaches from the latch side and hinged side of the doorway. It can be seen that the rectangular prescriptions are even less efficient in accommodating the angled approaches and that the unused parts of the rectangles are far greater than in Figure 2.

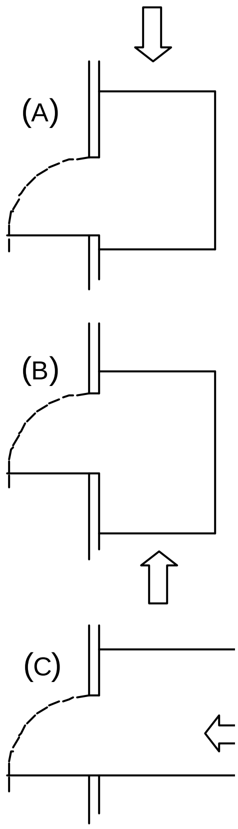

Figure 1: Australian doorway approach spaces

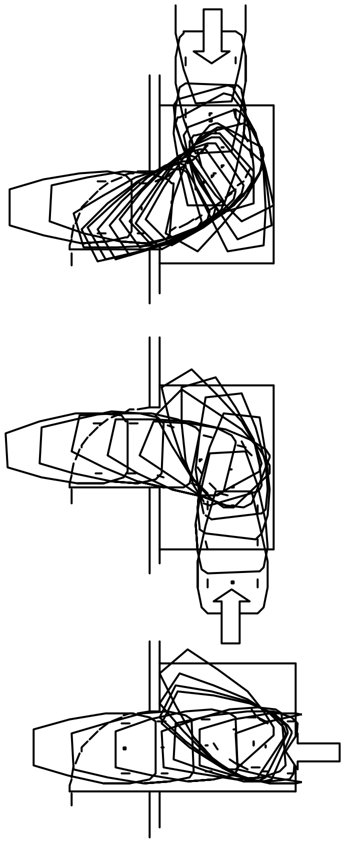

Figure 2: Required doorway manoeuvring spaces

One response to the multiplicity of possible approaches would be to propose that additional rectangular or other shaped spaces be prescribed. However, because differing approach angles have differing manoeuvring space characteristics, the number of possible approach geometries would make fully comprehensive prescriptions infeasible. Two examples of different approach geometries are shown in Figure 4, which depicts offset approaches to the doorway of Figures 1 and 2. Again, it can be seen that none of the rectangular prescriptions efficiently accommodate the offset approaches. In these examples, whilst the final stage of the approach path is similar to the angled approaches in Figure 3, the initial part of the approach results in a differently shaped manoeuvring space.

Notwithstanding the infeasibility of a complete set of spatial prescriptions, there would be a legitimate and valuable role for a set of several prescribed manoeuvring templates, providing that they accurately corresponded with manoeuvring paths. Such templates would not only serve as design aids but also as regulatory deemed-to-comply evidence. However, it would be far better if there were also available a performance-based compliance procedure. A computer-based manoeuvring simulation program, such as the one used here, represents a basis for such a procedure. It would be quite feasible for inexpensive versions of such programs to be made available by design and regulatory code agencies, and their resulting use would thus facilitate a far greater range of design options and greater building efficiency.

There are three requirements for such applications: manoeuvring protocols would need to be stipulated; representative wheelchairs would need to be prescribed; and the representative wheelchairs would need to incorporate margins for driving variability[5].

[4] The manoeuvring space requirements will be different for front-wheel-drive and mid-wheel-drive wheelchairs, and scooters compared with those shown here. The wheelchair outline is derived from 'Project Report on the Field Testing of Australian Standard 1428 – 1977, Part 2 Details of Field testing of AS1428, Volume 5, Detailed Report 23', prepared in 1983 by J H Bails of the Public Buildings Department of South Australia for the Australian Uniform Buildings Co-Ordinating Council. The outline is not representative of rear-wheel drive wheelchairs in Australia.

[5] The manoeuvring diagrams discussed here do not incorporate margins for variability in driving accuracy.

Manoeuvring protocols that would need to be established could include, for example, the disallowance of other than partial rotations in a direction opposite the pathway turn direction, and the disallowance of more than one reversing turn: in other words, manoeuvres that could be regarded as inconvenient and unreasonably required of people in wheelchairs if equivalently inconvenient manoeuvres were not required of ambulant people.

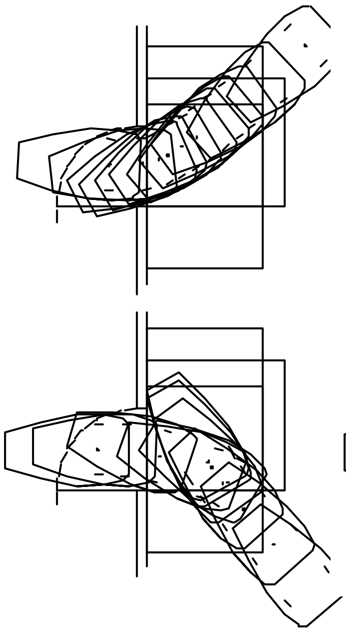

Figure 3
Space for angled doorway approaches

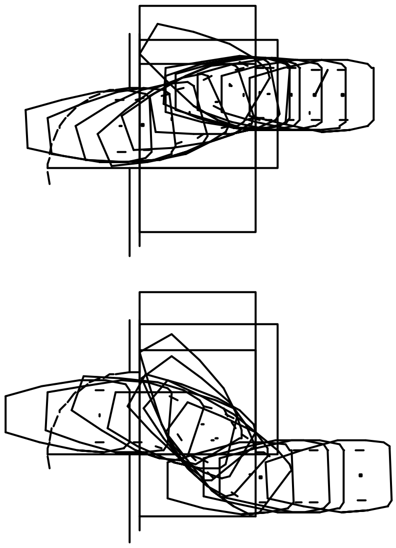

Figure 4
Space for offset approaches to doorway

Representative vehicles would be those representative of a particular percentage of the population, and would be defined in terms of the parameters of the geometry of wheelchair manoeuvring using appropriate multivariate statistical techniques. For example, recent research for the Australian Government[6] measured 560 occupied wheelchairs and scooters and, from them, identified wheelchairs representing 90% in the community using factor analysis for thirteen rotational parameters and percentile values exceeding 90%.

Establishing margins for driver accuracy is relatively simple. One method that has been developed[7] uses a small slalom course of lightweight impact-responsive bollards, and a special travel surface to record wheel tracks. There are two configurations: a four bollard “square” within which 180º rotations are performed, and two bollards around which a figure-of-eight circuit is completed. These two configurations have been adopted because they entail two key types of rotations in wheelchair manoeuvring: those about the mid-axle and those about either drive-wheel. Variations between actual travel paths and calculated perfectly driven paths can be determined for each wheelchair and a margin then calculated for the wheelchairs collectively.

Such close consideration of wheelchair manoeuvring may be unnecessary in spaces such as large lobbies and wide thoroughfares, however in spaces such as hotel bedrooms, office corridors and toilet areas, circulation areas suitable for pedestrians are commonly inadequate for wheelchair use.

Social justice requires equity of access for people who use wheelchairs, and constructional economics requires that this be achieved in as spatially efficient a way as possible. Computer-based wheelchair manoeuvring simulation programs would facilitate the achievement of both goals if used as design aids and if used as the basis of a performance-based regulatory compliance system.

[6] Unpublished research by Hunarch Consulting
[7] Current research by Hunarch Consulting