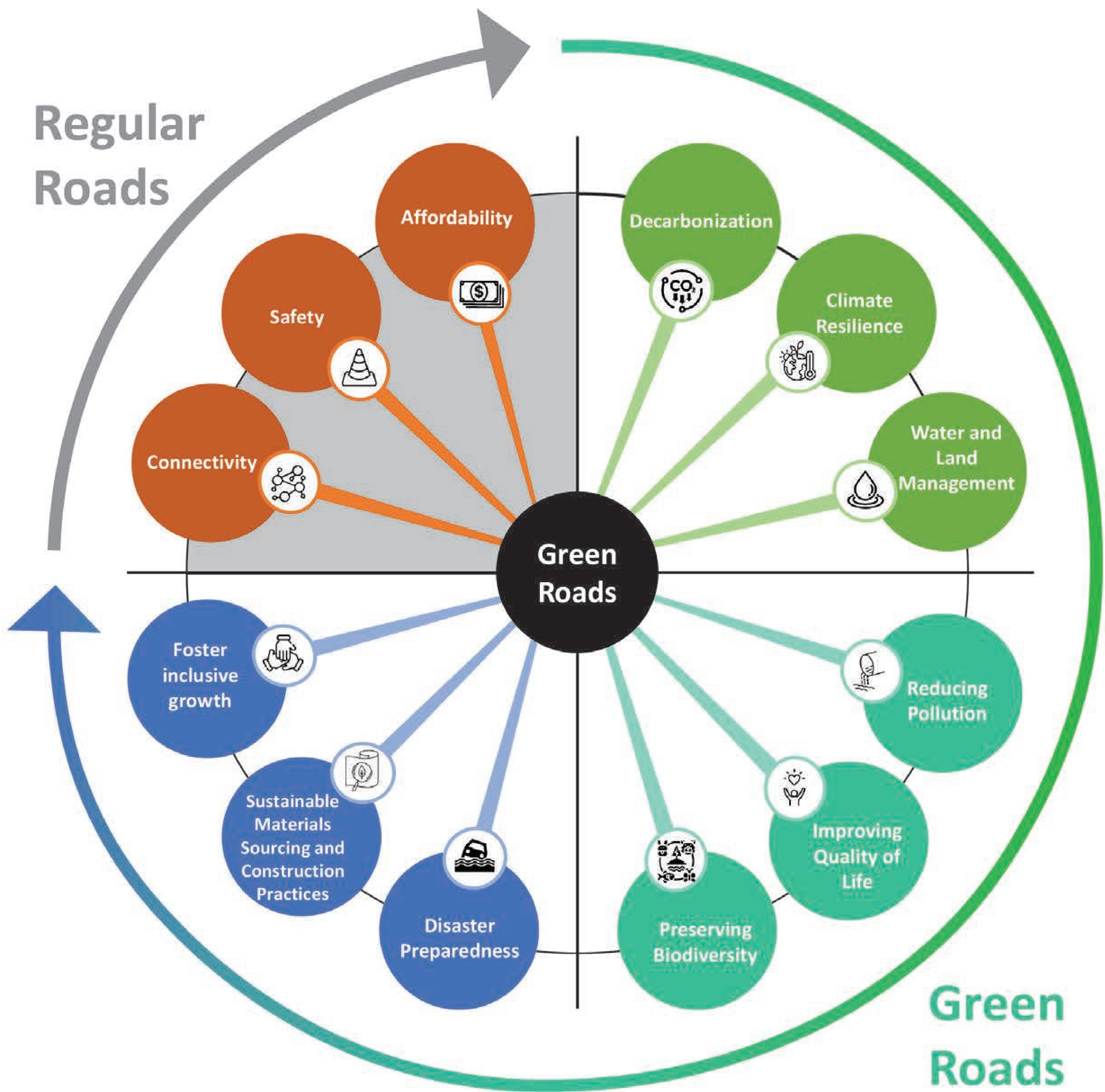
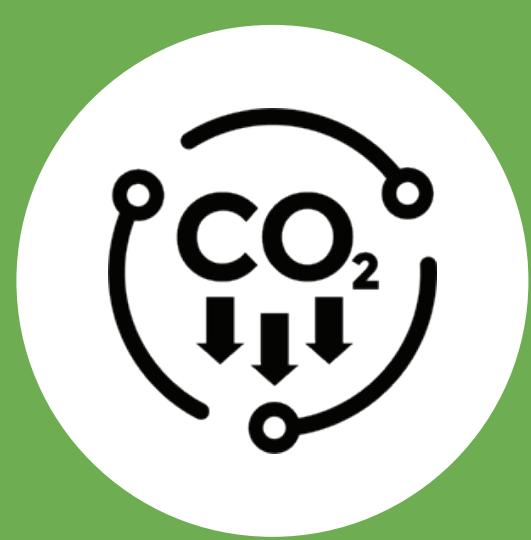
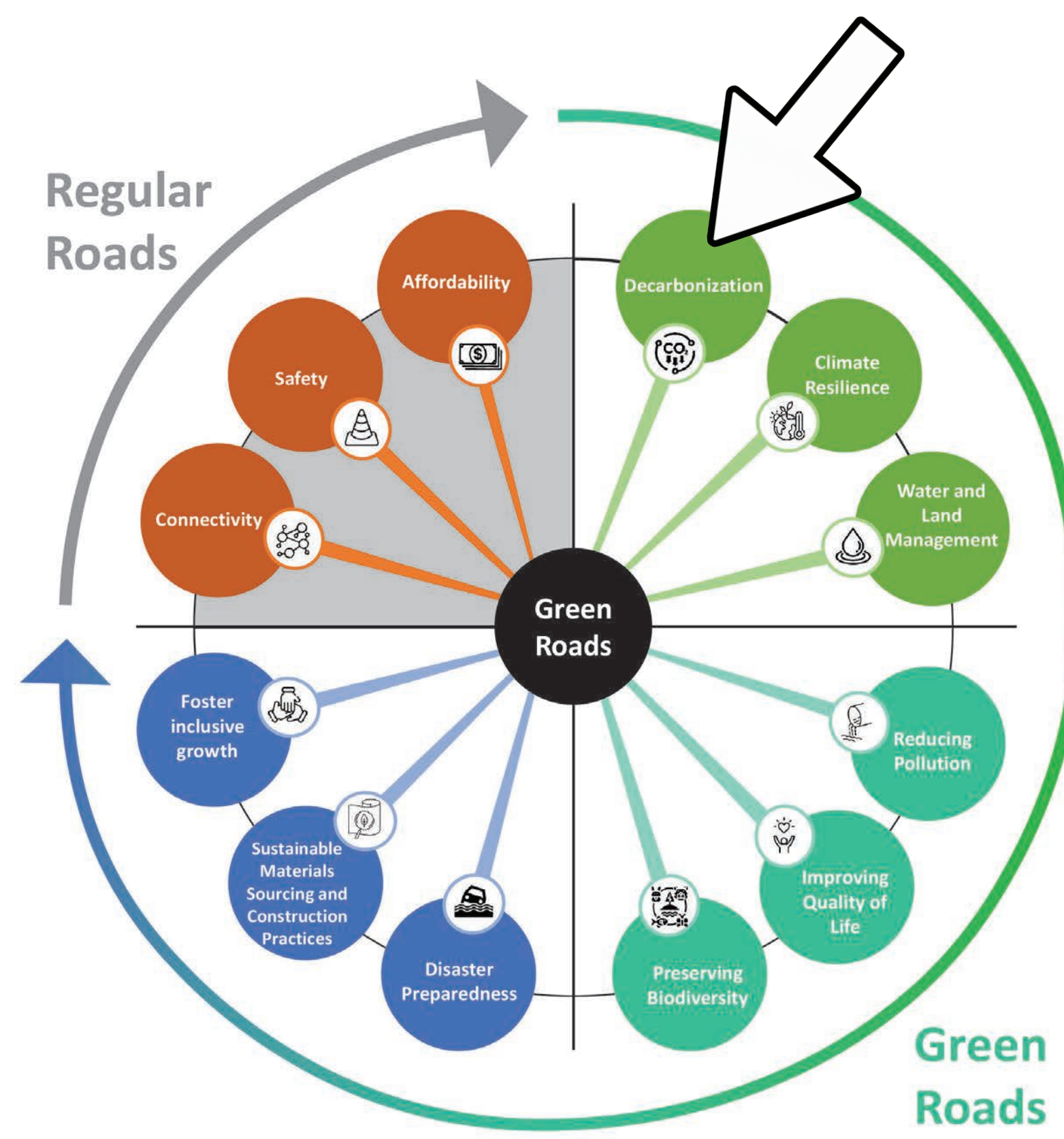
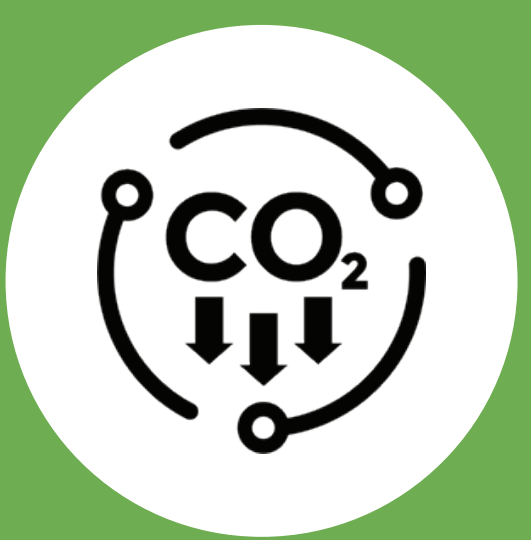


Green Roads Overview

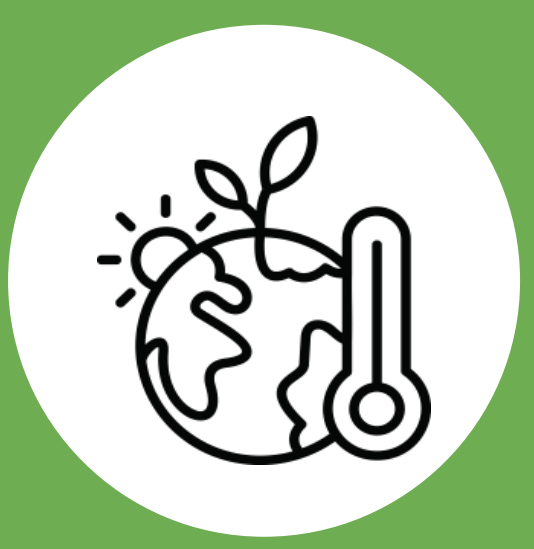




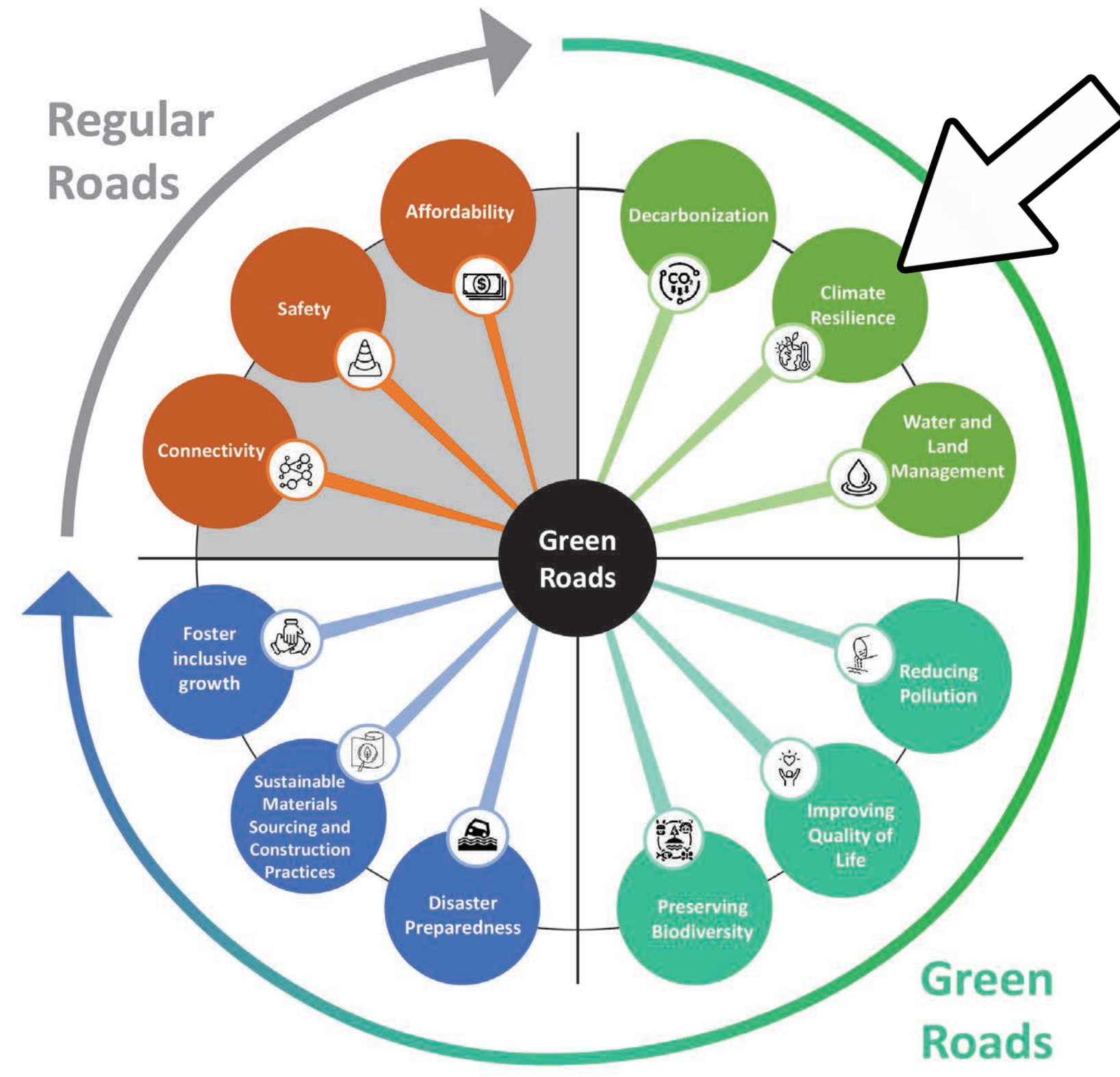
1. Decarbonization



	Key intervention areas:	Solution Areas
1.1.	Material production and transportation	<ul style="list-style-type: none"> to be discussed in table 8 'Sustainable Material Sourcing and Construction Practices'
1.2.	Design of roads and road appliances	1.2.1. Low carbon road specifications
		1.2.2. Using carbon sequestering road material (olivine)
		1.2.3. Reducing road friction - Smoother asphalt (incl ZOAB) reducing fuel consumption with factor 3-5%
		1.2.4. Energy generation with roads: solar panels (limited succeed, only on bicycle tracks), heat exchange with black-topped roads, thermo-electric generators)
		1.2.5. Use of energy-efficient LED lighting along roads and in tunnels
1.3.	Road construction	1.3.1. Asphalt mixture manufacturing technology
		1.3.2. Construction process energy substitution
		1.3.3. Recycling technologies
		1.3.4. Emerging and other technologies
1.4.	Road Transport Management	1.4.1. Encourage use of fuel-efficient vehicles
		1.4.2. Traffic management to limit peak hour congestion
		1.4.3. Optimize traffic signal timing
		1.4.4. Encourage movement to buses
		1.4.5. Reduce congestion
		1.4.6. Ordinances prohibiting idling of trucks
1.5.	Vegetative measures to sequester CO2	1.5.1. To be discussed in theme number 6 "Safeguarding biodiversity"
	Examples	Example of roadside tree planting in Bangladesh (see blog here)
		Example of calculating CO2 sequestration from roadside tree planting (see blog here)
		Exploring the use of olivine in road construction in New Zealand



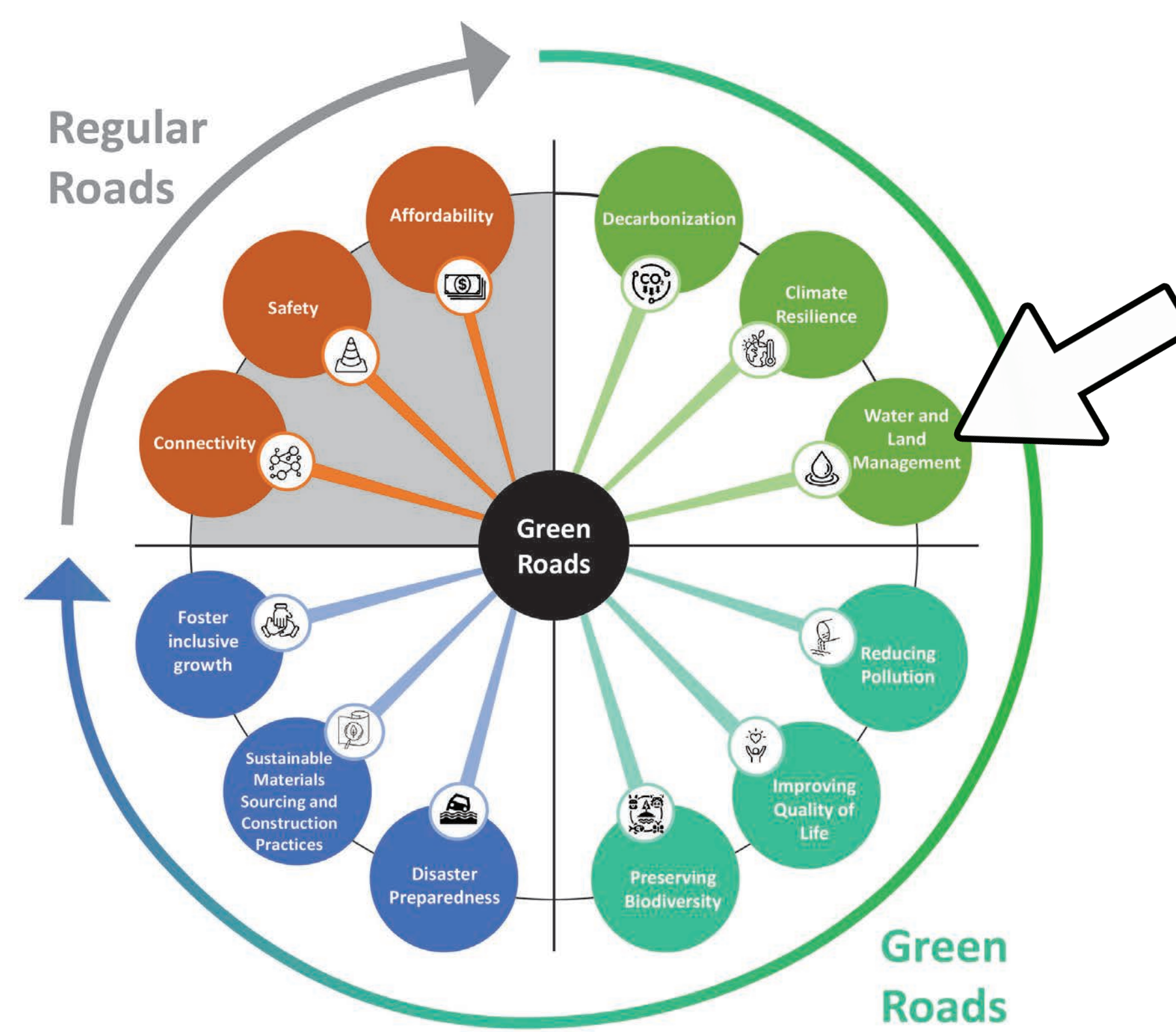
2. Climate Resilience



	Key intervention areas:	Solution Areas:
2.1.	Climate resilient road drainage design	2.1.1. Preventing stream diversion at road crossings
		2.1.2. Avoid using multiple small pipes
		2.1.3. Climate resilient culvert design
2.2.	Increased Stabilization of road sides	2.2.1. Complete ground cover in disturbed areas
		2.2.2. Deep-rooted vegetation for slope stabilization
		2.2.3. Hardening road embankments
		2.2.4. Preventing road surface water concentration
		2.2.5. Armoring the roadway driving surface
		2.2.6. Stabilization of unstable cut and fill slopes
2.3.	Resilient routing/avoiding vulnerable areas	2.3.1. Moving roads out of channel migration zones
2.4.	Resilient road maintenance	2.4.1. Staying current on road maintenance
2.5.	Landscape Management	<i>To be discussed in theme 3 "Water and Land Management"</i>
	Examples	<p>Use of the "Low-Volume Roads Engineering Best Management Practices Field Guide" http://pdf.usaid.gov/pdf_docs/Pnadb595.pdf</p> <p>Green Roads for Water : Guidelines for Road Infrastructure in Support of Water Management and Climate Resilience https://documents.worldbank.org/en/publication/documents-reports/documentdetail/102951623742853259/green-roads-for-water-guidelines-for-road-infrastructure-in-support-of-water-management-and-climate-resilience</p>



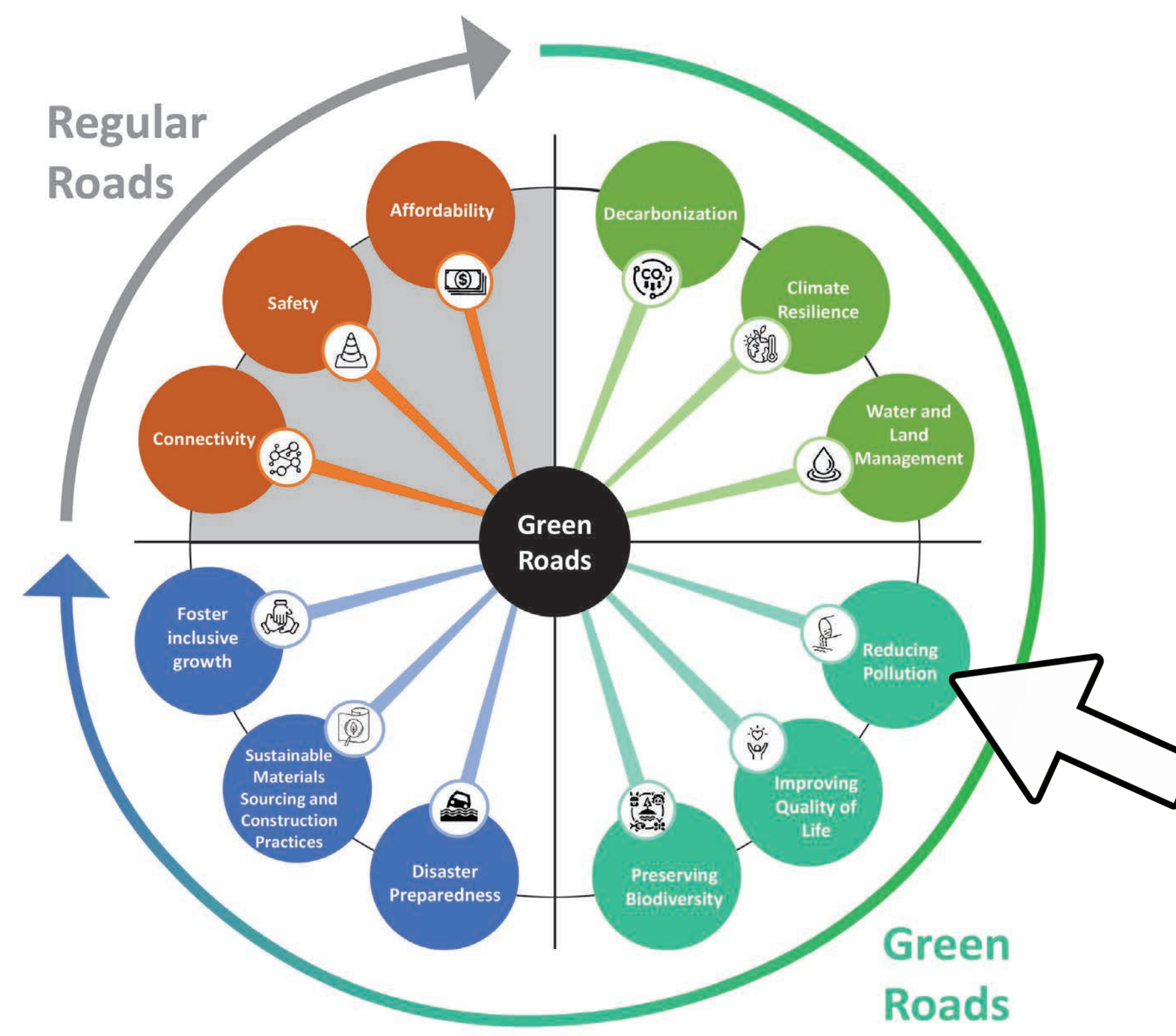
3. Water and Land Management



	Key intervention areas:	Solutions areas:	
3.1	Water harvesting and run-off storage	3.1.a. Diverting runoff to storage structures	3.1.1 Floodwater spreaders along road surfaces (relevant for arid, semi-arid areas)
			3.1.2 Directing water to retain ponds/ditches at the roadside (relevant for arid, semi-arid areas)
			3.1.3 Flow diversion from culverts and road drainage (relevant for arid, semi-arid areas)
		3.1.b. Storing Runoff	3.1.4. Infiltration structures fed from road drainage (relevant for arid, semi-arid areas)
			3.1.5 Surface storage fed from road drainage (repurposed borrow pits, ponds and cisterns)
			3.1.6 Using roads as reservoir embankments
3.2	Agricultural Water management	3.2.1 Cascading irrigation fed from road drainage (relevant for arid, semi-arid areas)	
		3.2.2 Connecting road drainage cuts to farm trenches	
		3.2.3 Controlled (gated) culverts	
		3.2.4 Fodder gardens along culvers in arid areas	
3.3	Groundwater management	3.3.1 Use of infiltration bunds for groundwater recharge along roadsides	
		3.3.2 Roadside spring protection and management (relevant for mountain areas)	
		3.3.3 Non vented road drifts as sand dams	
		3.3.4 Converting borrow pits to infiltration/groundwater recharge structures	
		3.3.5 Use of water harvesting measures upstream and downstream of the road	
3.4	Reduced waterlogging and protecting natural channels	3.4.1 Adequate cross drainage to prevent water concentration and adjusted bridge sills	
3.5	Preventing landslides	3.5.1 Avoiding most vulnerable areas	
		3.5.2 Catchment management in sensitive and unstable areas	
		3.5.3 Slope stabilization using hard measures and bio-engineering, vetiver planting, sludge-seeding, vegetated reinforced soil slopes	
		3.5.4 Using hybrid labor-intensive construction methods in vulnerable areas	
3.6	Erosion and Gully control	3.6.1 Road planning: dispersed cross drainage	
		3.6.2 Gully control	
3.7	Reducing sedimentation from road surfaces	3.7.1 Proper design of road slope, road crowns and surface drainage with frequent cross-drains in particular of unpaved roads	
		3.7.2 Road and road verge surface stabilization	
3.8	Avoiding sand dune movement	3.8.1 Disconnecting road alignment from prevailing wind direction	
		3.8.2 Windbreak and soil stabilization planting	
3.9	Green routing	3.9.1 <i>To be discussed in theme 2 "Climate Resilience, 2.3"</i>	
	Examples	Green Roads for Water : Guidelines for Road Infrastructure in Support of Water Management and Climate Resilience Series of roadside infiltration trenches with bund to intercept additional surface runoff in Tigray Ethiopia (photos)	



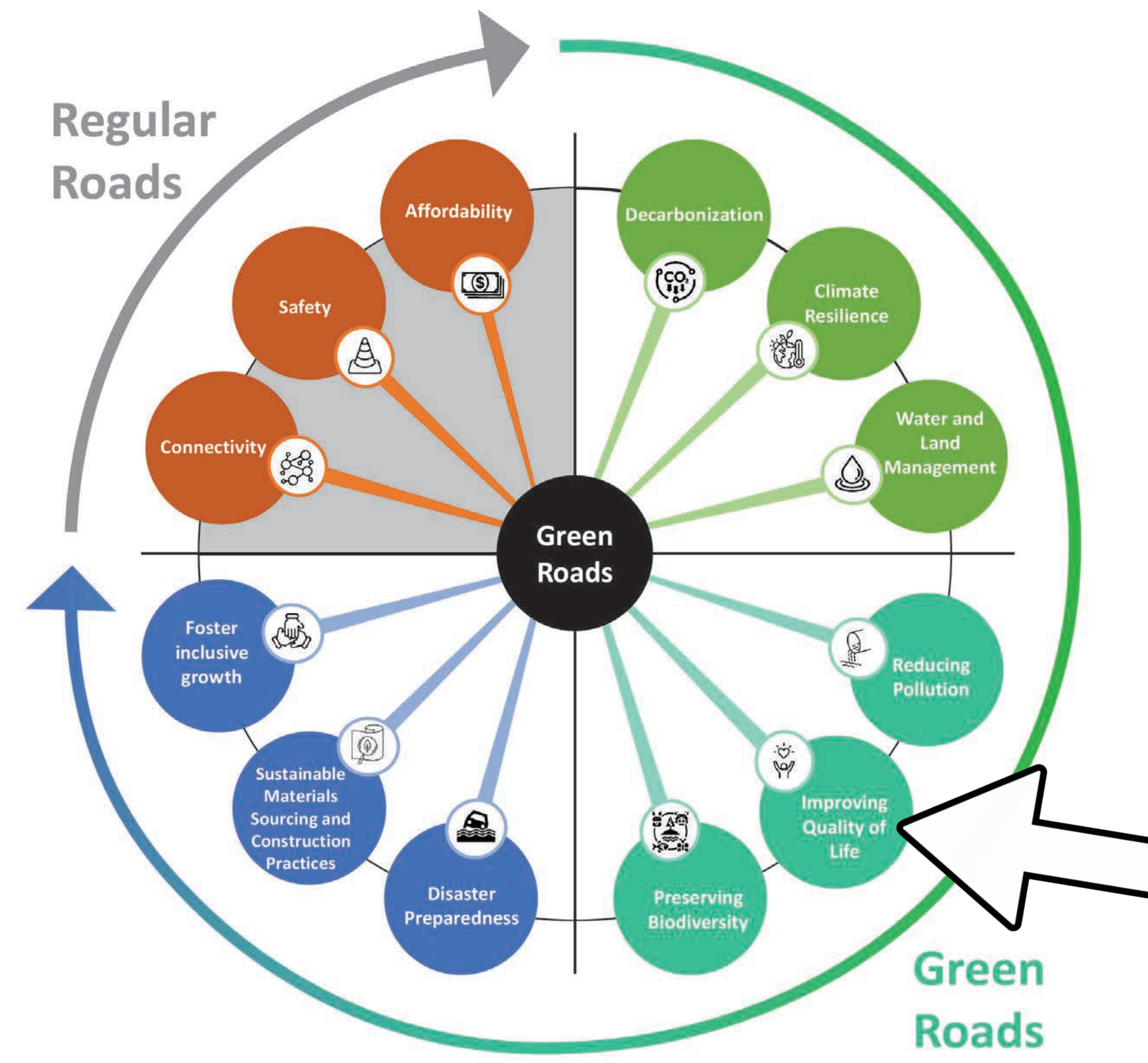
4. Reducing Pollution



	Key intervention areas:	Solutions areas:
4.1	Consider road construction materials	<p>4.1.1. Reduce to use the materials with high content of fine particles, Coal tar-based pavement sealants which contain PAHs for instance should be avoided. Avoid use of materials containing asbestos fibers</p> <p>4.1.2. Be aware of the additives used in road materials as they can be potential sources of pollutants in road runoff</p>
4.2	Source control: Minimize pollutants from vehicles	<p>4.2.1. Regulate traffic flows and avoid congestions</p> <p>4.2.2. Set minimum standards for vehicles and essential spare parts, fuel and oil composition and tires</p> <p>4.2.3. Implement anti-idling ordinances</p> <p>4.2.4. Enabling framework</p>
4.3	Road maintenance	4.3.1. Maintaining abrasion and erosion resistance in roads and roadside structures
4.4	Prioritize road drainage	<p>4.4.1. Avoid disposal of untreated road run-off near sensitive areas (groundwater recharge, open water bodies) areas to prevent potential contamination; prioritize controlled road drainage systems</p> <p>4.4.2. Porous pavements: Use porous asphalt to treat water quality</p> <p>4.4.3. Treat road effluent from controlled concentrated disposal systems through detention ponds, wet ponds, infiltration trenches, sand filters, grassed swales or constructed wetlands</p> <p>4.4.4. Incorporate frequent road surface drainage measures to prevent accumulation of water.</p>
4.5	Proper use of de-icing agents/traction agents	4.5.1. Controlling the use of salts under national regulations or limit their application to specific amounts and use precise short-term weather forecasts to decide whether to apply de-icing salts or not. Avoiding using traction agents that contain high concentrations of suspended particles and sediments
4.6	Capture and remove pollutants	<p>4.6.1. Planting roadside grass buffer filter strips to absorb dispersed road runoff pollutants. Keep deicing agents and dust palliatives out of water sources and streams.</p> <p>4.6.2. Planting roadside vegetation to intercept road dust and ambient pollutants taking into account distance from the road and aerodynamics</p> <p>4.6.3. Using special accumulator plants for bioremediation of soils along roads</p>
	Examples	<p>Infiltration into road shoulders, road embankments and grass side ditches</p> <p>Stormwater ponds and wetlands</p> <p>Sedimentation basins and centralized infiltration facilities</p> <p>Monitoring of micro-plastics Sweden</p> <p>Implement adequate road surface drainage measures to prevent the concentration of water on road surfaces and prevent erosion and sedimentation.</p>



5. Quality of Life



	Key intervention areas:	Solutions areas:
5.1	Dust control	5.1.1 Double layered permeable road-side vegetation, taking into account aerodynamics
		5.1.2 Providing road stabilization through towns or inhabited areas
		5.1.3 Binding agents on unpaved roads
5.2	Beautification	5.2.1 Regreening
		5.2.2 Coloured pavement
		5.2.3 Scenic roads, vantage points
		5.2.4 Roadside facilities, trash cans, rest areas, etc.
5.3	Noise control	5.3.1 Reducing noise from roads
5.4	Temperature control	5.4.1 Cool pavements as part of reducing urban heat islands
		5.4.2 Bike paths separating bicycles from vehicles
5.5	Traffic Safety	5.5.1 Raised pedestrian crossings to slow down vehicles
		5.5.2 Divided highways and road shoulder mowing
	Examples	Green Highway Program India 'Anyway' soil binders



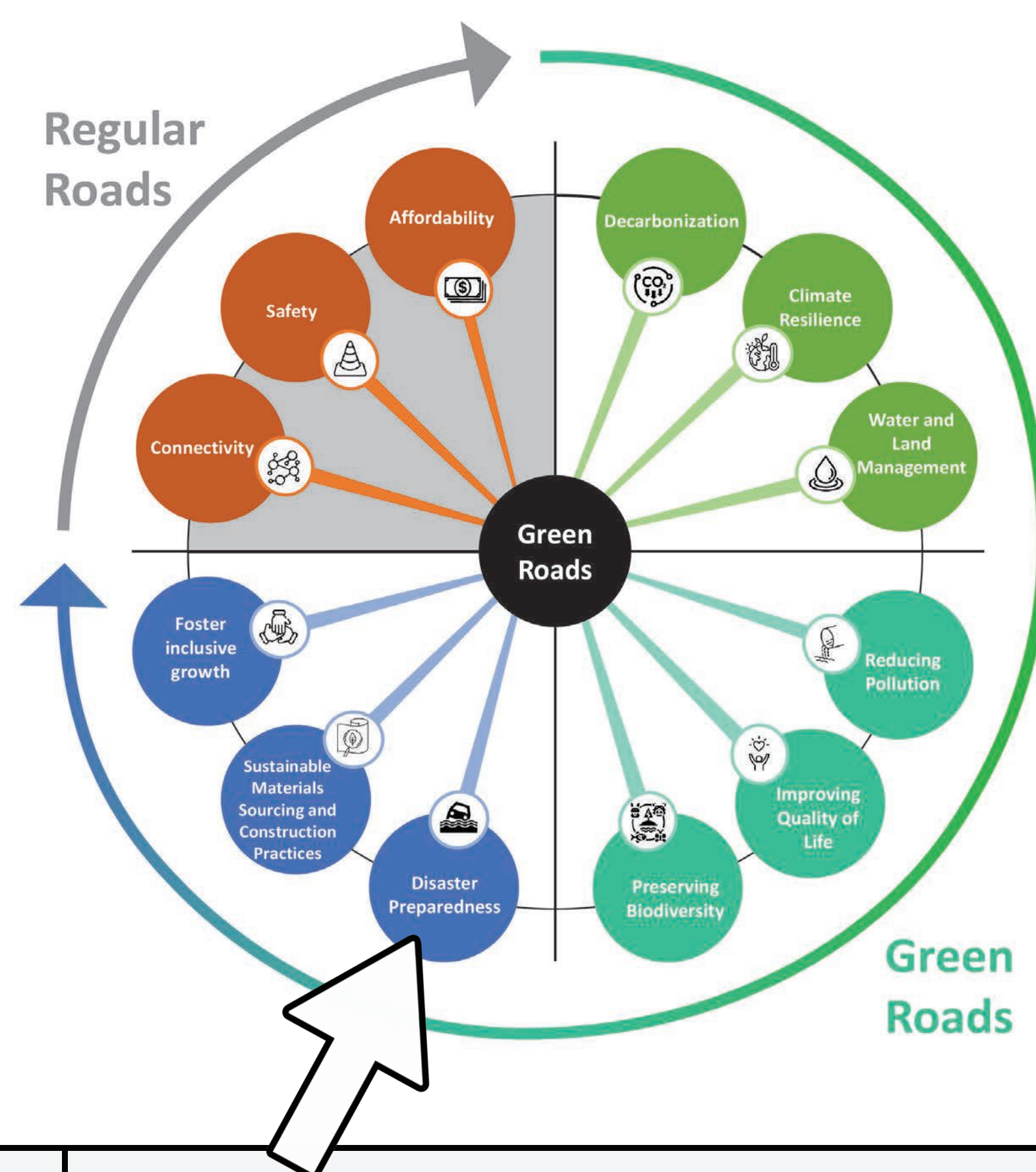
6. Preserving Biodiversity



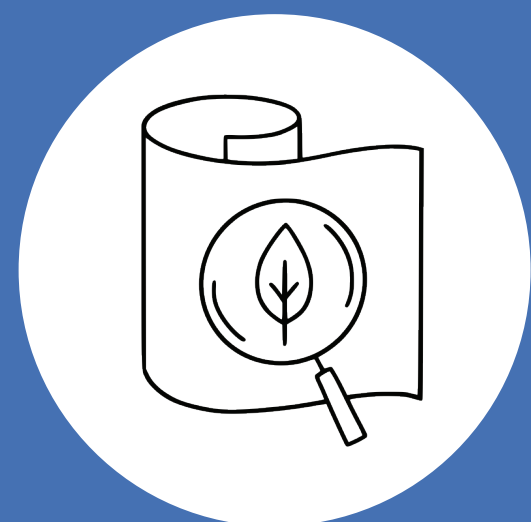
	Key intervention areas:	Solutions areas:
6.1	Protect and harness invertebra biodiversity	6.1.1. Habitat management
		6.1.2. Developing water points (with road water harvesting) away from roads
		6.1.3. Controlling of invasive plant species
		6.1.4. Native plant selection (habitat alteration)
		6.1.5. Ecologically safe road routing - To be discussed in theme 2 "Climate Resilience, 2.3"
		6.1.6. Butterfly nets
		6.1.7. Safe passages (culverts, climate tunnels) – also for migrations - combined with stump lines and stump walls
		6.1.8. Reduce light pollution
		6.1.9. Creating biodiversity corridors by linking road side tree planting with perpendicular hedges
6.2	Protect and harness vertebra biodiversity	6.2.1. Fencing of sensitive areas (91% effective) complemented with sign-posting and speed reduction measures
		6.2.2. Safe passages (culverts, ecoducts, wildlife overpasses and underpasses) - 63% effective - combined with landscaping, fencing and limiting human presence
		6.2.3. Road-side oases and mini-wetlands (fed by road water harvesting)
		6.2.4. Bridges to harbor species (like bats)
		6.2.5. Broken road-side vegetation to foster species diversity
6.3	Protect aquatic ecosystems	6.3.1 Culvert design (profile, bottom area) adjusted to fish passage
		6.3.2 Avoid alteration and sedimentation of streams that affect fishing grounds
6.4	Protect Improved roadside flora	6.4.1. Manage road-side verges and hedges, including the mowing (timing, removal) and pruning and Mowing practice
		6.4.2. Seeding and hydroseeding
	Examples	<ul style="list-style-type: none"> • Safe passage using culverts and overpasses/underpasses (Nepal, the Netherlands, Canada, US, Argentina) • Wildlife underpass in Pench National Park on National Highway 44, India • Controlling spread of ragweed through road network (Germany)



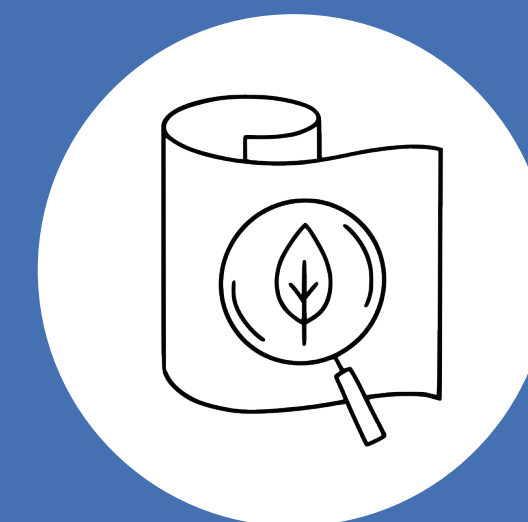
7. Disaster Preparedness



	Key intervention areas:	Solutions
7.1	Flood mitigation by road network	7.1.1. Flood compartmentalization by road and cross drainage infrastructure to slow down floods in controlled manner
		7.1.2. Roads-cum-flood embankments
		7.1.3. Permeable pavements in urban areas
		7.1.4. Prevent stream diversion at road-stream crossings
7.2	Flood resilience by road network	7.2.1 Elevated roads and bridges (adjusted to flood levels)
		7.2.2 Overflow roads
7.3	Road network capacity to deal with emergencies	7.3.1. Access routes, evacuation routes and redundant road systems
		7.3.2. Lifeline facilities
		7.3.3. Safe shelters and staged equipment to clear roads after a disaster
7.4	Evacuation and access plans	7.4.1 Emergency communications (signage and messaging)
		7.4.2 Traffic management
7.5	Fire prevention	7.5.1. Access for fire equipment and to serve as a fire break.
		7.5.2. Fire break along roads
		7.5.3. Use of fire resistance material
		7.5.4. Adequate drainage
	Examples	IRF Climate Resilient Roads training, FHWA Publications



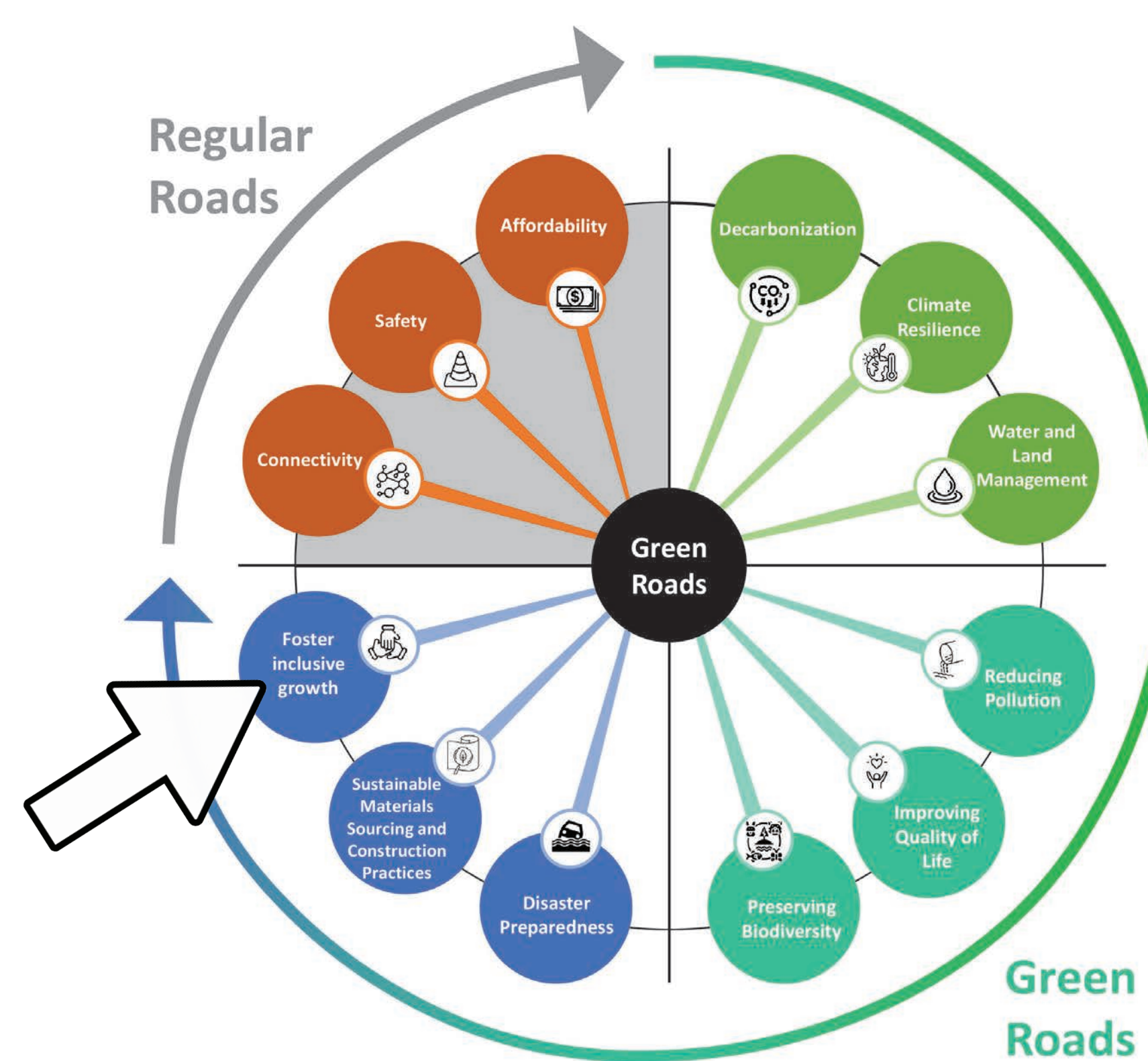
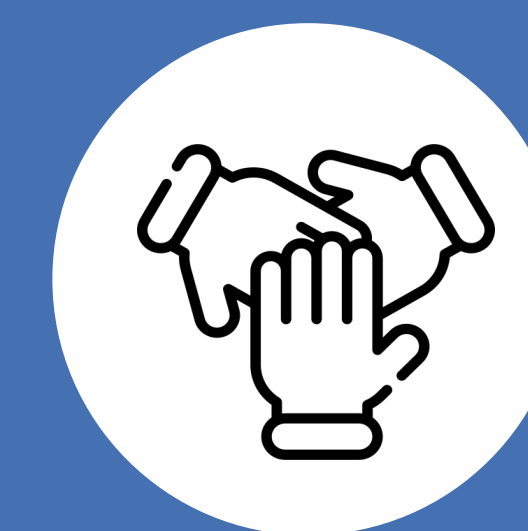
8. Sustainable Materials Sourcing and Construction Practices



	Key intervention areas:	Solutions areas:
8.1.	Design	8.1.1 Economical design
		8.1.2 Specifications for construction material and technique
		8.1.3 Technology choice: alternative to hot mix asphalt warm mix asphalt (and half warm and cool mix asphalts)
8.2.	Material choice	8.2.1 Efficient life-cycle use of material
		8.2.2 Safe use of recycled material (reclaimed asphalt pavement (RAP), construction and demolition (C&D) waste, waste rocks, glass, steel slag, cement dust, rice husk and straw, wood sawdust, waste plastic bags, crumb rubber, waste engine and cooking oils, composites)
		8.2.3 Use of bio-based material, such as self-healing asphalt, bio-oil rejuvenators, bio-based geotextile, bio-based road foundation, bio-degradable tree anchoring,
		8.2.4 Use of eco-friendly material (and eco-friendly working methods), use of lignite to replace asphalt. Use of jute mesh vs plastic netting
8.3	Sourcing	8.3.1 Avoid competition with other uses of scarce source material
		8.3.2 Reduce environmental costs of extraction and production: avoid sensitive areas
		8.3.3 Reduce haulage costs
		8.3.4 Repurposing of extraction sites (borrow pits, stone/clay removal) flat land-play fields,
8.4	Operation and Maintenance – tailored to Small Island material options	8.4.1 Have end-of-life strategy (reuse or safe removal) for existing roads
		8.4.2 Environmental analysis and reclamation plans for pits/quarries
		8.4.3 Stabilization of coral rock and sands
	Examples	<ul style="list-style-type: none"> • Phasing out of red bricks in construction in Bangladesh • Material choices (local, imported) in small island states. • Soil stabilization of coral aggregates • Chaplin project - testing lignite but also setting up entire production chain • Innovative procurement of new bio-based techniques in Zeeland (Netherlands) • Re-using sand and clay excavated from drainage canals for local road building in Bangladesh • Sourcing strategy in Malaysia Green Highway Index • Qatar - reuse strategy, central collection points



9. Fostering Inclusive Growth



	Key intervention areas:	Solutions areas:
9.1.	Local sourcing	9.1.1 Local fair sourcing of material (sand, gravel)
		9.1.2 Repurposing material excavated from water ways (drains, canals, rivers) for road construction
9.2.	Employment generation and local capacity building	9.2.1 Safety net programs and employment guarantee programs connected to road building
		9.2.2 Developing local road maintenance groups, community maintenance programs
		9.2.3 Using road building programs to support young local contractors (loans, capacity building, contracts, gender equality)
9.3.	Promoting road-side business	9.4.1 Assign road side land for business and industrial parks
9.4.	Ensuring last mile access	9.4.1. Motorcycle paths
		9.4.2. Trail bridges
9.5.	Safe management of construction site	9.5.1. Road construction is a major undertaking with considerable implications for the environment. There are several good practices that minimize negative impacts of construction activities such as (1) reuse of soil and spoil heaps and safe disposal of spoil heaps (2) using noise and dust screens (3) managing/ reducing haulage so as to minimize impact of construction traffic and (4) managing impact on habitat
9.6.	Gender and Indigenous population considerations	9.6.1. Promoting gender equality among workers
		9.6.2. Including indigenous populations in projects
	Examples	<ul style="list-style-type: none"> • Road maintenance groups and road construction groups in Nepal were a major source (30-40%) of local monetary income • Labour contracting societies in Bangladesh have been by decree to implement 25% of locally contracted works • Community-based road maintenance in Latin America (Costa Rica) • Sand harvesting groups Ethiopia • Effect of quality roads and maintenance on employment in Indonesia: https://www.youtube.com/watch?v=rWotnPpL_Ig&t=58s