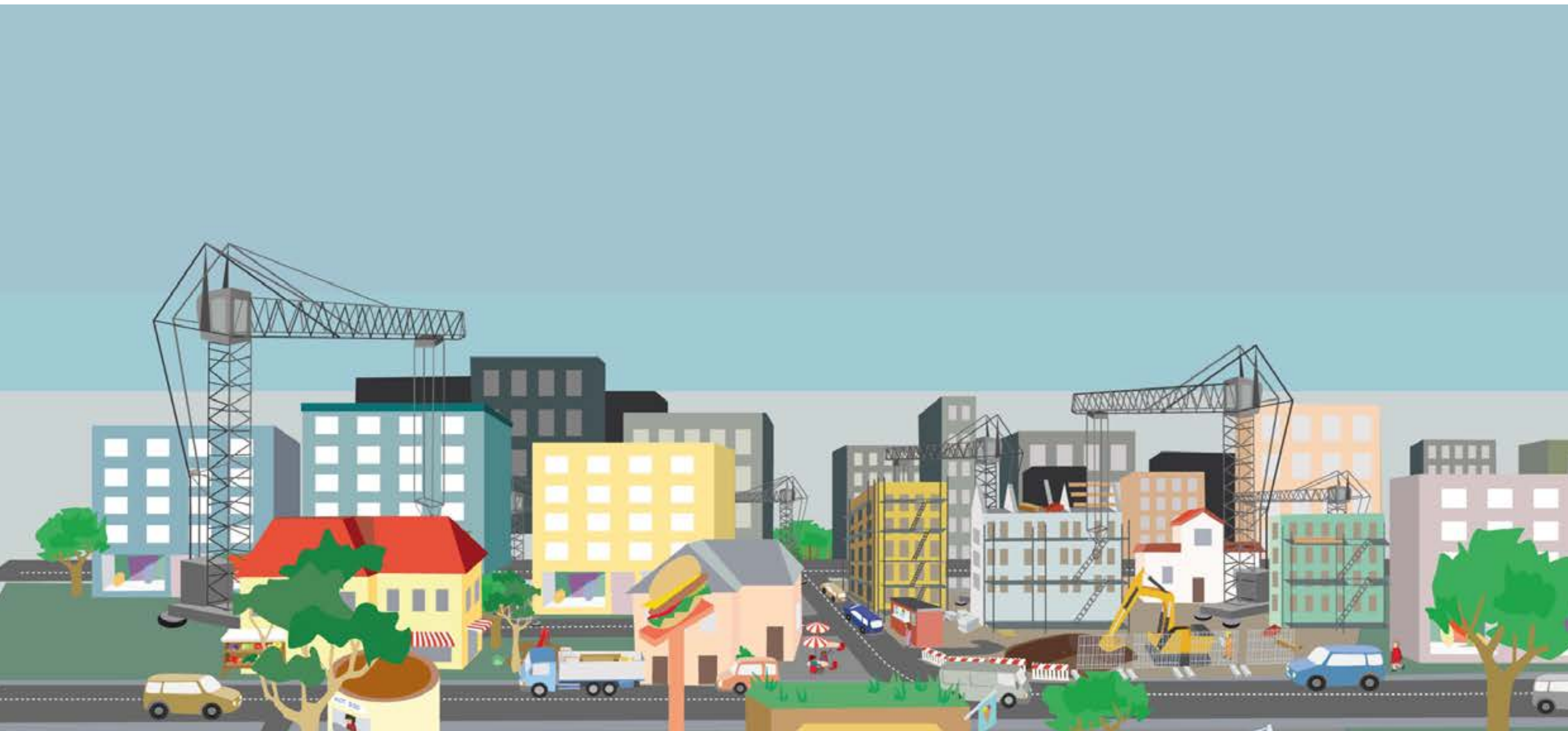
WP2: Impact assessment

Deliverable 2.2: Evaluation of the construction logistics impact assessment framework

December 2021



Document change record			
Version	Date	Status	Modified by
0.1	19.11.2021	First draft D2.2 report framework, including draft introduction, impact assessment framework, LCA in demonstration pilots from Oslo and implementation in Smart governence.	Selamawit Mamo Fufa, SINTEF
0.1	05.12.2021	Revised impact assessment framework, LCA in demonstration pilots from Oslo and implementation in smart governance. Suggestions for ECC in demonstration pilots from Brussels.	Selamawit Mamo Fufa, SINTEF
0.1	09.12.2021	Addition to impact assessment framework and implementation in Smart Goverence	Selamawit Mamo Fufa, SINTEF
1.0	13.12.2021	Final version	Selamawit Mamo Fufa, SINTEF, and Nicolas Brusselaers, VUB

MIMIC Deliverable 2.2: Evaluation of the construction logistics impact assessment framework

Version: 1.0

Date: 13 December 2021

Responsible partner: SINTEF Community, Dept. of Architectural Engineering & Vrije Universiteit Brussel – Mobility, Logistics and Automotive Technology Research Centre (VUB-MOBI)

Authors: Selamawit Mamo Fufa, Sintef & Nicolas Brusselaers, Vrije Universiteit Brussel

Contributors: Koen Mommens, Vrije Universiteit Brussel, Christoffer Venås, Oslobygg

Table of contents

1. Introduction

The purpose of MIMIC – *Minimizing impact of construction material flows in cities: Innovation co-creation* project is to demonstrate how Smart Governance concepts can be used as an aid in the construction and city planning processes to facilitate and support logistics to, from and on urban construction sites. It aims to improve mobility and reduce congestion within cities and thereby reduce the negative impact of construction sites on the surrounding community.

The MIMIC project integrates research within construction logistics, construction management, city logistics, environmental and social impact assessment, and optimization of flows, with the goal of developing the Smart Governance Concept 2.0. The Smart Governance Concept 2.0 provides the implementation partners (Cities and companies in the construction process and supply chain) a framework with a structure of tools by integrating several different aspects:

1) A description of possible construction logistics scenarios and strategies (D1.1) (Fredriksson et al., 2020a) to increase knowledge of construction logistics,
2) A construction logistics serious game (D1.3) (Bergström et al., 2020) and stakeholder analysis (D1.4) (Brusselaers, 2021; Brusselaers et al., 2019) to identify needs and facilitate discussions on the evaluation of impact of construction activities,
3) An impact assessment framework to evaluate the environmental, economic, and social performance of on-site and off-site construction logistics scenarios (D2.1) (Brusselaers et al., 2020) and D2.2),
4) Simulation and optimisation models to evaluate construction logistics scenarios (D3.1 and D3.2) (Fredriksson et al., 2021),
5) A policy framework to set logistic requirements in the early planning process issues in the urban development decision and procurement processes (D4.3, (Bø et al., 2021)).

1.1 Impact assessment

This deliverable (*D2.2 Evaluation of the application of impact assessment framework of construction logistics)* is part of the MIMIC project, under WP2 Impact assessment. The aim of WP2 is to integrate impact assessment methods in a practical and easy-to-use framework to assess the sustainability effects of on-site and off-site construction logistics and assessment of their impacts. Life cycle assessment (LCA) and external cost calculations (ECC) are the two methods used to evaluate the environmental, economic and social performance of construction logistic solutions and setups. D2.1 (*Methodologies for impact assessment of on-site and off-site construction logistics* (Brusselaers et al., 2020)) presented background information on the importance of conducting impact assessments and detailed description of quantitative LCA and ECC methodologies. D4.1 also provided a first draft of the construction logistics impact assessment framework.

1.2 The present report

The aim of this report (D2.1 *Evaluation of the application of impact assessment framework of construction logistics*) is to further develop the impact assessment framework presented under D2.1 and adapt the framework within the implementation demonstration pilots using real world data.

After this introduction chapter, Chapter 2 gives an overview of impact assessment framework and the LCA and ECC methods. Chapter 3 presents LCA and ECC methods' implementation using demonstration pilots from Oslo and Brussels, respectively. Chapter 4 presents the link between impact assessment framework and Smart Governance Concept 2.0 and limitations and approaches for further work on the impact assessment framework.

2. Impact assessment framework

Construction logistics impact assessment framework is developed to support evaluation of construction logistic scenarios and providing decision support to relevant stakeholders (Figure 1).

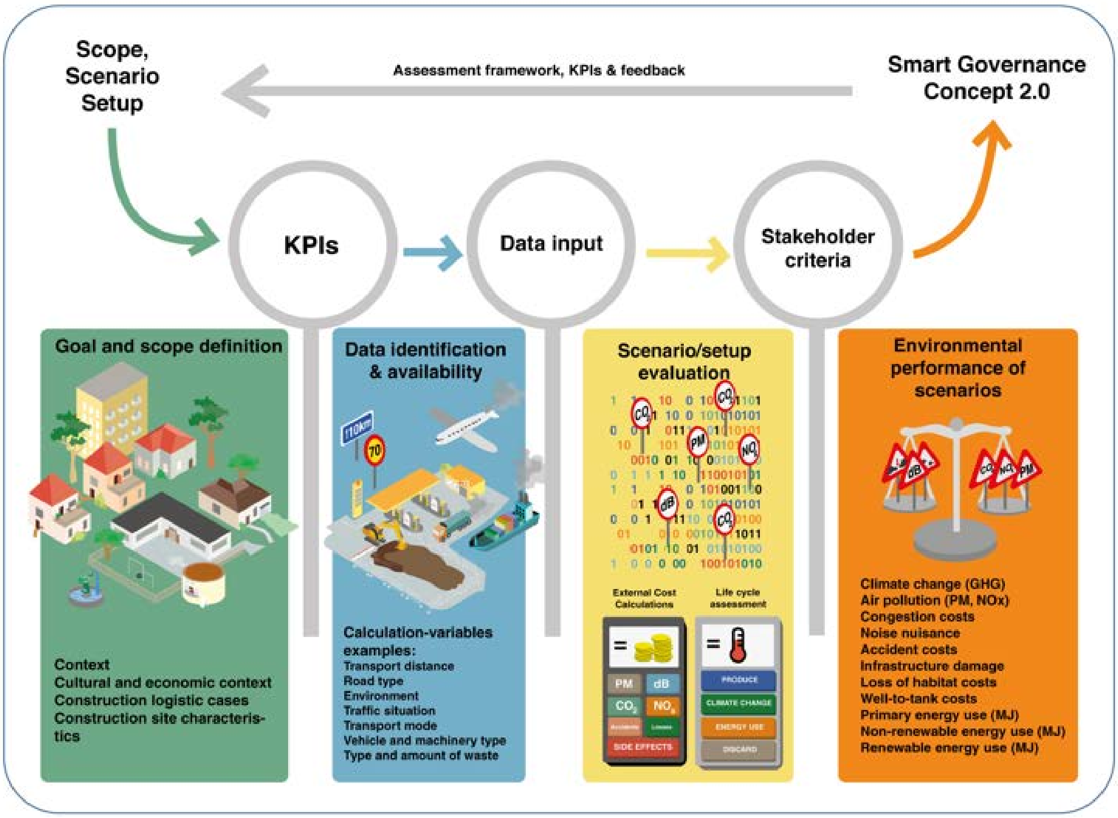


Figure 1 Impact assessment framework (Brusselaers et al., Forthcoming. Revised illustration: Jackie Forzelius)

The framework is designed to be flexible enough to cope with specific local constraints, including data availability issues, whilst generic enough to allow comparability across the national demonstration cases within the project and ultimately beyond the project globally. In addition, the framework can accommodate for different scenario & setup scopes, upscalable to the project/city size and needs based on relevant KPIs. In addition, the framework can provide for setting achievable goals and procurement criteria, and follow up procedures at strategic and operational level in the Smart Governance Concept.

The framework is developed based on life cycle approaches and cover four main iterative steps: 1) goal and scope definition, 2) data identification and availability, 3) scenario and setup evaluation and, 4) environmental performance of scenarios. The following section gives an overview of these four steps.

2.1 Goal and scope definition

The first step is defining the goal and scope of construction logistics impact assessment including definition of the system boundary for construction logistic activities (see Figure 2), construction logistic scenarios, key performance indicators (KPIs) and other methodological choices.

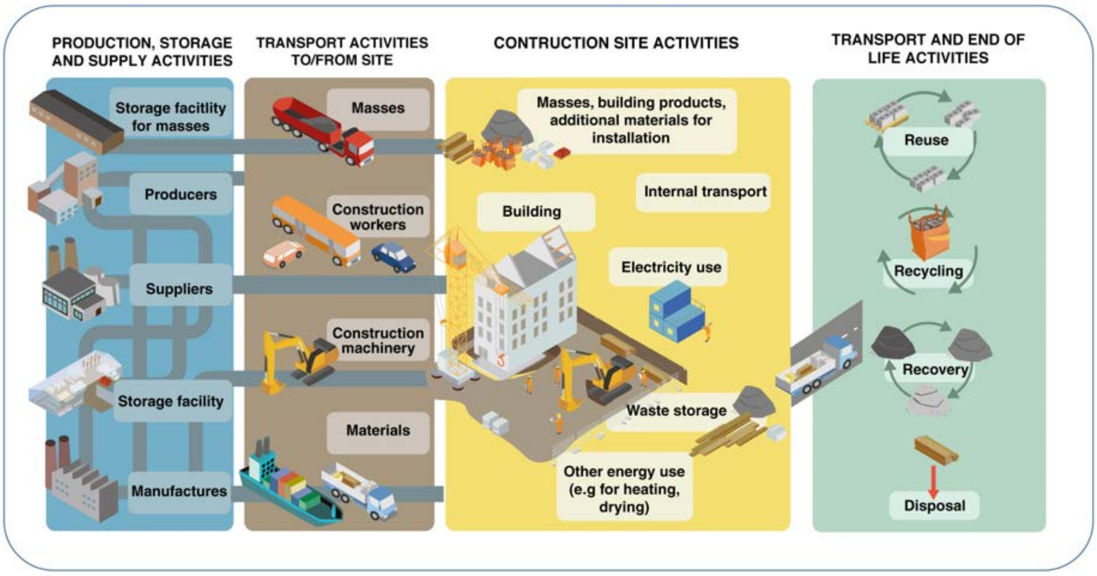


Figure 2 Physical system boundaries for on-site and off-site logistic activities (adopted from Fufa et al., 2019b. Revised illustration: Jackie Forzelius)

Construction logistics scenarios can enable to consider alternative construction logistics solutions to improve the efficiency and performance of construction logistics activities defined in Smart Governance Concept 2.0: (1) defining goals and scope (based contextual foundations) at strategic level in decision making process, (2) planning possible contextual and logistics scenarios to achieve the goals defined at the strategic level, (3) testing and implementation of selected setups of scenarios in operational level (Fredriksson et al., 2020b). The goals and scope definition of the construction programme, portfolio or project, thus has direct influence on the choise of indicators which are considered in the evaluation methods (LCA and ECC explained in 2.3).

2.2 Data identification and availability

Both LCA and ECC methods need detailed inventory data (e.g., based on actual data or assumptions) from construction logistic activities (e.g., vehicle and machine type, transport distance) and good background data sources (e.g., emission factors for fuel use). Both analysis are dependent on not only on the availability of data, but also on the quality of both the inventory and background data. Table 1 summarises LCA and ECC methods including the scope, inventory and type of data needs, scenario evaluation and KPIs.

Table 1 Basic information about LCA and ECC impact assessment methods (Adopted from Brusselaers et al., 2020)

	Life Cycle Assessment (LCA)	External Cost Calculations (ECC)
Logistics activities (scope / physical system boundaries)	**On-site and off-site construction logistics activities (road and water):** • Transport of building materials, masses and machinery to and from construction site; • Production and operation of construction machinery • Transport (from construction site) of waste (incl. packaging) and treatment of waste • Transport of construction workers; • Energy use; • Temporary work (production and transport)	**Transport activities (all transport modes off-site: cargobike, road, IWT, rail, maritime, air):** • Transport of materials to and from the construction site; • Transport of machinery to and from the site; • Transport of waste
Life cycle stages for logistics activities and geographical representativeness	**Entire life cycle of on-site and off-site logistics activities (A4 & A5), including:** • Production of machinery, vehicles, temporary installations etc.; • Operation of these (mainly energy use); • End-of-life of these Geographical representativeness: international and regional/local geographical level.	**Off-site construction logistics across all transport modes (cargobike, road, IWT, rail, maritime, air):** • IWT, hinterland & urban (or last mile) freight transport flows; • (Inter)national and regional/local geographical level The scope is clearly defined on the transport operation or vehicle usage part. Manufacturing and end-of-life are not considered.
Life cycle inventory, granularity and differentiation of calculation-variables	**Type of data for life cycle inventory:** • Vehicle and machinery type; • Number of trips/distance; • Transport distance; • Amount of fuel (or energy consumption); • Duration of on-site (e.g. vehicle, electricity) • Amount and type of products, temporary work/equipment (e.g. kg of fence, # of barracks); • Type and amount of waste.	**Calculation-variables:** • Origin-Destination (vkm/tkm): OD / route (GPS), road type, environment type (or receptor densities); • Time of the day; • Traffic situation; • Vehicle characteristics: transport mode, vehicle capacity, vehicle propulsion type, vehicle consumption (emission class), vehicle speed (link/segment), cargo type, loading rate.
KPIs (Impact categories/ Damage costs)	**KPIs in LCA:** • Climate change (GHG emissions in kg CO2-equivalent) • Resource use o Primary energy use (MJ) o Non-Renewable energy use (MJ) o Renewable energy use (MJ)	**KPIs in ECC:** • Air pollution (all regulated and important non-regulated air pollutants in g/pollutant and monetary • Climate change (in g/pollutant and monetary values) • Congestion (monetary) • Noise pollution (monetary) • Accidents (monetary) • Loss of habitat costs (monetary) • Well-To-Tank costs (monetary)
Scenario evaluation	**Scenarios** • Fossil free (e.g., biofuel) and emission free (e.g., electricity) fuel use • Mode of transport (e.g., Road vs water) • Construction method (e.g., (on-site vs prefabricated) • Material selection (e.g., local sourcing vs internationl order) • Storage (e.g., on-site storage vs consolidation center)	**Scenarios** • Baseline scenario (e.g., fragmented coordination) • Controlling center (e.g., consolidation center in collaboration with port) • Planning city (e.g., construction consolidation center) • Night time deliveries

2.3 Scenario and setup evaluation

The impact assessment itself is based on two methodologies, namely Life cycle assessment (LCA) and External cost calculations (ECC) (Figure 3). LCA is used to evaluate the direct and indirect environmental impact of both on-site and off-site construction logistics activities by utilizing climate change and resource use as KPIs. Whilst ECC is used to evaluate the monetarized environmental and social impacts of off-site construction logistics by utilizing cost related to climate change, air pollution, congestion, noise, accidents and infrastructure as main KPIs.

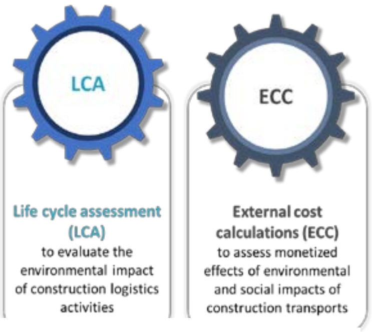


Figure 3 LCA and ECC impact assessment methods

The scenario and setup evaluation aims to investigate a wide range of solutions in comparison with a baseline (Business-as - usual) for the defined scenarios and setups and input criteria from the involved stakeholders. The evaluation is conducted based on input and background data collected, using LCA and ECC methods. Table 1 shows some examples of possible alternatives considered in demonstration pilots.

2.4 Environmental performance

The impact assessment framework output is used to evaluate the environmental performance of on-site and off-site construction logistic scenarios using relevant LCA and ECC KPIs listed under Table 1. The environmental performance evaluation should be conducted throughout the construction process (early phase, construction phase and as built phase) to plan and follow up the fulfilment of the defined goals and requirements set at strategic and operational levels of Smart Governance Concept 2.0 (Figure 4), respectively.

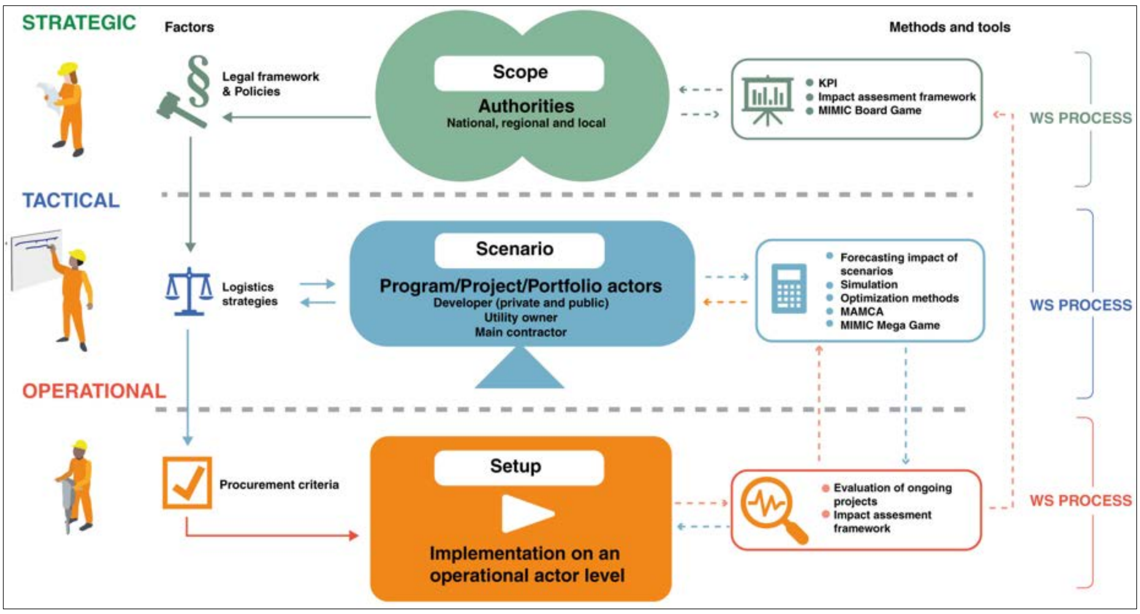


Figure 4 Smart Governance Concept 2.0 (adopted from Janné et al., 2021. Revised illustration: Jackie Forzelius)

3. LCA and ECC in demonstration pilots

LCA and ECC methods were applied in demonstration pilots from Oslo and Brussels, respectively. This section gives a summary of the main findings. Detailed LCA and ECC analysis are presented in Fufa and Venås (Forthcoming), Brusselaers, Fufa & Mommens (Forthcoming)and Brusselaers, Huang & Mommens (Forthcoming).

3.1 LCA in demonstration pilot from Oslo

Environmental impact assessment was conducted in a demonstration pilot from Oslo following the LCA methodology. Basic information about the demonstration pilot is given in Table 2 and LCA method and results are given in the text below. Detail analysis can be found in forthcoming article (Fufa and Venås (forthcoming).

Table 2. General information about the demonstration pilot from Oslo

Project name	**Oslo storbylegevakt**  Illustration: Oslo municipality
Project type	Emergency ward
Loaction	Trondheimsveien 235, Oslo, Norway
Gross floor area	27 000m^2
Ambitions	Passive house, BREEAM Excellent, fossil free construction site
Building owner	Oslobygg
Contractor	Skanska
Construction period	2020 – 2023
Data collection	March 2020 – April 2021
Construction logistics solutions	Digital scheduling - planning system for transports and (material) deliveries; time restrictions for intermediate storage on site, time restrictions on deliveries; use of fossil and emission free solutions

3.1.1 Goal and scope of LCA

The LCA method follows four steps, 1) goal and scope definition, 2) life cycle inventory, 3) impact assessment, 4) interpretation of results, in accordance with LCA principles and requirements as defined by ISO 14040/44.

The ***goal*** of LCA is to evaluate the environmental impact of on-site and off-site construction logistic activities. The ***physical system boundaries*** included in the analysis are transport of masses, transport of materials, transport and operation of machineries, transport and treatment of waste and energy use (see Figure 2).

The ***life cycle system boundary covers*** transport to construction site (A4) and construction installation (A5) life cycle modules (Figure 4). ***GWP***, expressed in GHG emissions (CO_2eq) and

resource use, expressed in renewable and non-renewable energy use (MJ) are the ***indicators*** used in the LCA study.

A1-3 Product Stage			A4-5 Construction		B1-7 Use Stage							C1-4 End of Life				D Benefits and loads
A1: Raw Material Supply	A2: Transport to Manufacturer	A3: Manufacturing	A4: Transport to building site	A5: Installation into building	B1: Use	B2: Maintenance	B3: Repair	B4: Replacement	B5: Refurbishment	B6: Operational energy use	B7: Operational water use	C1: Deconstruction / demolition	C2: Transport to end of life	C3: Waste Processing	C4: Disposal	Reuse; Recovery; Recycling; Exported energy/Potential

Figure 5 Lifecycle modules (Adopted from NS-EN 15978:2011 (Standards Norway, 2011))

3.1.2 Inventory and calculation method

The ***life cycle inventory*** was conducted based on the actual inventory data collected from construction site from March 2020 - April 2021. Since the project is on-going, the data was collected only from the ground and foundation and superstructure building elements construction phase.

The ***background emission and energy factors*** were collected from generic databases and relevant resources. Figure 6 gives an example of LCA calculation method following the method developed under Fufa (2018), Fufa et al. (2019) and Brusselaers *et al* (2020).

Construction machinery														
	Type of construction machinery	Amount (pcs)	Weight (kg)	Production of machinery				Machinery energy use on site			Transport of Machinery to site			
				reference service life (days)	*Duration on site(days)*	*Utilization (%)*	*Emission factor for production of machinery (kgCO2eq/kg)*	*Energy use*	*Amount (litre)*	*Emission factor for fuel used (kgCO2eq/liter)*	*Transport distance (km)*	*No of trips*	*Mode of transport*	*Emission factor for mode of transport (kgCO2eq/kgkm)*
Examples /description/ source of data	*Excavator; bulldozers; digger; loader; dril; crane; dumpers; truck*	*Contractor/subcontractor*	*sources like: https://www.hitachicm.eu/machinery/excavators/medium-excavators/ https://www.naste.no/anleggsmaskiner/gravemaskin/minigraver/*	*sources like: https://www.hitachicm.eu/machinery/excavators/medium-excavators/ https://www.nasta.no/anleggsmaskiner/gravemaskin/minigraver/*	*Data from contractor/subcontractor*	*Data from contractor/subcontractor*	*Ecoinvent databse*	*Contractor/subcontractor*	*invoice*	*Ecoinvent database*	*Contractor/sub contractor*	*Contractor/sub contractor*	*Contractor/sub contractor*	*Ecoinvent database*

Figure 6 Examples of LCA calculation method for construction machinery

3.1.3 GWP and resource use results

The LCA results show largest contibution of mass transport, followed by material transport and machinery to the total GHG emissions from construction logistic activities. Mass transport is the main contributor to both renewable and non-renewable embodied energy. Whilst, machinery is the second largest contributor to renewable embodied energy (due to use of emission free and fossil free fuel) and material transport is the second largest constributor of non-renewable embodied energy use (due to use of diesel driven vehicles). Use of consolidation center and collaboration with the nearby construction sites would have been resulted in more reuse of masses, reduce transport need and associated impacts. The significant impact from mass and material transport highlihted the importance of considering off-site construction logistic activities in the current emission free construction site activities.

Table 3 Percentage contribution to the total GHG emission and embodied energy (Fufa and Venås, Forthcoming)

Construction activities	GHG emissions	Renewable embodied energy	Non-renewable embodied energy
Energy use	1%	3%	1%
Machinery	16%	37%	14%
Mass transport	42%	58%	45%
Material transport	37%	3%	33%
Construction waste	0.01%	0.00%	0.01%
Demolition waste	5%	0.12%	7.23%

3.1.4 Scenario analysis and uncertainties

Scenario analysis was conducted for fossil free and emission free solutions for machinery and mass transport and mode of transport solutions for material transport. The results from scenario analysis demonstrated large potential in electrification of both on-site and off-site activities to achieve emission free construction logistics. The current focus in Norway is electrification of on-site activities. The results from scenario analysis illustrates the importance of to go beyond electrification of on-site construction logistics by considering electrification of off-site construction logistics activities. It is also important to conduct scenario analysis for other construction logistic setups (e.g., consolidation center).

The quality of the inventory and background data source significantly affect the LCA results. Collecting actual construction data is very time-consuming. Furthermore, there is lack of data (e.g., material transport) and harmonised methods (e.g., emission factors for fuel use).

3.2 ECC in demonstration pilot from Brussels

The Environmental impact assessment was conducted in collaboration with Van Roey Vastgoed and CutyDev on the City Campus construction site following the ECC methodology. Basic information about the demonstration pilot is given in Table 3 and ECC method and results are given in the text below. The detailed analyses can be found in forthcoming articles ((Brusselaers et al., Forthcoming; Brusselaers and Mommens, Forthcoming)).

Table 4 General information about the demonstration pilot from Brussels

Project name	**City Campus (Anderlecht, Brussels-Capital Region)** 
Project type	An SME park for agri-food companies and social and student residences.
Location	Anderlecht (Brussels), Belgium. The site is located within the Brussels Outer Ring (R0) and the BCR. The location offers a variety of relevant and potential transport accessibility entries and exits: the area is in proximity of major road axes such as the R0 ring of Brussels and the E19 highway as well as the main navigable inland waterway axes of the Brussels- Charleroi Canal and the Willebroekse Vaart.

Gross floor area	17,600 m^2
Building owner	CityDev
Contractor	Van Roey Vastgoed
Construction period	2020 – 2023
Data collection	Nov 2020 – Oct 2021

3.2.1 Goal and scope of ECC method

The ***goal*** of ECC is to evaluate the environmental impact of on-site and off-site construction logistic activities. The ***physical system boundaries*** included in the analysis are transport of masses, transport of materials, transport of machinery and transport of waste. The scope is clearly defined on the transport operation or vehicle usage part. Manufacturing and end-of-life are thus not considered. However, the considered ***indicators*** are broad, covering not only GHG emissions (cliamte change) and air pollution, but also externalities related to infrastructure, congestion, accidents, noise, habitat loss and well-to-tank costs.

3.2.1 Inventory and calculation method

In Brussels, the construction-related transport data is retrieved from On-Board Units ('OBU') (Figure 7). These GPS-based devices were introduced in 2016 in the implementation of the kilometer charge mandatory for i.a. trucks above 3,5t on motorways and certain regional axes in Belgium. This kilometre charge scheme covers all roads in the Brussels Metropolitan Region. The associated data collection includes specific vehicle characteristics, as the kilometre tax is differentiated based on, amongst others, the distance travelled and how environmentally friendly the vehicle is. This OBU dataset is thus a strong dataset in order to collect the vehicle's geometry by means of a unique identifier, the vehicle mode and capacity, the EURO norm, the time of day accurate on a 30 seconds interval basis, and the velocity of the vehicle. VUB-MOBI developed an algorithm to map the vehicle's trajectory (Origin-Destination-matrix), which allows for very precise derivation of travelled vehicle-kilometres (vkm) as well as the duration and speed of the trip. Furthermore, these data can be overlaid to match the network, environment and road types, hence further enriching the analyses by means of geocoding, linking its response to the hierarchical classification of roads on the network by means of geographical information systems (GIS). This is most useful to determine the shortest path and route optimizations. The loading rate and volumes have been based on assumptions (Brusselaers et al. (forthcoming).

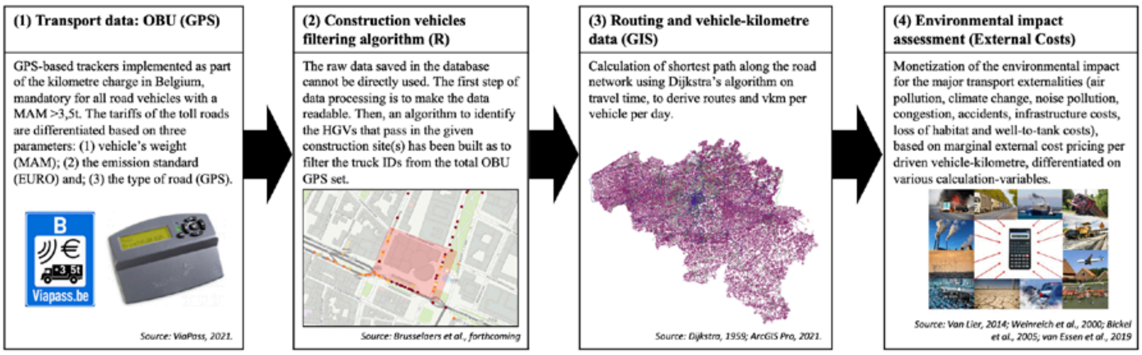


Figure 7. Methodological pathway (taken froom Brusselaers et al., forthcoming).

3.2.2 ECC results

Figure 8 shows the month-over-month external costs and measured vehicle-kilometres generated by transports from the City Campus construction site. Generally, a correlatino is found between transported volumes and the generated external costs. This analysis allows to highlights insights in different material and mass deliveries, as well as the considered transports in different phases of the construction site. Thus, the most ferocious transport modes and/or volumes can be identified in order to optimize the transport process.

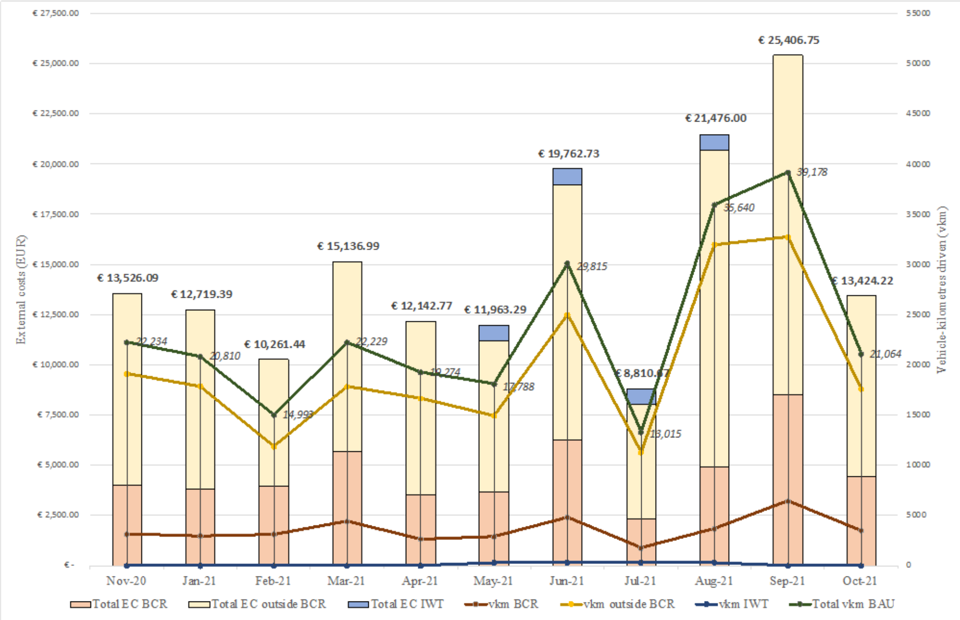


Figure 8. Month over month external costs and vehicle-kilometres for the Brussels pilot site (taken from Brusselaers et al., Forthcoming).

3.2.3 Scenario analyses and conclusions

In the case of Brussels, 3 alternative scenarios (to BAU) have been assessed: (1) Increased material deliveries by barge (IWT), (2) Zero-emission last mile delivery and (3) Electric concrete trucks.

Results highlight that off-site zero-emission construction vehicles are the way forward if cities want to achieve zero-emission logistics in the near future. Important to note here is that market readiness needs to be considered in order to assure sufficient vehicle offerings in the heavy-duty truck segment. Otherwise, perverse effects are noticeable: air pollution, climate change and noise are at risk of being offset by saturation of the road transport network and its associated congestion and infrastructure damage costs as transports will be operated by vehciles with a lower capacity. Furthermore, results of the analyzed scenarios indicate that a multitude of measures will be necessary in order to achieve sustainable off-site construction logistics.

4. Implementation in Smart Governance Concept (SGC)

The following section presents how the impact assessment framework can be implemented and tested in the SMART Governance Concept.

4.1 Impact assessment in SGC

The Smart Governance Concept 2.0 developed within MIMIC project aim to promote implementation and continues improvements of construction logistic activities in urban areas through an iteration of (1) defining goal and scope at the national, regional and/or local levels, (2) implementation of actual setups in projects through legislation and procurement procedures and (3) follow up through data collection, simulation, evaluation and communicate the results with different actors using KPIs (Janné et al., 2021).

The impact assessment framework can be implemented at the strategic and tactical levels of Smart Govervence Concept 2.0 to evaluate the environmental performance of construction logistic using LCA and ECC methods (Brusselaers et al., 2020).

Conducting LCA and ECC at ***strategic and early planning phase*** can enable to evaluate, test and compare several environmentally sound construction logistics setups and make informed selections. This enable to set ambitious but achievable goals and scopes for implementing the selected construction logistic solutions with potential environmental impact reduction measures. The LCA and ECC analysis can be conducted based on assumptions, discussions with involved actors, previous experience and references due to lack of actual data availability in the early phase evaluation. Thus, developing a platform to collect best practices and reference values can enable to increase the availability of data. As shown in the demonistration pilots, consducting scenario analysis can enable to evaluate alternative solutions.

At the ***operational level***, the impact assessment framework can enable to evaluate the actual performance of the setup during implementation phase. The LCA and ECC analysis can be conducted using actual data collected from construction logistic activities to get clear overview of the actual impact reductions.

4.2 Recommendation and further work

LCA and ECC methods can be used as a decision support tool to evaluate the environmental performance of construction logistic activities. The analysis should clearly describe the system boundary (e.g., on-site and offsite construction logistic activities (Figure 2), life cycle stages (Figure 4), and KPIs (e.g. Climate change), assumptions and background data source. Including the whole life cycle (production (A1-A3), use phase (B1-B7), end-of-life (C1-C4), (D)) in addition to construction logistic activities, widening the scope (e.g., neighbourhood or city level) and considering several indicators (e.g., indicators given within the framework and beyond) can enable to give a holistic approach and avoid problem shifting.

There are some limitations which need to be considered in further work:

- Digitalization of data collection or inventory method and background database;

- Collaboration method/platform between construction projects and actors to develop construction logistic solutions and increase availability of data;
- Collect best practices from pilots and good reference projects, reference or benchmark values;
- Methods to evaluate how environmental impact reduction measures from construction logistic activities can contribute to reaching global, national and regional goals.

Acknowledgements

This project has received funding from the European Union's H2020 research and innovation programme and is part of the research programme JPI Urban Europe with project number 438.15.403 (MIMIC). This project is subsidised by the Brussels Capital Region - Innoviris and the European Union and receives funding from the Swedish Governmental Agency for Innovation Systems (Vinnova), the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) in the framework of the research programme "Stadt der Zukunft" and the Austrian Federal Ministry of Science, Research and Economy (BMWFW) and The Research Council of Norway.

References

Bergström, K., Billger, M., Fredriksson, A., Janné, M., 2020. The MIMIC construction logistics game: facilitating group discussion and understanding of construction logistics through gameplay. IOP Conf. Ser. Earth Environ. Sci. 588, 052014. https://doi.org/10.1088/1755-1315/588/5/052014

Bø, L.A., Fufa, S.M., Flyen, C., Venås, C., Fredriksson, A., Janné, M., Brusselaers, N., 2021. WP4: Smart Governance. Deliverable 4.3: Policy instrument. November 2021.

Brusselaers, N., 2021. WP1: Stakeholder involvement Deliverable 1.4 (v.2): Stakeholder analysis framework for construction logistics. November 2021.

Brusselaers, N., Fufa, S.M., Mommens, K., Forthcoming. Environmental impact assessment framework for on-site and off-site construction logistics.

Brusselaers, N., He, H., Mommens, K., Forthcoming. A GPS-based approach to measure the environmental impact of construction-related HGV traffic on single-site, city and country level.

Brusselaers, N., Mommens, K., Forthcoming. Collaborative off-site construction logistics: a sustainability impact assessment of the Brussels Construction Consolidation Centre.

Brusselaers, N., Mommens, K., Fufa, S.M., Venås, C., Macharis, C., 2020. WP2: Impact assessment Deliverable 2.1: Methodologies for impact assessment of on-site and offsite construction logistics. August 2020.

Brusselaers, N., Mommens, K., lebeau, P., Macharis, C., 2019. WP1: Stakeholder involvement Deliverable 1.4: Manual for stakeholder involvement in construction logistics. September 2019.

Fredriksson, A., Flyen, C., Fufa, S.M., Venås, C., Hulthén, K., Brusselaers, N., Mommens, K., Macharis, C., 2020a. WP1: Construction logistics scenarios and stakeholder involvement. Deliverable 1.1: Scenarios of construction logistics. October 2020.

Fredriksson, A., Flyen, C., Fufa, S.M., Venås, C., Hulthén, K., Brusselaers, N., Mommens, K., Macharis, C., 2020b. WP1: Construction logistics scenarios and stakeholder involvement. Deliverable 1.1: Scenarios of construction logistics. October 2020.

Fredriksson, A., Nolz, P.C., Seragiotto, C., 2021. A mixed method evaluation of economic and environmental considerations in construction transport planning: The case of Ostlänken. Sustain. Cities Soc. 69, 102840. https://doi.org/10.1016/j.scs.2021.102840

Fufa, S.M., 2018. GHG emission calculation from construction phase of Lia barnehage. SINTEF Notes 23. ISBN: 978-82-536-1586-8.

Fufa, S.M., Venås, C., Forthcoming. Environmental impact assessment of on-site and off-site construction logistics activities: A Case study from Norway.

Fufa, S.M., Wiik, M.K., Andresen, I., 2019a. Estimated and actual construction inventory data in embodied GHG emission calculations for a Norwegian zero emission building (ZEB) construction site, in: Kaparaju, P., Howlett, Littlewood, J., Ekanyake, C., Vlacic, L. (Eds.), Smart Innovation, Systems and Technologies. Springer Nature Switzerland, Switzerland.

Fufa, S.M., Wiik, M.K., Mellegård, S.E., Andresen, I., 2019b. Lessons learnt from the design and construction strategies of two Norwegian low emission construction sites. IOP Conf. Ser. Earth Environ. Sci. 352, 012021. https://doi.org/10.1088/1755-1315/352/1/012021

Janné, M., Fredriksson, A., Fufa, S.M., Brusselaers, N., MacIntyre, S., 2021. WP4: Smart Governance. Deliverable 4.2: Smart Governance 2.0. October 2021.

Standards Norway, 2011. NS-EN 15978:2011 - Bærekraftige byggverk - Vurdering av bygningers miljøpåvirkning - Beregningsmetode/ Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method.