TYPE OF INFRASTRUCTURES	REFERENCE	ORIGIN/CITY	TARGETED INDIVIDUALS	AIM / OBJECTIVES / HYPOTHESES	JUSTIFICATION	PARTICIPANTS	METHODOLOGY / SET UP	RESEARCH TOOLS	VARIABLES / INDICATORS STUDIED	ANALYSIS / INTERPRETATION	RESULTS	STATED LIMITS	CONCLUSION (THE BEST INFRASTRUCTURE/PRACTICE)	QUALITY
Crossfall	**Brubacker,** C. & McLaurin, C. (1996). Effects of side slope on wheelchair performance. *Journal of Rehabilitation Research and Development*. 23(2): 55-57.	**Charlottesville, Virginia, United States**	**Mobility impaired, self-propelling wheelchair users**	To identify and quantify the factors affecting direction stability of manual wheelchairs on uneven and sloping surfaces and to recommend potential means of controlling wheelchairs.	One nearly universal problem is the downhill turning tendency on sloping surfaces. This results from the characteristic mass distribution of a wheelchair and its occupant relative to the wheel orientation and the fact that nearly all outdoor, improved surfaces (e .g ., streets and sidewalks) are sloped for drainage.	n=1. The subject was an athletic 20-year old male paraplegic (T12, L1).	Drag forces were determined for two different wheelchairs at 3 and 4 km/hr on a motorized treadmill with the bed level and with the bed inclined laterally at 2°. Measurements were determined with the chairs tethered to a load cell attached to the front frame of the treadmill. The measurements were made with the test subject seated in the wheelchairs. The wheelchairs were "steered" for the slope condition by having the subject apply a resistive force to the uphill handrim. Each of the above conditions was repeated with the subject propelling the wheelchairs at the pace set by the treadmill. The subject's oxygen consumption, heart rate, and stroke rate were determined while he propelled the wheelchairs. The exercise bouts were conducted over 5-minute periods with the measurements determined for the fourth and fifth minutes. The wheelchairs used were a standard model with the rear axle located on the rear vertical frame member and a sport model with adjustable axle. The axle.position used for the latter model was 2 .5 in. in front of the rear vertical frame member. This wheelchair also had a 3° camber in each drive wheel.	Not presented	Angle of the sidewalk Speed Drag (N) Power (W) Strokes per minute Heart rate Energy cost Mechanical efficiency	A statistic analysis of the 2° slope condition was made to determine the downhill turning moment to provide a basis for comparison with the results of the drag tests. Not described.	The factors that produce the downhill turning effect are: the slope, the moment arm of the center of gravity about the downhill wheel, the mass of the wheelchair and occupant and the distance between the wheels at the surface. Drag was approximately 12% higher for the standard wheelchair. Drag was higher for the 4 km/hr condition on the level surface, but was higher for the 3 km/hr condition on the sloped surface for both models. Drag was roughly two times as large for both chairs at both speeds on the sloped surface as it was on the level surface. The physiological effort required for the various conditions is reflected by the respective oxygen consumptions and heart rates. Oxygen consumption increased by only about 30% from the level condition to the slope condition, whereas the power required to propel the wheelchairs increased more than 100% with respect to these conditions. Efficiency of propulsion on the sloped surface is higher. When efficiency is interpreted as the ratio of net oxygen consumption (or energy cost) to distance traveled, it can be seen that propulsion on the level surface is more efficient.		The higher mechanical efficiency obtained for the side-slope conditions may be attributed to the more favorable conditions with respect to the force-velocity relationship of the muscles and also to the fact that only one arm was used for propulsion. The significance of the latter is in part a result of having only one arm active in the recovery phase. The recovery phase typically accounts for 75% of the stroke time and consumes metabolic energy but does not produce any work. Two potential design solutions to eliminate the side slope effect are the center-of-gravity (c .g.) wheelchair and "steerable" casters . Although a properly balanced c .g . wheelchair eliminates side-slope effect, it also eliminates the directional stability or tracking tendency of the wheelchair and, therefore, requires nearly constant steering corrections. Differences in drag forces between level and slope conditions.	24
	Cooper, R.A., Molinero, A.M., Souza, A., Collins, D.M., Karmakar, A., Teodorski, E., & Sporner, M. (2012). Effects of cross slopes and varying surface characteristics on the mobility of manual wheelchair users. *Assistive Technology: The Official Journal of RESNA*. 24(2): 102-109.	**Pittsburgh, Pennsylvania, United States**	**Mobility impaired, self-propelling wheelchair users**	To identify the difficulty that cross slopes present to manual wheelchair users as compared with other driving obstacles such as curbs, doors and gravel, and second to evaluate how and to what degree cross-slope surface characteristics impact the mobility of MWC users. A goal of this study was to identify the common cross-slope related pathway characteristics that MWC users report to be the most troublesome or hazardous for the design of a future biomechanical and workload study.	Surfaces and obstacles, including cross-slopes, that require the individual to push harder and more often, may increase the risk of repetitive strain injuries by overloading the arms, which are already at increased risk of injury due to the stresses of wheelchair usage. Upper extremity injuries due to repetitive strain of individuals who rely on manual wheelchairs for their mobility have been shown to be related to wheelchair set-up, technique, activity, and pathway characteristics. The Americans with Disabilities Act Accessibility Guidelines states that for access routes and ramps, the cross slope should not exceed 2%. These standards, however, apply specifically to routes that allow access to, and inside of, buildings. In addition to the running slope (i.e., slope parallel to the path of travel) and cross-slope, many attributes of the pathway including weather condition, surface type, integrity, and surface roughness may influence the degree of difficulty experienced by the user.	**Phase 1.** n=560 manual wheelchair users (primary means of mobility) >18 years old who are enrolled in the Human Engineering Research Laboratories (HERL) Wheelchair Users Registry. They were sent a letter along with a recruitment flyer inviting them to participate in the study. **n=107 participated** (78 men, 29 women, 25-85 years old, mean age of 49.64 ± 11.08 years, average time of wheelchair use:19.90 ± 12.26 years). Variety of different diagnoses (spinal cord injury (75,7%), progressive diseases (14,9%) and other diagnoses such as cerebral palsy, spina bifida, and amputation (8,4%). **Phase 2.** Those respondents who reported cross slopes as harder than the other obstacles in Phase I were invited to participate in a web-based survey. **n=76** participants completed the web survey.	Cross-sectional questionnaire based research study. Phase I of this research surveyed MWC users to identify cross slope scenarios that they reported to be more difficult to traverse compared to other common driving obstacles. A questionnaire was used. Phase II focused on identifying the responses (e.g., avoid, explore alternative, experience a sense of insecurity, no effect) people had when viewing pictures of various cross-slopes scenarios (e.g., narrow space, compound angles, extreme weather) that wheelchair users encounter. Data were collected via a secure web server.	**Questionnaire:** Collected basic demographic information, diagnosis and/or injury, co-morbid conditions, and wheelchair type. It also presented 66 pictures of various cross slope scenarios. Participants were asked to rate the difficulty (1 = easier, 3 = same, and 5 = harder) of the cross slope with accompanying attributes as compared with other driving obstacles on a Likert scale. The driving obstacles presented to the participant were: 4 in. curb, 6 in. curb, stairs, narrow door, manual door, and gravel. The web survey included the same 66 digital images as Phase I, with various slope and cross-slope angles in various weather conditions with different surfaces types and varying types of surface integrity. For each image, participants were asked four questions: (1) I would feel safe going over this pathway; (2) traversing this pathway would not require much effort; (3) I would feel comfortable traversing this pathway; and (4) I would hesitate going over this pathway. The first 3 of 4 questions were worded positively and participants were asked to respond on an ordinal scale ranging from strongly agree (1) to strongly disagree (5). The answers to the 4th question were transposed so they could be summed with the other questions to derive an average score.	Level of difficulty Weather condition (rain, snow, ice) Cross slope angle Cross slope angle Paving surface Weather condition (rain, snow, ice) Surface roughness Path width Combination of the most severe characteristics	Descriptive statistics, such as frequency counts, medians, and percentages were reported on the various scenarios presented on the questionnaires. For example, ordinal data were collected from participant ratings of relative degree of effort compared to other wheelchair activities it would take to traverse cross-slope surfaces. Due to the ordinal ratings of the survey data, the descriptive statistics include: frequencies, medians, and percentages. The median score for each cross slope (n = 66) and obstacle (n = 6) were obtained. Data were compiled so that the median score for each obstacle could be analyzed. Frequencies were run to obtain one overall median score for each obstacle. Median scores of 4 or 5 were considered as more difficult. The participants' average score per image were analyzed using a One Sample T-test with a test value of 3 which indicated "neutral." Those average scores that were significantly higher than 3 per the One Sample T-test were then identified. Rankings ranged from 7–19 with a median score of 13.	Across all 66 scenarios, regardless of cross slope angle or other factors, cross slopes were considered more difficult to traverse than manual doors (n = 11; 16.65%) and narrow doors (n = 9; 13.6%).The 66 scenarios presented to study participants were then separated into three categories based on the severity of the cross slope angle. 34 questions (51.5%) presented mild cross slope angles, 9 (13.6%) showed moderate cross slopes angles, and 23 (34.8%) pictured severe cross slope angles. In 23 cases the cross slope, with a median score of 4 or 5, was reported to be harder to traverse than at least one other wheelchair mobility activity or obstacle. These 23 occurrences represented 11 different cross slopes conditions that were rated by participants as being more difficult to negotiate than the other wheelchair mobility activities or obstacles. 24 of the 66 scenarios presented a weather condition such as rain, snow, or ice that may make traversing the cross slope more difficult. 10 of the scenarios with difficult weather had a mild cross slope angle, 1 scenario had a moderate cross slope, and 13 had a severe cross slope angle. In these scenarios, participants rated the cross slope to be more difficult than a narrow door in 6 instances (25%) and more difficult than a manual door in 7 cases (29.1%). 26 of the 66 scenarios presented rough surfaces. 13 of these had a mild cross slope angle, 3 had a moderate cross slope angle and 10 had a severe cross slope angle. Participants rate surfaces with cross-slopes in combination with rough surfaces such as cracks, debris, rocks, and raised areas as more difficult to traverse than other wheelchair mobility activities or obstacles. In these scenarios, participants rated the cross slopes to be more difficult to traverse than a narrow door in 5 cases (19.2%) and more difficult than a manual door in 6 cases (23%). Compound cross slopes, those with a severe running slope and a severe cross slope angle, were also reported to present a greater challenge to participants. 23 of the 66 scenarios presented compound cross slopes. These were rated as more difficult to traverse than a manual door in 10 cases (43.5%); more difficult than a narrow door in 8 cases (34.8%), followed by gravel in 2 instances (8.7%) and more difficult than a 4 in. curb in 1 case (4.3%). 8 images were rated by respondents most frequently to be avoided or as difficult to negotiate, all of which had similar characteristics as determined by the investigators. All but one image had a cross-slope angle with a "severe" rating. The exception was rated "moderate" but other characteristics such as rocks, raised surface areas and a narrow pathway were present. 5 images had a "severe" slope angle. 3 images had a "mild" slope angle. 6 images were "concrete" surface types, 1 was "brick" a pathway and 1 pathway had sections of broken concrete or had sections of gravel. 5 of the images depicted surfaces covered with "snow," 1 depicted a surface covered with "ice" and 1 depicted a surface under "dry" conditions. Smooth was the surface characteristic in 3 of the images, cracks in the pedestrian pathway were visible in 2 of the images, and pedestrian pathways with raised areas and gravel were each in 1 image. 2 were "narrow," 2 were "adequate' and the remaining 4 were "wide." Adequate was defined as the standard ADA compliant pedestrian pathway. Severe cross slope angle, severe slope angle, snow, concrete with rocks, and a narrow pathway.	The presentation of the various scenarios and scoring may have been confusing to some participants. The design of the questionnaire used in Phase I made it difficult to determine which individual factor (e.g., cross slope angle severity, weather, surface integrity, etc.) made the cross slope more difficult to traverse. Our study population included a majority of individuals with spinal cord injury and a minority of individuals with a progressive disease. People who use manual wheelchairs with progressive diseases that limit movement and cause upper extremity weakness may find traversing cross slopes and other obstacles more difficult than people with non-progressive injuries.	Phase I results indicate that cross slopes with severe angles were likely to be rated as more difficult than the obstacles presented for comparison, manual and narrow doors, in particular. Participants often rated cross slopes with severe angles and compound angles to be more difficult to traverse compared to manual and narrow doors. Cross slopes with compound angles and poor surface conditions were frequently rated as more difficult to negotiate than other common wheelchair mobility activities. Improved surface qualities traversed by manual wheelchair users would not only decrease frequency of propulsion, but would also decrease propulsion power and possibly repetitive strain injuries of manual wheelchair users. In Phase 2, those characteristics of cross-slopes that MWC users identified or perceived as most likely to impede their mobility included cross-slope angles at or near the current standard, with uneven brick surfaces, surfaces with debris or rocks, and narrow pathways. Pictures of sidewalks depicting weather related conditions such as snow and ice were also identified as impediments.	45
	Holloway, C. & Tyler, N. (2013) A micro-level approach to measuring the accessibility of footways for wheelchair users using the Capability model. *Transportation Planning & Technology.* 36 (7): 636-649.	**United Kingdom**	**Mobility impaired, self-propelling wheelchair users**	Measure the accessibility of footways in relationship with the characteristic of their crossfall. A crossfall is the traverse gradient used to aid drainage. This paper considers only the self-propelling wheelchair users, depending on the interaction between the capabilities of the user, the type of wheelchair they are using, the weight of the wheelchair system, and the design of the footway. **Hypothesis:** There is an additional capability provided by people as they push a wheelchair over a footway with a 2.5% and 4% crossfall compared with one which has a 0% crossfall.	An essential component of footway design is the crossfall. It affects every user of the footway, and is a particular issue for wheelchair users. A crossfall will naturally turn any wheeled divide downslope because of the influence of gravity. Current UK footway guidelines state that the crossfall gradient should not exceed 2.5% because a steeper gradient could hinder the accessibility of wheelchair users and others with mobility impairments. UK Highways Agency states that crossfall greater than 3% can be uncomfortable to walk on. They recommend a crossfall of between 2% and 3,3%, with an absolute minimum of 1,5% and a maximum of 7%. The Americans with Disabilities Act Accessibility Guidelines (US Access Board, 1994) stated that a maximum crossfall gradient of 2% must be maintained on footways to ensure their accessibility for wheelchair users.	n = 12 able-bodied people were recruited along with 2 regular wheelchair users (12 males, 3 females). This gender imbalance was not designed in the experiment. Average weight: 69,08kg, standard deviation of 14,86kg. Average age: 34,6 ± 9,9 years. 11/14 were right-handed.	**Experimental design.** The Capability Model was developed as a way of measuring the accessibility of the built environment. It has two sets of measurements: provided and required capabilities. The former are all the things a person is able to do; the latter are all the things one would need to be able to do in order to complete an activity. It can be adjusted to include people who use assistive technologies. This study is about mapping the interactions between the person and the wheelchair and the environment for any given task. Capabilities have been fixed: the task is to travel in a straight line along a footway both with and without a crossfall. The Pedestrian Accessibility and Movement Environment Laboratory (PAMELA) facility was set-up so that it contained 3 lanes of footway (10,2m long and 2,4m wide). Each footway had a different crossfall gradient: 0%, 2,5%, and 4%. The surface was constructed with standard concrete pavers. Participants were asked to propel the wheelchair upslope and downslope each lane. This was repeated 3 times for each lane condition. Wheelchair used: Quickie GPV.	A SmartWheel was installed on each wheelchair, measuring three-dimensional forces and moments applied to its hand rim, as well as the velocity.	Work made by the user (tangential force with respect to distance travelled over each contact period) Mass of the user Mass of the wheelchair	The data were trimmed to exclude the first and last push which were responsible for starting and stopping the wheelchair. Contacts with the handrim were identified by finding local maxima peaks and local minima peaks of tangential force. An inside-out search was then used to find where the tangential force dropped below or rose above 0 N. These times were recorded and the work done was calculated for each contact. The 2 capabilities (work done and work difference between each side) were calculated by summing successive runs (an upslope and a downslope) on the same surface to get the "sum of work". The values for the sum of work and the difference of work were checked for normality using the Shapiro-Wilk test and then analyzed using multiple linear regression analyses with occupant mass and crossfall gradient regresors. A Bonferroni adjustment was applied to the significance level, which resulted in a significance level of p=0,017.	The regression model for the **sum of work** was a very poor fit (R2=0,063, R2adj=0,047), and although the relationship is significant (F(2,123)=4,04, p=0,023), meaning statistically the model has predictive ability, it is only capable of modelling approximately 5% of the variance recorded in the sum of work and it is not a generally useful model. The regression model for the effect of crossfall gradient on the **difference of work** shows a good degree of fit (R2=0,865, R2adj=0,863), and was significant at explaining the variation in the data (F(2,123)=388,914, p<0,0001). When the individual variables are examined with the aid of a t-test both crossfall and occupant mass are significant. Crossfall was positively correlated to the work difference. The coping strategies employed by people when applying a difference of work while continuing to provide the work necessary to move the wheelchair ranged from those who simply reduced the magnitude of force on the upslope side, to those who had to apply frequent breaking forces to the upslope side while increasing the magnitude of their pushes on the downslope side. The results show that on average a person will have to create a difference of force resulting in a difference of work approximately 50Nm for a footway built to current UK construction standards with a 2,5% crossfall. In order to ensure footways are accessible for wheelchair users, it is proposed that they are designed within the recommended guideline.	1) Participants were mostly inexperienced wheelchair users. 2) The way the individuals applied additional forces is beyond the scope of this study. 3) Further studies should consider other surfaces, longer distances, and experienced wheelchair users.	Crossfalls present a barrier to wheelchair users which necessitates them to provide increased forces. During the study, cadence (pushes per minute) was noted to change significantly as crossfall increased. This research has showed a linear increase of the difference of work provided by people as crossfall gradient increases, and the necessity for all users to use at least one break in lieu of a push on the downslope side.	39
	Kockelman, K., Zhao, Y., & Blanchard-Zimmerman, C. (2001). Meeting the intent of ADA in sidewalk cross-slope design. *Journal of Rehabilitation Research & Development.* 38(1), 101-110.	**Austin, Texas, United States**	**Mobility impaired**	To develop maximum and desirable limits for sidewalk cross-slope at driveway crossings. To evaluate the usable range of sidewalk cross-slopes under the current ADAAG with regard to user perception and effort.	The ADA Accessibility Guidelines (ADAAG) clearly state that accessible sidewalks require limited cross sloping. Unfortunately, existing infrastructure and terrain conditions, restricted right-of-way (ROW), and city ordinances often prevent these agencies from achieving the standard of a 2% cross-slope at all points along an accessible route. Currently, one primary area of concern is maintaining the prescribed cross-slope where sidewalks intersect with driveways. No research has been undertaken as to the effect of cross-slope on the accessibility of sidewalks to persons with disabilities. Prior research is insufficient to support the ADA's 2% cross-slope requirement. Existing studies have used fairly homogeneous populations of young males with good upper-body strength and stamina as their test subjects. Because of these deficiencies, the validity of existing requirements for less physically capable users and users with different mobility aids may be questioned. A reasonable maximum slope standard is urgently needed for design standards and construction cost estimation.	Respondents to the field survey. n=19 (10 women, 9 men, range: 27-59 years, 4 manual wheelchair users, 8 electrically powered wheelchair users, one used both, one scooter user, 2 cane users, 1 crutches user, 1 no aid, 2 blind individuals (seeing eye dog)). n=10 for the heart-rate survey, n=22 for the perception survey. In the process of soliciting participants, 16 different agencies and organizations were contacted, 5 public presentations were given (including one televised presentation), and 2,000 pieces of literature were distributed, both through direct mail and through more general marketing methods.	Surveys were held at locations along bus routes identified as those having high numbers of riders with disabilities. These surveys required the participants to traverse a series of delineated sections with varying cross-slopes and attributes. Participants were instructed to traverse the sidewalk sections at a comfortable pace, pausing as needed and simulating the way they would typically use a sidewalk. Before and after each section, the participants' heart rates, and the participants' subjective assessments of the sidewalks, were recorded. The selected location (for almost just under half of the perception survey sites and all of the heart-rate surveys) was a church parking lot. However, due to the serious difficulty in finding locations where cross-slopes and grades can be maintained for long distances, the lot's traversable distances may not be as long (and the ranges not as varied) as would be ideal. These tests varied in length, from 125 to 292 feet, and exhibited constant grades, ranging from 0.4 to 4%, and constant cross-slopes, ranging from 0.5 to 3.6%.	2 field surveys were used: one where participants stated their perceptions of ease of sidewalk use before and after crossing various sidewalk sections, and another where their heart-rate changes in response to traversing distinct sidewalk sections were recorded before and after they traversed distinct sidewalk sections. Athletic-type pulse meters, which measure the blood flow rate in the earlobe and display the rate in beats per minute. one's resting heart rate is most accurately measured upon waking, a reasonably close measurement can be taken after having the participant sit quietly for a few minutes.	Cross-slope Primary slope Width Length Set-back distance Participant's heart-rate change Participant's sidewalk assessment Explanatory variables: age, gender, fitness level, type of disability, type of mobility aid, and resting heart rates	Linear regression with Weighted Least Square (LRWLS). It involves the heart rate changes of subjects after having traversed distinct sidewalk sections. The change in heart rate is an important indicator of energy consumption as a result of crossing a sidewalk section. Ordered Response Probit Analysis (ORPA).Categorized assessments (ranging from "easy-to-cross" to "impassable") of distinctly sloped sidewalk sections are modeled using an ordered-response probit structure. Five levels represent the dependent, ordinal-response variable.	The weighted and adjusted R2 value is rather high (0.780), indicating that the explanatory variables in the model explain much of the variation in recorded heart-rate changes. **LRWLS** Coefficient: 13.41, sd: 7.75, t-statistic: 0.23. **ORPA:** Coefficient: 0.11, sd: 0.02, t-statistic: 5.84 (significant). **LRWLS** Coefficient: 1.42, sd: 6.04, t-statistic: 0.23. Likelihood ratio index (LRI) is a goodness-of-fit measure very similar to an R2--is 0.10. Thus, the model specification is useful for predicting user assessment. the effects of primary slope and cross-slope are positive, suggesting an increase in traversing difficulty as the primary slope and/or cross-slope increase. The relative magnitudes of the coefficients suggest that the effect of the primary slope is larger than that of the cross-slope. **ORPA:** Coefficient: 0.15, sd: 0.03, t-statistic: 4.99 (significant). The effects of primary slope and cross-slope are positive, suggesting an increase in traversing difficulty as the primary slope and/or cross-slope increase. The relative magnitudes of the coefficients suggest that the effect of the primary slope is larger than that of the cross-slope. Likelihood ratio index (LRI) is a goodness-of-fit measure very similar to an R2--is 0.10. Thus, the model specification is useful for predicting user assessment. The variable of distance traversed was statistically insignificant, suggesting that heart rates may have stabilized before the completion of most of, if not all of, the sections. the negative coefficient of gender suggests that a male will feel more comfortable crossing a sidewalk section than will a female. The mobility aid variable has positive effects, suggesting that traversing sidewalks will be more difficult for people with manual wheelchairs than for people with this model's default mobility aid type: cane/crutch. **LRWLS** Coefficient: 0.51, sd: 0.12, t-statistic: 4.17 (significant) suggesting that heart rates may have stabilized before the completion of most of, if not all of, the sections. The coefficient of distance suggests that the average heart-rate change will increase if the sidewalk section distance increases. **ORPA:** non statistically significant (heart rates may have stabilized before the completion of most of, if not all of, the sections). Physical fitness level: **LRWLS** Coefficient: -29.34, sd: 5.29, t-statistic: -5.54 (significant). Heart rate increases in a linear fashion in relation to work and oxygen uptake during exercise, and its measurement is therefore an appropriate way to test the correlation between perceived and actual effort. The effect of physical fitness level suggests that the higher the level of physical fitness, the less the heart rate increases in response to cross-slopes.**ORPA:** Coefficient: -0.20, sd: 0.10, t-statistic: -1.93 (significant). The heart-rate target zone for physical training is defined as between 60% and 80%t of one's maximum heart rate. While 75% may be an acceptable target zone for training or exercise, it may be higher than acceptable for persons negotiating sidewalks simply for reasons of access to activities and services. **ORPA gender:** Coefficient: -0.98, sd: 0.17, t-statistic: -5.64 (significant). The negative coefficient suggests that a male will feel more comfortable crossing a sidewalk section than will a female. **ORPA:** The mobility aid variable has positive effects, suggesting that traversing sidewalks will be more difficult for people with manual wheelchairs than for people with this model's default mobility aid type: cane/crutch. **LRWLS:** The related magnitudes of the parameters imply that people using canes/crutches consume more energy than do people using other aid types.**ORPA age:** Coefficient: 1.91, sd: 1.57, t-statistic: 2.00 (significant), which suggests that older users may experience greater change in heart rate than will younger users.	It should be noted that without tests of 5 or more minutes duration, heart rates of the participants probably did not stabilize during these experiments. In fact, during short periods of exertion, heart rates often are biased high and the results are likely to suggest more exertion is necessary than would be required under a rate-stabilized scenario. If sites can be found for much longer tests and exertion periods, this weakness of the data could be remedied. Also, because the site used for the heart rate surveys was less than ideal, participants were required to travel along some paths that were perpendicular to the main grade of the area, and some paths that were parallel to the main grade. Additionally, the limited dimensions of this particular site necessitated that they travel out from and back to a point of origin for each section. Note, however, that these heart-rate equations and target zones may not be highly reliable for individuals with physical disabilities or those performing special tasks (for example, significant arm exercise in the propulsion of manual wheelchairs). Ideally, peak heart rates for individual participants may be predicted by collecting individuals' heart-rate data across a series of work-load tests. These values could then be used to more reliably ascertain critical heart-rate levels and changes. Because of sample-size limitations and other experimental issues, this work may be viewed as a prototype.Larger sample sizes, longer heart-rate tests, and a stronger recognition of the population of interest are necessary before definitive, legislated maxima can be ascertained. However, the models and methods applied should be of significant use to the rehabilitative research and development community.	Results suggest that the critical cross-slope for 60-year-old manual wheelchair users is about 2.2 % when the primary slope of the sidewalk is about 5%, and 9% when the main grade of the sidewalk is 0%. Considering that the average age of the test sample is 40 years (with a standard deviation of about 10), the resulting critical cross-slopes for 0% and 5% main grades are 12.1% and 5.3%, respectively. ADA-based 2% maximum cross-slope may be too conservative for most disabled users, particularly in relatively short sections where terrain and/or other conditions do not permit such gradual slopes. While many of those with disabilities who were sampled here are able to traverse sidewalks having up to a 20% cross-slope, many are not. In recognition of the tradeoff between construction feasibility and user comfort, a 10% maximum cross-slope may be recommended, based on this research. Such a slope is estimated to preclude the use of those who describe themselves as being in very poor physical shape. However, anecdotal evidence gathered in this study suggests that persons in this category either do not rely on sidewalks to meet their daily travel needs or do not normally rely on their own propulsion when traveling on sidewalks. In order to accommodate the largest number of possible users, a 4% maximum cross-slope is recommended. Where a 4% maximum is not feasible and the primary slope is less than 5%, a 10% maximum cross-slope appears to be very reasonable. The most easily accessible sidewalks are those where cross-slope is minimized, and width is maximized. The demonstrated relationship between the increase in heart rate and the increase in cross-slope further supports this recommendation.	43

See also "Descriptive-Comprehensive"	**Laakso**, M., Sarjakoski, T., & Sarjakoski, L. T. (2011). Improving accessibility information in pedestrian maps and databases. *Cartographica*. 46(2), 101-108.