MODERN ROUNDABOUT TECHNOLOGY UNLOCKS THE STIFLED WALKING MODE IN CANADA AND UNITED STATES

...Toward a Roundabout Centered “Walking Service Level” Classification

Introduction

The modern roundabout brings unique benefits to the walking mode, unlocking a mode stifled by a century of automobile travel growth in Canada and the United States (U.S.). As auto travel increase slowed in the Canada and the U.S at century change, the roundabout technology dating from 1966 quietly ascended to the gold standard applicable in the developed world to most busy and problem intersections. Roundabouts feature: (1) saving lives and reducing injuries and their severity for all users; (2) cutting gas consumption and major pollutants including global warming gases an average of about 30% (Varhelyi 2002); (3) slashing users delay; (4) creating scenic quality and lowering noise; and (5) enabling and inducing more compact development, i.e., attacking sprawl (Redington 1999).

In developed North America urban transportation inattention to the walking mode remains widespread during unprecedented challenges to policy and programming. Challenges include addressing climate change, installing the first high speed rail, and the roundabout itself which offers the first auto age walking friendly intersection treatment.

Car travel may decline in some states and provinces 2000-2010 with more facing stagnating car travel numbers for 2010-2020. Montreal area car travel 2003-2008 dropped 1%, the first decline since periodic surveys began in 1970 (Agence Metropolitaine de Transport 2010). Car trips dropped while transit, bicycle, and walking trips increased double digits and population 5%.

A new challenge from the health community calls for a vastly improved North American walking mode as part of strategy to address the overweight and obesity epidemic. Canadian data, similar to U.S. trends, shows overweight or obese boys aged 15-19 up from 14% to 31% during the 1981-2009 period while adults aged 20-29 with waist size placing them in the "high risk" category for health problems quadrupling to 21% for men and 31% for women (Statistics Canada 2010). For North America correcting deficient walking and bicycling infrastructure along with upscaled education and enforcement comprise the major elements for raising these modes to quality standards found elsewhere.

This paper focuses on the walking mode and the 44-year-old modern roundabout, an intersection infrastructure able to unlock the walking mode now blocked primarily by the dominance of the car at unsafe, delay-ridden, and wasteful signalized intersections.

Modern roundabout origin

Applying traffic movement in a circular design, termed rotaries and traffic circles in North America, first occurred in the U.S. (1904), France (1907) and the United Kingdom (U.K.) (1909). The "modern roundabout" era began in 1966 when the U.K. adopted the yield-at-entry rule (offside priority) at roundabouts. Compared to in roundabout traffic yielding to entering traffic, yield-at-entry cut delay 40% (compared to no control, signals, or police control), injury crashes 40% with walker crashes "almost halved" (Todd, p 149 and 154; Brown p 16).

Modern roundabout technology spread quickly to western European countries and some far beyond, especially Australia and New Zealand. The first U.S. modern roundabout arrived in 1990 and Canada in 1999. Comparatively by the mid-1990s France installed over 1,000 yearly while the U.S. 1990-1997 total--just 38 (Guichet 2005; Transportation Research Board 1998). Slow Canadian and U.S. adopting roundabout technology arises in great part from institutional resistance from transportation departments at all levels as well as from traffic engineering and planning communities.

By the end of 2009 Canadian and U.S. roundabouts reached an estimated 2,000 with yearly production growing 500 to 1,000, or two-to-three a day. Roundabout leaders report states with at least 100 roundabouts as of 2009--Colorado, Florida, Maryland, North Carolina, Utah and Washington, with New York and Kansas expecting 100 before the end of 2010 (Kansas State University 2009).

Only the New York State Department of Transportation starting in 2005 and British Columbia Ministry of Transport in 2007 adopted policies amounting to "roundabouts only" (NYSDOT 2006; BCMOT 2009). Jurisdictions are moving toward pro-roundabout policies. At least five state transportation agencies give equal consideration or preferences for roundabouts. The North America city with the most roundabouts, Carmel, IN, estimates 60 built and 50 in planning and design; and it reports they provide "better pedestrian connectivity" (Brainard 2009).

Canada and U.S.--large walking potential

Modal share in walking and bicycling in urban areas separate the North America, low shares, and Europe, high shares (Table 1). While nine Western European nations urban walking and bicycling modal shares median stood at a third of all trips, Canada with 13% and the U.S. (including "other" modes), 8%, fell far below. U.S. data reveals a downtrend in the two modes, 10% (excludes "other") in 1977 to 6.3% in 1995, numbers from the U.S. National Personal Transportation Survey (Pucher and Dijkstra 2003).

Walking numbers show greater disparity. Walking and bicycling trips shares in Germany and the Netherlands for those aged 75-or-more amount to about half while U.S. numbers remain the nation average, 6%. Numbers for aged 75-or-more walking mode shares, Germany 48% and Netherlands 24% with the U.S. number also 6% (bicycling numbers about zero) (Pucher and Dijkstra 2003).

Short urban trips reveal high walking potential

While U.S. urban trip mode split for walking was 10% and for motor vehicle 89% (Table 1), the Nationwide Personal Transportation Survey (FHWA 1994 Table 6-1) reveals 16.4% of all urbanized central city (50,000 and above population) trips less than 0.5 mile, 16.4% (11.7% outside central city); and, 0.5 to 2 miles 15.1% (13.4% outside central city). Together person trips 0-2 miles of 31.5% central city and 25.1% outside the central city.

Table 1: Travel Mode Shares for Urban Trips--The United States, Canada and Medians of Nine Western European Nations

Mode	U.S.	Canada	Nine European Nations Median
		Percent	
Motor vehicle	89	76	46
Walking/Other	7	12	24
Public transit	2	10	14
Bicycle	1	1	10
Other	1	2	10

SOURCE: Transportation Research Board (TRB) (2001) p 30; Pucher and Dijisrra (2003)

NOTE: 1. Median share for motor vehicle, transit and other, seven nations: Denmark, U.K., France, Germany, Netherlands, Sweden and Switzerland. For bicycle and walking, Austria and Italy included.

2. Share data approximate comparisons as collected in different methods nation to nation; data primarily from 1995.

In spite of lower Canadian and U.S. urban densities, the potential for more walking trips remains strong with a third of U.S. urban commute trips under 3 miles and half of under-0.5- mile by motor vehicle (FHWA 1994, Table 4-2). U.S. tax law allows tax free commuter benefits for drivers in the form of several hundred dollars a year for parking as well as smaller amounts for transit, carpool and bicyclists—but nothing for walking to work

One study summarizes the North American walking problem:

> ...[O]ne of the biggest impediments to more walking and cycling is the appallingly unsafe, unpleasant, and inconvenient conditions faced by pedestrians and bicyclists in American cities…much could be done in the short-term to improve walking and bicycling conditions to make them both safer and more attractive (Pucher and Dijistra (2003).

This paper posits the single infrastructure component to cure “unsafe, unpleasant, and inconvenient conditions” for pedestrians requires connection of existing and new sidewalk networks through use of roundabouts at important intersections.

The critical element for walking safety--speed

Lower urban speeds mean for pedestrians: fewer accidents, fewer

Table 2: United States Walking Injury and Fatality Profile 2003

Total Walker Fatalities	4,749
Total Walker Fatalities and Injuries	70,000
Walker % of All Injuries in All Highway Accidents	2 Percent
Walker % of All Highway Fatalities (42,643)	11 Percent
Walker Fatalities per Walker Injuries	1/16 (6 Percent)
At intersections	1/25 (4 Percent)
Car Occupant Fatalities per Car Occupant Injuries	1/77 (1 Percent)
Walker Crashes at Intersections	24,500 (35 Percent)
Walker Fatalities at Intersections	1,012
Percent of All Walker Crashes at Intersection by Age	
45 to 65 About 50% Over 65—336 persons 59%	
Percent of Walker Crashes in Urban Areas	86 Percent
Percent Walker Crashes Resulting in Fatalities by Age	
Under 14--Less than 8% Over 75—over 20%	
Speed A Fatal Pedestrian Crash Factor	31 Percent
Fatality Rate at Speeds:	
20 mph—20% 30 mph—45% 40 mph—85%	
Walker Fatalities Percent with Blood 0.8 or more by Age	
All 34% 21-24 55% 25-34 57% 35-44 55%	

SOURCES: 1. U.S. Department of Transportation, "Pedsafe"
www.walkinginfo.org/pedsafe/crashstrats.cfm
2. NHTSA (2009) for 2003 crash data

fatalities, fewer injuries and fewer severe injuries. Reducing speed underpins walker safety approaches in policy, facility engineering and programming. A pedestrian injury and speed literature review by the U.S National Highway Traffic Safety Administration (NHTSA1999 p i) concluded "...higher speeds are strongly associated with both the likelihood of pedestrian crash occurrence and more serious resulting pedestrian injury." Increasing speeds by half from 20 to 30 mph increases walking fatality rate eight times, 5% to 40%. One in five walkers aged 75-and-above in an intersection crash dies (Table 2).

Over a third of walking crashes occur at intersections accounting for 21% of fatal walking crashes. One death occurs per 77 car injuries (1.3%) while for walkers one fatality occurs per sixteen walking crashes (6.25%) (Table 2). About 50% of walking fatal crashes for those aged 45-65 occur at intersections and for those over 65, 59%.

Table 3 shows U.S. fatality rates per kilometer traveled three to five times higher than in Germany and the Netherlands (Pucher and Dijstra 2003). Netherlands and Germany rates with many more roundabouts, also carry out stronger enforcement and education for all modes.

Table 3: Fatality Rates for Pedestrians and U.S. Motor Vehicle Fatality Rates 2000

Nation	Fatality Rate per 100 Million Kilometers Travel
German Pedestrians	4.4
Netherlands Pedestrians	2.5
U.S. Pedestrians	14.0
U.S. Motor Vehicles	0.95

SOURCES: Pucher and Dijstra (2003) for pedestrian rates and NHTSA (2009) for U.S. motor vehicle rates.

In world terms the walking mode remains universal, bicycling next, and then various forms of motorized modes. With walking mode universality any innovation providing marked safety improvement demands attention

Roundabouts reduce vehicle speeds

If roundabouts reduce vehicle speeds then walkers likely avoid accidents and injuries as well as injury severity declines. Roundabouts do physically restrain vehicle speeds. The primary speed constraint comes from forced deviation from a straight path on approach at the splitter island and maintaining speed constraint throughout the circular travelway. For the “fastest vehicle path,” vehicles moving in a “straight though” intersection crossing, three constraints intervene: (1) the splitter island extending back from the entry diverts a straight ahead movement to the right; (2) the central island area (including often a raised truck “apron”) causes a second diversion from a straight through movement, usually a further diversion to the right; and (3) a final diversion to the left around the circle itself which is both curbed and curved (FHWA 2000 p 27). The initial approach, entry and central island speed reduction and constraint is termed “deflection.” For immediate first exit turns, exit curvature controls the speed of that movement. The smaller the roundabout the greater the speed constraint, the lower the speeds. At lower speeds walkers can more easily escape and drivers avoid crashes.

Knowing delay is not an issue, drivers tend to focus on lower speed approaches timed ease into the roundabout without stopping. Consider peak hour delay drop of six minutes to six seconds at the Keene (NH) Main Street west leg, or the reductions at the Keene Turn Roundabout in Vermont, a stop delay drop of 33 seconds (from 44 to 12) at a.m. peak and of 20 seconds (from 46 to 26) at p.m. peak (Clough Harbour 2003; Redington 2001 p 691). Roundabout off-peak times operate with at most five to ten seconds stop delay.

A typical urban roundabout with 90 to 110 foot diameter restrains speed maximum of about 15 to 20 mph. The speed reductions at the roundabout itself and within 200 feet or so from intersection center is well accepted. A landmark "before and after" empirical study of roundabout speed reduction effect comes records a 1998 0.6 mile conversion of a 5-lane, commercial strip corridor from five lanes with two signals and two two-way-stop-controlled intersections to four roundabouts with four lanes with a median (Sargeant and Christie, 2002 p 207). Speeds measured on the Denver suburb of Golden, South Golden Road corridor between intersections: 48 mph before, 33 mph after. This research confirms roundabout traffic calming feature extends hundreds of feet outward.

Traffic calming and shared space

An indirect measure of roundabout impacts on speed comes in the European pioneered traffic calming of residential and commercial urban spaces during the late 1900s aimed at improving safety and ease of use by walkers and bicyclists. A recent more pervasive traffic calming termed "shared space" creates urban enclaves with no signs or signals, reduced curbing and allowing all modes to mix and move based on human interaction. Traffic calming and initial "shared space" area treatments both result in improved safety for all modes and appears to reeive strong public acceptance (Spiegel Online International 2006). With few exceptions, roundabout designs make up a key component in traffic calming and shared space installations.

While traffic calming in North American is commonplace, “shared space” remains unusual. The Burlington, VT Church Street Market Place is one example.

Roundabouts reduce injuries and fatalities--reduction amount unknown

Two principal variables effect walking crash rates at intersections: numbers of walkers crossing the intersection and numbers of vehicles, essentially an exposure to possible accident. The 86% of walking crashes occurring in urban areas (Table 2) reflects the areas with the highest walker and vehicle traffic exposures.

Modern roundabouts from the start, compared to signs and signals, reduced walking crashes and serious injury when crashes occur. A 1984 U.K. study of conventional (single and two-lane) roundabouts walking crash rates cut by 33% compared to signals and min-roundabouts cut rates by 53% (FHWA p 117). Extent of reductions remain unknown since crash assessments apply to about 200 hundred feet from intersection center leaving out much roadway contained in the full “traffic calming” zone of each roundabout.

French roundabout and U.S. non-roundabout intersection fatality data indicate lower roundabout injury severity. The U.S. walking fatality rate per crash, 4%, (Table 2) compares to 1.7% at 27,000 French roundabouts (Guichet 2005), a reduction of about one third. At Melbourne's more than 2500 roundabouts (including many residential traffic calming circles) during the five years 2002-2006 not a single walking fatality occurred (O'Brien 2008). Injuries in Melbourne also add evidence to roundabout safety--263 per year composed of 140 minor injury and 123 requiring hospitalization (O'Brien 2009).

An early walking before-and-after roundabout conversion crash study found a 73% crash reduction and 89% injury reduction (Schroon and van Minnen 1994 p 143). The 181 single-lane roundabouts study mostly had just under 100 feet diameters. This Dutch study confirms both reduction in crashes and lower crash severity. With almost a fifth Dutch urban trips walking, this study provides assurance of continued walking safety in the U.S. and Canada when walking volume increase at roundabouts.

The first U.S. study using statistical measures found roundabouts reduced all crashes by 39%, injury crashes 76%, and fatal and incapacitating injury crashes by 89% (Persaud et al 2000). So few walkers injuries had occurred, statistical conclusions applied only to car occupants and overall safety

From 500 roundabouts in 1985 France moved to first worldwide, about 30,000 in 2008. With growth 1993-2003 from 10,000 to 24,000 in 2003, about 1,400 yearly, injuries and fatalities remained fairly level (Guichet 2005). The French injury and fatality rates per roundabout per year dropped about 60% 1993-2003. At French roundabouts in 2003 two fatalities and 116 injuries occurred (Guichet 2005). During 1993-2003 all French crashes declined 36% while roundabout crashes dropped 58%. Four possibilities suggested for better roundabout performance: (1) presence of more roundabouts; (2) improved design; (3) increased driver familiarity; or (4) other factor (Guichet 2005).

The "more roundabouts" suggestion appears most likely since the "traffic calming zone" does exist but safety effect remains unknown and unstudied. As the density of roundabouts increases in an urban area, individual "traffic calming zones" may well overlap with one adding additional safety to one or more others plus positive impact on other non-roundabout intersections and roadway.

Other roundabout elements contribute to walking safety. The typical intersection crosswalk width (two two-lane streets) exposes walkers to four vehicle conflicts (FHWA 2000 p 26) which a roundabout cuts in half to two—dealing with traffic from one direction at a time due to the splitter island median. The roundabout pavement width exposure is less, particularly at signals with turn lanes.

The German and Netherlands experience with walking and bicycling initiatives in the 1990s suggests undertaking measures can improve urban walking and bicycling "both to reduce fatalities and injuries and to encourage more walking and cycling...." (Pucher and Dijkstra 2003). Pucher did not identify the role played by large numbers of roundabouts as a factor in safety performance (Redington 2005). Of the top seven highway safety leading nations measured by fatalities per vehicle mil (followed by Canada, eighth and the U.S. ninth) (Joint OECD/ECMT Research Centre 2006)---all top seven invested heavily in roundabouts during the last three decades.

Walking mode: importance of ease and comfort of crossing intersections

Ease of crossing an intersection provided by the roundabout plays a major role in a viable walking mode (Redington 1997 p 248). "Ease of crossing streets" comprises one of four factors required for a viable walking mode (1000 Friends of Oregon 1993). From community design comes a call for "a physical arrangement" which favors pedestrians over cars at road crossings (Alexander, et al 1977 pp 280-284). The roundabout uniquely fulfills the need in both cases, unlocking the walking mode at intersections.

The first U.S. area all roundabouts design reflects the ease of crossing and enhancing a bustling tourist community commercial center. The Manchester, VT "Manchester Commercial District Parking and Pedestrian Plan" (Manchester 1995) replaces all signalized and busy sign controlled intersections with roundabouts.

Toward a North American Walking Service Level (WSL)--a mid-level theory

Meager attention to a walking service measurement over almost three decades leaves two service approaches, one using a delay criterion and the other walker density (Transportation Research Board 2010). Neither delay nor density presents a problem at roundabouts. With the walking mode evolution as roundabouts became incorporated, the criterion of safety becomes paramount, a criterion measured by presence of roundabouts and a sidewalk network. The roundabout erases most delay and establishes safety and ease of crossing for walkers. The roundabout combined with other traffic calming techniques enable walking mode dominance—such as traffic calming or shared space areas--with little or no sacrifice to the previous commanding motor vehicle mode.

A "walking service level" (WSL) measured by safety from Level 0 to Level 3 is outlined in Table 4. Even with a sidewalk network, the lowest Walking Service Level 0 characterizes much existing urban space in the U.S. and Canada except for a few small enclaves and the nodes connected to grade separated walking networks (for example, the Montreal and Toronto undergrounds plus additional spaces connected by rapid transit supplemented by further points through bus routes). Parts or all of these exceptions mostly fit WSL 3.

WSL 1 applies to areas and corridors served by sidewalk networks with considerable interconnection via single and multi-lane roundabouts. Nodes, small areas and short corridors begin to meet WSL 1 as roundabouts create sidewalk network interconnections.

Table 4: An Urban Walking Service Level Categorization

Walker Service Level	Level Characteristics
0	Absence of a full network of sidewalks or connectivity provided through roundabouts. Exception: network of rapid transit serviced nodes, such as subway systems and grade separated locations like the Montreal and Toronto undergrounds which qualify for up to WLS 3.
1	An area, corridor, or enclave with full walking facilities and extensive single and multilane roundabouts surface connectivity. Surface traffic numbers tend to be high. Some areas of Carmel, IN areas may now qualify.
2	A small area, roadway segment, or node featuring full walking facilities and speed management through to the level of single-lane roundabouts. Some traffic calmed areas. Manchester Town (1995) plan provides an example.
3	WSL 3 reflects the least restrictive and safest environment "shared space" and strong traffic calmed areas. Characteristics include minimal or no traffic signs, low speeds and considerable walker and bicyclist shares in mixed mode, mixed use environments. Grade separated areas may reach this level.

WSL 2 and WSL 3 apply to smaller urban areas and smaller towns and cities plus those metropolitan networks noted WSL 0, above, where grade separation connected by transit reaches WSL 3. WSL 2 may be described as nodes, corridors and areas with the sidewalk network connected with single lane roundabouts or the equivalent. WSL 3 areas feature the highest level of walker safety and lowest speeds through mostly traffic calmed or shared space areas as well as grade separation, such as the Montreal and Toronto undergrounds. Prevailing speeds and traffic volumes also differentiate WSL 2 and WSL 3. Main streets at WSL 3 generally do not exceed 20,000 vehicles a day, volumes found in smaller towns and cities as well as lower density metropolitan areas. Dratchten, Netherlands "shared space" provides an example of WLS 3 shared space as does the Burlington, VT Church Street Marketplace.

This middle theory Walking Service Level approach suggests a way to categorize the walking mode quality allowing mapping communities and developing prioritized plans for improving the walking networks. A Walking Service Level enables describing changes in a more objective, measurable framework.

U.S. Access Board pursues walker signals at multi-lane roundabouts

The U.S. Access Board (Access Board) administers the Americans with Disability Act of 1990. After establishing building accessibility standards the Access Board began pursuing "access to public rights-of-way" regulation under the law. An initial draft requiring walker signals at all roundabouts preceded the current 2005 "revised draft guideline" applying walker signals only to multi-lane roundabouts (Wisconsin State Department of Transportation 2009).

Signalization arose to serve primarily the small segment of those with handicap, persons with severe visual disability, perhaps one person in a few thousand of the general population. The mobility paradigm for persons with severe visual handicap asserts these individuals can--given sufficient tactile guidance, auditory cues and the sounds in the immediate environment--move safely along the sidewalk system and intersection crosswalks.

Most public rights-of-way--streets and highways--will always remain inaccessible to persons with handicap. Most roadways do not the minimum for safe walker access, sidewalks; and many urban sidewalks with steep grades cannot meet handicapped standards (for example, San Francisco hill neighborhoods).

The U.S. alone identifies a handicap access problem at roundabouts. Alternatives for persons with severe visual handicap include a guide animal or personal assistant. Another approach uses a comprehensive localized planning process identifying existing accessible rights-of-way and setting investment strategies for expansion with breakdowns of accessibility by handicap category.

Walker signals study began recently as no significant prior experience existed. Data on walking signal effects and effectiveness remain sketchy. Signalization requires at least a dozen signal heads and actuation posts for a four-leg roundabout. Estimated walker signal costs are $160,000 to $200,000 for a four-leg roundabout ($40,000-$50,000 per leg) (Rodegerdts 2009) and maintenance based 10% of the capital cost, $16,000 to $20,000 yearly. Since the greatest gains in vehicle and walking service and safety, reductions in pollution, and land use benefits occur from multi-lane roundabouts, new or from signal conversion, walker signals seriously compromise the gains.

The first study (Schroeder et al 2009) positing a "working definition of "accessibility" at roundabouts sets criteria applicable to any intersection type. The four "accessibility criteria" posited for persons with a severe visual handicap: crossing opportunities, opportunities taken to cross, delay, and safety. The study did not reach "a crisp determination of accessibility for single lane roundabouts." The empirical study one percent rate of "interventions" to avoid danger of a crash during a crossing by a person with severe visual disability meant a person with the handicap crossing morning and afternoon commuting would face a risk a crash once a month.

From a policy perspective both absent a definition of accessibility and indication of single lane roundabout inaccessibility, a rationale for roundabout walker signals remains elusive. High costs and other questions require attention including safety for all users and environmental impacts (fuel use, pollutants and sprawl), and accessibility increase. Informed regulatory action mandating roundabout walker signals remains premature.

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