



# Transportation

The Science of Resilience

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## Definition

Transportation can be defined as the act, process, or instance of being transported or transporting a good or service from one location to another. When our transportation needs are met, we experience better access to the places we need to be, such as school or work and our communities are more accessible.

Morris (2011) identifies four factors that lead to improved access. These include *knowledge* to identify opportunities, *monetary means* to exploit opportunities, *physical proximity* for participation, and *bridging space* to access areas of distance (Morris, 2011). (A summary of factors that affect accessibility can be found in Appendix A). Transportation can provide a strong level of access to people who are spatially and economically disadvantaged. Planners use transportation as a way to improve access conditions through developing transportation infrastructure, broadening transportation mode choices, reducing congestion delays by changing economic incentives, and improving automobiles (Morris, 2011).

Transportation systems are designed to promote access under normal circumstances (Snelder et al., 2012). When these systems are disrupted, the social and economic wellbeing of those who rely on them are affected (Weilant et al., 2019; Clark et al., 2019). Natural events, such as extreme weather and climate change, or anthropogenic events, like car accidents, construction, cyber-attacks, and engineering failures, can be detrimental to communities whose welfare depends on these systems. A robust system should be capable of overcoming such obstacles while minimizing deviations in supply and demand (Snelder et al., 2012). However, unexpected disruptions can burden the system and result in deviated travel times that affect private and public transportation users (Snelder et al., 2012). When transportation systems cease to function normally, they reduce economic productivity, commercial activities, and tax revenues (Weilant et al., 2019).

Weilant et al. (2019) investigated how to incorporate resilience into the transportation system. The study comprised of interviews with transportation stakeholders and experts, and an extensive literature review. Stakeholders were asked about how they implement resilience in the transport system and what they believe their future needs are. Weilant et al. (2019) found that stakeholders emphasized the importance of system infrastructure and services, transportation systems, and community welfare. Results show that many community members use public or private transportation as a means of getting to work, daycares, senior centers, other recreational activities etc. Transportation systems influence economic development, urbanization, and population movement by their proximity to major roads and routes (Weilant et al., 2019). Lastly, it was highlighted that transportation is an economic fuel. It allows people, especially vulnerable populations, to access employment and other services that might not otherwise be available to them (Weilant et al., 2019).

Often, transportation access issues fall short on political agendas and are replaced by income and health issues (Hudson, 2001). Vulnerable people who lack access to cars or can no longer drive, rely on other methods of transportation (Managing Mobility, 2016). Alternative modes of transportation can include walking, cycling, public transit, paratransit, taxis (including Uber and Lyft), and rides from friends, family, and community organizations (Munro, 2016). However, recognizing that these modes might not always be available, or viable for some demographics has important policy implications when assessing vulnerable population needs. Addressing such challenges can be difficult for vulnerable populations since each person has their own transportation needs. Hoff and Jordan (2012) argue that generic transportation can promote independence, integration, and inclusion and are less complicated than other services (e.g. paratransit).

## Relationship to Resilience

Often, transportation networks are described on a scale between efficient and resilient. Efficiency and resilience do not directly correlate but should be considered as complementary to each other (Ganin et al., 2017). Resilient transportation networks, unlike efficient networks, comprise of many alternative routes and connections as opposed to high-capacity routes. Snelder et al. (2012) measured ‘Vehicle loss hours’ that resulted from car incidents in South Holland, Netherlands from January 1<sup>st</sup> – April 15<sup>th</sup>, 2017, and found that vehicle incidents that occurred on roads with high flow rates, in intersections, or on roads with a high intensity-capacity ratio, demonstrated a higher number of loss hours. In contrast, incidents at locations that had alternative routes showed a lower loss. Additionally, Snelder et al. (2012) found that there was a higher chance of incidents occurring on bridges and in merge locations. Given the data from the analysis, the information can be further distributed to community members to better plan their routes.

### Public Transportation

Public transportation and transportation development are generally good for society and can provide many economic and health benefits (Litman, 2015). Public transportation allows people to reside in lower income areas while providing affordable access to medical care and other essential services. Public transportation can also reduce transportation related deaths by eliminating the need of extra cars, reduce pollution, and provide economic stability (Litman, 2015). Litman (2015) argues that, after considering the impacts of public transportation, it can be one of the most cost-effective ways to reach public health objectives. Many transportation services recognize their impact and offer discounts to those who use public transportation on a regular basis. The Whitfield County Transit Service in Georgia charge \$4 for a one-way ticket but offer a 25% discount on books of 10 tickets (Bunch, 2020). Similar discounts are also applicable for children, students/youth, and seniors and on bus passes or prepaid bus cards. Some areas in Ontario use a pass called the Presto Card. The card is a reloadable bus card that discounts your bus fare when you pay with it (PRESTO, n.d.). Britain

has started offering free 'off-peak' bus travel to elderly people and has mandated that every bus be low floored (Mackett, 2020a). Britain also offers Journey Assistance Cards to people who may have hidden disabilities so that drivers can better accommodate them. All rail stations are fully accessible for people who are physically, audio and visually impaired and offer free staff member assistance. Seniors can save over 30% on rail tickets with the purchase of a Senior Railcard. (Mackett, 2020a).

Aside from these benefits, public transportation can cause inflated real estate prices in vulnerable communities. Since public transportation usually operates along main roads and routes for easy public access. Home and property owners close to public transportation stops or stations can use their proximity to raise rent and real estate prices. The convenience that public transportation aims to have can be used as a means of justifying the raise (Weilant et al., 2019). As a result, this can cause equity challenges in low income families who are forced to move further away from public transportation. This ends up being counterintuitive because low-income demographic households are one of the main populations who benefit the most from public transportation (Weilant et al., 2019). This is known to exacerbate hardship in vulnerable and low-income families who rely on these services (Weilant et al., 2019). Nevertheless, Marshall et al. (2015) note that expanding and diversifying transportation choices can promote adaptation during extreme conditions. From a policy perspective, communities can be better supported by improving transportation accessibility for lower income households further from the city center or increasing affordable housing (Marshall et al., 2015). These ideas can help support improved resiliency and community strength (Marshall et al., 2015).

## Transportation and Well Being

Advances in technology and innovation have made traveling faster and easier. The World Health Organization found that physical inactivity is one of the leading risk factors for mortality. Physical activity has also been linked to decreasing morbidity and mortality in chronic diseases (Sahlqvist et al., 2012), diabetes, stroke, high blood pressure, a variety of cancers, osteoporosis, heart disease, bone density (Booth et al., 2017), and energy and punctuality (Loong et al., 2017). Moreover, regular exercise is a protective factor against the emotional consequences of stress and can build emotional resilience (Childs and Wit, 2014) [See our write-up on physical activity for more information]. Active transportation can lead to less traffic, reduce air and noise pollution, and reduce accidents (Litman, 200; Litman, 2015). In a study by Yang et al. (2013), active transportation was found to be associated with increased physical activity. However, active transportation has also been shown to decline with age, especially in elderly demographics (Mackett, 2020a). St-Louis et al. (2014) reported that people exhibited higher levels of satisfaction when they walked or cycled. Although, weather was found to be a dependent factor when choosing a mode of transportation. A further association is seen between active transportation and women living in poverty (Lee et al., 2018). Women of color, women living in poverty, and women living in unsafe neighborhoods are more likely to use active transportation (Lee et al., 2018).

Decreased travel times to work are likely to increase job and leisure satisfaction, decrease strain and poor mental health (Clark et al., 2019). This association was found to be stronger in women than men. These effects can be mitigated by shorter and walkable commutes, or working from home (Clark et al., 2019). Individuals who work from home or commute less frequently allowed for more time to travel for personal matters (e.g. to the store or to meet a friend or family member) (Moeckel, 2017). Low income and other vulnerable communities can further benefit from walking, cycling or using another form of active transportation by eliminating automotive transportation costs.

## Vehicle Dependency and Transportation

Transportation is one of the factors that promotes access continuity. Car dependency is expected to rise, especially in older adults (Australian Bureau of Statistics). Buys et al. (2012) investigated car dependence in older adults through interviews and behavioural observations. Buys et al. (2012) found that convenience, affordability, availability and health/mobility were the main reason for car use. Respondents noted that some busses stop running after certain times and don't go along the routes they need (Buys et al., 2012). This supports the notion that good public transport can help alleviate the use of personal cars (Cullinane, 2002). Hamre and Buehler (2014) also provided evidence to support this claim in a study that investigated commuter benefits versus different modes of travel. Travel modes included cars, public transport, biking and walking, and the benefits included free car parking, public transport benefits, free/lockers and bike parking. The study was carried out in the Washington, DC region. A total of 4,630 adult full-time workers living in an urban or inner suburb neighbourhood were assessed. Hamre and Buehler (2014) found that free parking incited the use of cars but when parking was no longer free the likelihood of using alternative travel modes increased.

Rural communities are also typically car dependent and often have problems addressing transportation needs of vulnerable groups. The Independent Transportation Network of America runs a volunteer-based driving program that has helped elevate many transportation accessibility problems in rural communities (Hanson et al., 2018). The organization operates based on low-cost memberships. The program leverages volunteers who have their own cars to drive members in rural communities to a variety of places (Hanson et al., 2018). The Canadian Mental Health Association run programs that can include driving vulnerable community members to various destinations (Canadian Mental Health Association). An initiative called the Blue Badge Scheme in Britain provides accessible parking for people with mobility problems (Mackett, 2020a).

In other countries (e.g., Hong Kong) where car dependency is below the global average, once a car is acquired, it slowly becomes a necessity and part of people's lifestyle (Cullinane & Culliane, 2003). Further investigations show a positive correlation between mileage and length of ownership. This suggests that dependency increases with time (Cullinane & Culliane, 2003).

Vehicle dependency can further reduce participation in active activities, visiting friends, and events and increase asocial behaviours (Farber & Paez 2009).

## Carpooling and Transportation

Carpooling can be defined as the arrangement between two or more people who share a ride to a common or different destination (adapted from Shaheen et al., 2018). Carpooling has been widely associated with addressing issues surrounding traffic congestion and reducing energy consumption and emissions. (Shaheen et al., 2018; Do & Jung, 2018; Li et al., 2018; Librino et al., 2020). Li et al., (2018) found that, during workdays, carpooling can decrease trips by 30% in the morning, 24% in the evening, and increase roads speeds by 5-40% (during peak hours). In addition to these benefits, there are many socio-economic and cost-saving benefits (Do & Jung, 2018; Li et al., 2018; Librino et al., 2020) that have important resilience building implications. The literature suggests that carpooling can be used as a tool to favour social integration (Do & Jung 2018; Librino et al., 2020). Low income families can make car travel more affordable by taking advantage of the cost saving benefits. The average passenger car consumes an estimated 550 gallons of fuel per year (Shaheen et al., 2018). To put the savings into context, the addition of one person for every 100 cars would net a savings of 800-820 million gallons of gasoline each year in the United States (Jacobson & King, 2009). Carpools can take advantage of designated lanes and parking spaces which can help mitigate travel related stress and improve morale, increase satisfaction, and benefit productivity (Shaheen et al., 2018). New carpooling apps and websites are being established that allow people to find carpools on demand (Shaheen et al., 2018). Incentives to encourage carpooling are also offered by many stakeholders and employers. SHOUP (1997) found carpooling increased 64% when cash was offered to employees in exchange for their employee parking space to be turned into a carpooling space. Georgia's Cash for Commuters program offered a monetary incentive program for 90 days and found 57% continued to carpool for an additional 18-21 months. Many states have established various benefits through legislation and now require business that meet a specified threshold to offer carpooling incentives (Shaheen et al., 2018).

Do and Jung (2018) used the traffic flow theory to assess the direct and indirect benefits of carpooling in Korea. Results show that the direct and indirect benefits of carpooling is estimated between \$41,014 – \$61,275 USD/year and \$389,536 – \$557,991 USD/year respectively. The direct impacts of carpooling include saving access costs, waiting times, tolls, operating costs, receiving fares from passengers and public transportation costs. The indirect benefits include car operation costs, time-travel costs, accident reducing costs, environmental pollution costs, and noise cost. Non-carpooling drivers also benefit from the improved driving environment, decongested roadways, and parking lots (Do and Jung 2018).

## Other Notes: Barriers to Transportation

## Gas Prices

Gas pricing often rises and falls. This can cause great stress in individuals, households, and communities (Lipman, 2006). Marshall et al. (2015) analyzed how different modes of transportation contribute to resilience during abrupt increased in gas prices. Resilience to price fluctuations was found to be a function of the neighbourhood or individuals' proximity to the city center, household income, and the accessibility to other forms of transportation (Marshall et al., 2015). Wealthier families were found to be more resilient to increased prices since additional gas expenditures took a smaller percentage of a wealthy family's income compared to a low-income household (Marshall et al., 2015). Particularly, households with lower income and budget constraints, or those who live close to downtown may opt for alternative modes of transportation (especially ecofriendly modes), if the distance permits (Marshall et al., 2015). Some of the most vulnerable communities to increased gas prices are communities that have poor access to transportation (Fitzgerald, 2012) and significant house and/or transportation costs (Lipman, 2006). When alternative travel modes are not realistic, communities can incur serious economic impacts (Marshall et al., 2015). Families who allocate more than 15% of their income to transportation are also specifically vulnerable to abrupt fluctuations (CNT, 2010; Marshall et al., 2015). Marshall et al. (2015) found that increased resilience was seen in people who live in block groups and in areas of higher network density.

## Disabilities

Bezyak et al. (2017) examined public transportation barriers for people with disabilities. The study found that transportation was major environmental barrier and did not meet the needs of people with disabilities. It was reported that many bus stops, stations and the routes leading to them were inaccessible (Bezyak et al., 2017). Many problems were centered around the driver, including a lack of knowledge about disability etiquette and their needs, communication strategies, and how to use assistive equipment. Bezyak et al. (2017) also found many barriers to complementary paratransit services. People with disabilities had to schedule their pickup well in advance without any priority given to those with immediate medical needs (Scheer et al., 2003). Over one third of participants reported scheduling and reservation issues, long wait times, drivers missing pickup windows, and long transportation times (Bezyak et al. 2017). These findings line up with previous research by Scheer et al. (2003) and the National Council on Disability (2015). These barriers often lead to missed social and recreational events, healthcare meetings, and job insecurity (Bezyak et al. 2017).

Those who had cars but were unable to drive would often have a family member, personal assistant, or friend drive them. Although, appointments and meetings had to be scheduled during the personal assistants work schedule or around family members schedules (Scheer et al., 2003). Mackett (2020b) suggests building confidence in people with disabilities (especially people with mental health condition) through travel training to help build experience.



## Foster Barriers

Foster children often rely on their foster parents and managers to drive them where needed. Foster parents are not always available and willing to transport foster children and managers are often tied up with cases and other responsibilities (Paul-Ward, 2009).

## Improving

Connecting with national and local organizations and transportation officials can help individuals identify transportation resources in their area (Joff & Jordan, 2012). In the United States the Community Transportation Association of America, United We Ride, and Joblinks Employment Transportation Initiative are national organizations that have transportation resources available to the public (Hoff & Jordan, 2012). In areas with limited transportation options, people can advocate with local officials, help bring new and creative solutions such as volunteer driving programs to fruition, and in some cases negotiate monthly rates with cab companies (Hoff & Jordan, 2012). Hoff and Jordan (2012) further show that people can take advantage of shuttle systems or arrange for rides with coworkers to bus stops. Many senior centers have transportation of their own that residents can use for appointments, daily activities, and personal trips (Bunch, 2020). People can seek out local and federal government grant programs that help fund scheduled transport services to rural communities (Bunch, 2020). The granting program was proven successful by The Whitfield County Transit Service which received over \$300K and delivered over 34,495 trips in 2019 (Bunch, 2020).

## Interventions

Yeatts (1992) investigated different strategies to overcome barriers among low income and elderly people. The research, commissioned by the Texas Department on Aging and the Gerontological Society of America Postdoctoral Program, comprised of phone interviews to 28 Texas area agency directors or proxy agency staff, and 12 specialists and program directors from the Department of Aging. This was followed by a work session with the TDOA Minority Task Force and the Southwest Society on Aging to identify strategies to overcome barriers. Strategies used to overcome access include:

- Locating convenient service sites: it was found that if the service centers were not in communities already, accessing them was logistically problematic for many. To help combat the problem, satellite centers were set up in neighborhoods without service centers. These were set up near or next to community buildings such as schools, churches, and fraternal organization halls.
  - In this case, since building many new centers is quite expensive, they were finished without kitchens. The centers had hot meals delivered and microwaves to heat up frozen meals. If a center could not be established and clients were

unable to go to another center, then meals were typically delivered to their home

- Making transportation more attainable: To overcome transportation barriers, local public transportation authorities were contacted to see if they could permit reduced rates. Organizations and other clients were also asked if they could provide transportation.
- Scheduling services to accommodate the client’s schedule: Low-income minority schedules were often dictated by their access to transportation. This was addressed by trying to coordinate the program and transportation schedules.

## Assessments

The following assessments can be used to better determine suitable transport options.

**Table 1** This table can be used to evaluate the suitability of different transport modes. The following questions assess one’s ability to access transportation.

I can get to the services I need when I need them?	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Does not apply to me
I can get where you I to go?	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Does not apply to me
Do you experience transportation in this way	The transportation I have access to is fast	The transportation I have access to is slow	The transportation I have access to is efficient	The transportation I have access to is inefficient	The transportation I have access to is cheap	The transportation I have access to is expensive
I have access to multiple transportation modes	6-7 days a week	5 days a week	4 days a week	3 days a week	1-2 days a week	Does not apply to me
The roadways and sidewalks allow me to walk and ride a bike	6-7 days a week	5 days a week	4 days a week	3 days a week	1-2 days a week	Does not apply to me
Public Transportation is <i>available</i>	6-7 days a week	5 days a week	4 days a week	3 days a week	1-2 days a week	Does not apply to me
Public Transportation is <i>accessible</i>	6-7 days a week	5 days a week	4 days a week	3 days a week	1-2 days a week	Does not apply to me
Private Transportation is <i>available</i>	6-7 days a week	5 days a week	4 days a week	3 days a week	1-2 days a week	Does not apply to me

Private Transportation is <i>accessible</i>	6-7 days a week	5 days a week	4 days a week	3 days a week	1-2 days a week	Does not apply to me
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**Table 2** The *Importance of Transportation Modes* chart can be filled in by people in each demographic to better understand their changing needs and which transportation modes are most important to each demographic. Modified after Litman (2020).

Vulnerable Demographics	Walking	Cycling	Driving	Public Transit	Taxi	Air Travel
Low-income people	3	2	2	3	2	0
People with Physical Disabilities	3	2	1	2	2	2
People with Mental Disabilities	3	2	1	2	2	2
Elderly	2	1	1	2	3	1
Women	2	1	3	3	3	1
Children	3	3	2	1	0	1
Ill people	1	1	3	2	3	1
Immunocompromised people	2	2	3	2	2	1

**Table 3** A rating system to identify who has poor access to transportation and is transportation disadvantaged. The assessment can be modified to better suit the needs of a community. Modified after Litman (2020).

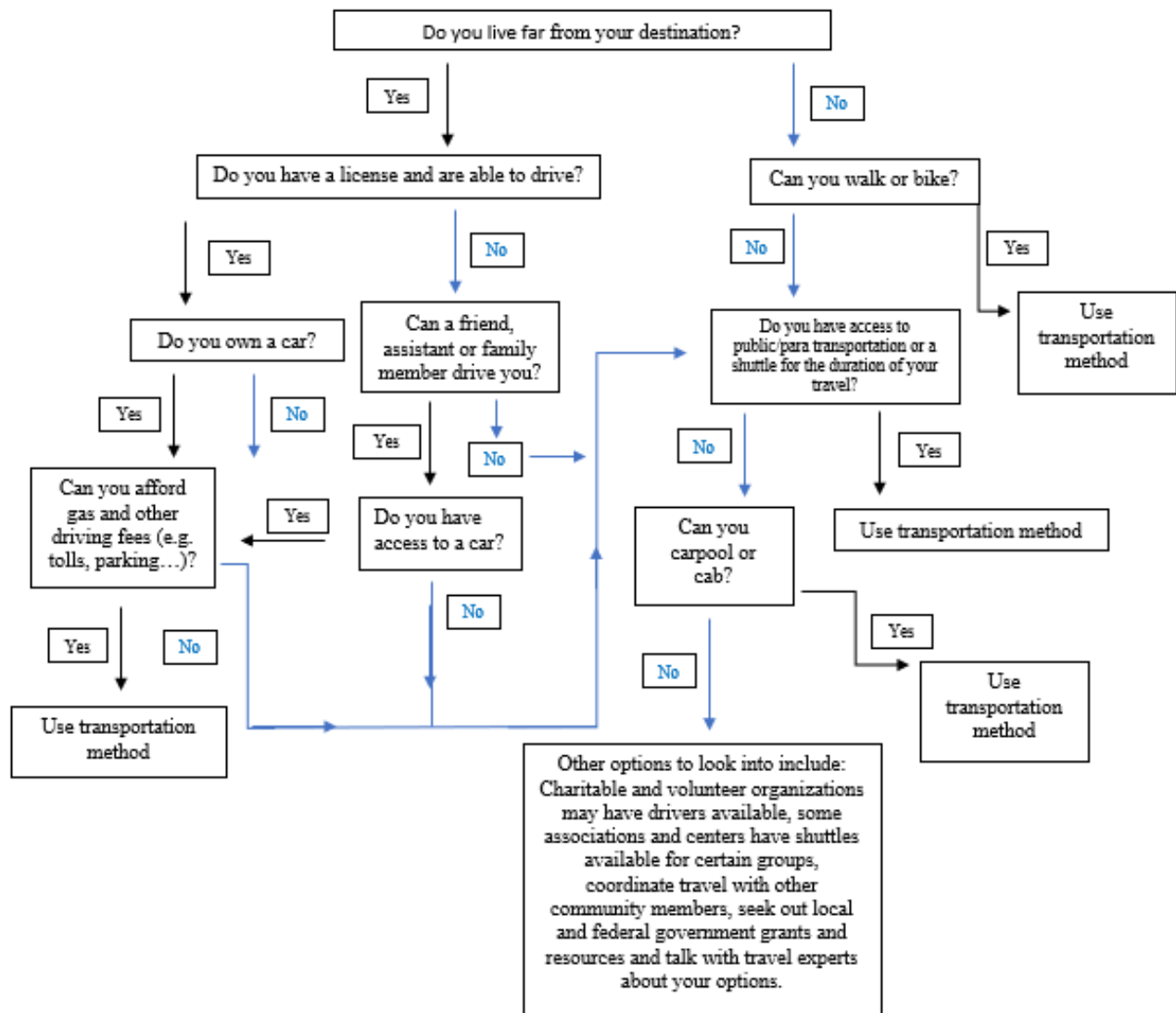
Factor	Rating System	Rating
Vehicle Accessibility	7 points if you own an automobile; 3 points if you have access to an automobile when you need it; 1 point if you need to be driven or rely on someone's schedule for automobile access; 0 points for no access to an automobile	
Access to Public Transportation	7 points if you are in walking distance to a bus, train or another form of public transportation; 2 points if you need to be driven to and from the transit stop; 0 points if a transit stop is not accessible or cannot accommodate for your physical disability	
Public Transportation Affordability	1 point for each day of the week you can afford a return ride on at least one public transportation mode that you have access to (this includes free transportation services)	
Active Transport (AT) e.g. walk or bike	7 Points if you are able to AT to work <i>and</i> areas for personal matters; 4 points if you can AT to work <i>or</i> areas for personal matters; 1 point if you require assistance to AT; 0 points if you cannot AT	
Income	7 points if you live above the poverty line; 3 points if you live below the poverty line; 1 point if you are in the lowest 10% income class; 0 points if you have no income	
Totals	+21=minimal-no disadvantage. 14-20 = moderate disadvantage. >14 = severe disadvantage	

**Table 4** The *Community Transport Rating* can be used to evaluate community mobility and accessibility. This can be further used to identify accessibility gaps and indicate if new transportation methods are needed. Each factor should be rated on a scale from 1 to 10. Modified after Litman (2017).

Accessibility Factors	Rating (1-10)
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All-weather (paved) roads, and reliable motor vehicle fuel supplies	
Good walking and cycling conditions. This includes adequate community sidewalks, crosswalks, paths, bike lanes.	
Community access to public transportation	
Community location with respect to urban villages	
Availability of car sharing and bike sharing, and taxi services	
Community shuttle services	

The following flowchart is an approach to choosing various transportation options:



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## Appendix A: Factors Affecting Accessibility

Litman (2020)

Name	Description	Current Consideration	Improvements
<b>Transport Demand</b>	The amount of mobility and access people and businesses would choose.	Motorized travel demand is well measured, but non-motorized demand is not.	More comprehensive travel surveys, statistics and analysis of travel demands.
<b>Mobility</b>	Travel speed and distance.	Primarily evaluates motor vehicle traffic speeds and vehicle mileages traveled.	More comprehensive evaluation of mobility by other modes.
<b>Transport Options (modes)</b>	The quality (speed, convenience, comfort, safety, etc.) of transport options including walking, cycling, public transport, etc.	Motor vehicle travel speed and safety are usually considered, but other modes and other travel factors are often overlooked.	More multi-modal evaluation (speed, convenience, comfort, safety, etc. of walking, cycling, transit, etc.)
<b>User information</b>	Availability of reliable information on mobility and accessibility options.	Sometimes considered for particular modes or locations, but seldom comprehensive.	More comprehensive and integrated information to help users navigate transport systems.
<b>Integration</b>	The degree of integration among transport system links and modes.	Automobile transport is generally well integrated, but not connections between other modes.	More integrated planning to improve travelers' ability to connect between system components.
<b>Affordability</b>	The cost to users relative to their incomes.	Automobile operating costs and transit fares are usually considered.	More comprehensive evaluation of transport costs relative to users incomes.
<b>Mobility Substitutes</b>	Telecommunications and delivery services that substitute for physical travel.	Not usually considered in transport planning.	Consider mobility substitutes as part of the transport system.
<b>Land Use Factors</b>	Land use density and mix.	Usually considered in land use planning, but less in transport planning.	Measure how land use factors affect travel distances and costs.
<b>Transport Network Connectivity</b>	Density of road and path connections, and therefore the directness of travel between destinations.	Transport planning is starting to consider roadway connectivity impacts on accessibility.	Measure how roadway connectivity affects travel distances and costs.
<b>Transport Management</b>	How transport management affects accessibility.	Limited consideration.	Consider how various transport management strategies affect access.
<b>Prioritization</b>	Strategies that favor more efficient travel activity.	Limited consideration.	Consider transport prioritization strategies.
<b>Inaccessibility</b>	The value of inaccessibility and isolation.	Not generally considered in transport planning.	Recognize the value of sometimes limiting access.

*This table indicates factors that affect accessibility, how they are currently considered, and potential improvements for more comprehensive planning.*





For more information about R2 or to discover how you can bring the program to your organization, business or educational setting, please contact us.

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