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PROCEEDR
OPTIMISING RESOURCE USE FOR ROADSIDE INFRASTRUCTURES

A list/table of reasonable and representative assumptions of production, construction, maintenance, end-of-life as well as transportation processes of roadside infrastructure solutions

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AIT AUSTRIAN INSTITUTE OF TECHNOLOGY
CHALMERS UNIVERSITY OF TECHNOLOGY
ERF EUROPEAN UNION ROAD FEDERATION
TRL

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CEDR TRANSNATIONAL RESEARCH PROGRAMME
Call 2020: Resource Efficiency and the Circular Economy

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Author(s) of this deliverable:

Simin Tavajoh, Holger Wallbaum, Jieming Yan and Xingda Guo (Chalmers University of Technology)

Reviewer of this deliverable:

Alison Hewitt, TRL

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1 Introduction

The aim of this task is to define a set of reasonable and representative assumptions of production, construction, maintenance, end-of-life and transportation processes of roadside infrastructure solutions. Table 1 shows the considered roadside infrastructure solutions (noise and safety barriers) which have been defined in D1.2[1] report.

This report aims to establish a framework for conducting a thorough environmental Life Cycle Assessment (LCA) and Life Cycle Costing assessment (LCCA). As a result, expert estimations (see D2.1 report[1]) and different Environmental Product Declarations (EPDs) serve as a foundation for breaking down each barrier into their consisting elements and materials (Table 2).

Table 1 Considered noise and safety barriers

Noise barrier types	
SM	Steel supporting structure + Metal panels
SP	Steel supporting structure with plastic panels
ST	Steel supporting structure + Transparent modules
SC	Steel support structure + Concrete panels
SW	Steel supporting structure + Wooden panels
CB	Self-supporting concrete or brick system
GB	Green barrier
Safety barrier types	
SB	Steel safety barrier
WB	Mixed wood steel safety barrier
PB	Precast concrete safety barrier
IB	Integrated noise safety barrier

[1] https://proceedr.project.cedr.eu/publications/

Table 2 Noise and safety barriers' elements and materials

Noise barriers			
Element	**Type**	**Materials**	
Foundation	SM, SP, ST, SC, SW, CB, GB	Concrete (single/strip) or Steel core piling	Precast concrete Steel core piling
Post	SM, SP, ST, SC, SW, GB	Steel	Steel profile (HEB, IPE or HFRHS) and Steel base plate
Acoustic Panels	SM	Aluminium+ Stone wool/ Polystyrene	• Cassette aluminium alloy, • Stone wool panel/ Polystyrene foam panel, • Polypropylene end cap element • Side gasket EPDM type (Rubber)
	SP	PVC+ Stone wool/ Polystyrene	• Cassette PVC, • Stone wool panel/ Polystyrene foam panel, • Polypropylene end cap element • Side gasket EPDM type (Rubber)
	ST	Polycarbonate/ Safety glass	• Polycarbonate panel/ Safety glass • U-shape steel profile • Clamping profile • Rubber
	SC	Concrete+ Expanded clay/ Wooden mineralized chips	• Concrete (C30-37), • Expanded clay light concrete/ Wooden mineralized chips light concrete, • Bolts, self-perforating screw rivets

	SW	Wood+ Stone wool/ Polystyrene	• Wooden structural beam • Wooden boards • Stone wool panel • Bolts, self-perforating screw rivets
	CB	Steel Gabions	• Reinforced galvanized steel, • Natural stone plate
	GB	Reed+ Clay or Earth+ Greenery	• Reed • Clay • Themo wood or • Steel net + Supporting structure, • Soil, • Coco netting, • vegetation
Safety barriers			
Element	**Type**	**Material**	
Post	SB	Steel	U-shape Steel profile
	WB	Wood+ Steel	• IPE 140 Steel profile • Pressure-treated wood
Railing	SB	Steel	W-shape Steel profile
	WB	Wood+ Steel	• U-shape steel profile • Pressure-treated wood
	PB	Precast Concrete	Precast reinforced concrete
	IB	In situ Concrete	Ready-mix concrete (C30-C37)

2 Representative data for noise and safety barriers

The used life cycle inventory database is ecoinvent 3.9.1. https://ecoinvent.org/the-ecoinvent-database/data-releases/ecoinvent-3-9-1/ The market provider has been chosen to cover average transportation modes within each process and to avoid inaccurate assumptions. The geographical boundary is Europe. However, if providers within Europe were not available, a global provider can be chosen. In case of unavailability of the exact material in the database, substitute materials or processes have been considered for both virgin and secondary materials. All the assumed materials and processes for production from virgin material can be found in Table 3 and for production from secondary materials in Table 4. The default proportion of secondary materials udedd in production is presented in Table 5.

The default transportation mode for carrying products to the installation site and for carrying them after the end of life to the recycling or waste processing centre is “lorry, unspecified” which is representative of the average value of different kinds of lorry in Europe. However, various kinds of transportation modes have been considered should specific data be available (Table 6).

For installation and dismantling, the estimation of machinery fuel consumption is presented in Table 7. Maintenance consists of regular cleaning and module replacement after element end of life (production, transportation, and installation of each element). For cleaning, consumed water and detergent have been considered (Table 7).

After end-of-life, materials can be disposed or recovered for secondary use of material or energy usage. In the case of disposal, common waste treatment for those materials has been taken into account (Table 8).

Table 3 Inventory data for virgin material processing

Material	**Chosen material/activity from Database**	**Provider/Market**	**Assumption/ Reference**
Foundation concrete	Concrete, 25MPa	Market | RoW (Rest of World)	
	Steel, low-alloyed (1% of concrete mass for reinforcing)	Steel production, converter, low-alloyed | RER (Rest of Europe)	Process description in ecoinvent (primary steel production).
	Hot rolling, steel	Market | GLO (Global)	
Galvanized steel profile	Steel, low-alloyed	Steel production, converter, low-alloyed | RoW	Process description in ecoinvent (primary steel production).
	Sheet rolling, steel	Market | GLO	
	Zinc coat, pieces	Market | GLO	The average surface per 1 kg steel assumed to be 0,03 m^2 (based on different kinds of profile has been assumed).
Cassette aluminum alloy	Aluminum, primary, cast alloy slab from continuous casting	Market | GLO	
Stone wool panel	Stone wool, packed	Market | GLO	
End cap elements polypropylene	Polypropylene, granulate	Market | GLO	
	Extrusion of plastic sheets and thermoforming, inline	Market | GLO	

Side gasket EPDM type	Synthetic rubber	Market | GLO	
Polystyrene	Polystyrene, expandable	Market | GLO	
PVC	Polyvinylchloride, bulk polymerized	Market | GLO	
Polycarbonate	Polycarbonate	Market | GLO	
Glass	Flat glass, uncoated	Market | RER	
	Tempering, flat glass	Market | GLO	
Bolt, screw	Steel, low-alloyed	Steel production, converter, low-alloyed | RER	Process description in ecoinvent (primary steel production).
	Section bar rolling, steel	Market | GLO	
	Zinc coat, pieces	Market | GLO	The average surface per 1 kg steel assumed to be 0,04 m^2.
Expanded clay light concrete	Lightweight concrete block, expanded clay	Market | RoW	
Wooden mineralized chips light concrete	Cement, Portland	Market | Europe without Switzerland	
	Lime mortar	Market | GLO	
	Wood chips, dry, measured as dry mass	Market | RER	
Wooden structural beam	Structural timber	Market | RER	
Wooden boards of pine, fir, larch essence	Sawnwood, board, softwood, dried (u=10%), planed	Market | Europe without Switzerland	

Reinforced galvanized Steel	Steel, low-alloyed	Steel production, converter, low-alloyed | RER	Process description in ecoinvent (primary steel production).
	Wire drawing, steel	Market | GLO	
	Zinc coat, pieces	Market | GLO	The average surface per 1 kg steel assumed to be 0,05 m^2.
Natural stone plate	Natural stone plate, cut	Market | GLO	
Reed	Straw	Market | RER	
Clay	Light clay brick	Market | GLO	It's a combination of 1 kg clay + 0,162 kg straw.

	Straw (excluded[1])	Market | RER	Subtracting the straw amount.
Thermal wood	Sawnwood, beam, softwood, dried (u=10%), planed	Market | Europe without Switzerland	
Steel net & supporting structure	Steel, low-alloyed	Steel production, converter, low-alloyed | RoW	Process description in Ecoinvent (primary steel production).
	Wire drawing, steel	Market | GLO	For Steel net.
	Sheet rolling, steel	Market | GLO	For Steel structure.
	Zinc coat, pieces	Market | GLO	The average surface per 1 kg steel assumed to be 0,05 m^2.

[1] In the database, "Light clay concrete" consisting of clay and straw. Therefore, to measure just the environmental impact of clay, the amount of straw has been excluded.

Soil	Excavation, skid-steer loader	Market for excavation | GLO	
	Transport, freight, lorry, unspecified	Market for transport | RER	Soil will be carried for 5 km.
Coco netting	Coconut husk	Market | GLO	
Vegetation	Grass, organic	Market | GLO	
Pressure-treated wood	Sawn wood, softwood, raw	Market | GLO	
	Wood preservation, pressure vessel, creosote, outdoor use, ground contact	Market | GLO	
Ready-mix concrete (C30-C37)	Concrete, 35MPa	Market | RoW	

Table 4 Inventory data for secondary material processing

Market	Chosen material/activity from Database	Provider/ Market	Assumption/ Reference Reference
Foundation concrete	Concrete, 25MPa	Market | RoW	55 to 80% of the concrete mass is aggregate. The energy consumption of producing recycled aggregate is negligable (less than one per cent of concrete production) (Visintin et al., 2020). Therefore for recycled concrete, concrete production will be calculated - gravel and sand production (natural aggregates).
	Gravel, round (excluded[1] from concrete production)	Market | RoW	
	Sand (excluded from concrete production)	Market | RoW	
Galvanized steel profile	Steel, low-alloyed	Steel production, electric, low-alloyed | Europe without Switzerland and Austria	Process description in ecoinvent (secondary steel production).
	Sheet rolling, steel	Market | GLO	
	Zinc coat, pieces	Market | GLO	
Cassette aluminum alloy	Aluminum scrap, post-consumer, prepared for melting	Market | GLO	
	Market group for electricity, medium voltage	Market | Europe without Switzerland	Aluminium scrap processing energy consumption: 6,07 MJ/kg (Adeniji & Waheed, 2021).

[1] The term "excluded" is recurrent, specifically referring to the portion of virgin material intended to be replaced by secondary material in the product. Consequently, this portion is omitted from the database, aligning with the cut-off allocation method. Under this method, the environmental impact of each material is allocated to the initial usage cycle, and subsequent cycles only account for the environmental impacts associated with the recycling process.

Stone wool panel	Market group for electricity, medium voltage	Market | Europe without Switzerland	Energy consumption: 6,66 MJ for 1 kg stone wool (Väntsi & Kärki, 2015).
	Tap water	Market | Europe without Switzerland	Water consumption: 5,6 kg for 1 kg stone wool (Väntsi & Kärki, 2015).
End cap elements polypropylene, Rubber, Polystyrene, PVC and Polycarbonate	Market group for electricity, low voltage	Market | Europe without Switzerland	Plastic mechanical recycling electricity consumption: 324,18 kWh/ton Water Consumption: 136 L/ton (Santos et al., 2021).
	Tap water	Market | Europe without Switzerland	
	Extrusion of plastic sheets and thermoforming, inline	Market | GLO	
Glass	Glass cullet, sorted	Treatment of waste glass from unsorted public collection, sorting | RER	
	Electricity, medium voltage	Market group for electricity, medium voltage | RER	6,54 MJ for remelting 1 kg cullet (Hartwell et al., 2022).
	Tempering, flat glass	Market | GLO	
Bolt, Screw	Steel, low-alloyed	Steel production, electric, low-alloyed | Europe without Switzerland and Austria	Process description in ecoinvent (secondary steel production).
	Section bar rolling, steel	Market | GLO	
	Zinc coat, pieces	Market | GLO	
Expanded clay light Concrete	Lightweight concrete block, expanded clay	Market | RoW	90% expanded clay and 10% cement.

	Expanded clay (excluded from concrete production replaced by post-consumer expanded clay)	Market | GLO	
Wooden mineralized Chips light concrete	Cement, Portland	Market | Europe without Switzerland	Wooden chips can be provided and used from recycled chips.
	Lime mortar	Market | GLO	
	Wood chips, dry, measured as dry mass (excluded from concrete production, will be replaced by post-consumer wood chips)	Market | RER	
	Wood chips, from post-consumer wood, measured as dry mass	Market |RER	
Wooden structural beam	Structural timber	Market | RER	Downcycled to be used in other industries or as fuel (Material recovery or energy recovery) (Besserer et al., 2021).
	Wood chips, from post-consumer wood, measured as dry mass (9.99 MJ/Kg based on ecoinvent)	Market | RER	
	Wood chips, dry, measured as dry mass (excluded, will be replaced by post-consumer wood chips)	Market for wood chips, dry, measured as dry mass | RER	
Wooden boards of pine, fir, larch essence	Sawnwood, board, softwood, dried (u=10%), planed	Market | Europe without Switzerland	Downcycled to be used in other industries or as fuel (Besserer et al., 2021).

	Wood chips, from post-consumer wood, measured as dry mass (9.99 MJ/Kg based on ecoinvent)	Market | RER	
	Wood chips, dry, measured as dry mass (excluded, will be replaced by post-consumer wood chips)	Market for wood chips, dry, measured as dry mass | RER	
Reinforced Galvanized Steel	Steel, low-alloyed	Steel production, electric, low-alloyed | Europe without Switzerland and Austria	Process description in ecoinvent (secondary steel production).
	Wire drawing, steel	Market | GLO	
	Zinc coat, pieces	Market | GLO	
Natural Stone Plate	–	–	Natural stone can be either reused or construction waste can be crushed to be used to fill gabion (less than 1% of virgin stone production, which is neglectable(Visintin et al., 2020).
Clay	Light clay brick	Market | GLO	Based on EPD[1], they will be crushed to be used on other systems.
	Waste brick	Treatment of waste brick, recycling | RoW	
	Clay (excluded, will be replaced by waste brick)	Market for clay | RoW	
	Straw (excluded, subtracting the straw amount from light clay brick)	Market | RER	

[1] https://api.environdec.com/api/v1/EPDLibrary/Files/0cbd0b42-8096-4ad3-74ff-08dba3f6d3f1/Data

Thermal Wood	Sawnwood, beam, softwood, dried (u=10%), planed	Market | Europe without Switzerland	Downcycled to be used in other industries or as fuel (Besserer et al., 2021).
	Wood chips, from post-consumer wood, measured as dry mass (9.99 MJ/Kg based on ecoinvent)	Market | RER	
	Wood chips, dry, measured as dry mass (excluded will be replaced by post-consumer wood chips)	Market for wood chips, dry, measured as dry mass | RER	
Steel net & supporting structure	Steel, low-alloyed	Steel production, electric, low-alloyed | Europe without Switzerland and Austria	Process description in Ecoinvent (secondary steel production).
	Wire drawing, steel	Market | GLO	For Steel net.
	Sheet rolling, steel	Market | GLO	For Steel structure.
	Zinc coat, pieces	Market | GLO	The average surface per kg based on different kinds of profiles and wires.
Pressure-treated Wood	Sawnwood, softwood, raw	Market | GLO	Downcycled to be used in other industries or as fuel (Material recovery or energy recovery) (Besserer et al., 2021).
	Wood preservation, pressure vessel, creosote, outdoor use, ground contact	Market | GLO	
	Wood chips, from post-consumer wood, measured as dry mass (9.99 MJ/Kg based on Ecoinvent)	Market | RER	

	Wood chips, dry, measured as dry mass (excluded, will be replaced by post-consumer wood chips)	Market for wood chips, dry, measured as dry mass | RER	
Ready-mix Concrete (C30-C37)	Concrete, 35MPa	Market | RoW	55 to 80% of the concrete mass is aggregates. The energy consumption of producing recycled aggregates is neglectable (less than one per cent of concrete production) (Visintin et al., 2020). Therefore for recycled concrete, concrete production will be calculated - gravel and sand production (natural aggregates).
	Gravel, round (excluded from concrete production)	Market | RoW	
	Sand (excluded from concrete production)	Market | RoW	

Table 5 Default proportion of secondary material used in production stage.

Materials	%	Assumption/ Reference
Concrete	30%	55 to 80% of the concrete mass is aggregate. Based on studies, to keep the mechanical performance of concrete, up to 30% (or 50%) of total aggregate can be made of recycled aggregate[1] (Pavlů et al., 2019).
Steel	90%	European steel producers have reached a the byproduct recycling rate of up to 95% (Rieger & Schenk, 2019). (In steel EPD this number varies between 90-95%)
Aluminum	87,50%	The global aluminum recycling fractions for scrapped parts from the transportation and building sectors, with their characteristically long lifetimes, range between 80% and 95% depending on region (differences are mainly due to market access and logistics) (Raabe et al., 2022).
Stone wool	25%	Based on one of manufacturers' sustainability reports[2]
End cap elements polypropylene	2,50%	Average recycling rate for different kinds of plastic. In construction sector in Sweden (Fråne et al., 2020).
(Side gasket EPDM type) Rubber		
Polystyrene		
PVC		
Polycarbonate		
Glass	0%	Flat glass manufacturers typically operate at < 1% post-consumer cullet in England and Sweden, (Hartwell et al., 2023; Forslund & Björklund, 2022). However, using recycled content in flat glass is technically feasible up to 30% (Westbroek et al., 2021).

[1] This percentage indicates the extent to which natural aggregate can be substituted with recycled aggregate in the closed-lope recycling of concrete, while still maintaining the acceptable properties of the concrete.
[2] https://www.Stone wool.com/en-cn/about-us/sustainability-local/

Expanded clay light concrete	0%	It is 100% recyclable without changing its mechanical properties (Bogas et al., 2015). However, the EPD[1] of manufacturers shows they are using 100% virgin material, but they suggest 80% recycling for the end-of-life scenario (the same assumption has been applied here).
Wooden mineralized chips light concrete	38%	Wood chips which constitute 38% of concrete are from recycled wood.[2] [3]
Wood	0%	Wooden beam and boards are from virgin materials however after end of life they will be downcycled (wooden chips) to be used in other industries or as fuel (30%: Material recovery and 30% energy recovery) (Besserer et al., 2021).
Natural Stone Plate	50%	It can be 100% from used stone. However, the side which faces the street is better filled with virgin stone to fulfil the aesthetic requirement.

[1] https://www.finja.se/storage/ma/27686bd061f94c958d6b53f482616920/76dc4fa4f11742cc9dbe311541a6802a/pdf/A84FE848DA8B526D340DA59F3A9E7C3DEA5781AE/Murblock%20Bas%20ECO_epd_sv.pdf
[2] https://api.environdec.com/api/v1/EPDLibrary/Files/9bfbe948-e473-4931-aae4-46076499a750/Data
[3] https://www.epditaly.it/en/epd/blocchi-di-cemento-con-trucioli-di-legno/

Table 6 Transportation modes

Chosen transportation mode from database	**EURO**	**Provider/ Market**
Freight, lorry 3.5-7.5 metric ton	EURO3,4,5,6	RER
Freight, lorry 7.5-16 metric ton	EURO3,4,5,6	RER
Freight, lorry 16-32 metric ton	EURO3,4,5,6	RER
Freight, lorry >32 metric ton	EURO3,4,5,6	RER
Freight, lorry, unspecified	Average of all	RER
Freight, sea, ferry	-	RER
Freight train	-	RER
Freight, aircraft, unspecified	-	RER

Table 7 Inventory data for installation, dismantling and maintenance

Life cycle stage	**Chosen material/activity from Database**	**Provider/Market**	**Assumption/Reference**
Installation (A5)	Diesel, burned in building machine	Market | GLO	Estimated machineries'[1][2] [3][4]fuel consumption for drilling, post setting, lifting, and setting panels (20,77 kWh/m^2 for Noise barrier and 0,7 kWh/m for Safety barrier).
Cleaning (Maintenance: B2)	Tap water	Market | Europe without Switzerland	
	Cleaning consumables, without water, in 13.6% solution state	Market | GLO	
Dismantling (C1)	Diesel, burned in building machine	Market GLO	Energy consumption: 50% of installation.[5]

[1] https://www.bsp-if.com/clientfiles/files/datasheets/JX%20Piling%20Rig%20Range%20V1.pdf
[2] https://www.jcb.com/en-gb/products/telescopic-handlers/532-60-agri
[3] https://www.vermeer.com/na/pile-drivers/pd5r
[4] https://vermeer-want.com.au/machinery/pd10-solar-pile-driver/
[5]https://www.rics.org/profession-standards/rics-standards-and-guidance/sector-standards/construction-standards/whole-life-carbon-assessment

Table 8 Inventory data for waste processing and treatment

Materials	**Chosen material/activity from Database**	**Provider/Market**
Foundation concrete	Waste reinforced concrete	Treatment of waste reinforced concrete, collection for final disposal | Cutoff, U - Europe without Switzerland
Steel	Scrap steel	Treatment of scrap steel, municipal incineration | Europe without Switzerland
Cassette aluminum alloy	Scrap aluminum	Treatment of scrap aluminum, municipal incineration | Europe without Switzerland
Stone wool panel	Waste mineral wool	Treatment waste mineral wool, inert material landfill | Europe without Switzerland
End cap elements polypropylene	Waste polypropylene	Treatment of waste polypropylene, municipal incineration | RoW
(Side gasket EPDM type) Rubber	Waste rubber, unspecified	Treatment of waste rubber, unspecified, municipal incineration | Europe without Switzerland
Polystyrene	Waste expanded polystyrene	Treatment of waste expanded polystyrene, municipal incineration | Cutoff, U - RoW
PVC	Waste polyvinylchloride	Treatment of waste polyvinylchloride, municipal incineration | Cutoff, U - RoW
Polycarbonate	Waste plastic, mixture	Treatment of waste plastic, mixture, municipal incineration | Cutoff, U - RoW
Glass	Waste glass sheet	Treatment of waste glass sheet, collection for final disposal | Europe without Switzerland
Expanded clay light concrete, Wooden mineralized chips light concrete	Waste concrete	Treatment of waste concrete, inert material landfill | Cutoff, U - Europe without Switzerland

Wooden structural beam, Wooden boards of pine, fir, larch essence, Thermal Wood and Pressure-treated Wood	Waste wood, untreated	Treatment of waste wood, untreated, municipal incineration | RoW
Natural stone plate	Limestone residue	Treatment of limestone residue, inert material landfill | Cutoff, U - RoW
Reed, coco netting and vegetation	Biowaste	Treatment of biowaste, municipal incineration | Cutoff, U - GLO
Clay	Waste brick	Treatment of waste brick, collection for final disposal | RoW
Soil	Eexcavation, skid-steer loader	Market for excavation | GLO
	Transport, freight, lorry, unspecified (Assumed to be carried for 5 kg)	Market for transport | RER
Ready-mix Concrete (C30-C37)	Waste concrete, not reinforced	Treatment of waste concrete, not reinforced, collection for final disposal | Cutoff, U - Europe without Switzerland

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