The potential of cargo bicycle transport as a sustainable solution for urban logistics

Proefschrift voorgedragen tot het behalen van de graad van doctor in de toegepaste economische wetenschappen aan de Universiteit Antwerpen te verdedigen door

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The potential of cargo bicycle transport as a sustainable solution for urban logistics

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“FedEx, for example, can deliver a package from New York to Los Angeles by tomorrow, but only a bike messenger can get something from midtown to downtown by lunchtime.”

Jeffrey L. Kidder

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ATC	Average Transport Cost
AQG	Air quality guidelines (of the WHO)
BAU	Business As Usual
B2B	Business to Business
B2C	Business to Consumer
BeNeLux	Belgium Netherlands and Luxemburg
CBA	Cost Benefit Analysis
CEP	Courier, Express, Parcel services
C2X	Consumer and small business parcels market
EMS	Express Mail Service
EU28	28 Member States of the European Union
GHG	Green House Gas
HDV	Heavy Duty Vehicle
IA	Impact Assessment
LAU	A local administrative unit
LCV	Light Commercial Vehicle
LEZ	Low-Emission Zone
LUZ	Larger urban zone
LSP	Logistics Service Providers
MCA	Multi Criteria Analysis
MAMCA	Multi Actor Multi Criteria Analysis
Mtoe	Million tonne of oil equivalent
MTC	Marginal Transport Cost
NGV	Natural Gas Vehicle
PPP	Purchasing Power Parity
Pkm	Passenger kilometre
PUDs	Pickup and deliveries
SATC	Social Average Transport Cost
SCBA	Social Cost Benefit Analysis
SMTC	Social Marginal Transport Cost
STTC	Social Total Transport Cost
Tkm	Tonne kilometre
TTC	Total Transport Cost
UCC	Urban Consolidation Centre
UPU	Universal Postal Union
Vkm	Vehicle kilometre
WHO	World Health Organization

Acknowledgements

It is said that the last mile is the toughest. This Ph.D. research started years ago with some first ideas about the challenges in urban logistics, and how research could contribute to the uptake of innovative solutions. Various of these innovations attracted my attention during my time at Steunpunt Goederenstromen / Research centre on commodity flows, embedded at the University.

Using inland waterways for urban freight transport, optimising rail freight so urban areas can be supplied (again) via rail, but also cargo bikes and Electric Vehicles. Various research ideas were developed, aside my intrinsic interest in railways.

These innovations and ideas were always seen in a policy context. Because of my interest in policy, I also published papers on e.g. Low Emission Zones, Time Widows and contributed to the Flanders Logistics publications ‘Wegwijzer Stedelijke distributie’ and the ‘Roadmap Groene Logistiek’.

During my time as researcher at the University I had the opportunity to visit various conferences, present my (preliminary) research, get to know the (EU) freight transport research projects, meet the famous City Logistics professors and explore new topics. Surprisingly, cargo bicycle transport was seldom one of the discussion topics. It appeared, that the urban freight transport community only saw it back then as a pilot-test and dissemination topic. The cargo cyclists on the other hand, had no relationship to the Academic world and were just interested in developing their business and passion for cycling.

It was therefore a joy to be able to explore the Belgian cargo bicycle transport scene from a research viewpoint and fill a major (economic) research gap. The first publication on the topic "Kunnen fietskoeriers een rol spelen in de Vlaamse logistieke sector?" attracted already national attention. Minister Crevits was enthusiastic and organised in the framework of Flanders Logistics a round table discussion in which valuable background and points of attention were collected. This round table was the real starting point of a journey in cycling logistics publications, conferences and direct contacts with these entrepreneurs.

This kick-start resulted in more specific publications on cargo cycling. With the Conference on City Logistics (2013), a poster session at TRB (2015) and frequent METRANS I-NUF (2009-2011-2013) visits were the most memorable outreach.

I had most fun though meeting the cargo cyclists and following their business developments. These entrepreneurs have the cities as their office. They have a wonderful can-do mentality. Regardless of the weather or traffic jams, they pedal. They are the real urban freight experts. I want to thank many for contributing to this research, De Fietskoerier (Dolf Kok), Pedal BXl (Karl-Heinz Pohl), Cargo velo (Sander Vandenberghe), Bubble post (Felix Vanvuchelen), Ecopostale (Nicolas Etienne), ibutler (Tjerk Homminga), TNT Express (Jan-Harmen Hietbrink), ASX Ibeco (Jean-Claude van den Berghe) and Max Mobiel (Pieter Vercruyssen).

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Jochen MAES
Antwerp
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Managementsamenvatting

De impact van stedelijke mobiliteit en met name stedelijk goederenvervoer op de leefbaarheid van steden is groot. Groeiende weg congestie in de meeste Europese steden, waar het stedelijk goederenvervoer actief aan bijdraagt, de uitstoot van vrachtvervoer en de stedelijke verkeersveiligheid zijn belangrijke uitdagingen voor de samenleving. Verschillende andere (negatieve) effecten zijn bv. geluidsoverlast door voertuigen en logistieke activiteiten, schade aan het publieke domein door zware vrachtwagens en het parkeergedrag van vrachtwagen- en bestelwagen chauffeurs. Over het algemeen wordt stedelijk vrachtvervoer geschat op ongeveer 10-15% van de wegenkilometers, maar het staat in voor ongeveer 25% van de uitstoot van broeikasgassen in de stedelijke omgeving (bv. CO_2) en 30-50% van andere vervoersverwante emissies (bv. (PM en NOX) (ALICE en ERTRAC, 2015). De bevolking in steden in Europa blijven groeien: bijna 4 op de 10 Europeanen wonen in steden. Ook de Belgische steden kenden een sterke bevolkingsgroei, met een gemiddelde groei van 8,5%. Belgen hebben wonen wel eer dan gemiddeld in de landelijke gebieden dan Europeanen. Niettemin leefde in 2014 en 35% van de bevolking in verstedelijkte gebieden (Eurostat, 2017a).

Steden kunnen proberen om mobiliteit te beperken, maar kunnen de toegang tot steden niet te veel beperken. Economische en sociale activiteiten aldaar vereisen goederenvervoer: dit vervoer is slechts een afgeleide vraag van onderliggende economische activiteiten. De problemen met luchtkwaliteit en ongevallen leiden ertoe dat stakeholders de stedelijke leefbaarheid in vraag stellen, en de uitdagingen protesteren. De objectieve en subjectieve elementen van stedelijke leefbaarheid en de impact van het stedelijk goederenvervoer daarop worden steeds meer erkend door beleidsmakers en transportondernemers. Het witboek van de Europese Commissie in 2011 (COM (2011) 144 def.) is bijvoorbeeld ambitieus: de uitstoot van emissies door het vervoer moet aanzienlijk worden verminderd. De belangrijkste Europese doelstelling voor dit Doctoraat is: "De Unie moet tegen 2030 CO_2-vrije stadslogistiek organiseren in z'n grote stedelijke kernen".

Het ambitieuze (Europese) transport- en emissiebeleid verhoogde de druk op de stakeholders om de efficiëntie van hun voertuigen en bedrijfsvoering te verbeteren, te investeren en duurzamer te worden in hun activiteiten. Een van de oplossingen in het stedelijk goederenvervoer is om in stedelijke gebieden een andere vloot van lage-emissie voertuigen in te zetten. Vaak worden elektrische voertuigen voorgesteld, terwijl geen-emissie voertuigen zoals cargofietsen een minder vaak voorgesteld alternatief zijn. De centrale onderzoeksvraag is daarom **"Kunnen cargofietsen bijdragen tot een betere economische/duurzame/sociale leefbaarheid van stedelijke gebieden, en in hoeverre?"**

Het concept is niet nieuw. Fietsvervoer is mogelijk één van de oudere en nog steeds actieve, stedelijke logistieke systemen in de wereld. Niettemin is het al decennia onder de radar als een haalbare transportoptie. De groei van de commerciële fietsvervoermarkt wordt gezien in bijna alle Europese steden. Cargofiets vervoer is tegenwoordig georganiseerd via diverse start-ups. Nieuwe fietsen met elektrische assistentie en IT-ontwikkelingen zorgen ervoor dat nieuwe bedrijfsmodellen kunnen bloeien (voorbeelden zijn Deliveroo, Foodora en Bubble Post). Ook bestaande internationale spelers (zoals UPS, DHL en FedEx) ontwikkelen cargofiets vervoer.

Het onderwerp werd eerder in onderzoeksprojecten als CycleLogistics (AHEAD), Pro E-bike en Straightsol onderzocht; met in het algemeen positieve resultaten. Het uitgebreide literatuuroverzicht laat echter zien dat de bedrijfseconomische levensvatbaarheid van cargofiets vervoer in veel mindere mate werd onderzocht. Onderzoek ernaar als een oplossing voor het goederenvervoer in stedelijke gebieden kan worden beschouwd als een vrij nieuw en onderontwikkelde academische onderzoeksstroom, met onvolkomenheden in de kennis.

Het onderzoek van dit doctoraat richt zich op de (welzijn) economische aspecten van het stedelijk vrachtvervoer met vrachtfietsen. Het wordt onderzocht in een concrete setting waar last mile transport, first mile transport, Business to Business (B2B) en Business to Consumer (B2C) sleutelbegrippen zijn.

- Last mile vervoer wordt gedefinieerd als het laatste traject tot de eindontvanger, door een voertuig dat een depot / overslag faciliteit verlaat; d.w.z. waar de laatste goederenbehandeling wordt gedaan.
- De first mile is gedefinieerd als het ophalen van goederen in de stedelijke omgeving, het vervoer binnen het stadsgebied en de levering naar de eerste vervoersplaats (vaak dezelfde locatie als de depot of overslagfaciliteit genoemd in het eerste punt).
- Het onderzoek in dit doctoraat richt zich op het goederenvervoer naar de eindontvanger, in een stedelijk gebied. Deze ladingstromen kunnen zowel B2B zijn als B2C-type zendingen.

Na een marktscan, interviews met logistieke- en cargofiets ondernemers en een uitgebreid literatuuronderzoek werd geconcludeerd dat de meest belovende markt voor cargofietsen: bijdragen aan de last mile diensten van de Courier, Express, Parcel (CEP) markt.

Om een goede evaluatie te maken, wordt het concept in het Doctoraat beoordeeld in een spreadsheetmodel, waarin de evaluatie wordt gestructureerd en de resultaten van bedrijfs- en welvaartseconomische evaluaties in verwerkt zijn. Op basis van onderzoek is een toegepaste Sociaaleconomische (Maatschappelijke) Kosten Baten Analyse (MKBA) ontwikkeld, waarbij het gebruik van cargofietsen in twee stappen wordt geanalyseerd.

- De eerste stap van de evaluatie is een business case opgezet, dat is het onderzoekskader voor het analyseren van de bedrijfseconomische effecten van het implementeren van het cargofietsvervoer in stedelijke gebieden. De gegevens die in de beoordeling zijn gebruikt, zijn gebaseerd op eigen onderzoek naar de Belgische fietsvervoermarkt.

- De tweede stap binnen de evaluatie is het uitbreiden van de zuivere bedrijfseconomische blik naar een welvaartseconomische evaluatie. Hierbij worden externe kosten geïntegreerd in de beoordeling. Daarna worden ook beleidsmaatregelen en hun effecten gesimuleerd.

Uitkomsten business case analyse

Het spreadsheetmodel maakt het mogelijk om conclusies te maken over de totale transportkosten (TTC), de gemiddelde transportkosten (ATC) en de marginale transportkosten (MTC). De gemiddelde transportkosten (ATC) voor cargofietsen zijn hoog. Alleen voor kleine bedrijven is cargofietsvervoer een nicheproduct dat zeer competitief is met bestelwagenvervoer.

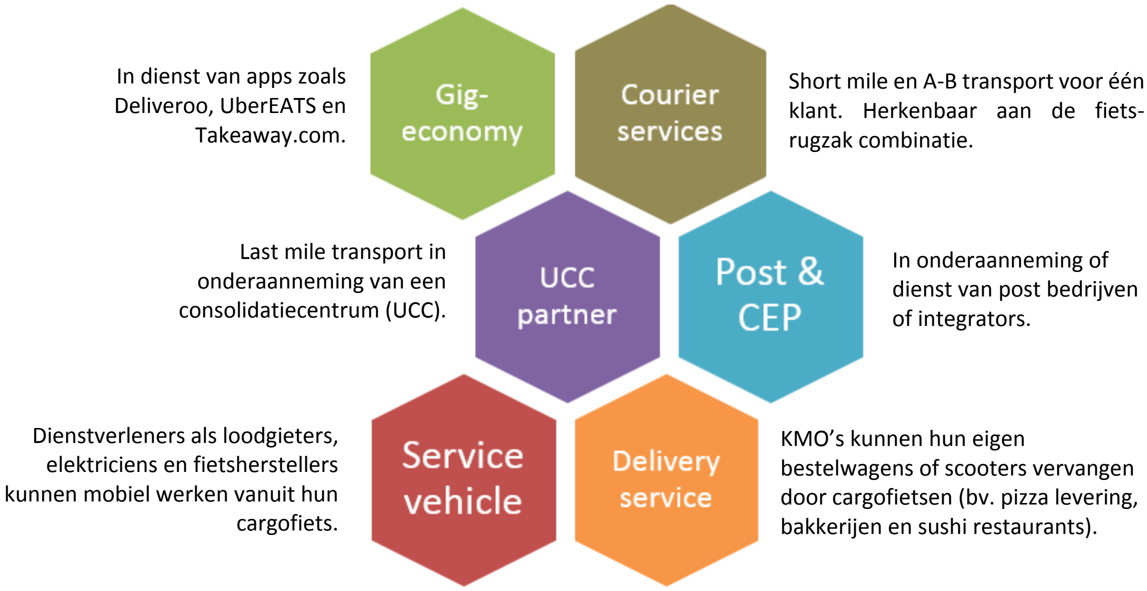
Over het algemeen kan bestelwagenvervoer tegen aanzienlijk lagere kosten per stop worden georganiseerd. Wanneer een bedrijf slechts ongeveer 50 stops per dag uitvoert, bedraagt de Bestelwagen (LCV) kosten per stop met 5,82 EUR aanzienlijk lager dan de kosten voor cargofietsen (6,63 EUR per stop). Wanneer een bepaalde schaal wordt behaald, kan bestelwagenvervoer in deze onderzoekssetting georganiseerd worden voor ongeveer 3,50 EUR per stop, waar vrachtfietsen niet goedkoper kunnen aanbieden dan 4,6 EUR per stop.

De marginale transportkosten (MTC) zijn lager voor bestelwagenvervoer dan voor cargo fietsen. Het kan opgemerkt worden dat de kosten bijna naar een vaste prijs per stop dalen vanaf ongeveer 250 stops per bedrijf per dag, en daarboven Een minimumschaal is nodig om actief te zijn op de 'Post & CEP' markt.

MTC Cargofietsen (in EUR)	**MTC Bestelwagens (in EUR)**
4.61	3.40

Op basis van de business case analyse is geconcludeerd dat de economische duurzaamheid van cargofietsen voor het vervangen van bestelwagens in de CEP-markt een uitdaging is. Loonkosten is de belangrijkste kostenfactor, waardoor de bezorgkosten van de cargofietsen aanzienlijk stijgen. Scenario's toonden aan dat de voertuigkosten relatief minder belangrijk zijn. Het brandstofverbruik is minder relevant dan verwacht, net als de dieselprijs.

De markt 'Post & CEP' heeft het grootste mogelijke marktvolume voor cargofietsen, en de groei in e-commerce toont veel potentiële groei. Maar ook nichemarkten bestaan, bijvoorbeeld ‘voor eigen rekening vervoer’ en A-B trajecten in de koeriersmarkt. Ze zijn echter kleiner dan de CEP-markt en werden daarom niet gedetailleerd geanalyseerd in dit onderzoek. In de specifieke markten van minder stops per dag per bedrijf zijn de bezorgkosten hoog voor beide modi. Bijv. Bedrijven met eigen transport zouden kunnen profiteren van de inzet van cargofietsen als alternatief voor hun eigen LCV.



Resultaten welvaart-economische evaluatie

Tijdens het uitvoeren van hun leveringsdiensten compenseren de logistieke sector en de consumenten momenteel niet volledig hun aanzienlijke hoeveelheid externe kosten. Transport beïnvloedt de maatschappij positief omdat goederen de consument bereiken, maar ook negatief omdat de exploitanten en consumenten niet de volledige of eerlijke prijs dragen van hun beslissingen.

Als deze kosten zouden worden geïnternaliseerd in de commerciële tarieven die aan klanten worden aangeboden, zou de competitieve balans fiets-bestelwagen worden gewijzigd. Om inzicht te krijgen in de echte welvaartseconomische effecten, werden de sociale totale transportkosten berekend. Het spreadsheetmodel wordt gebruikt om de sociale totale transportkosten (STTC), sociale gemiddelde transportkosten (SATC) en sociale marginale vervoerkosten (SMTC) te berekenen.

SMTC Cargofietsen (in EUR)	SMTC Bestelwagens (in EUR)
4.52	6.05

Als de externe kosten zouden worden opgenomen in de tarieven, zou dit voornamelijk resulteren in een stijging van de eerder geschatte MTC_{LCV}. De $SMTC_{bike}$ daalt na de internalisering van arbeidsmarktvoordelen slechts iets tot 4,52 EUR, de werkgelegenheid daalt als de lading wordt verplaatst van bestelwagen naar vrachtfietsbedrijven. Gezondheidsvoordelen van fietsen zijn niet inbegrepen. De oorspronkelijke MTC_{LCV} verschuift aanzienlijk na internalisatie, naar 6,05 EUR, de $SMTC_{LCV}$.

Toekomstige marktvraag 'Post & CEP' marktsegment

Huidige CEP-volumes zijn bepaald via proxy-methodologieën. De markt zal waarschijnlijk groeien, doordat de E-commerce sterk groeit. De verkoop stijgt, de vraag naar pakketdiensten in stedelijke gebieden groeit. De pakketvolumes in België groeiden tussen 2013 en 2015 met 24,3%. 79% van de Belgische e-shoppers verkiezen de goederen thuis te laten leveren. In 2015 bestelde een gemiddelde Belgische 12,4 pakketten per jaar, dat slechts 8,1 was in 2010. Op basis van deze gegevens en het aantal Belgische inwoners in 2016 komt het jaarlijkse aantal pakketten voor een stad in zoals Antwerpen op bijna 6,72 miljoen stop op een jaarlijkse basis. En voor Brussel is de benadering 15,44 miljoen pakketten per jaar.

E-commerce is nog steeds snel aan het groeien. En meer dan de helft van deze verkoop heeft invloed op de vraag naar CEP-goederenvervoer. Op basis van recente rapporten werden groeiscenario's gebruikt voor het ontwikkelen van een hoge en lage groeivooruitzichten voor de Belgische CEP-transportvraag in Vlaamse stedelijke gebieden (de groei kan snel stijgen met tussen 3% en 4,5% CAGR). In 2025 zal de Belgische CEP markt in Vlaamse stedelijke gebieden naar verwachting 44,53 miljoen pakketten per jaar bedragen in het lage groei scenario of 50 miljoen in de hoge groeivariant. De ramingen voor Belgische steden Antwerpen en Brussel zijn op het lijf geschreven van cargofiets ondernemers.

Als de externe kosten zouden doorgerekend worden verschuift dit vervoer naar cargofietsen. Deze verschuiving leidt tot een nettowinst voor de arbeidsmarkt van 249 banen in Antwerpen en 571 banen in de Brusselse regio. Dit is het absolute maximum, ervan uitgaande dat alle CEP-leveringen zouden verschuiven naar vrachtfietsvervoer. De totale Belgische netto-impact zou maximaal 1.262 FTE's zijn.

Gevoeligheidsanalyse en beleidsopties

Gezien de onzekerheden van enkele hypothesen in het kostenmodel, worden een aantal gevoeligheidsanalyses getest om de impact van veranderingen in belangrijke modelparameters te begrijpen. De belangrijkste parameters in de kostenfunctie zijn: i) de afhaal- en leveringsdichtheid, inclusief een capaciteitsmaximum per voertuigtype, ii) het gemiddelde aantal pakketten per stop per voertuig, iii) de brandstofprijs, iv) brandstofverbruik van bestelwagen en v) arbeidskosten van fietsers en bestelwagenbestuurders.

i) In de gevoeligheidsanalyse werd geconcludeerd dat bij een stijging van de dichtheid en een toename van het aantal pakketleveringen per stop de ladingfietsen zouden kunnen concurreren

   Een dichtheidsverhoging geeft aan dat het voertuig meer afleveringen kan uitvoeren in één afleverronde, bijvoorbeeld, zijn er meer klanten per km². Uit de analyse blijkt dat de efficiëntie per cargofiets wel met meer dan 30% moet toenemen om een even concurrerende MTC te bereiken die momenteel wordt verkregen door bestelwagens (3,40 EUR). Als de leveringsdichtheid de cargofietsen toelaat om meer dan 55 leveringen per dag per voertuig te bereiken, dan is de MTC_{Bike} minder dan 3,54 EUR (q x Q = 54, p = 3,54 EUR), of competitief.

Dichtheid is gerelateerd aan de stedelijke morfologie, maar niet alleen daaraan. De infrastructuurkenmerken van stedelijke gebieden definiëren voor een groot deel de toegankelijkheid van stedelijke kernen voor bestelwagens, vrachtwagens en vrachtfietsen. Historische stadscentra met smalle straten en beperkte parkeermogelijkheden zijn een natuurlijke leefomgeving voor fietsen. Maar lokale overheden kunnen ook de groei helpen door het invoeren van venstertijden autovrije zones, fietspaden, enz. De toegangsregels voor steden bepalen steeds meer de gemakkelijke toegankelijkheid van fietsen, in het nadeel van de toegankelijkheid van (meestal) grote vrachtwagens en bestelwagens

ii) De gevoeligheidsanalyse geeft aan dat een brandstofprijsverhoging voor diesel (alleen van toepassing op de bestelwagens) de concurrentiebalans niet zal veranderen. Bestelwagens transport heeft een lage elasticiteit m.b.t. brandstofprijs- schommelingen. Brandstof is slechts een van de kostenelementen van de TTC-functie.

iii) Een lagere loonkost voor cargofietsers zou het concurrentievermogen ervan aanzienlijk beïnvloeden. Dan kan een gemiddelde kosten per stop van 3,35 EUR worden bereikt.

Dit leidt tot de conclusie dat het stedelijk logistiekbeleid gericht moet zijn op de belangrijkste kostenparameters van vrachtwagenvervoer, om de groei van het aantal cargofietsen in de transportmarkt ’Post & CEP’ te verhogen. Er is een breed scala aan beleidsopties, die individueel of collectief bijdragen aan een stimulans voor en groei van vrachtfietsvervoer.

- **Planning- en infrastructuurmaatregelen** (bijvoorbeeld infrastructuur) kunnen een kader scheppen voor fietsen in het algemeen, en voor cargofietsen in het bijzonder. Fietspaden en autovrije zones zijn directe maatregelen om fietsen meer ruimte te geven. Als er een consolidatiecentrum is in de stad, kunnen cargofietsers een leveringspartner zijn.
- **Regulerende maatregelen** beïnvloeden het gedrag van de gebruikers van de stedelijke ruimte. Toegangsbeperkingen voor bestelwagens kunnen het gebruik van cargofietsen stimuleren (bijvoorbeeld LEZ en venstertijden), mits fietsen dan een preferentieel toegangsbeleid krijgen.
- **Fiscale maatregelen** zullen de kostenbasis van ladingfietsen of bestelwagens veranderen. De internalisatie van de externe kosten zal leiden tot hogere bestelwagen transportkosten, zodat cargofietsen profiteren
- **Stakeholder Engagement en nudging**. Communicatie en bewustmaking rond het gedrag van e-commerce beslissingen op de lokale problemen op het gebied van leefbaarheid kan ander bestelgedrag sturen. De overheid kan ook alternatieven

faciliteren: bijv. pakkeetkluisjes laten installeren op het publiek domein, waardoor deze groenere leveringsopties aan de consument kan worden aangeboden. Dit is vooral een actie voor de particuliere sector.

- **Technische innovaties**. Dit heeft betrekking op innovaties in de voertuigtechnologie, verkeerssturing en planning. De voertuigtechnologie van cargofietsen maakt het mogelijk ze snel uit te rollen. De voertuigen zijn goedkoper dan bestelwagens en vereisen geen motoren, brandstof of opladen.

Beleid kan de plaatselijke groei van de cargofietsmarkt beïnvloeden of een nationale en regionale strategie kan ze beter kenbaar maken en fiscaal ondersteunen. Het getrapte beleidskader voor stedelijk goederenvervoer bemoeilijkt de beleidsvorming echter. De meest toegepaste lokale beleidsopties zijn: toegangsregels (tijdvensters en autovrije zones), infrastructuurinvesteringen (fietspaden en consolidatiecentra), bewustmaking en economisch beleid (km heffing, subsidies voor vrachtvervoer). Het leiden van werklozen naar de arbeidsmarkt via cargofietsvervoer kan ook banen creëren en zou ook een beleidsoptie kunnen zijn. De sociale economie kan profiteren van pilots met lading cargofietsvervoer. Dan worden de arbeidskosten verlaagd, wordt de cargofiets een echte optie en profiteert arbeidsmarkt profiteert van minder werkloosheid.

Daarnaast kunnen ladingfietsen worden gebruikt als dienstvoertuigen, voor eigen transport van KMO's en horeca, en als niche-sector voor koeriersactiviteiten. Deze laatste markt is een echte strekte van de fietskoeriers. Ze zijn snel en betrouwbaar van A naar B, ondanks files. Deze markt is echter veel kleiner dan de CEP markt. Waarschijnlijk is de inzet van cargofietsen voor eigen vervoersdiensten een onderontwikkelde optie. Lokale bedrijven kunnen worden gestimuleerd om na te denken over deze optie via bewustmakingscampagnes. Dit is een beleidsoptie voor lokale beleidsmakers. De beleidsmakers die het gebruik van ladingfietsen willen verhogen, kunnen bovendien het goede voorbeeld tonen en stadsvoertuigen vervangen naar fietsen (interne post, reparaties, groendiensten ed.).

Jochen MAES
Antwerpen
Oktober 2017

Executive summary

The impact of urban mobility, and urban freight transport in particular, on the liveability of an urban area is elevated. Growing urban road congestion in most European cities, to which urban freight transport is an active contributor, vehicle emissions and road safety are pertinent challenges for society. Several other (negative) impacts are noticeable. Noise in urban areas by vehicles and logistics activities is a challenge, next to wear and tear of the public domain by heavy goods vehicles (HGVs), and not to mention the parking behaviour of freight vehicle drivers. Overall, urban freight traffic is estimated to account for about 10-15% of road kilometres driven, for approximately 25% of urban transport related Green-House Gas (GHG) emissions (e.g. CO_2) and 30-50% of other transport related pollutants (e.g. particulate matter (PM) or nitrogen oxide (NO_X)) (ALICE and ERTRAC, 2015). Europe's cities continue to grow: almost 4 out of 10 of Europe’s inhabitants live in cities. Also Belgian cities realised a steep population growth in urban areas, with an average 8.5% growth pace. Belgians still tend to live more than average in suburbs than Europeans. Nevertheless, in 2014, 35% of the its population lived in urban areas (Eurostat, 2017a).

Cities can try to curb mobility but cannot restrict access too much. Economic and social activities require freight transport to further subsist: transport is just a derived demand of their economic activities. The challenges lead to stakeholders identifying urban liveability challenges and protesting there against, as well as proposing solutions on how to turn the current state of affairs around. This is the urban liveability challenge, overarching the quantifiable concerns.

The objective and subjective observations on urban liveability, and the impact of urban freight transport thereon, is also increasingly recognised by policy makers and transport entrepreneurs. The European Commission’s (EC) 2011 Transport White Paper (COM(2011)144 final) for example is ambitious: emissions of air pollutants from transport need to be reduced significantly. The most important objective for this Ph.D is “The Union should achieve essentially CO_2-free city logistics in major urban centres by 2030” [1].

The ambitious (European) transport, and environmental, policies increased pressure on stakeholders to ameliorate vehicle efficiency, innovate and become more sustainable in their day to day business. One of the solutions in urban freight transport is to deploy in urban areas a different fleet of low emission vehicles. Often, electric vehicles are proposed while non-

[1] The envisaged steps are: halve the use of ‘conventionally-fuelled’ cars in urban transport by 2030; Phase them out in cities by 2050; Achieve essentially CO_2-free city logistics in major urban centres by 2030 (COM(2011)144 final).

emitting vehicles like bicycle transport is a less commonly proposed alternative. The central research question was developed as: **"Can cargo bicycles contribute to an enhanced economic/environmental/societal liveability of urban areas, and to what extent?"**

The concept is not brand-new. It is possibly one of the older, and still active, urban logistics systems in the world. Nevertheless, it has been under the radar as a viable transport option for decades. Growth of the commercial bicycle transport market is seen in almost all of Europe's urban areas. Cargo bicycle transport is nowadays organised via various start-ups. New cargo bikes with electric assistance and IT developments allow for new business models to flourish (examples are Deliveroo, Foodora, and Bubble Post). Also long-existing global transport organisations (like UPS, DHL and FedEx) develop cargo bicycle transport solutions.

The topic was paid attention before in research and dissemination projects like CycleLogistics (ahead), Pro E-bike and Straightsol; with in general positive outcomes. However, the comprehensive literature review shows that the business economic viability of cargo bicycle transport is researched to a far lesser extent. Research on bicycle transport as a solution for freight transport in urban areas can be considered a rather new and under-developed academic research stream, with pertinent knowledge imperfections: (business) economic research gaps exist.

The dissertation's research focuses on the (welfare) economic aspects of urban distribution of freight by cargo bicycles. It is researched in a concrete setting where last mile transport, first mile transport and Businesses to Business (B2B) and Business to Consumer (B2C) are keywords.

- The last-mile is defined as the last trip, to the final receiver, by a vehicle leaving a depot/transhipment facility; i.e. where the last handling is undertaken.
- The first mile is defined as the pickup of goods at the urban shipper's premises, the transport within the urban area, and the delivery to the first handling location (often the same location as the depot or transhipment facility mentioned in the first bullet).
- The research in the dissertation focuses on the transport of goods towards the end receiver, located in an urban area. These cargo flows can be B2B as B2C type of shipments.

After a market scan, interviews with logistics and cargo bicycle entrepreneurs, and reading literature, it was concluded that the most promising market for cargo bicycles is: contributing to the last mile delivery of the Courier Express, Parcel (CEP) market.

To make a sound evaluation, cargo bike transport is assessed in a spreadsheet model, therein structuring the evaluation and making the results of business and welfare economic evaluations comparable. Based on research, an applied Social Cost Benefit Analysis (SCBA) framework is developed, analyzing the use of cargo bicycles in two steps.

- The first step of the evaluation is a **business case** set-up, which is the research framework for analysing the economic effects of implementing the cargo bicycle transport in urban areas. The data used in the appraisal are based on research on the Belgian bicycle transport market.
- The second step within the evaluation is expanding the pure business economic view towards a **welfare-economic evaluation**. Here, external costs are integrated into the appraisal. Then, also policy measures and their impacts are simulated.

Outcomes business case analysis

The spreadsheet model allows to developed conclusions on the Total Transport Costs (TTC), Average Transport Costs (ATC) and Marginal Transport Costs (MTC).

The Average Transport Costs (ATC) for cargo bikes are elevated. Only for low volume companies, bicycle transport has a niche product which is very competitive with LCV oriented transport.

In general, LCV transport can be organised at a considerable lower cost per stop. When a delivery company performs only some 50 stops per day, the LCV cost per stop is with 5.82 EUR considerably lower than the cost for cargo bikes (being 6.63 EUR per stop). When a certain company scale is obtained, LCV transport in this Ph.D.'s setting can be organised at around 3.50 EUR per stop, while cargo bikes cannot go below 4.6 EUR per stop.

The Marginal Transport Costs (MTC) are lower for LCV transport than for cargo bike transport. It can be noticed that the costs go to an almost fixed cost per stop from around 250 stops per company per day, and beyond. A minimum scale is needed to be active in the 'Post & CEP' market.

MTC Bike (in EUR)	**MTC LCV (in EUR)**
4.61	3.40

Based on the business case analysis, it is concluded that the long-term economic sustainability of cargo bicycles for replacing LCVs in the CEP market is a challenge. Labour is the most important cost factor, increasing cargo bicycle's delivery costs considerably. Scenarios showed that the vehicle cost is relatively less important. The fuel consumption is less relevant than expected, so is the diesel price.

The 'Post & CEP' market has the biggest possible market volume for cargo bicycles, and the boom in e-commerce shows a lot of potential growth. But niche markets exist too, e.g. own account transport, heavy load cargo bike transport and A-B trajectories in the courier market. They are however smaller than the CEP market, and were therefore not analysed into detail in this research. In the specific markets of less stops a day per company, delivery costs are high for both modes. E.g. own-account transport will benefit of deploying cargo bikes as an alternative to their own LCV.

Outcomes welfare-economic evaluation

While performing their delivery services, operators and final consumers currently do not fully compensate for their considerable quantity of external costs. Transport operations influence society positively as goods reach consumers, but also negatively as operators and consumers do not pay the full or fair price for their shipments.

If these costs were to be internalised in the commercial tariffs offered to customers, the competitive balance bike-LCV would be altered. To get insight in the real welfare-economic effects, the social total transport cost is calculated. The spreadsheet model is used to calculate the Social Total Transport Costs (STTC), Social Average Transport Costs (SATC) and Social Marginal Transport Costs (SMTC).

SMTC Bike (in EUR)	**SMTC LCV (in EUR)**
4.52	6.05

When the external costs were to be included, then this would mainly result in an upward rise in the earlier estimated MTC_{LCV}. The $SMTC_{bike}$ decreases after internalisation of labour market benefits just a little till 4.52 EUR, the employment drops if cargo is shifted from LCV to cargo bicycle transport companies. Health benefits are not included. The original MTC_{LCV} shifts up significantly after internalisation, to a value of 6.05 EUR, the $SMTC_{LCV}$.

Future 'Post and CEP' market demand

Current CEP volumes are determined via proxy methodologies. The market is highly likely to grow. E-commerce fuels this growth. E-commerce sales are rising, parcel demand in urban areas grows. The parcel volumes in Belgian grew by 24.3% between 2013 and 2015. 79% of Belgian e-shoppers usually choose to be delivered at home. In 2015, an average Belgian ordered 12.4 parcels per year, which was only 8.1 in 2010. Based on this data, and the number of Belgian inhabitants in 2016, the yearly number of CEP PUDs for a city as Antwerp comes near to 6.72 million stops on an annuals basis. And for Brussels the approximation is 15.44 million PUDs per year.

E-commerce sales is still rapidly developing. And over half of these sales has an impact on demand for CEP freight transport. Based on recent reports, growth scenarios were used to develop a high and low growth forecast for Belgian CEP transport demand in Flemish urban areas (growth is expedite to increase by between 3% and 4.5% CAGR). By 2025, Belgian CEP PUDs in Flemish urban areas are expected to amount up to 44.53 million in the low-growth scenario or 50.70 million in the high growth variant.

The estimates for Belgian cities Antwerp and Brussels are exemplary for the increased need for bicycle riders. Growth leads to a net gain for the labour market of 249 jobs in Antwerp and 571 jobs in the Brussels region. This is the absolute maximum, assuming all CEP deliveries would shift to cargo bicycle transport. The total Belgian net-impact would be maximum 1.262 FTEs.

Sensitivity analysis and policy options

Given the uncertainties of some hypotheses in the cost model, a number of sensitivity analyses are tested to understand the impact of changes to key model parameters. The key parameters in the cost function are: i) the pick-up and delivery density, including a capacity cap per vehicle type, ii) the average number of drops per vehicle stop, iii) the fuel price of diesel (only applicable to the LCV), iv) fuel consumption of LCVs and v) labour cost of cyclists and LCV drivers.

i) In the sensitivity analysis, it was concluded that a **density** increase and an increase of the number of parcel deliveries per stop could make cargo bicycles more competitive.

   A density increase indicates that the vehicle can perform more PUDs in one delivery round, for example, there are more consumers per km². The analysis shows that the efficiency per cargo bicycle should increase by over 30% to reach an equally competitive MTC currently obtained by LCVs (3.40 EUR). When the delivery density would allow the bikers to reach over 55 PUDs per day per vehicle, then the MTC_{Bike} will result below 3.54 EUR (q x Q = 54, p = 3.54 EUR).

   Density is related to the urban morphology and terrain, but not only. The infrastructure characteristic of urban areas define for a big deal the accessibility of consumers by LCV and/or cargo bikes. Historic city centres with narrow roads and limited parking opportunities are a natural habitat for cargo bicycle transport. But local governments can also assist the uptake when they put in place time-windows, car-free zones, bicycle paths etc. The access regulations to cities define more and more the easy accessibility by bicycles, in the contrary the accessibility of (mostly) large trucks and also LCVs.

ii) The sensitivity analysis also pointed out that a **fuel price** increase of diesel (only applicable to the LCV) will not alter the competitiveness. LCV transport has a low elasticity to fuel price fluctuations. Fuel is only one of the cost elements of the TTC function.

iii) A lower **labour cost** for cargo cyclists and LCV drivers would significantly impact the competitiveness of cargo bikes. Then, an average cost per stop of 3.35 EUR could be reached.

This leads to the conclusion that policy should target the main cost parameters of cargo bike transport, for increasing the uptake thereof in the 'Post & CEP' transport market. Analysing wide range of policy local policies, these can either individually or collectively, contribute to increased uptake of cargo bicycle transport.

- **Planning measures** (e.g., infrastructure) can assists the bicycles. Bicycles paths and car-free zones are the direct measures, helping the bicycles to better move true traffic. If there is an UCC, they can be a delivery partner.
- **Regulatory measures** influence the behaviour of stakeholder. Access restrictions for LCVs can help the use of cargo bicycles, (e.g. LEZ and time windows), provided they receive a preferential access policy.
- **Fiscal measures** will change the cost basis of cargo bicycles, or LCVs. Internalisation of external costs will lead to higher LCV transport costs, benefiting cargo bicycles.
- **Stakeholder Engagement and nudging**. Communication and awareness raising can change e-commerce delivery behaviour and resolve local liveability issues. E.g. installing lockers, offering local green delivery options to consumers. This is mainly an action for the private sector.
- **Technical innovations**. This relates to innovations in the vehicle technology, traffic steering and planning. The vehicle technology of cargo bicycles allows rapid roll out. The vehicles are cheaper than LCVs and do not require engines, fuel or charging.

Policy can influence market uptake locally, or can define a national strategy. The stacked policy framework for urban freight transport complicates the policy approaches. Most applicable local options are: access regulations (time windows and car free zones), infrastructure investments (bicycle paths and if present UCCs), awareness raising (dissemination projects) and economic policies (road pricing, subsidies for cargo bike transport). Leading unemployed to the labour market via cargo bicycle transport jobs could also be a policy option. The social economy can benefit from pilots with cargo bicycle use. Then labour costs are lowered, and the labour market benefits from less unemployment.

In addition, cargo bikes can be used as service vehicles, for own-account transport and as niche sector for courier activities. Probably the own-account transport services, are the must under developed cargo bicycle market. Local SME's can be stimulated to think about this option via awareness raising campaigns. This is a policy option for local policy makers. The policy makers willing to increase cargo bicycle use can in addition show the good example and shift city vehicles to cargo bikes (internal mail, repairs, greenery, etc.).

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1. Introduction: the main challenges for urban logistics

Urban freight transport services and residents of urban areas are confronted with particular economic, sustainability and liveability challenges. Ambitious (European) transport and environmental policies increased pressure on transport service providers to ameliorate vehicle efficiency, to innovate and become more sustainable in their day-to-day business. Residents doubt the future liveability of their urban area, and question the impact of urban freight transport thereon. This chapter depicts the main trends and challenges related to urban freight transport services, sets the dissertation's research scope, identifies research gaps via a literature overview and adds fundamental definitions. All in order to develop research questions.

For creating, or maintaining, liveable and attractive urban areas, it is key for policy makers to allow mobility and logistics service providers to continue to grow, in that way assisting to the urban area's economic competitiveness. It is on the other hand important to aim for a more sustainable urban economic growth: economic growth without (further) increasing local negative societal effects of vehicle movements (of which tailpipe emissions, accidents and road congestion are pertinent). Currently, finding this right balance is one of the general challenges for city policy makers, just as for transport service providers who need to find new ways to organise their services (Russo and Comi, 2010). New approaches and strategies will be needed in order to attain a combination of (long-term) sustainable growth in urban areas, which needs transport and logistics, maintaining a competitive urban economy while building liveable and attractive urban areas.

A growing urban population and general trends in society, mobility and logistics (for example an increase in e-commerce and at home deliveries, Just In Time logistics, an increase in shopping frequency, omni-channel logistics, digitalisation of logistics, electrification of transport, on-demand delivery, the 'shareconomy', Uber, deliveroo, but also a desire for more local production and warehousing, and more general aspects for instance ageing or an increased variety of products in supermarkets) might combined lead to an increase in transport demand. Certainly in dense urban areas. More mobility, logistics, goods transport and services to the resident's doorsteps is envisaged. Therefore, the current pertinent challenge for keeping urban areas liveable, will be growing in the face of an increased demand for goods transport.

One of the solutions for urban freight transport providers is to deploy a diverse fleet of low emission vehicles in urban areas, other than in non-urban areas. New technologies allow for new approaches. Often, electric vehicles are proposed as an alternative to Internal Combustion Engines (ICE) (currently the majority of goods vehicles run on diesel, petrol or gas) found in LCVs (Light Commercial Vehicles) and HGVs (Heavy Goods Vehicles) (Melo et al, 2014). Even though they become better and more accessible, the limited range of these alternative fuel vehicles make them currently not attractive for long distance transport, but highly appropriate for local urban goods distribution. A lot of attention is devoted to electrification of vehicles, while the use of non-emitting vehicles like cargo bicycle transport is a less common proposed alternative.

Electrification of current vehicles is not the only way to go forward. In order to achieve the urban liveability goals, cities need to push forward their transformation, exploring new ways of organising goods transport as well as new transportation modes (Gruber and Kihm, 2016). This dissertation therefore develops knowledge on the commercial use of cargo bicycles as an alternative to the current deployment of traditional LCVs, as likely a means of meeting ambitious European urban freight policy ambitions and to increase urban liveability in general. Based on an initial market analysis of different urban freight solutions, urban cargo bicycle transport was concluded to be an interesting innovation to further analyse (Gevaers, Van de Voorde et al, 2009; Maes and Vanelslander, 2012; Maes, 2015).

This dissertation researches in detail this one possible solution for reaching or assisting to the objective: “a sustainable economic growth for the urban area, in combination with an improved urban mobility and urban logistics, and liveability and attractiveness of urbanised areas.” Notably the European Commission’s policy goal, “The Union should achieve essentially CO_2-free city logistics in cities by 2030” is targeted (2011 White Paper European Commission).

The dissertation’s central research question was developed as:

“Can cargo bicycles contribute to an enhanced economic/environmental/societal liveability of urban areas, and to what extent?”

The dissertation’s research focuses chiefly on the economic aspects of urban distribution of freight by cargo bicycles. The new vehicles possess in contrast to regular bicycles many advantages for commercial use. They combine a low operating cost, with a higher payload. Less driver fatigue and especially low energy use compared to LCVs are their key strengths (Transport for London, 2009). In addition to the analysis of their business-economic impact, also their welfare economic benefits (lower emissions, social aspects etc.) are regarded. The transport concept is researched and benchmarked against LCVs in a concrete setting where last mile transport, first mile transport and Businesses to Business (B2B) and Business to Consumer (B2C) an C2X (serving consumers and small businesses) are keywords.

i) The last-mile is defined as the last trip, to the final receiver, by a vehicle leaving a depot/transhipment facility; i.e. where the last handling is undertaken.

ii) The first mile is defined as the pickup of goods at the urban shipper's premises, the transport within the urban area, and the delivery to the first handling location (often same location as the depot or transhipment facility in the first bullet).

iii) The research in the dissertation focuses on the transport of goods towards the end receiver, located in an urban area. These cargo flows can be B2B as B2C type of shipments. Especially CEP (courier, express, parcel) shipments are targeted, as these are in general light per shipment and low in (transport) volume.

This introductory chapter starts with section 1.1, introducing the rationale to research cargo bicycle transport. Five main trends and (urban) challenges are highlighted. These are: European inhabitants move to urban areas (i), this increase in population leads to an increased demand for urban freight transport (ii), while the urban freight transport sector has already sustainability challenges (iii), which lead to an urgency for policy makers for increasing urban liveability (iv), while solutions and innovations for tackling the sustainability concerns are developed (v). Then, there is a non-exhaustive overview of cargo bicycle transport, which is the core subject of this dissertation. This to outline the developments in this field to the reader non-familiar with this logistics concept (section 1.2). This introduction leads to a definition of the research gaps (section 1.3). The research scope and questions are discussed in the chapter's final section 1.4.

1.1. The main trends and challenges

This general introduction presents in a brief way, in light of current developments in Europe's (urban) freight transport sector and recent ambitious European urban transport policies, the current sustainability and liveability challenges of most of Europe's urban areas. Specific attention is devoted to Belgian urban mobility and logistics challenges.

1.1.1. European inhabitants move to urban areas

Europe's cities continue to grow: four[4] out of 10 of Europe's inhabitants live in cities already (Eurostat, 2016a; Eurostat, 2016b; Eurostat, 2017a; Grimm et al, 2008), a slight decrease in share compared to earlier years but not in number of inhabitants. Cities and urban areas concentrate activities and are vital places to exchange goods, services and social interaction; the heart of our economy and way of life. This concentration allows economies to flourish.

[4] In the EU, the share of the population living in cities stood at 40.4% in 2015 compared with 27.9% for rural areas and 30.5% for towns and suburbs (Eurostat, 2017a).

First, cities and urban areas needs to be well-defined. According to Dunn (1993), the differences in size are:

- **Towns** are small clusters of population which are self-governed. A town is generally larger than a village, but smaller than a city. Some geographers further define a town as having 2,500 to 20,000 residents.
- A **city** however is referring to a legal definition that defines a physical geographic zone. An urban area however is more flexible as it refers often to a region, cluster of population or a certain population density. There is no clear boundary as respect to the number of residents needed. Density is also a factor.
- The **urban area** then, is an area including and surrounding a city with high density which is very developed, meaning there is a density of human structures such as houses, commercial buildings, roads, bridges, and railways.
- A **metropolitan area** is the most nebulous term in that it comprises an urban area and the outlying region(s) that share utilities, industries, and various institutions.
- And to conclude, when two or more metropolitan areas grow until they combine, the result may be known as a **megalopolis**[5].

These definitions of cities and urban areas align with the definitions by DG REGIO, Eurostat and the OECD (OECD, 2003, Eurostat, 2016b) which defined cities and their surrounding areas (2011) as:

- A **city** consists of one or more **local administrative unit** (LAU[6])); the majority of people live in an urban centre of plus 50,000 inhabitants (this is then the core city).
- A **greater city** approximates the urban centre and stretches beyond the administrative city boundaries (also referred to as the kernel). Approximately half of the cities in the EU had a relatively small urban centre of between 50,000 and 100,000 inhabitants
- A **functional urban area** consists of the city and its surrounding commuting zone (also known as a larger urban zone (LUZ).

Further in this dissertation the term 'city' relates to the physical geographic zone where many people live in one self-governed area, which is more a legal term. 'Urban area' is used to describe the wider region around this city. The urban area is not self-governed, and consists of the city and several towns around it. The density makes the biggest difference between the city and urban area. The two distinguish themselves in essence by density from the suburbs and rural areas.

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[5] In the United States, the urban area of Boston, Massachusetts, eventually spread as far south as Washington, D.C., creating the megalopolis of BosWash, or the Northeast Corridor. The 'Randstad' region in The Netherlands is another example, where the whole region of Rotterdam, The Hague, Amsterdam and Utrecht form a strong economic region with social and economic relationships between their 7 million residents.

[6] A local administrative unit (LAU) is a low level administrative division of a country, ranked below a province, region, or state.

In the European Union (EU), in case of applying the Eurostat definition of urban areas, the level of urbanisation (number of people living in the functional urban areas) is projected to rise to just over 80% by 2050 (Eurostat, 2016b). Also according to Eurostat, the average population growth in the EU27 urban areas was higher than the increase of population in rural areas. For example, Belgian cities had between 2000 and 2015 a steep population growth of 11% (Eurostat, 2017b), exceeding the general population growth in Belgium. Belgians though still live more than average in suburbs than Europeans do (De Decker, 2010). In Belgium, also in 2015, 47% of population lived out of the densest urban areas (Eurostat, 2017b), while 59.9% of population has a job in the densest areas of the country (Eurostat, 2017c). This indicates a concentration of people in urban areas, also in Belgium, but far from the projected 80% expectations for Europe in 2050.

The move of population to urban areas, and the increase in urban density, is a global trend. This urbanisation is often combined with the growth of population in general, which together influence density of countries and especially of their (main) cities.

And the more people live in one country, region or city, (in general) the stronger the local economic growth and local demand for products, services, mobility and transport will be. As stated by the OECD (2003) freight transport is a fundamental component of urban life. Consequently, urban regions generate a significant share of the Union's GDP, up to 80% in some EU Member states (MDS Transmodal, 2012). For example, a Brussels resident generated in 2014 an average GDP of 49,688 EUR; an average resident in Antwerp generated 43,984 EUR for. In non-metropolitan Belgian areas, this drops to 30,085 EUR (60% of the contribution of a Brussels resident). This is as well reflected in the urban GDP share in the national economy. The urban areas in Belgium generated in the same year jointly a GDP of 239.59 bn. EUR, 60% of Belgium's GDP (Eurostat, 2017b).

Urban freight transport thus plays an essential role in meeting the needs of residents. Nevertheless, it contributes at the same time significantly to the non-sustainability of the environment, economy and society. This link is the second main trend and challenge, discussed in the next section.

1.1.2. Population and economic growth strongly influence demand for transport and its nuisances

In Europe, urban mobility and urban freight transport in particular, takes place in densely populated areas. These dense areas attract businesses, citizens and commuters, which consequently generate more demand for mobility and goods transport.

The past showed that population growth, just as general economic activity and a growth therein, more than equally increases transport demand. Because goods are brought to the urban area, responding to the inhabitants' and businesses' demands. More economic wealth, jobs and consumption, create more transport demand. Recent trends in logistics increased the demand for goods transport even more.

i) First, the almost non-existence of stock in stores requires more frequent delivery of goods to retailers. This 'logistics sprawl' is the movement of logistics facilities (warehouses, cross-dock facilities, intermodal terminals...) outside of the city boundaries towards suburban areas (Dablanc and Rakotonarivoa, 2010; Melo et al, 2014).
ii) Second, different from before is the strong increase of transport of goods towards the final consumer's address. 84% of European e-shoppers usually choose to be delivered at home, slightly more than Belgians (79%) (DPD, 2016). This transport service is called the last mile stretch and is mainly fuelled by e-commerce growth. The parcel volumes in Belgium grew by 24.3% between 2013 and 2015, reaching a 6% share in total mail volumes nonetheless contributing to 40% of the total mail revenue. In 2015, an average Belgian ordered 12.4 parcels per year, a strong increase from 8.1 in 2010 and 9.8 in 2013 (ERGP, 2016; BIPT, 2015; BIPT, 2017).

Though the urban last mile services meet the inhabitants' and businesses' demands, they also generate nuisances for society. For example in the form of concerns on road congestion[7] partly because of frequent stops for loading or unloading operations, local air quality, greenhouse gas emissions and accidents between freight vehicles or between freight vehicles and other (often vulnerable) road users. The increase of car-free zones, urban transport corridors, separate bicycle lanes, access regulations (e.g. time windows for motorised vehicles to enter a shopping street) increased conflicts between loading-unloading and other activities. Often, peaks of goods transport are created because of local regulations.

The increase of tailpipe emissions of logistics vehicles is a specific growing worry for urban inhabitants and their health. Urban mobility accounts for 40% of all CO_2 emissions of road transport and up to 70% of other pollutants from transport (European Commission, 2015). And responding to their voters' concerns, the nuisances are recognised by policy makers too.

As a result of these trends in the transport sector and in the urban areas, conflicts of economic growth and urban liveability are inevitable. Retailers and logistics operators have other preferences than residents, business owners or commuters. Without fundamental changes to the current system, the ever-increasing congestion and emissions will conflict more with the resident's demand for urban liveability and urban attractiveness (Schliwa et al, 2015).

To summarise, an important and growing conflict is observed in many of Europe's cities: an urban area, and its citizens, depend for their existence on a substantial flow of goods into, out of and within their boundaries. But these transport flows and the logistics organisations behind them, are at the same time increasingly confronted with negative societal impacts of

[7] Every year ca. 1% of Europe's GDP is lost in congestion (Christidis & Ibanez-Rivas, 2012).

vehicle movements. Logistics operators are accounted for the negative societal impacts in an indirect form, as they see a cost increase in their operations due to road congestion. According to Gevaers et al (2009), the last mile transport is, due to its very specific delivery needs, now correctly considered the most expensive part of the urban supply chain[8]. Consumers themselves do not bear the external costs of their consumption decisions. Almost 90% of e-shoppers consider free delivery as a driver when buying online; it has become a global standard as it motivates customer purchases (DPD, 2016).

Urban freight transport is a highly challenging part of the total supply chain, given its specific operational characteristics. This challenge is discussed in the next section.

1.1.3. Urban freight transport is a specific supply chain discipline

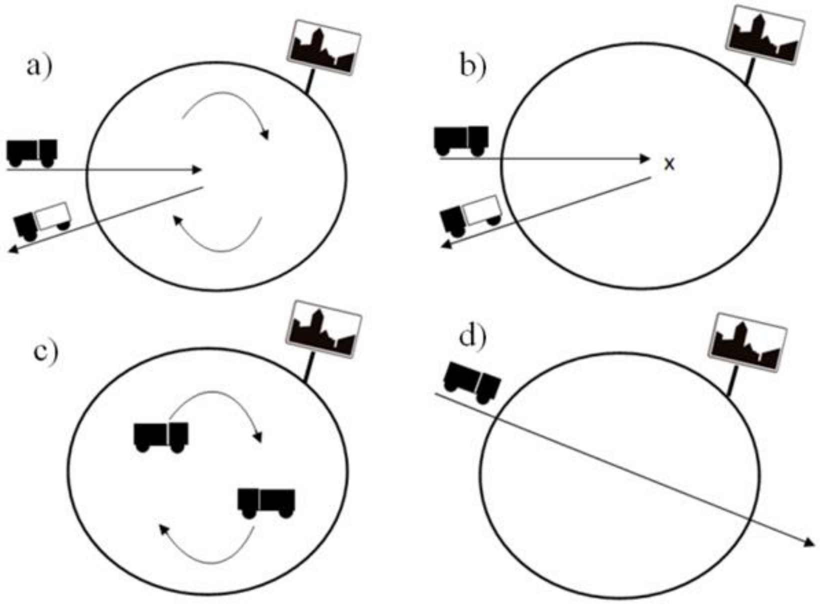
This section outlines the main freight transport patterns in urban areas. Urban freight transport, or city logistics depending on the focus of the research, encompasses flows that often originate from out of the city (production and logistics are located in industrial zones outside the city), whereas the transport to the city increases as consumers are located there.

Urban freight transport is a specific transport discipline. Meryburg and Stopher (1975) classified four flows of urban freight transport: shipments of goods into an area to be consumed within that area; shipments of goods out of an area produced in that area; intra-urban collection and delivery and local shipment in which the vehicle, though not necessarily the commodity, has its origin and destination within the same area and transit movements, maybe with temporary storage and warehousing in the defined area.

The impact on the urban are is presented in Figure 1 on the next page. Pattern a) consists of full trucks, delivering freight from outside the urban area to several delivery locations. At the end of the round trip, the truck exits the urban area empty, or the delivery round is combined with a pick up route. Examples are found in the retail sector, e-commerce deliveries and the postal distribution. Pattern b) is similar to a) but here, the truck only delivers goods at one certain location. The trip is starting outside the urban area, and exits empty. An example is the supply of supermarkets. In this market, often full truckloads are shipped to one retail location. Pattern c) is uncommon, and consists of transporting goods from one urban location to another urban location. As last, pattern d) consists of traffic passing urban areas, but not picking up or delivering goods to an urban location.

[8] The last mile, described in his research as 'the last stretch of a parcel delivery to the final consignee who has to take reception of the goods at home or at a cluster/collection point or at the office' accounts, depending on its characteristics, for 13 up to 75% of the total supply chain expenditures. The upper estimate shows the cost increase for services on congested urban trajectories. Higher urban supply chain costs are illustrated by the many inefficiencies and the poor environmental performance (Gevaers et al, 2009).

Figure 1: City logistics' patterns



Hence, these urban transport activities feature specific challenges related to the geographic location where the transport infrastructure can barely handle the growing demand. There, the challenges are even harder as also (infrastructure) capacity is likely to decrease as cities in recent times decrease the number of road lanes, in an attempt to increase the urban core's attractiveness and liveability. The high density of activities and people make also external costs of emissions higher as vehicles emit much more per km when driving at (urban) congested road stretches. Given the specific flows, depicted above, some transport services are organised via large trucks, others via small delivery vans, and it is difficult to apply a one-size-fits all policy approach.

This leads to a need to define the role and characteristics of urban freight transport and urban freight logistics, often referred to as city logistics. It is generally accepted that these city logistics activities are operations delivering and collecting goods in towns, urban areas, city centres and metropolitan areas.

Taniguchi et al (1999) defined city logistics as:

"the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption within the framework of a market economy."

The OECD (2003) defined urban freight transport as:

"the delivery of consumer goods (not only by retail, but also by other sectors such as manufacturing) in city and suburban areas, including the reverse flow of used goods in terms of clean waste."

Behrends, Lindholm and Woxenius (2008) noted that this definition excludes considerable traffic flows in urban areas, such as goods transported through urban areas (through traffic, flow d) in the figure on the previous page), building and demolition traffic, the provision of industry with raw materials and semi-manufactured articles, and the provision of the wholesale trade.

According to MDS Transmodal (2012), the definition is:

"the movement of freight vehicles whose primary purpose is to carry goods into, out of and within urban areas."

The definition of urban freight transport is according to among others Taniguchi et al (2001), and Marinov, Zunder and Islam (2008) also wider:

"The processes include transportation, handling and storage of goods, the management of inventory, waste and returns as well as home delivery services."

The transport activity as such does not differ significantly from general logistics practices, but the location where these go on is for the most part defining the contents of the term 'city logistics'. The definitions exclude shopping trips in passenger vehicles and movements of 'white vans' for servicing and maintenance (as well as personal) purposes (Transmodal, 2012). City logistics' research scope cannot be defined too narrow as the impact of city logistics can be measured both locally (micro level) and on a supply chain basis (macro level). The latter, broader view is undoubtedly necessary as changes in parallel or related activities undertaken outside urban areas, e.g. logistics handling or a first or last mile stretch of an urban trajectory, can still have impacts on urban freight transport operations' performance. Dablanc (2007) as well as Patier (2002) have been argumenting that the single retained logistics activity in the urban area is loading- and unloading. Other transport and logistics activities (per definition out of the urban area) are of importance too. Dablanc (2007) defined the main change in the urban logistics sector as the shift of the logistics part of the activities from the city core to the periphery.

"*Therefore, freight transport and logistics operations in urban areas cannot be viewed and studied in isolation but rather in the context of the entirety of supply chains that typically cross the geographical boundaries of urban areas*" Dablanc (2007).

Based on these definitions, the own definition of city logistics is:

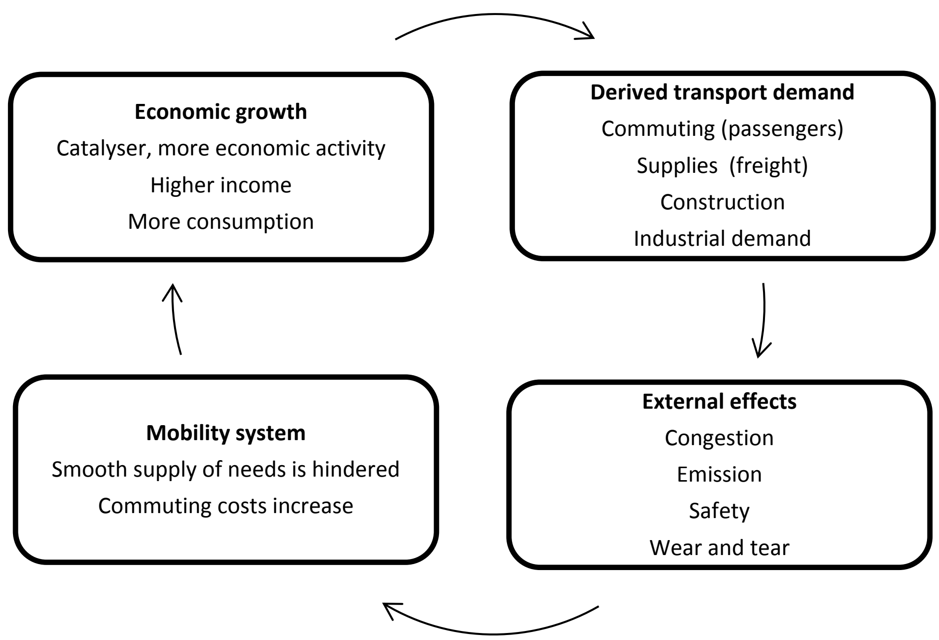
"the activities related to the professional delivery of goods in cities and urban areas, including home delivery services and the reverse flows of used goods and waste. The activities include transportation in, out, and through the cities and urban areas as well as the supporting activities as ICT, handling and (short term) storage of goods, and the management thereof."

1.1.4. Sustainability of urban freight transport is a challenge: four facets

It turns out that the business costs and societal impacts of transport in urban areas are a challenge. As freight vehicles pollute urban areas on the one hand, and freight transport companies lose due to road congestion a vast amount of time and money, the issue of last-mile freight transport in urban areas is gaining importance not only among policy makers but as well at logistics companies' boardrooms.

Figure 2 illustrates the relationship between economic activities, derived demand for freight transport and their external effects. Too many negative effects can cause the economy to spiral down. In fact, transportation potentially affects the nature of the urban area itself (Small, 1997). Urban freight transport is influenced negatively by this circle, and is clearly a negative influence for urban liveability: as vehicle emissions, noise pollution and the vehicle accident risk increase, cities (and urban areas) become less attractive to live in.

Figure 2: The relationship between economic growth and transport activities



Source: Based on Steunpunt goederenstromen, s.d. (Adaptation from Molina & Molina, 2002).

The research in this dissertation explores one specific solution for altering this trend, so the derived transport demand would not spiral down the economy and urban liveability.

The current challenges for the sustainability of urban freight transport are numerous: first road congestion, second, vehicle emissions (local air quality and climate change) and last, urban road safety are the main facets. These all result in a fourth overarching challenge: urban liveability. The next three pages provide more characteristics of the challenges.

The first challenge, **road congestion** can be named the uppermost important European transport problem, certainly in urban areas. It was estimated in the Impact Assessment (IA) accompanying the EC's 2011 White Paper on transport, that European cities together face annually a congestion challenge of on economic value of 80 bn. EUR.

Regional differences are important, as illustrated by Table 1. London is ranked first when congestion is concerned. An average road user lost in 2015 a 101 hours a year, as a consequence of road congestion.

Belgium, and its main cities, are as well one of the worst performers when road congestion is concerned. While the average number or lost hours per user per year in 2015 was countrywide totalling to 44, the number of lost hours in the Brussels and Antwerp urban area were more elevated; respectively 70 and 71 lost hours. Belgian cities are not performing well. Inrix's annual reports (data of 2015) show that the top 20 of most congested[9] cities includes with Brussels, Antwerp and Ghent no less than three Belgian cities. And congestion in metropolitan and city regions is a larger challenge than national road congestion[10].

Table 1: Top 10 Most European Congested Cities (2012 - 2015)

	Metropolitan area ranked by 2015 value	**Hours lost per user in 2012**	**Hours lost per user in 2013**	**Hours lost per user in 2014**	**Hours lost per user in 2015**	**Trend**
1	London commuter zone	72	82	96	101	▲
2	Stuttgart	65	60	64	73	▲
3	Cologne	58	56	65	71	▲
4	**Antwerp**	76	77	64	71	▶
5	**Brussels**	83	83	74	70	▼
6	Karlsruhe	48	52	63	54	▲
7	Utrecht	61	48	53	53	▶
8	Milano	50	55	57	52	▼
9	Düsseldorf	47	49	53	50	▶
n.a.	**Ghent** (10th in 2014)	53	54	53	n.a.	▶

Source: Inrix, 2013, 2014, 2015 and 2016

Congestion originates from increasing passenger and freight flows on a dense urban road network. This dissertation focuses only on freight flows.

Improving local **air quality** in cities and urbanised areas is of major importance to resident's health. BESTUFS (2006a/b) found that total urban freight transport accounts for only 14% of

[9] Congestion is calculated by Inrix in the following way: First Travel Time Tax (T3) is calculated. This is used to measure overall congestion and to establish Urban Area T3. This T3 expresses the average amount of extra time it takes to travel relative to free-flow travel. A T3 of 30%, for example, indicates a 20-minute free-flow journey will take 26 minutes during the peak travel time periods, a 6-minute (30%) journey time penalty. For each road segment, a T3 is calculated for each hour of the week, using the formula T3= Reference Speed (RS) minus Hourly Average Speed (HS)/RS. The T3 is a direct derivative of Travel Time Index, a metric used in congestion analyses.

[10] In INRIX's publications, Hours spent in congestion is the average number of hours a driver would spend in congestion during peak hours based upon 240 commuting days.

the vehicle kilometres while it is responsible for 19% of the energy use and 21% of the CO_2 emissions in urban areas. Transiting HGVs travelling through the area add another 4% of the vehicle kilometres, 12% of the energy use and 10% of the CO_2 emissions (BESTUFS, 2006a; BESTUFS, 2006b). Urban mobility accounts for 40% of all CO_2 emissions of road transport and up to 70% of other pollutants from transport (European Commission, 2015). The problem of transport emissions is greatly pertinent. The 2017 Air quality in Europe report (EEA, 2017) states that in 2015, 19 % of the EU28 urban population was exposed to PM_{10} levels above the daily limit value. And approximately 53% was exposed to concentrations exceeding the stricter WHO Air quality guidelines (AQG) value for PM_{10}. Regarding $PM_{2.5}$, 7 % was exposed to levels above the EU limits, and approximately 82% was exposed exceeding AQG values (EEA, 2017). Public health is influenced negatively, 70% of cancerous substances find their origin in traffic emissions (Silva and Ribero, 2009). In view of a statement of IARC[11], the specialised cancer agency of the WHO, which officially classified outdoor air pollution as carcinogenic to humans, this pollution problem needs political attention (IARC, 2013), and action!

Urban **road safety** is the last of four main challenges. With 26,134 fatalities in 2015, even though coming from 45,943 ten tears before, road freight transport is in Europe responsible for over 95% of all freight transport related fatalities (European Union, 2017). Still, the pace of making roads more safe is not reflected in the urban road transport network's trend. With 35% of the total transport fatalities, the share of urban areas stays high. Freight transport can be a key contributor to road injuries, especially in urban areas. HGVs are fore example responsible for over 42 % of cyclist deaths in London (Keigan, Cuerden and Wheeler, 2009). Of the 756 bn. EUR external accident costs, road transport's share is 30%. Of that same total, freight transport is likely responsible for 14% (Ricardo-AEA, 2014).

The last and overarching challenge is the **urban liveability challenge**. Aside the urban congestion, emission and a pertinent road safety problems, several other (negative) impacts are noticeable. Congestion affects not only logistics costs or the reliability of transport services, but also tackles the well-being of citizens in urban areas (EEA, 2013; EEA, 2017). In addition, it affects road users' stress. Also noise in urban areas is a challenge[12], next to wear and tear of the public domain (by for example HGVs).

Cities and urban areas can curb mobility, but cannot restrict access too much as passenger and freight transport are required given the areas are concentrating economic activities (offices, super markets, leisure activities, tourism etc.). All of these activities need supplies, need to transport their products and need to get rid of their waste. As such, these need freight

[11] International Agency for Research on Cancer

[12] More than half of the EU's urban population is exposed to noise levels above 55 dB. The EC (2010) states that more than half of urban people find noise a major problem; this proportion ranged from 51% in Rotterdam and Strasbourg to 95% in Athens (EC, 2010a). In this respect, freight traffic can make a significant contribution as it is accounting for 40% of noise emissions in urban areas (Korver et al, 2012).

transport to subsist: transport is a derived demand of economic activities (Anderson et al, 2005; Maes and Sys, 2012). This common conception is challenged by Hesse and Rodrigue (2004), who claim that improvements of freight transport capabilities also foster transport demand, boosting transport demand faster than previously expected.

This cluster of a variety of challenges leads increasingly to stakeholders identifying them themselves and proposing solutions, policies and actions on how to turn the situation. Cities are confronted by groups of inhabitants stepping up against the local mobility challenges. These people are often identifying their problem in a narrow way by means of slogan demands, “Less trucks”, “No freight transport in my street”, “Car free zones now”, “Ban large trucks”. One can often recognize a number of subjective elements. However, how can liveability of urban areas then objectively be defined? Should only external costs be regarded, and what is the influence of non-transport activities on liveability of urban cores?

Hence, in addition to the quantifiable challenges, the attitude and feelings of the public towards urban mobility challenges are also important to take account of. A recent special Eurobarometer survey concluded for example that a strong majority of EU citizens consider congestion, and the impact of urban mobility on health and the environment as an important problem[13]. Moreover, many respondents were rather pessimistic regarding expected improvements in their city’s traffic situation (TNS Opinion & Social, 2013). Indeed, citizens in developed economies understand mobility as a right, especially in large cities where congestion and pollution make private transportation more inconvenient and expensive (Albalate and Bel, 2009).

Many local governments are inspired in their policies by the urban liveability challenges, partially in relation to freight transport. Especially when voters step up against the local government. Governments aim in general with local policies at decreasing the vehicles’ impact on society by curbing the amount of vehicles in urban areas, by greening them or by stimulating innovations. It can be said that in general politicians are less aware of the impact of their policies on the logistics side of vehicle movements. Logistics companies, as it is their nature, optimise transport flows (creatively). However, clearer policies would help them reaching better performance. Public authorities can also be instrumental in bringing together all stakeholders to establish a shared diagnosis of the existing situation, identifying the potential for progress, and devising a strategy (Savy, 2016).

[13] European Commission Special Eurobarometer 406 (2013) ‘Attitudes of Europeans towards urban mobility’

1.1.5. An increased shared sense of urgency in local and EU policy and within the urban logistics sector

There is a shared benefit to research the urban freight transport sector into more detail and innovative solutions therein (like cargo bicycle transport); for companies, policy makers and academics. Urban freight transport constitutes both a societal challenge and an opportunity for improving operations (supply chains). And academic research can link the welfare and business economic perspectives.

First, an end goal and measurable objectives should be developed. What is 'sustainability' when urban freight transport is concerned? Behrends et al (2008) developed a definition of Sustainable Urban Freight Transport (SUFT). The term 'sustainable development' first gained a major prominence in the report 'Our Common Future', published by the World Commission on Environment and Development, which is also commonly known as the Brundtland Report. Its definition of sustainable development is still widely used today (Brundtland, 1987) as a beginning:

"Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

This definition highlights three fundamental components of sustainable development: (1) economic growth; (2) social equity for meeting the needs of today's generation; and (3) environmental protection for the ability to meet today's and future generation's needs. It also disproves the widely spread perception that some impacts on environment and society are trade-offs with economic prosperity.

Based thereon, Behrends et al (2008) proposed that sustainable urban freight transport should fulfil the following four objectives:

i) to **ensure** the **accessibility** offered by the transport system to all categories of freight transport;
ii) to **reduce air pollution**, greenhouse gas emissions, waste and noise to levels without negative impacts on the health of the citizens or nature;
iii) to **improve** the resource- and **energy-efficiency and cost-effectiveness** of the transportation of goods, taking into account the external costs and;
iv) to **contribute to** the enhancement of the **liveability** in the form of more attractiveness and quality of the urban environment (avoiding accidents, minimising the use of land and without compromising the mobility of citizens).

Policy approaches were at first mainly developed as a reaction to road congestion and emission challenges. Objectives originate from the local, but also from the EU level. European policy goals for the transport sector, also showing the way for local policy approaches, became of paramount importance for the future performance of the European urban freight transport industry. The EU policy goals of relevance for the sector are consolidated in Table 2 below. A variety of policy documents mentioned a variety of sustainability goals for mobility and transport.

The policy goal of halving the use of conventionally-fuelled cars in urban transport by 2030 and the aim for CO_2 free city logistics in major urban centres, both depicted in the 2011 White Paper, are greatly ambitious. Currently the vast majority of transport is organised via fossil fuel powered vehicles (HGVs and LCVs). The use of (more) CO_2 friendly vehicles like cargo bikes and electric vehicles in day-to-day urban freight transport is currently still scarce.

Table 2: Summary of main (urban) freight transport policy objectives

	Target date	Source
A framework is provided to internalise external costs of congestion, noise and emissions (maxima apply)	2011 >	Directive 2011/76/EU (EC, 2011)
Target average type-approval emissions for new LCVs **175 gCO_2/km** **147 gCO_2/km**	 '14-'17 2020	Target CO_2 emissions from new light commercial vehicles (EC, 2012)
10% share of renewable energy in the transport sector	2020	2011 White Paper on transport EC (2011)
Transport GHG emissions (incl. international aviation, excl. maritime shipping) **↓20% (versus 2008)** **↓60% (versus 1990)**	 2030 2050	2011 White Paper on transport EC (EC, 2011)
Use of conventionally fuelled cars in urban transport **↓50%** **↓100%**	 2030 2050	2011 White Paper on transport EC (EC, 2011)
CO_2 free city logistics in major urban centres	2030	2011 White Paper on transport EC (EC, 2011)
70% reduction of transport oil consumption from today	2050	2011 White Paper on transport; Impact Assessment (EC, 2011)

Source: Own composition based on EU policy documentation

Urban freight transport operators are influenced by these European policy goals directly and should change their performance in order to meet the set objectives. In addition, local policy makers will need to develop local approaches to help the industry in meeting these high-level policy goals.

1.2. EU policy goals are ambitious, however stakeholder expectations and approaches differ

Different views and expectations are encountered when stakeholder preferences are mapped. The origin is found in the fact that this urban core is being perceived differently by e.g. commuters, inhabitants, transport operators, retailers and many of the other stakeholder types. Research by Balm, Macharis, Milan and Quak (2014) distinguished some five main stakeholder groups. These are the logistics service providers (abbreviated LSP), freight shippers, local authorities, the receivers and citizens. Balm et al (2014) then surveyed these stakeholders on their preferences and asked these to assign weights to the preferred criteria (see Table 3 below).

Their research clearly illustrates the diverting views. While the LSP's clearly have a preference for aspects like profitable operations, the visibility of investments and high levels of service, local authorities have more attention for the business climate and the 'quality of life'. Especially in dense urban environments, transport effectiveness and efficiency not only affect local and regional economic productivity, they have an impact on citizens' quality of life. Thus, a smooth urban freight distribution might even increase the liveability of urban areas (Albalate and Bel, 2009).

Which aligns with LSPs which want to make a profit. Difficult, as while their clients (shippers and receivers) are focused on low costs for freight transportation. The local authorities, managing access of LSPs to the urban area, to a lesser extent take account of cost or price sensitivities but mainly want the citizens' support for measures. These citizens also do not take account of costs that much (transport costs are in general a minor share of total products costs), but want to see a lower impact of freight transport on their liveability (e.g. reduced emissions and congestion).

Table 3: Stakeholder groups' preferences regarding urban freight policy measures

Stakeholder	Preferences	Criterion definition
Logistics service providers (LSPs)	Profitable operations	Making profit by providing logistics services
	Viability of investment	A positive return on investment
	High level service	Receiver and shipper satisfaction
	Employee satisfaction	Employees are satisfied with their work and working environment
	Green concerns	Positive attitude towards environmental impact
Shippers	Successful pick-ups	Punctual and secure pick-ups with no damage
	Cost of deliveries	Low out-of-pocket costs for transport
	High level service	Receiver satisfaction
	Green concerns	Positive attitude towards environmental impact
Local authorities	Positive business climate	Attractive environment for companies
	Quality of life	Attractive environment for citizens
	Social and political acceptance	Citizen support for measures

Receivers	Convenient high level deliveries	Deliveries that do not compromise the receiver operations
	Attractive urban environment	Nice and liveable surroundings
	Green concerns	Positive attitude towards environmental impact
	Security	Security of the goods, less theft
	Transportation costs	Low costs to receive goods
Citizens	Emissions	Emission reduction of CO_2, NO_x, $PM_{2.5}$, PM_{10}
	Visual nuisance	Less space occupancy by trucks
	Urban accessibility	Reduce freight transport, less congestion

Source: Balm et al, 2014

As such, conflicts of interest are imminent. It is likely difficult to implement fair measures, profit-enhancing, cost-decreasing and with lower emissions, accidents or congestion. This ascertainment will be the main challenge for the policy maker.

1.2.1. Policy plan: encapsulate innovative solutions for making urban freight transport more sustainable

The somehow largest challenge is the lack of a 'one size fits all' policy for influencing urban freight transports performance, and for reaching an elevated sustainability.

Without trying to be too comprehensive, cities need minimal supplies of food, office supplies, clothing, tools, postal services, energy supply and e-commerce deliveries. In addition, niche leisure activities like for example hotels need laundry services and food, and they produce waste which needs to be collected. Activities like jobs, housing and retail are needed for making cities attractive places to live. All these economic activities generate a different demand for supplies (Small, 1997; Albalate and Bel, 2009). Moreover, cities and real estate within the area are repeatedly in construction or renovation. For these activities, large flows of building materials are brought to the building sites, which is another aspect of urban supply chains (Gevaers, Sys, Vanelslander, 2012).

It becomes clear that urban freight transport is part of this wider urban liveability challenge (challenges are expressed in measurable indicators like emissions, congestion or accidents but also in the feeling the public has on the attractiveness of an urban area), as well as a part of the solution (supply chain innovation, electric vehicles, UCCs etc.). The urban economic activities should try to break the cited vicious circle by lowering their impact on society, while continuing to meet growing demand.

The strategy of the EU for sustainable development is for example based on the principle that the economic, social and environmental effects of all policies should be examined in a coordinated way and taken into account in decision making (European Commission, 2001a).

It requires however a more clearer set of objectives. A lower impact per tkm could be the objective, by for example increasing efficiency within the supply chain (less truck kms per unit of freight), by behavioural changes like eco-driving, or by decreasing the vehicle’s environmental impact (lowering tailpipe emissions). These changes should preferably be economically viable, as otherwise the previously cited vicious circle will be spiralling negatively. These are actions where the logistics sector is leading, possibly steered by government policies or customer’s expectations.

The next two sub-sections deal with the innovations and develops a policy framework. The first section deals with the innovations in the sector and makes an argumentation for cargo bicycles as on likely solution for the liveability challenges. In the second, a list policy options for the main stakeholders in this liveability challenge: the transport sector, the (local, regional and national) policy makers, and supply chain customers/residents of urban areas.

1.2.2. Innovative solutions

As technical innovation, especially in vehicle design, plays an important role for the future of the logistics industry’s sustainability, new concepts, technologies and vehicles are identified: e.g. freight trams (Delanghe et al, 2017), electric vehicles (Davis and Figliozzi, 2013; Quak and Nestrova, 2015), drones (Rawn, 2015), water transport in cities (Maes, Sys and Vanelslander, 2012b) and (electric) cargo bicycles (Maes, 2015 and Gruber et al, 2015). Despite the growing interest in electric vehicle (EV) technology and the fact that electric trucks can indeed contribute to mitigate the environmental impacts of city logistics, they will never be effective in reducing traffic disturbance caused by commercial vehicles during unloading operations (Melo et al, 2014).

This more ambitious policy was already proactively approached by some entrepreneurs. Frequently, new initiatives are developed, with or without any state support. Some entrepreneurs received support from government in the development phase. Previously, unconventional transport solutions were tested on a micro (pilots) and large scale. A constant in these pilots is that the economic data on the pilots is scarcely published, but it is becoming clear that the likely societal effects of certain solutions are significant. Cargo bicycle transport was aside rail freight transport, urban waterway transport and the use of electric vehicles concluded to be among the most interesting solutions to further research.

The transport industry already showed some good innovative approaches. In in Annex II, likely long-term viable urban freight transport innovation initiatives are discussed in depth. All are supporting the European policy objectives.

These were preliminary assessed via a self-developed methodology assessing five criteria, i.e. their ‘Innovativeness’, ‘Feasibility’, ‘Capital intensiveness’, ‘Implementation phase’ and as last the ‘Public availability of knowledge’. How these evaluation parameters are understood is developed in in Annex II. Every parameter was evaluated on a scale from 1 to 5 points. A score of 5 is higher, more positively scored, than a score of 1. Table 4 below summarises a quick scan on innovative urban logistics concepts contributing to achieving the urban transport policy objectives. These are multi-modal (‘Monoprix’, ‘Bierboot’, ‘DHL Floating Service Centre’ and ‘Cargo trams’) or work on lowering externals costs of vehicles (‘DHL Floating Service Centre’, ‘Electric urban freight vehicles’, ‘Chronocity’ and ‘Bicycle freight transport’). During the analysis, it became clear that some are not market-ready (yet). Certain solutions depend still heavily on subsidies to subsist.

Table 4: Initiatives ranked on basis of own assessment

Initiative	**Score**
Bicycle freight transport	21
Chronocity	19
Electric urban freight transport	15
Bierboot	14
DHL Floating service centre	13
Monoprix urban short rail	12
Cargo tram transport	9

Source: Own research. See Annex II, .

The transport over water was scored second, and also shows potential. But there, cities need the specific morphology for setting up this delivery concept. Industry already experimented with smaller vehicles, electric vehicles and cargo bicycles. Pilot projects were awarded European funding.

For example, also rail freight transport needs a specific infrastructure, a transhipment site and enough volumes. Furthermore, even being able to consolidate enough volumes (20 rail cars), ‘Monoprix’ admited the concept not being economically viable yet. Some years after, the pilot was suspended. The ‘Bierboot’ concept, of urban transport by water, scores higher. The concept proved to be feasible in Utrecht’s historic centre. This concept however also needs a waterway infrastructure in the city centre, which is often found but seldom accessible for freight transshipment to the urban area.

‘Chronocity’, closely linked with bicycle freight transport, gives indications on a good chance of feasibility. The bicycle freight transport in particular seems to be less capital-intensive than the former innovations, and seems to be economically viable, as the Paris pilot testing company is still operational.

The examples show also that to innovate successfully in the transport sector, many different stakeholders need to be taken into account in the change process. A lot of parties, from shippers, transporters, receivers, police, the European policy level, national, regional and local governments, representatives of various groups in society, etc. need to informed or motivated to join a change in the urban freight transport industry. Successful innovation initiatives like the 'La Petite Reine' bicycle transport solution, were supported in the development phase, had a contribution of researchers in researching the concept and were supported by tightened mobility policies.

In this research, the use of bicycle transport is regarded a potentially efficient solution to overcome the challenges, given its seemingly sustainable character and positive score in Table 4 above. Cargo bicycle specific projects like 'Cycling logistics' and 'Cycling logistics ahead' resulted in qualitative estimates on the market size for cargo bicycle transport, innovative approaches and even in founding the European Cycle Logistics Federation. Research on the use of bicycle transport for freight deliveries is a rather new research stream, but it was regarded already chanceful by many (e.g. Dablanc, 2011; Leonardi, Browne and Allen, 2012; Lenz and Riehle, 2012; Gruber et al, 2013, Holguin-Veras et al, 2014, Gruber et al, 2014, Melo et al, 2014). Also according to Glaser (2000) and Witte et al (2011), bicycle courier services are seen as an appropriate sector for an in-depth evaluation, as they are the most reliable, flexible for operating with small-scale shipments in densely populated urban centres. This is especially true for carrying shipments in the CEP market (Gruber et al, 2013).

It was moreover politically confirmed as a chanceful alternative mode via the Luxemburg Declaration of 2015. The 'Luxembourg Declaration' or Declaration on Cycling as a climate friendly Transport Mode is a publication following an informal meeting of EU ministers for Transport in Luxemburg on the 7th of October 2015. The declaration states that "Ministers and State Secretaries ... are committed to promoting cycling as a climate friendly and efficient transport mode" The declaration calls on action to integrate cycling into the EU policies. As bicycle innovation will boost jobs, health of citizens, growth and support EU industry through new technology and services. There, it was mentioned explicitly as a likely alternative for the current traditional urban freight vehicles (Luxembourg Declaration, 2015).

Cargo bicycle transport has some key advantages over the other solution to mitigate urban freight transport challenges. These companies still exist, years after the pilot testing. And many of them grew considerably, like for example 'La Petite Reine'. The easy transferability, due to the limited capital investment costs, is a second argument for further researching this innovation.

The use of cargo bicycles fur urban CEP shipments aligns with the (European) sustainability goals (1.2). Cargo bicycles score good on sustainability criteria (low emissions, no noise and not any fuel needed) and have a limited impact on wear and tear of infrastructure. However, cargo bicycles cannot transport all freight in the urban area (e.g. building materials or waste flows), though they can do more than generally perceived. The vulnerability of cyclists is a downturn.

The next section links this transport concept with policy options. It was already stated that public authorities can accelerate urban logistics innovations by implementing appropriate measures that could allow stakeholders changing behaviour, overcoming barriers and opting for innovations. Some examples are provided to frame the possible approaches.

1.2.3. Policy options

An important first is the consideration the Sustainable Urban Mobility Plan (SUMP) or a Sustainable Urban Logistic Plan (SULP). A SUMP is a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. The SUMPs are fostered by European policy[14]. And a SULP proposes a set of specific freight transport related measures and actions that contribute to reduce the energy consumption and environmental impacts of urban freight logistics with the aim of increasing its economic sustainability.

Some policy approaches can, either individually or collectively, contribute to more sustainable urban goods transport. Behrends et al (2008) proposed that sustainable urban freight transport should fulfil the following four objectives: ensure accessibility, reduce air pollution, improve the resource- and energy-efficiency and cost-effectiveness of the transportation of goods, and contribute to liveability. As a general introduction, a non-exhaustive list of policy measures have been clustered into groups according to their nature and application and are linked to the four main challenges: road congestion, local air quality, road safety, and liveability of urban areas (illustrated in Table 5 on pages 22-24).

- **Planning measures** refer to changes in the city (e.g., infrastructure, built environment) or changes in the way business organise activities and goods transport.
- **Regulatory measures**. Influence the behaviour of stakeholder by enabling or prohibiting certain selected activities in specific conditions (e.g. time windows).
- **Fiscal measures** will change the impact taxes and fees have in business economy, including internalising external costs.
- **Stakeholder Engagement and nudging**. Through communication and awareness raising measures aimed at informing and educating stakeholders.
- **Technical innovations**. This relates to innovations in the vehicle technology, traffic steering and planning.

The selection of the policy measure depends on the identification of the drivers and nature of the problems and challenges, expected objectives, physical properties of the city, national and

[14] European Commission, “COM(2013) 913 final - A concept for Sustainable Urban Mobility Plans: together towards competitive and resource-efficient urban mobility,” Brussels, Belgium, 2013.

local legislation, or even the nature of the logistic and transport chains. Urban regions often present distinguishing and unique features and policy measures must be chosen accordingly. Moreover, each category of policy measure will impact the urban logistic activity differently, either in terms of intensity or scope. Also, the transfer of policy measures between cities should as such be subjected to ex-ante impact studies. Just because a policy measure was successful in one city, success in another is not guaranteed.

The choice of policy options should be built on technical analysis (social, environmental, economic and operational dimensions), ideally accompanied by stakeholder engagement initiatives. A stakeholder engagement initiative is a recognised method to achieve enhanced decision and promote stakeholders' acceptability.

Table 5: Characterisation of measures for urban goods transport in relation to cargo bicycle transport

		Assessment			
Measure	Impact	Congestion	Air quality	Road safety	Liveability urban areas
Planning measures	Urban Consolidation Centre	Urban consolidation centres have a benefit in terms of emissions, road safety and congestion if they are able to cluster goods into less vehicles. They group half-empty trucks at a logistics facility at the outskirts of the urban areas. They therefore do not work if vehicles are fully loaded and routings are optimised already (e.g. supermarket deliveries). Often, an opportunity is provided for pilot tests with EVs and cargo bikes, docking at the UCC. UCCs prove to be loss making, government subsidies are needed, especially in the start-up period.			
	Car free zones	Car free zones hinder the traditional vehicles accessing the zones. Cargo bikes are often still allowed, as such becoming the only and preferred delivery partner. Often, zones are not 24/7 car-free, see as well 'time windows'.			
	Bicycle paths	The expansion of dedicated bicycle infrastructure provides an opportunity for cargo cyclists, provided the cargo cycles fall within the legal dimensions to access the bicycle paths. As such, road congestion has little influence on the bicycle's speed. What currently applies for the 3-wheelde cargo bikes which can get stuck in regular traffic too.			
	Grouping cargo loads from shippers	Grouping cargo from different shippers in one delivery vehicle is a planning measure the private sector can work on. The grouping can be organised without an UCC. Bundling cargo provides better efficiency, which results in less truckkms, less congestion, emissions and maybe better liveability.			
	Parcel lockers	Parcel lockers are often installed in public spaces by logistics service providers. The cooperation between government and private sector is needed, in order to install the lockers in the public domain. Lockers help to decrease non-at-home delivery attempts, as such increase efficiency and decrease emissions and congestion. Cargo cyclists can fill the lockers with parcels, and can organise the return flows too. Especially when lockers are			

		installed on public terrain or in car free zones, bikes have an operational advantage.
	Waste collection	Waste collection can be optimised by installing waste collection points in street replacing at home collection. This decreases the number of stops, and has a positive influence on road safety and congestion. Bicycle couriers can only play a minor role in waste collection, e.g. they can collect return goods or cardboard.
Regulatory measures	Low emission Zones (LEZ)	Via regulation, cities can curb access of vehicles to streets, zones or the city; permanently or for a number of hours. A regulatory action tackling emissions are LEZs. These restrict polluting vehicles to access the LEZ zone (e.g. based on EURO emission class). This has a direct effect on logistics' vehicle deployment. Cargo bicycles can benefit from LEZs as these are non-promoting, provided the LEZ criteria are very strict (e.g. only allowing EVs).
	Time Windows	Via time window regulation, cities can curb access of vehicles to streets, zones or the city. Permanently or for a number of hours a day. This regulatory action can tackle congestion or increase road safety. This has a direct effect on vehicle deployment. It could also lead to more vehicles deployed in peak periods, hindering vehicle optimisation and as such increasing logistics costs. Nevertheless, cargo bicycles can benefit as these are often not regarded.
	Night/off peak deliveries	Off-peak deliveries is a way logistics service providers deal with congestion, and/or time windows. By shifting to less congested hours, vehicles are deployed more efficiently. Road safety is often the main effect, as pedestrians and cyclists are not met at these off peak hours. This currently is a challenge in the morning rush hour. Cargo bicycles are often not fitted for off-peak deliveries, given these are often organised via full truck loads (44 tonnes trucks).
	Preferential policy for vehicle types	This regulation is related to LEZs and Time Windows. The opposite approach could be to develop preferential policies for certain vehicle types, e.g. EVs, cargo bicycles or vehicles proving to have a certain load factor.
Fiscal measures	Taxes to change behaviour	Taxes can be a way to steer behaviour of the logistics sector. E.g. fuel taxes and congestion charging can be used to steer the sector towards different behaviour, or different vehicles. Cargo bicycles can benefit from taxes on LCVs and their cost factors. Taxes are often a national competency. Cities have limited freedom in this respect.
	Subsidies for vehicle types.	The opposite of the taxes is subsidies. These can also be a way to steer behaviour of the logistics sector. E.g. fuel taxes and congestion charging can be used to steer the sector towards different behaviour, or different vehicles. Often pilot test projects provide subsidies to cargo bicycles, EVs or off-peak solutions.
	Internalisation of external costs	The logistics sector, and its clients, do not fully bear the costs the lay on society (e.g. emissions). Internalisation or taxing external costs of vehicles can be a way to steer behaviour of the logistics sector. It could for instance be used to steer the sector towards different behaviour, or different vehicles. Cargo bicycles can benefit given their benefits.
Stakeho lder Engage	Awareness on real costs e-commerce	Final consumers do not fully bear the costs of their transport decision, nor are they fully aware of the impact of their decisions on logistics performance. More awareness of 'ASAP', 'same-day', 'morning' and other delivery decisions could help to increase efficiency and liveability.

	Freight round tables and partnerships	In freight round tables, the relevant stakeholders – transport operators, public authorities, shippers, receivers, residents' groups – meet regularly to debate matters of urban freight logistics. The relevant stakeholders – transport operators, public authorities, shippers, receivers, residents' groups – meet regularly to debate matters of urban freight logistics.
	Show sustainability effect of e-commerce choices to customers	Final consumers do not fully bear the external costs of their transport decision, nor are they fully aware of the impact of their decisions on sustainability. More awareness could help to increase the sustainability. Retailers have tried to show the 'most green' options to customers already; then, the choice of delivery time and day is influenced by providing more information on the impact. The website can for example suggest 'we have one delivery in your neighbourhood already at day x, if you choose the same day we can jointly optimise the routing and avoid emissions'.
Technical innovations	Electric vehicles	This last policy measure deals with innovating the vehicles deployed in urban logistics. The use of EV is still scarce given their battery range is limited. It could be beneficial to have a consolidation centre bundling long distance transport, and then delivering the urban area by these electric vehicles (see also UCC). City policy makers can assist uptake of EVs by deploying preferential policies, subsidies and awareness raising campaigns.
	Freight trams	The use of the tram network for urban freight is only piloted given the innovative character. Freight trams are deployed in some urban areas, e.g. Dresden, and in some Swiss mountainous areas.
	Autonomous LCVs	Autonomous vehicles are developed. But the on-street use is not allowed by regulation, nor is the technology market ready.
	Cargo bicycle deliveries	The use of the cargo bicycles for urban freight was piloted in some EU research projects. Many EU cities saw a boom of cargo cyclists after the introduction of the app-based economy, characterised by companies as Deliveroo and UberEATS. The vehicles have clear benefits for society given their sustainable character. Research on the economic viability is not rich. City policy makers can assist uptake of cargo bicycles via preferential policies, subsidies and awareness raising campaigns.
	Dynamic planning, route optimisation	Dynamic planning and route optimisation is a technological development which was developed by the transport and the tech industry. IT tools allowed the sector to increase efficiency, e.g. via better vehicle routing or via increasing load factors. IT tools also allowed new business models. Cargo bicycles are used in the app-based economy, for delivering orders on platforms as Deliveroo and UberEATS.
	Intelligent Transport Systems (ITS)	ITS are tools where the city policy makers and the logistics sector co.innovate. The tools can help to implement preferential policies, enforce LEZ or Congestion charging, collect data on urban freight and further develop policies.

Source: Own composition.

Analysing the table above, some policy approaches can, either individually or collectively, contribute to further deployment of cargo bicycle transport.

- **Planning measures** (e.g., infrastructure) can assists the bicycles. Bicycles paths and car-free zones are the most direct measures, helping the cargo bicycles to better move true traffic. UCC is a more advanced idea, to which cargo bicycles can be delivery partner.

- **Regulatory measures** influence the behaviour of stakeholder. Access restrictions for LCVs can help the use of cargo bicycles, (e.g. LEZ and time windows), provided they receive a preferential policy.
- **Fiscal measures** will change the cost basis of cargo bicycles, or LCVs. Internalisation of external costs will lead to higher LCV transport costs, benefiting cargo bicycles.
- **Stakeholder Engagement and nudging**. Communication and awareness raising can change order behaviour and resolve local liveability issues. Of organised, cargo bicycles are seldom present.
- **Technical innovations**. This relates to innovations in the vehicle technology, traffic steering and planning. The vehicle technology of cargo bicycles allows rapid roll out. The vehicles are cheaper than LCVs and do not require engines, fuel or charging.

Given the first observations, a sincere interest was developed in the bicycle cargo transport market. This translated into a research plan. Cargo bicycles could become an innovative solution tackling the four main facets of the urban challenges: congestion, local (tailpipe) emissions, road safety, and general urban liveability. By lowering congestion in urban areas (smaller vehicles), increasing employment it could lead to lowering the cost for the logistics sector. The state of research is depicted in the next section.

1.3. Scientific literature overview

This provides an overview of scientific literature on the wider topic of urban freight transport (section 1.3.1), as well as specific literature on cargo bicycle transport and urban logistics (section 1.3.2). Section 1.3.3 wraps up the findings to determine the research gaps.

1.3.1. Research focused on urban freight transport

The research on urban freight transport services developed from a general research stream to a very specific international topic more or less from the 90's on (Meimbresse and Sonntag, 2000; Thompson and Taniguchi, 2003; Ambrosini et al, 2004). Urban transport literature was first seen in Europe, fuelled by European research projects like CITY FREIGHT and COST 321 (see Table 6 on page 31 for details on these projects). From an urban transport oriented research stream at first more limited to passenger transport, a more freight-focused sub-stream flourished. In 1977, for example Hicks wrote the first papers on the issue of urban freight transport (Hicks, 1977). In trying to form a separate research community, the Institute for City Logistics (ICL) was established in Japan (Koto) in 1999. There, academics and practitioners share knowledge, experiences and information, through conferences and short courses (Institute for City Logistics, 2017).

However, urban freight transport research developed mainly within the framework of European research projects. Academic research on urban freight transport at first was still limited. Many papers have a bivalent scope. So, sustainability of transport activities (passenger transport in particular) is often the main research focus, besides traffic safety and the uptake of innovative technologies. Freight operations then came under attention as a second-ranked research topic. The projects listed in Table 6 combine academic research with pilot tests, which makes them interesting for researchers as well as for practitioners; but also for local governments working on urban freight transport policies. Cargo bikes are rarely the main focus of these urban freight demonstration projects, but sometimes accompanying modules (Gruber et al, 2014). The most relevant for the scope of this dissertation are highlighted in the next four pages.

European research projects mapping best practices (for cargo bicycle transport)

Actually, best practices on last mile transport are published in European projects like BESTUFS and BESTUFS II. Both aimed at maintaining and expanding an open European network between urban freight transport actors and experts in order to identify, describe and disseminate best practices, success criteria and bottlenecks with respect to City Logistics Solutions (CLS). Several projects on urban freight transport were mapped and researched. Two involved cycle logistics. Migros, a Swiss super market chain tested home deliveries and pick up deliveries in 2001 within BESTUFS. A small scale pilot, offering home delivery by electric bike and trailer for goods bought conventionally at the supermarkets, was tested. There is no information available about the economic success of the initiative (BESTUFS, Best Practice Handbook Year 2 by Glücker and Egger, 2001). Cyclone couriers was mapped as a British example of parcel delivery by bicycle in York. The congested medieval city with a vehicle ban from 11 to 4 allowed cyclone couriers to operate a next-day delivery service on behalf of their contracted parcel carrier customers. The cycles were similar to cycle rickshaws but built for freight and could accommodate loads up to 250 kg. *“Since a bike and rider cost amounted to £ 60 a day, as opposed to £ 250 a day for a van and driver, it was cheaper to use bikes to achieve multiple 9 am delivery slots than the equivalent number of vans”* (BESTUFS, Best Practice Handbook Year 3 (2002) and Zunder et al (2006)).

La Petite Reine is one case in BESTUFS II where bicycle transport was researched. The city of Paris has for example been supporting the La Petite Reine[15] company in the experimentation of deliveries using tricycles since May 2003. This experiment was also supported by the ADEME[16], providing financial aid representing 50% of the feasibility study and evaluation reports and 15% of the investment in tricycles. The results were promising: an increase was seen from 796 trips in month one to 14,631 trips in month 24. Parcel freight became the most important type of freight during the course of the trial. 156,248 LCV kms have been avoided during the trial. This has saved 43.3 toe[17] of energy consumption, and helped avoid 112 tonnes

[15] La Petite Reine is a French company providing last mile transport solutions by electric tricycles in e.g. Paris.
[16] French Agency of Environment Management
[17] Toe = tonnes oil equivalent.

of CO_2, 1.43 tonnes of CO, and 280 kg of NO_X (BESTUFS, 2007). In 2009, La Petite Reine was purchased by a company for people with a distance to the labour market (i.e. ARES). In 2011, Star's Service (French company leader in home delivery) acquired 51%. La Petite Reine reoriented its activity, from parcel distribution to home delivery from large stores (BESTFACT, 2013). Nowadays it employs some 70 people for 80 cargo bicycles and 15 electric LCVs.

Sugar, following the BESTUFS project in 2009, focused on addressing the problem of inefficient and ineffective management of urban freight distribution. Project participants exchanged, discussed and transferred policy experience, knowledge and good practices. La petite Reine was included again. Urban planning, ITS and technical, supply chain and information characteristics were evaluated. The organisation was evaluated as being efficient, adaptable and cheap. The project evaluator concluded that the concept could be up-scaled and is applicable to other comparable cities (Sugar, 2011).

BESTFACT developed, disseminated and enhanced the utilisation of best practices and innovations in freight transport. These best practices contribute to meeting European transport competitiveness and environmental objectives. The project focused on three main working areas (clusters) of which urban freight transport was one. Several best practices were mapped. The ones involving bicycles are listed below.

- The use of battery-electric tricycles and vans for retail of Gnewt Cargo, based in London. The vehicles were manufactured in France by La Petite Reine[19] (BESTFACT, 2013).
- Urban consolidation by French company Distripolis in order to replace the use of standard diesel trucks. As part of BESTFACT, GEODIS, a large French road transport operator was testing UCCs and electric vehicles in a large scale trial in France. Distripolis build on the existing Monoprix service and developed the use of SNCF stations for the receipt of freight with "last mile" delivery of low weight parcels by tricycle or light electric vehicles. No results published.
- Bentobox[20] and 'urban freight laboratory' area Berlin (a residential and mixed-use business and retail area in a central borough of Berlin) tested innovative freight transport solutions. The research consisted of the use of a new locker bank for parcel storage, and of electrically assisted bikes for final delivery (BESTFACT, 2013). The BentoBox has been installed in the framework of the CityLog project, co-funded by FP7.
- In San Sebastián, an urban freight system was implemented that replaces the use of diesel vans making direct deliveries from a UCC. The local delivery company Txita used

[19] These carry a load of up to 180 kg, have a load space of 1.5 cubic metres, are 2.35 metres long and 1.03 metres wide. The vehicle has a typical speed of approximately 15 km per hour. The tricycle requires a four-hour recharging overnight.

[20] Two types of electrically-assisted bikes are used in the Bentobox test: Cargo (e)-bikes with a load capacity of up to 70 kg; and cruiser bikes with a capacity of 250 kg (the dimension of a EURO pallet) and a 80 km range.

cargo bicycles. Txita was supported by the municipality by supplying a Freight distribution centre (a municipal warehouse of 500 m²) (BESTFACT, 2013). It is still active today.

- Next to the commonly known La Petite Reine case, The Green Link (TGL), a Paris-based last mile delivery service with electric cargo bicycles and vans, was included. TGL is a company making parcel deliveries in central Paris with an entire fleet of battery-electric vehicles[21]. The business is proving to be profitable when actually delivering over 2,000 parcels per day (BESTFACT, 2013). Still active today. The organisation of the TGL logistics process is shared. A first delivery of parcels arrives at the depots between 07.00, and 09.30, brought by truck and vans operating from the clients' distribution centres. After unloading and sorting, they are loaded onto TGL's vehicles (a fleet of electric vans and electric cycles). The delivery rounds are organised with part-time and full-time drivers. Most rounds start in the morning at around 09.00 and end in the early afternoon mostly before 15.00. A few evening rounds are performed for collection. Information is communicated in real time (BESTFACT, 2013).

Straightsol, a 3-year EU-funded project, mapped effects of seven innovative urban freight demonstrations. First, Straightsol developed an impact assessment framework for measures applied to urban-interurban freight transport. Secondly, Straightsol facilitated a set of innovative demonstrations showcasing urban freight innovations. Third, it applied the impact assessment framework to the demonstrations and concluded with recommendations for future freight policies and measures. Demonstration project B was researching the project of TNT Express in Brussels. The CEP company used cargo bicycles for distributing freight in the city of Brussels. The demonstration project used its Mobile Depot[22], shown in the picture on the next page.

[21] The cargo cycles have a capacity of 1.5-2.1 m3 , an empty weight of about 100 kg, a load weight capacity of 200 kg (max. 30 kg per parcel), a gross vehicle weight of 400 kg, a maximum speed of 25 km/h and an range of 20 km with a lithium battery (Bestfact, 2014).

[22] The Mobile Depot has a length of 14m and a width of 6.5 m. The trailer is extendable, has a loading ramp, toilet, office space and can as such serve as warehouse. It fits 4 large and 7 smaller cages (Kok, 2012).

Figure 3: TNT Express' mobile depot pilot in Brussels

Source: Straightsol, 2013

This depot, based on a classic truck-trailer combination, was designed by TNT and Delft University of Technology. It linked the suburb-based depot and the last-mile transport services of the Brussel biycle couriers of Ecopostale (Kok, 2012; Straightsol, 2014). The project resulted, over a three-month test period in a 24% decrease in CO_2 and SO_2 emissions, an 78% decrease in NO_X emissions, a decrease by 98% in PM_{25} and 22% in PM_{10} emissions. The delivery cost in the project was twice the cost of the traditional situation, which was (partly) accounted to the deliberately low loading degree of the depot of 40%. The sorting within the depot and the transport of larger parcels were two disadvantages of the concept (Straightsol, 2014). The pilot was stopped and TNT Express did not continue the project.

PRO E-bike was an EU-funded project (2013-2016) to promote electric bicycles and electric scooters (common name 'E–bikes'), for delivery of goods and passenger transport in urban areas. The main objectives were: testing and analysing E- bike technology (via pilots), building understanding and raising confidence in E-bike technology, organising info days in pilot cities to promote E-bikes, the creation of favourable conditions for market development and setting up a platform for manufacturers, distributors and potential users. The project was focussed on extensive national and international dissemination, less on research (PRO E-bike, 2016).

The European Cyclelogistics project (study by a consortium of FGM-AMOR, Outspoken, ECF and CTC) was awarded European funding via Intelligent Energy Europe (2011-2014). It researched the likely opportunities for freight transport by bicycle in Europe. Within the motorised trips in urban areas, 21% is estimated to be commercial traffic (delivery, service and business) and 28% private logistics (shopping, leisure and commuting). Via an analysis Cycling Logistics filtered out the trips being less than 7 km in total, and limited to 200kg. So the potential for cargo cycling was defined. A quarter of the total motorized freight trips in urban areas was identified as being interesting for cargo bicycles. Then, the project defined USPs (fast and reliable, flexible and environment-friendly image and local for example) and likely customers (local authorities, pharmacies, delivery organizations, publishers, shops and stores for example) and scanned the possible fleets (Cycling Logistics, 2014).

The service types were split into mail, A-B and last-mile transport. Examples from European cases were added in the final deliverable. Questionable conclusions were made on the economic viability of cargo bicycle transport. The final deliverable includes a one page opaque cost estimation, where the parameter for driver costs is set at 9.6 EUR per hour and 1.59 EUR per stop for bicycle and LCV respectively (Cycling Logistics, 2014).

The project did create a **CycleLogistics Federation**, and a communal feeling between European cargo cyclists. The closing meeting in April 2014 in Nijmegen was coupled with the cargo bike festival, many vehicles were shown and cargo cyclists cycled from their hometown to Nijmegen (Cycling Logistics, 2014). More than analysing the economic potential, the project mapped the European knowledge on cycling couriers.

The CycleLogistics project ended in May 2014. then, it was followed by the CycleLogistics AHEAD project, which continued with a stronger focus on business applications. Many other research projects, not included in Table 6, like SMARTSET[23], GIFTS[24], C-Liege[25], MOSCA[26] and eDRUL[27] focus mainly on technological aspects and are therefore deliberately not included. The table provides the main focus of the research projects, and briefly depicts outcomes relevant for this dissertation. The far left column provides the projects' name, the second column depicts the project scope, the third column 'Focus and remarks' provides remarks and the last column highlights the research results.

[23] Sustainable MARketdriven Terminal Solutions for Efficient freight Transport (IEE funding between 05/2013 - 04/2016)

[24] Global Intermodal Freight Transport System, (IEE funding between 04/2002 - 03/2005), Focusing on the application of ITS for urban freight transport

[25] Clean Last mile transport and logistics management for smart and Efficient local Governments in Europe, Showcase for good practices and a helpful hand for all European cities striving for cleaner and sustainable urban transportation. (IEE funding between 06/2011 - 11/2013)

[26] Decision Support System For Integrated Door-To-Door Delivery: Planning and Control in Logistic Chains (IEE funding between 07/2001 - 07/2003)

[27] Ecommerce enabled Demand Responsive Urban Logistic, (IEE funding between 04/2002 - 01/2005)

Table 6: Overview of (European) urban freight transport research projects

	Scope	Cargo bikes?	Focus and remarks	Results
REFORM **01/1997 - 12/1997**	Consolidation centres		Pilot testing Results	REFORM aimed to provide guidelines for designing, locating and organising freight platforms in urban areas. The project has demonstrated freight platforms. Conclusions: A reduction in urban traffic as a result of 1) an increased co-operation between companies which results in higher load factors and a reduction of the number of truck trips and 2) the provision of onsite services iii) increased operational efficiency.
UTOPIA **1998 - 2000**	Information, tools and actions for cleaner urban freight vehicles European research project		Recommendations	• An assessment of the most promising applications • Recommendations on policy actions at the European and national levels • A good practice guide to setting up and running pilot and demonstration projects; • A software framework ('NAVIGATE UTOPIA'), which provides information and assessment methodologies covering clean transport solutions
COST 321 **1998 - 2002**	European research project on the design and implementation of innovative measures to improve the environmental performance of freight transport		Recommendations	The project suggested that urban freight transport should take into account: transhipment technology, land use management, conditional access regimes, fleet composition, infrastructure capacity, political drive and available money.

IDIOMA **1998 - 2001**	To improve the distribution of goods within metropolitan areas and between intermodal transport terminal/freight centres and metropolitan areas		Conclusions and recommendations	Freight transport, urban transport , multimodal transport , awareness, information and user rights. The main project objective was to demonstrate different concepts aimed at improving the distribution of goods within urban areas and between intermodal terminals/freight centres and urban areas. Small container concepts are good for the city but not commercially viable A substantial part of the delays in intermodal transport can be eliminated if high quality (reliable, detailed and up-to-date) traffic information is available.
CITY FREIGHT **2002 - 2004**	European research project on problems of road freight transport in urban areas	**v**	Analysing freight transport problems in cities	Best practices • Reducing noise emissions of off-peak deliveries • Consolidating consignments • Combining freight with passenger traffic (e.g. through the use of Cargo Tram, electric and hybrid electric vehicles, bicycle couriers and freight distribution by walking) • Integrating land use and transport planning
BESTUFS **2000 - 2004**	European research project on facilitating the establishment of personal connections and the widening of contact networks in the field of urban freight transport for all interested persons. Published a best practice handbook, Was followed by BESTUFS 2.	**v**	Networks Recommendations Best practices	A questionnaire *'European Survey on Transport and Delivery of Goods in Urban Areas'* was developed to map major issues in different European cities A best practice handbook on different topics (Vehicle access and loading in urban areas', 'last mile solutions' and 'urban consolidation centres') was the outcome.

BESTUFS II **2004 - 2008**	European research project Building further on BESTUFS More focus on the network building and guidebooks	**v**	Networks Best practices	A guidebook was written (in 17 languages), so that the results and guidelines can be used in many European cities. Variety of topics, like urban consolidation centres, last mile solutions, urban freight in small and medium sized cities, urban waste logistics, port cities, innovative urban freight solutions, managing urban freight transport by companies and local authorities, environmental zones in European cities and accommodating the needs of passenger and freight transport in cities.
UCC's **2000 -**	Private initiatives like Binnenstandsservice.nl Literature like Browne, Sweet, Woodburn and Allen (2005)	**v**	Best practices Research	Private entrepreneurs set up UCC's via public support There is a lack of knowledge in the economic viability of these centres Many were heavily subsidized and are not profitable Results are not always transparently published.
TRENDSETTER **2000 - 2005**	Focus on sustainable urban mobility, mainly passengers		Network setting Common learning	The Trendsetter project was one of four projects financed by the Civitas I Initiative. 52 specific measures were implemented in different thematic areas The concept of LEZ's was taken into account specifically Regarding these LEZ's no transport-economic analysis was reflected in the results
CIVITAS I **2002 - 2006**	Network setting for cities Four projects were launched		Network setting Common learning	19 cities participated via three consortia (Miracles, Tellus, Trendsetter and Vivaldi). Specific mobility-related topics were researched and networks were created to obtain common learning. (TRENDSETTER was part of CIVITAS I)

CIVITAS II **2005 - 2009**	Network setting for cities Four other projects		Network setting Common learning	17 cities participated via the consortia Caravel, Mobilis, Smile and Success CIVITAS SMILE looked al LEZ's in Sweden, in CIVITAS SUCCESS guidance was developed to improve routes for goods vehicle operators
CIVITAS Plus **2008 - 2012**	Network setting for cities		Network setting Common learning	25 cities were participating in five collaborative projects (Archimedes, Elan, Mimosa, Modern, Renaissance). CIVITAS MIMOSA was looking at more efficient logistics and distribution to enhance attractiveness and accessibility of economically vital areas
SUGAR **2007 - 2013**	European research project Focused on addressing the problem of inefficient and ineffective management of urban freight distribution	**v**	Conclusions and research	44 measures were identified All were analysed on critical success factors Five successful policy types were identified i) traffic and parking regulations; ii) ITS; iii) planning strategies; iv) consultation processes; and v) consolidation processes.
CIVITAS Plus II **2012 - 2016**	Network setting for cities		Network setting Common learning	Two groups of cities participate: DYN@MO (Aachen, Gdynia, Koprivnica and Palma), 2MOVE2 (Stuttgart, Brno, Malaga, Tel Aviv – Yafo)
Straightsol **2011 - 2014**	European research project Developed an evaluation framework for urban freight transport innovations	**v**	Research and pilot testing	The Straightsol project developed an evaluation framework to enable a comprehensive and fair comparison between alternative urban freight options. The project closed August 2014.
Smartset **2013 - 2016**	SMARTSET is a consortium by and for practitioners, coordinated by the City of Gothenburg, composed of 14 partners from Austria,	**v**	Research , knowledge sharing and pilot testing	The project consortium have been testing various approaches to the introduction of cleaner fleets ; e.g. electric cargo bikes. Research conducted in the project shows that, apart from the costs, the other most important factors in the selection were

	Germany, Italy, Sweden and the United Kingdom.			most important factors in the selection were the availability , parts and servicing, and their technological maturity and functional specification, such as range, payload and monitoring capability.
Smartfusion 2007 - 2013	European research project to demonstrate transport innovations that will improve the efficiency, social and environmental sustainability of urban freight in last-mile operations	**v**	Research and pilot testing	Three technology providers developed technological solutions to solve specific problems. Two supply chain providers developed and implemented innovation in both port-centric logistics and last mile deliveries (office depot and clipper logistics). Three demonstration sites were identified: Berlin (DE), Lombardy Region (IT) and Newcastle upon Tyne (UK). The project also consults stakeholders and takes care of common learning actions.
Pro E-bike 2013 - 2016	Programme promoting the use of electric bicycles for the delivery of goods and passenger transport	**v**	Information dissemination, awareness and pilot testing	Some 30 pilot companies in 8 European cities. Funded by Intelligent Energy Europe April 2013 – March 2016
CycleLogistics (ahead) 2011 - 2014	The European funded project researched the use of cargo bicycles.	**v**	Stakeholder awareness and market analysis Network setting Common learning	From the reactions of the stakeholders at the Focus Group Seminars it became obvious that there is potential and interest in this transport mode. Though, economic data are lacking. The project also founded the European Cyclelogistics Federation. The research is continued by the follow-up project Cyclelogistics AHEAD.
LaMiLo 2012 - 2014	Last mile logistics		LaMiLo (last mile logistics) – an INTERREG IVB North West Europe (NWE) project part-funded by the European	The project aimed at benchmarking best practices in last mile logistics and establishing baseline sustainability indicators (stakeholders were consulted from December 2013 to January

			Regional Development Fund (ERDF)	2014. On the 21 invitations, only 7 answered the survey). The project resulted in a knowledge hub, with latest research, learning and best practice for a greener transport in cities in North West Europe. The site was not updated after December 2015.
NOVELOG **June 2015 - May 2018**	Cooperative Business Models and Guidance on Sustainable City Logistics Policies	**V**	Started in September 2015, no research results published. Focus on supporting development of last mile logistics.	The NOVELOG project focuses on knowledge on freight distribution and service trips by providing guidance for implementing effective and sustainable policies and measures. SUMPS (Sustainable Urban Mobility Plans) are regarded. Demonstrations are planned in different EU cities (E.g. Athens, Rome and Mechelen). In the latest city, cycling logistics will be supported and UCC's and IT will be researched.
SUCCESS **May 2015 - April 2018**	Construction sustainable Urban Consolidation Centres		This project has received funding from the European Union's Horizon 2020 research and innovation programme.	SUCCESS has chosen to target the construction industry. The project looks at to what extent and how the concepts of Supply Chain Management and Construction Consolidation Centres (CCCs). Started in May 2015.
SAILOR **October 2016 – September 2018**	Smart lAst mILe cOmmeRce		Aims to develop real-time solutions for matching parcel delivery companies and the final customer.	Goal: sshortening routing distance as well as increase first-time deliveries and reverse logistics in the last mile A prototype demonstration of SAILOR will be put to in four European cities: Amsterdam (Netherlands), Borlänge (Sweden), Graz (Austria) and the San Sebastian area (Spain) together with local stakeholders.
U-TURN **June 2015 - May 2018**	Freight urban distribution, focusing on food logistics		This project has received funding from the European	Three pilots will be tested in Milan, Athens and London:

			Union's Horizon 2020 research and innovation programme.	• Distribution of packaged goods from food manufacturers to retail outlets located in urban areas • Distribution of fresh food from local producers and online retailers to consumers in urban areas • Food delivery from online retailers to consumers in urban areas. Started in June 2015.
FREVUE **2013 - 2017**	Freight Electric Vehicles in Urban Europe. This project received funding from the EU's 7th Framework Programme		Disseminating and exchanging on best practices innovative city logistics solutions using electric freight vehicles.	The project was constructed on four axes: Bringing together, Providing evidence, Disseminating and exchanging and Designing and implementing.
Vitalnodes **2017 - 2020**	Link multimodal transport and special development		TEN-T networks and urban systems will be linked in pilot tests. Horizon 2020 programme under the lead of Rijkswaterstaat (NL).	Vitalnodes will deliver evidence-based recommendations for more (cost) efficient and sustainable integration of all 88 urban nodes in the TEN-T network corridors, addressing specifically the multi- and intermodal connection between long-distance and last-mile freight logistics. These recommendations will be validated by applying an appraisal tool and involving experts from the growing Vitalnodes network.

Source: Own composition based on projects' websites and deliverables

The projects depicted in Table 5 often mapped and analysed alternative vehicles to define their potential to improve sustainability and urban liveability. A concept likely improving these two joint aspects is the use of cargo bicycles for urban freight transport. This was predominantly researched by projects like CycleLogistics (ahead), PRO E-bike and Straightsol; with positive outcomes. Primarily the decreased emissions per tonkm and the increased employment related therewith is seen as positive properties of commercial cargo bicycle transport.

Principally, because these companies still exist years after pilot testing and the fact that many grew considerably since then urban freight by bicycle was concluded to be viable enough to further research, a best practice of a wider range of urban freight transport innovations. Their feasibility is under-researched, but the mode's potential is pertinent. It was understood from prior research that this low emission transport mode needs to be analysed fully: on its economic, environmental and social benefits. The easy transferability, due to the limited capital investment, was an additional argument for further researching this innovation.

Growth of the bicycle use is seen in almost all of Europe's urban areas. Non-commercial bicycle use is gaining importance, fuelled by increasing road congestion and technological innovations as e-bikes and speed pedelecs (high speed e-bikes). Cargo bicycle transport is nowadays organised via various start-ups. Especially the new cargo bikes with electric assistance, and access to IT tools allow for new business models to flourish. Afterwards even long-existing global transport organisations (e.g. DHL, UPS or FedEx) developed own cargo bicycle transport solutions. Some businesses were initiated via EU research projects and some continued.

Next section 1.3.2. provides an introduction to the characteristics of the mode. A focus on and non-exhaustive overview of freight transport by bike is provided to outline the developments to the reader non-familiar with these businesses.

1.3.2. Cargo bicycle transport services as a solution for urban goods transport challenges: positioning the concept

In this dissertation, the use of bicycle transport is regarded a potentially efficient solution to overcome the urban liveability challenges, given its seemingly sustainable character especially because of underdeveloped research on the economic benefits thereof.

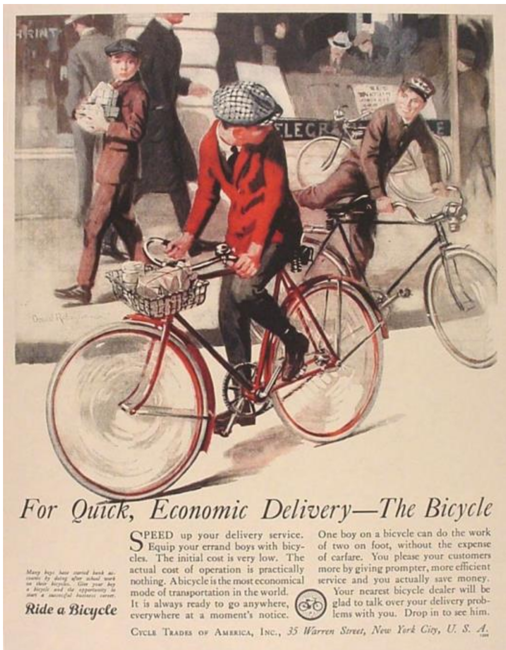
Research on bicycle transport as a solution for commercial goods transport in urban areas can be considered a rather new study topic. Therefore the focus in this section will be mostly on an introduction and overview of the concept of cycling logistics.

Section I provides a brief historical overview of bicycle transport and freight distribution, based on academic literature, to the extent that papers on it are available. Section II continues with more soft - cycling culture - aspects. The entrepreneurs which establish start-ups of courier/messenger activities often originate from a particular population group with a distinct 'urban culture' and therefore have specific motivations and often different viewpoints on urban freight transport. Next, section III deepens out the current academic research on cargo cycling logistics, and is more focused on the economic aspects of the concept. The last section gives an overview of concepts and European research projects which mapped current best practices in cycling logistics.

I. Cycling logistics' history

The concept of bicycle couriers, or freight transport by bike, is not brand-new. It is possibly one of the older, and still active, urban logistics systems in the world. Nevertheless, it has been under the radar as a viable transport option for decades. The two figures below, show the possibly oldest, and still active, bicycle-based logistics systems in the world.

Figure 5: For quick, economic delivery - The Bicycle



Source: Robinson (1920)

Figure 4: Dabbawalas in Mumbai

Source: Saritha (2007)

Since 1890, Mumbai (India) has an efficient system running to distribute food in urban areas. Every day, more than 175,000 lunchboxes are transported by 4,500 to 5,000 *Dabbawalas*, the local bicycle couriers. In 2002, Forbes magazine researched and concluded that the reliability of the services is high enough to comply with the highly valued six-sigma norm[29] (Harding, 2005; Thakker, 2005; Vidal, 2014 and Saritha, 2007).

[29] Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes. It uses a set of quality-management methods (Antony, 2004).

In addition, historic European examples exist. Throughout the early years of the 20th century 'les triporteurs', tricycle messengers, were to be seen throughout France (IFBMA, 2004 and Rosen, Cox, Horton, 2007). The bicycle manufacturer Bayliss-Thomas Company sold already in 1881 their first tricycles to the British Post Office. These were also adopted by tradesmen for the delivery of goods and by artisans to carry the tools of their trade (Basterfield, Geffen, 2011). This early development is illustrated by Figure 4, showing an advertisement by the Cycle Trades of America delivery work, already dating from the 1920's. In contrast to the current situation, the cyclist's focus was mainly on transport costs and speediness; looking at the advertisements, sustainability of the transport service seemed to be less an issue at that time.

Also American success stories exist. In the 1890's, the Western Union Telegraph Company in the United States employed bicycle couriers. In 1907, in Seattle, C. Ryan and J. Casey, founded a delivery services company 'American Messenger Company'. They started with two bikes and 100 USD of starting capital, later merged with Merchant's Parcel Delivery taking the latter's name. In 1919, Merchant's Parcel Delivery changed its name to the United Postal Service (UPS). Now it has 50 bn. USD annual revenue, delivering almost 4 bn. packages and documents a year (Hiskey, 2010; UPS, 2013). The cargo bike has been around for almost as long as the bicycle itself, with technical variations.

These developed from rather unhandy triporteurs to platform-based bicycles. In the late 1920's, an extended form of carrier bicycle first appeared in Denmark, in which a load-carrying platform was inserted between the rider and the front wheel, which now being entirely separate from the handlebars, was steered by a tie-rod passing under the platform. This platform was low for stability and ease of loading. The bikes earned the nickname 'Long John'.

Later models had a smaller front wheel, which allowed an even longer platform (Basterfield and Geffen, 2011). This type of bicycle is still identifiable in the Bullitt bikes' design (refer to table 6 for more details). This construction, with a cargo box between front wheels and handlebars, is generally favoured by messengers for point-to-point shipments compared to tricycles (Riehle, 2012).

Nowadays, the cargo bicycles are light-weighted and often are equipped with a battery-based electric assistance. The most common models are listed in the following table. These are split in historic, bakfiets, 3 wheelers, heavy lift cycles, 4 wheelers, modern cargo bicycles, heavy loads, trailers and innovative design types.

Table 7: Overview of cargo bicycle vehicles

	Examples	Characteristics and examples
Historical		Work Cycles Classic Dutch „Bakfiets“ XL (NL) Triporteur type Load capacity of 400 kg Not electrically assisted Around 4,000 EUR
Bakfiets	 	8-freight (UK) Load capacity of 100 kg Not electrically assisted Around 2,000 EUR Bakfiets CargoBikeLong (NL) Load capacity 200 kg Not electrically assisted Around 1,750 EUR
3 wheelers		Babboe Big E-Power (CH) Electrically assisted Around 2,000 EUR
Heavy lift cycles	  	MCS Maderna Truck (AU) 7 gear, not electrically assisted Heavy load capacity Around 1,500 EUR Larry vs Harry’s Bullitt bikes (DK) 8 gear light weighted Load capacity of around 200 kg From 2,760 EUR Urban-e’s iBullitt, electrically assisted 250W front wheel hub Load capacity of 100 kg Around 5,600 EUR

	Examples	Characteristics and examples
4 wheelers		Pick up vrachtfiets (NL) Developed in The Netherlands Different models Maximum payload: 400 km Electrically assisted
Modern cargo bicycle		Vehicle is designed by La Petite Reine (FR) Cargo bicycle V1 / V2/ Frigocycle Load volumes 1400 l / 1500 l / 1200 l Price not available
		Cyclopolitain Vehicules (FR) Load capacity of 1,5 m³ and 250 kg Electrically assisted Around 7,000 EUR
Heavy load		Bubble post (BE) Newly developed cargo bicycle able to transport up to 2 m³ and 250 kg The company also has a temperature-conditioned version (see below)
		Bubble post (BE) Stint by Noorenz B.V. (NL) Newly developed cargo bicycle able to transport up to 1.6 m³ and 400 kg Maximum speed of 16km per hour Electrically assisted
		Bubble post (BE) Newly developed cargo bicycle able to transport up to 2 m³ and 300 kg Battery-assisted (40 - 60 km) Model 'Tortuga XL', by The Opportunity Factory Designed and made in Belgium

	Examples	Characteristics and examples
Trailer		CyclesSpark CargoBikeXL (NL) (Proof of concept) Can be connected to any kind of bike Fitted for heavy lifts Can handle palletised goods (2) Upto 5 m³ and 500 kg
Innovative design		Cargotrailer (NL) New design of an innovative light weighted heavy lift cargo trailer by Jort Nijhuis In cooperation with PostNL Only a test model has been constructed
		Bubble post (BE) New cargo bicycle able to transport up to 2 m³ , but unlike the regular cargo bike this box is temperature-conditioned for transporting perishable items Has ordered 20

Source: Based on websites of retailers.

Biking and cargo bike transport are definitely making a comeback. This *renaissance* of bicycle messengers began in the 1970's in New York City and from the mid-1980's onward also in major German cities (Gruber, Ehrler and Lenz, 2013; Lenz, Rhiele, 2012; Hagen, Lobo and Mendonca, 2013).

Many opportunities for using bikes for freight were emerging, in particular in busy and congested urban centres where parking is difficult, expensive and vehicle journey times are slow and unpredictable. Pollution is becoming more of a concern as air quality controls tighten up. Cargo bikes demonstrate how some aspects of cycling exist as a function of other sectors in the economy. An economy looking for more sustainable ideas.

The reappearance of cargo bikes has been profoundly tied to changes in the vehicle design (of which battery assistance and new low-weight structures are most important), IT and the relationship with the sustainability demands of final customers. What virtually disappeared in the mid-1970s, re-emerged as part of a counter-culture arguing for a different mode of the economy and society (Cox, 2015). The most powerful argument for using cargo bicycles for the majority of businesses is often the competitive cost compared with motorised transport. Returning to their roots, in 2008, UPS began hiring bike delivery workers in Vancouver, Washington and various cities in Oregon (Hiskey, 2010). It re-implemented cargo bicycles in Belgium, since September 2017.

In Belgium, the economic aspects of freight transport by bike have not been researched a lot (Maes, Vanelslander, 2012a; Verlinde et al, 2014; Maes, 2015). A historical overview of the market is therefore not possible. But the use of pedal cycles for postal delivery is one of its first logistical roles, the most universal and well-known. Belgian Post (bpost) services employ bicycle drivers since a very long time. Bpost actually uses in the order of 3,000 cycles and electric cycles (Table 8). Over half of the deliveries of bpost are done by LCV, approximately 14% are done by scooter, 13.8% by e-cycle, 10,3% by classic cycles and 7.8% is delivered walking (Van Eetvelde, 2013). Table 8 highlights the most important, so it is non-exhaustive, bicycles used by bpost.

Table 8: bpost's two-wheelers

Ludo bicycle (2001 - 2009)	**E-move bicycle (Speedliner) (2009 - 2012)**
	
E-cycle (Granville) (> 2012)	**Scooter Yamaha Neo (> 2013)**
	
Cargo bicycle pilot	
	

Source: Le Vif (2012), Knack (2013), Granville (2014) and Baert (2015)

The historic Belgian post bicycle, produced by Ludo, was not electrically supported. This model was in 2009 partly replaced by Speedliner E-move (Proline) e-bicycles, which were at the time the first electrically-supported bpost bikes ever. E-moves' German manufacturer Speedliner was awarded the European tender. The bicycles were produced in Turkey. This model was badly received by the postmen and was shortly after replaced by other (Belgian) e-cycles of Granville, in 2012 (Granville, 2014).. This way, bpost returned to a Belgian manufacturer. Bpost has a strong historic position in the market. The company tested a three-wheeled cargo bicycle, but in 2016 suspended a tender for new cargo cycles because none of the manufacturers could meet the demands. Additionally, private firms are distributing printed advertisements and newspapers by LCV, scooter and/or bikes, often in subcontract of or in cooperation with the firm. In summer 2017, bpost has taken over the Belgian cargo cyclist company Bubble post and so acquired more than 100 cargo cycles.

New markets and innovations

The real boom of cargo cyclists in urban Europe started less than five years ago as a result of two changes: the rapid development and accessibility of the app-based economy, and the flexibilisation of labour markets. This new market was labeled On Demand Delivery (ODD) or Crowd Logistics (Buldeo Rai et al, 2017).

The ODD market results of a delivery concept which has been implemented since late 2014 by new start-up companies like Deliveroo, UberEATS, Take Eat Easy and Foodora. E-shoppers can order products using apps on their smartphones, and receive their orders at home in less than two hours. These goods, often food, are predominantly delivered by couriers using their own bicycles or by exception by cars. The services are offered only in dense urban areas. ODD is a concept being implemented to comply with e-shoppers' delivery expectations which is a combination of at home delivery, as fast delivery, low prices and easiness to use.

ODD, is not only disrupting the existing urban freight transport market, but also created new demand for transport. Crowd logistics currently includes large companies such as Amazon Prime Now and UberRUSH, as well as new start-ups. These grow tremendously fast, thought ODD start-up Take Eat Easy[30] went bankrupt already, just as Delivery Hero's 'Valk Fleet'. There are two types of operations that On Demand Delivery and Crowd Logistics companies use:

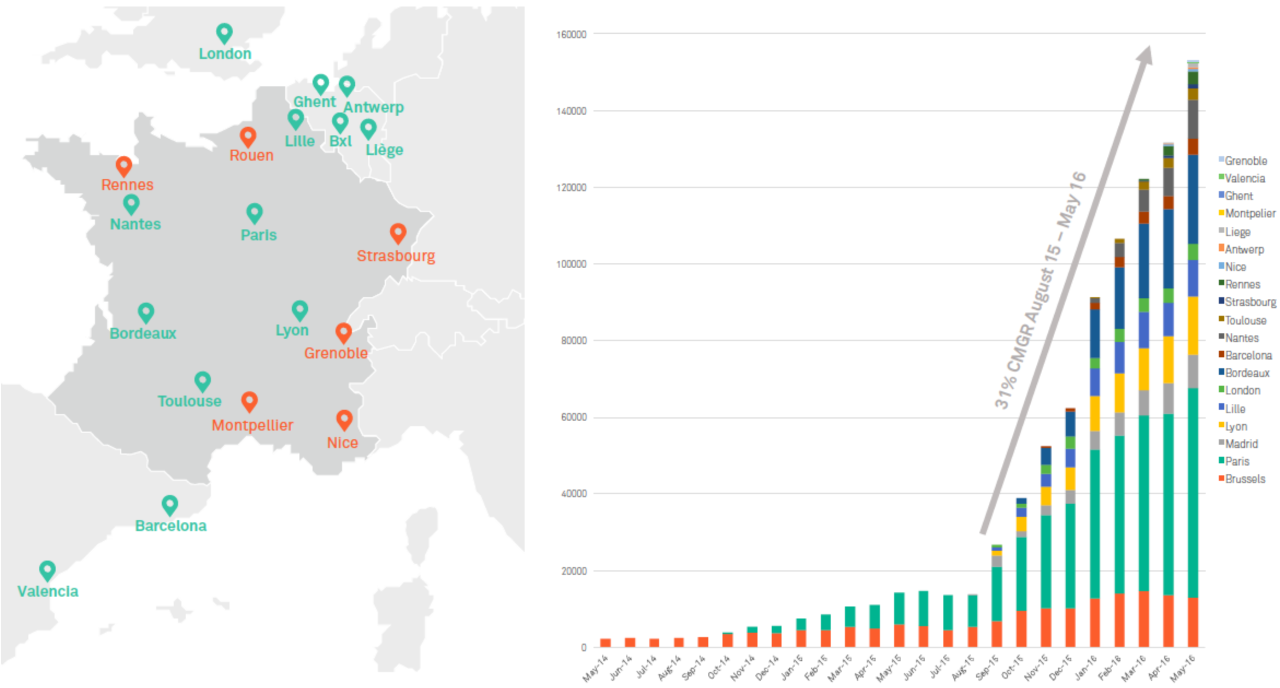
- With companies such as UberRUSH, the customer orders from a retail business and the ODD company **handles the delivery in the background**. Then, customers will not know which delivery company is handling their delivery until after they have checked out and received the text message with a trackable link that says the delivery is on its way. A Belgian example is 'Parcify. There, a customer buys online from any regular internet store, and chooses the Parcify address as the delivery address. They on their turn deliver the parcel to the final receiver. A platform was developed, to which independent bicycle couriers can connect (Parcify, 2017).

[30] On July 26th 2016, Take Eat Easy announced to suspend services, as a result of not succeeding in another capital round and not making profits.

- Other ODD companies such as Postmates and Deliveroo let e-commerce shoppers pick the bike delivery option when **buying goods** from connected retailers **on their platform**. They provides very fast options (+- 30 minutes). In March 2017, Postmates announced it is already on track to move more than 1 bn. USD across the platform (Postmates, 2017)

The start-ups are recognized by the boom in order volumes after they enter the market. The following figure shows for example the order volume per city on a monthly basis of Take Eat Easy. After the month of august 2016, a compound monthly growth rate of 35% was realised. This expansion required continuous inflow of new capital, which by July 2016 stocked, and resulted in bankruptcy soon thereafter.

Figure 6: Boom of take eat easy between May 2014 and May 2016

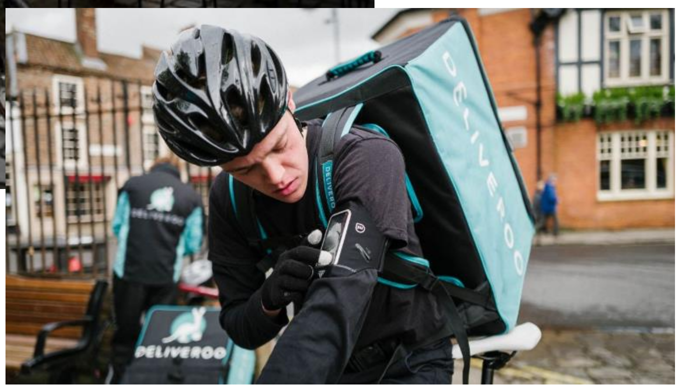


Source: Take Eat Easy, 2016

As a variant to the former of the two above-mentioned ODD solutions, crowd logistics has been gaining importance. Hereby, the ODD is not performed by a dedicated logistics operator, but rather by an individual person who is driving on purpose or just because of passing by, this way combining activities in the same trip. In this business model, the service is mostly yielded by the crowd (and not by the staff of the company). The persons within the crowd either demand or provide a service. Thereby, the company itself solely acts as a mediator (Mehmann, Volker and Teuteberg, 2015). A Belgian example is ‘Bringr’, which is a start-up of bpost. This app allows some 3,400 private drivers to reply to delivery requests of bringr users. bpost is providing the platform, not the transport services (Bring, 2017).

Thus, these ODD and Crowd Logistics companies are using their technological platform and for the services, they rely on an extended network of independent delivery couriers. The apps allow spreading demand to the connected couriers, and monitoring in real-time the delivery status, execute payments and to verify delivery to the end customers. By using these services, local retailers can establish home deliveries to serve their urban customers without developing their own technological platforms and logistics solutions. Couriers can find a job via installing the app. In general, they provide their own vehicle and smartphone as illustrated in the photos below.

Figure 7: Deliveroo riders



Source: Hendrix, 2016 and Ainsley, 2016

Criticism on new business models

The riders work all as independent service providers. This is the real difference with current logistics service providers. Full-time open-ended contracts of employment are still the most prevalent types of contract in the workplace in the EU (apart from the Netherlands). This standard form of employment accounts for some 59% of all contracts although this figure is declining (Sargeant, 2017).

According to the Flash Eurobarometer No 283 ‘Entrepreneurship in the EU and beyond’, the preference for self-employment has remained stable between 2007 and 2009: 45% of all Europeans like to be self-employed, while 49% say they would prefer to work as an employee. Men generally express a stronger preference for self-employment (51%) than women (39%) and, according to the results of the survey, young people are more inclined to start a business than older citizens do. This changed from the 354 Eurobarometer. Then, 37% of EU respondents expressed they would prefer to self-employed, while a majority (58%) would prefer to be an employee. These results contrast quite sharply with the data from the non-EU countries, with self-employment proving a more popular alternative in many of countries worldwide.

Nonetheless, the clear preference for open-ended contracts there has been a growth in more 'flexible' forms of employment, and it is possible that these flexible forms will become the norm in the future. In this new economy, those who work in it carry out a series of 'gigs', i.e. one off jobs (Sargeant, 2017). It is sometimes also labeled as the 'on demand economy' or 'sharing economy' (De Stefano, 2016). The ODD market is a primary source of this type of economy. This means that riders or drivers are either self-employed working perhaps for a number of employers or that they are employed on a series of employed contracts and are employees during their working periods (Sargeant, 2017). These forms of work present important differences to the still general open ended contract work, the most obvious being that the needed platforms operate online and can connect clients and workers from all over the word whilst 'work-on-demand via app' regards activities that are channeled online but are executed in the "real" world and locally (De Stefano, 2016).

In the UK, The House of Commons Business, Energy and Industrial Strategy Committee carried out an enquiry into the future world of work (UK Parliament, 2016). Deliveroo and Uber, two businesses in the gig-economy, provided a submission. In their view, they are Tech(nological) companies, which developed an online delivery platform which joins up customers. The platform is providing rider or drivers an opportunity to connect to demand for transportation. They both explicitly described themselves as technology companies and not as a delivery or a taxi business (UK Parliament, 2016; Sargeant, 2017). This is the essence of this new economy. It refers to people who are viewed as working as independent businesses carrying out a series of jobs 'and using a digital platform operated by a large company to match them to customers (Adam, Miller et al, 2017).

Concerns rose. The development of technology increases flexibility and induces a new labour market, with companies claiming not to employ those that work for them. Uber only employs some 600 office staff in the whole UK, but relies on thousands of disorganised individual riders. This has the eminent risk of precariat[31] for the riders. It creates a pseudo employment market where workers are said to be independent self-employed receiving work from and providing services via a digital platform created by the company. Over 40,000 drivers in the UK use the Uber app and some 10,000 riders use the Deliveroo app. Riders at Deliveroo work on average around 15 hours per week, and the vast majority are aged under 25 (Sargeant, 2017).

[31] The characteristics of precarious working are i) instability, i.e. short term horizons or when the risk of job loss is high; ii) insecurity, i.e. the lack of control over working conditions, wage, or pace of work; iii) lack of protection in employment and social security (stipulated either by law, collective organisation or custom and practice); and iv) social or economic vulnerability which is associated with low income resulting in poverty and insecurity (Rodgers, 1989; Sargeant, 2017).

Defining the correct employment status is important as differing employment protections apply to each category. Workers, who are not employees[32], have the rights like a minimum wage, protection against unlawful deductions from wages, paid annual leave, minimum length of rest break, protection from accidents at work, not be discriminated against if working part-time, to join a union. The self-employed, however, benefit from less provisions e.g. on health and safety and protection from discrimination. This lead to challenges of false self-employment. This issue is not a new one and is not a result of the gig-economy, although this puts a new argument when the companies claim not to be employers but technology companies (Sargeant, 2017).

This uncertainty on the status of riders connected to the delivery apps, has led to tensions between them and the app developers. Deliveroo riders went on strike. For example in March 2017, Deliveroo riders and supporters came together to demand a living wage and 5 GBP per drop (Cant, 2017a). Some workers have said that over-recruitment in some cities has led to riders being paid just 4 GBP an hour - less than the UK minimum wage of 7.20 GBP for the over-25s (McGoogan, 2017). The strike spread from Deliveroo to UberEATS, and then around the UK. A year on, that struggle has spread transnationally. Food delivery platform workers have now been on strike in over ten cities across the UK, Italy, France, Spain and Germany (Cant, 2017b).

Uber riders went to court. This is known as the Aslam and Farrar vs. Uber case, which was supported by The Independent Workers of Great Britain (IWGB) and was brought in front of the Employment Tribunal in the UK. The two riders argued that the written terms between Uber and themselves should be read skeptically. They argued that the terms misrepresented the relationship and that in reality they worked for Uber and that they therefore were to be regarded as workers. While Uber argued that this was not the case. The Tribunal cited a US case[33] involving Uber which rejected the company's claim that it was a technology company and not a transport one. The judge concluded that "*Uber does not simply sell software; it sells rides*" (Sargeant, 2017). Uber was allowed appeal.

A similar Employment Tribunal claim is being made mid-2017 on behalf of 20 drivers who work for Deliveroo (Butler, 2017). It follows the successful employment tribunal case brought by cycle couriers at 'CitySprint', which were entitled holiday pay after the case. Riders did not receive a guaranteed wage, sick pay or holiday pay, because the company regarded them as independent contractor (Butler and Osborne, 2017). Leigh Day, the solicitors, will be arguing that the riders are not self-employed and ought to be classified as workers and therefore are entitled to employment rights. The case is slightly different to the tribunal Uber lost last year. There, Uber drivers were classified as workers, which meant they were entitled to holiday pay

[32] Generally, there is a difference between self-employed and employees. But in the UK there is a more flexible form of labour, in between the two, named workers. This are not fully entitled to employees rights.
[33] Douglas O'Connor v Uber Technologies Inc Case 13-cv-032460EMC, March 2015.

and the minimum wage, but not redundancy pay. Deliveroo riders are pushing for the higher ‘employee’ status, which would give them extra rights, like a minimum notice period (Ghosh, 2017; Sargeant, 2017). In May, eight couriers have launched legal proceedings at the Employment Tribunal against delivery company Hermes alleging denial of their workers’ rights (Irvine, 2017).

It is to be seen if this boom in cargo cyclists working for tech players, providing ODD deliveries will find a legal place in the new economy. If not, they could as easily disappear as they emerged. With Take Eat Easy as an effective example.

II. Cycling culture research

International studies on the matter are scarce, but the ones that looked into the social aspects of urban cycling are worthwhile to highlight. This way, the mind-set of these start-ups of messenger activities can be sketched. Rosen, Cox and Horton (2007) devoted a book to cycling and society. The authors concluded that cargo bicycles can be a solution to numerous social problems across a wide range of policy areas in the modern car-dominated societies. Also Fincham (2007) analysed and described the cycling culture in detail. He stated that “*Bicycle messengers consider themselves, and are considered to be, out of the mainstream*” (Fincham, 2007). This publication focuses more on this outside mentality and the sociological impact, less on the business model. The job of the couriers is according to Fincham (2007) in essence “*Riding to and from the city centre or suburban offices, picking up and dropping off packages.*”

Kidder (2011) wrote on the social impact of the bicycle courier activities. Especially in the US, the bikers do form a sub-culture with specific behaviour. According to Weber (s.d.), bicycle couriers both “*Inject spirit and heart into their labour*”. He did not analyse the economic performance of these companies. But a smaller passage in Kidder (2011) on their business models refers to the specificity of the services: the on-demand part. He describes neatly their strengths “*FedEx for example can deliver a package from New York to Los Angeles by tomorrow, but only a bike messenger can get something from midtown to downtown by lunchtime”* Many couriers have 15 or 30 minutes delivery times within the urban territory. Many classical express operators cannot even deliver these narrowly-timed services (Kidder, 2011).

In 2015, Gruber and Kihm (2015) further developed their earlier research on cargo cyclists. They used a nationwide survey to draw a picture of the messengers as well as to model a binary decision of innovation rejection. Following a two-year German trial of 40 electrically assisted cargo bikes in various logistics service provider’s fleets, named “Ich ersetze ein Auto”, eight participating courier companies were sent invitation links for a survey. Almost all approximately 600 (mostly freelance) messengers working in the trial were invited, which resulted in 362 answers, in two waves. Some outcomes:

- The youngest courier was 18, the oldest 81 years old. Gruber and Kihm (2015) found a very similar distribution (mean 42.6) to the German population (mean 43.9 in 2011).

- Half of the messengers earn a net income of between 1,001 EUR and 2,000 EUR while the German average was then 1,685 EUR. Many have another job aside, or are student.
- Most have a higher education degree. Only 36% of the sample had a low (compulsory school) or medium (secondary school) level of education, the corresponding number for Germany is 68%.
- Courier logistics clearly is a male-dominated industry. Only 7% of the respondents was female.
- On average, the respondents drive a total daily mileage of 144 km, out of which 104 km are billed to the customers as net shipment distance. These numbers combine bike and car messengers of which the latter naturally tend to achieve higher total daily mileages.
- Flexibility is the most important job-related aspect for the respondents, with which they are also highly satisfied. The working hours differ a lot between companies. Night rounds are not favoured at all.
- Only 25.2% supported the statement that 'Electric cargo bikes will generally prevail in courier logistics'. 40.7% thinks electric cargo bikes can take over tasks of regular bike messengers. But 76.4% agrees that messengers on electric cargo bikes can take over tasks that have formerly been carried out by car messengers.

Also Dutch research on cycle couriers exists, though not from an academic nature. According to fietsdiensten.nl, a bike courier in The Netherlands cycles yearly between 10 and 12,000 kilometres and is for 90% active in dense urban areas. Delivered goods are mostly parcels, but fast moving consumer goods gain importance (Hoen et al, 2006; Fietsdiensten.nl, 2009). Fietsdiensten.nl (2009) saw in their research an increasing potential for the mode. When calculating with a 10% mode share for bike couriers, the study calculated that a shift of 1 million kilometres per year would be achievable. Calculating with average fuel consumptions, yearly savings of 85,000 litres of fuel would be possible. These assumptions show a possible increase of bike courier-related jobs to a maximum of 10,000 for The Netherlands (Fietsdiensten.nl, 2009).

Belgian bike use data is collected via a repetitive survey on how Belgian commute to work. So, data is limited to commuter travel. The modal share per mode in 2008, 2013 and 2016 is clarified in Table 9.

Table 9: Modal choice of Belgian commuters

	2008	2013	2016	Trend
Car (driver)	66.77	67.24	65.84	▶
Car (passenger)	3.65	3.35	1.50	▼
Train	7.12	5.34	6.79	▶
Tram/metro	1.03	1.11	1.91	▲
Bus	2.94	2.54	1.97	▼
Company bus	0.85	1.39	0.92	▶

Scooter	1.08	0.52	1.39	▲
Motorbike	0.74	1.06	0.86	▶
Cyclist	12.52	14.73	15.40	▲
On foot	3.30	2.71	2.45	▼

Source: Mobiel Vlaanderen (2017)

Compared to other EU Member States, The Netherlands in particular, Belgium has a less developed culture of commuting by bicycle. The car dominates modal choice and takes up a share of 66% of work-related trips in Belgium (in 2016). Nevertheless, bike use has increased from 6.2% in 2001 to 8.2% in 2008, and 15.4% in 2016. Although Belgium and Flanders are well-known for organizing professional cycling races, this seems to have little influence on people to use bikes for work. A comparison: in The Netherlands, biking takes up 25% of the work-related trips (KiM, 2016). However, there are as well worst performers. In Paris, cycling represents only 4.2% of the total commute (Insee Première, 2017), despite efforts to stimulate the use of bicycles. These are averages though. In cities, the bike accounts for a higher share of trips than on the countryside. Data on bike courier use in Belgium was not-systematically mapped.

These publications focused solely on the sociological aspects and the 'culture' of cycling in general and bicycle couriers specifically. Little logistics insights were specified. These will be retrieved from in the next section.

III. Progress in cycling logistics research, but economic reservations

In this section, the research developments on cycling logistics are outlined. Research is often initiated in European cities and as a result, several research projects guided, often subsidized (collaboration of the local city and EU funding often) cycling logistics start-ups.

The research is evaluated in Table 10 on page 54. The evaluation is shaped by scoring the reported data on five aspects of cycling logistics: cycling data, cycling culture, cycling logistics operations, cycling logistics economic insight, and the appearance of European best practices The availability of information on the aspects is valued on a scale from 1 to 3, where 3 represents the highest score, 'n.a.' indicates no information is available.

In 2012, Maes and Vanelslander first reported on cycling couriers in Belgium. The paper dealt with the use of bicycle messengers, in the modern logistics chain. Bike couriers were described as "*to deliver and transport post, parcels or freight with a low volume or weight.*" In the paper, specific markets for transport of freight by bike couriers were defined. Input was asked from the cargo cyclists themselves, via a round table discussion. The round table was organised in cooperation with the Flemish Regional Government in Belgium (2 September 2010). Also the Minister of transport was present. The paper discussed first whether these companies could be an economic viable alternative for fossil fuel powered transport. We drew conclusions on the business model and integrated encountered weaknesses and opportunities. The paper made a first simulation of a round trip delivery scheme in an urban area took place. The first conclusions were that bike couriers could be an alternative in some niche markets, but that further professionalization is needed in the start-up market.

The research further developed in the TRB poster session (Maes, 2015). There, a detailed simulation of the LCV and bike courier cost in delivering parcels in urban areas was presented. The conclusion was that niche markets could benefit from deploying cargo cyclists, while the larger volume markets (CEP for example) require supporting policies, in order to internalise the external costs. Then, the competitive balance could shift. Currently it seems that competition from LCVs is harsh, and that cargo bicyclist have a disadvantaged because of their low loading capacity.

Table 10: Summarising table of knowledge gaps in cycling logistics literature

	Cycling data	Cycling culture	Cycling logistics		European best practices
			Operations	Economic insight	
Basterfield, Greffen (2011)	n.a.	3	1	1	3
BESTFACT (2013)	1	n.a.	1	1	3
BESTUFS, Egger and Glücker (2001)	1	n.a.	1	1	2
BESTUFS, Zunder (2002)	1	n.a.	1	1	2
Browne et al (2005)	2	n.a.	2	2	2
Centraal Bureau voor de Statistiek (2008)	2	n.a.	n.a.	n.a.	n.a.
Conway et al (2011)	2	n.a.	3	n.a.	n.a.
Cycling logistics (2014)	n.a.	2	3	2	3
Cycling logistics ahead (2014-2016)	2	3	2	3	3
Dablanc (2011)	2	n.a.	3	2	2
FOD Mobiliteit en Vervoer (2010)	2	n.a.	n.a.	n.a.	n.a.
Fietsdiensten.nl (2009)	2	1	1	n.a.	n.a.
Finchham (2007)	n.a.	3	n.a.	n.a.	n.a.
Giuliano et al (2013)	2	n.a.	2	n.a.	n.a.
Gruber et al (2013)	3	n.a.	3	2	2
Gruber, Ehrler, Lenz (2013)	2	2	3	2	2
Gruber et al (2015)	2	2	3	2	1
Hoen et al (2006)	2	2	2	n.a.	n.a.
Heinrich, Schulz and Geis (2016)	n.a.	1	1	1	n.a.
Hofmann, Assmann, Neghabadi, et al (2017)	1	n.a.	3	2	1
Kidder (2011)	n.a.	3	n.a.	n.a.	n.a.
Leonardi et al (2011)	2	n.a.	3	2	2
Maes, Vanelslander (2012)	1	2	1	3	2
Maes (2015)	1	2	1	3	2
Melo, Baptista and Costa, 2014	1	n.a.	2	3	1
Pro E-bike (2016)	2	2	1	3	3
Riehle (2012)	2	n.a.	3	2	2
Rosen, Cox and Horton (2007)	n.a.	3	n.a.	n.a.	n.a.
Schliwa, Armitage, Aziz et al (2015)	2	1	2	1	2
Straightsol (2014)	n.a.	n.a.	2	2	1
Sugar (2011)	n.a.	n.a.	2	2	3
Verhetsel et al (2007)	2	n.a.	n.a.	n.a.	n.a.
Weber (s.d.)	n.a.	3	n.a.	n.a.	n.a.
Wrighton and Reiter (2015)	2	1	1	1	2

Note : Evaluation on a scale of: n.a., 1, 2 to 3. Based on availability of information.

Cargo cycling data, and the lack thereof in EU research projects

Basterfield and Geffen (2011) contributed to the publication 'Cycle Logistics – moving Europe forward' where the history of cargo cycling is outlined. Therein, a 2010 study by Mühlbacher is referenced. She did extensive research into the potential for providing various trades and services by bike in the city of Graz, but her research could apply to many towns and cities across Europe. Overall, Mühlbacher hypothesised that 32% of kilometres driven could be transferred to cargo cycle. Cycle Logistics stated that within the motorised trips in urban areas, 21% was estimated to be commercial traffic (delivery, service and business) and 28% private logistics (shopping, leisure and commuting). Research pointed out that one out of four of the total motorised freight trips in urban areas is interesting for cargo bicycles.

Furthermore, Basterfield and Geffen (2011) provide historic knowledge on cycling in general, and cargo cycling in particular. Vehicle types and historic pictures are included. No data whatsoever is provided on cycling logistics, also cycling culture is only shortly touched upon. Riehle (2012) complements a historic overview with an overview of bicycles and cargo cycles.

BESTFACT and BESTUFS I and II were discussed in detail in section 1.3.1. in which a selection of EU research projects was discussed. The three projects pilot tested several cargo bicycle transport concepts, in various cities. The most well-known is La Petit Reine (in Paris) which is still active. Others developed or were bought by logistics operators, or suspended services. The majority of deliverables is focused on the advantages the cargo bicycles have regarding the local surroundings, less emissions, more employment and the innovative edge of the cities collaborating in the projects. Given these type of projects are often focused on dissemination, this is no surprise. Sometimes data is reported, but then on avoided CO_2, but not on the daily volumes a cargo bicycle handles, transport costs, or willingness to pay by consumers. Cycling culture as such is seldom discussed.

Other Paris-based projects have proven successful. A fleet trial of cargo tricycles, in combination with an urban micro-consolidation centre, delivered good results (Dablanc, 2011). The pilot test was commenced under the TURNBLOW (2007) project, was expanded and grew to 80 employees and 70 cargo bicycles in 2014. Browne et al (2005) researched micro-consolidation of freight in urban areas. Bicycles were in his research seen as a competitive logistics last mile freight transport mode. Based on their research, Browne et al (2005) argue that, from a logistics view, operators of urban consolidation centres (UCCs) should focus on the major small retailers as well as on operators making small multi-drop deliveries, like bicycle couriers. It is expected that cycling logistics can deliver good results especially in areas constrained on delivery conditions (e.g. by restricting regulations or congestion). Based on an analysis of Browne et al (2005), Leonardi et al (2011) and Dablanc (2011), it can be concluded that the use of bicycles for urban freight transport results in a decrease to half of the CO_2 emissions and a decrease in distance driven, and that the use of these vehicles linked to UCC organisations is advisable.

In Browne et al (2005) and the follow-up project of Leonardi et al (2011) the effect of lean urban freight vehicles was researched. Trial projects were set up. In the London case of Leonardi, et al (2011), bicycles were one of the considered transport vehicles for organising last mile deliveries. But the focus is also on UCC's. The paper addresses the link between clean urban vehicles and UCC's. The case consisted of a major office supplies company (Office Depot) which was convinced to replace LCVs by electrically-assisted tricycles. The evaluation shows very good environmental results. The trail results in a decrease of CO_2 emissions by some 55%. Furthermore, the distance driven delivering the same volumes decreases by 14% (Browne et al 2005; Leonardi et al, 2011). No data was reported on costs, or on cycling culture.

However, this positive outlook is not shared all over the world. Analysing the US competitiveness for bicycle freight vehicles, Giuliano et al (2013) came to the conclusion that the use of alternative fuels and vehicles for inner-city deliveries is an urban freight strategy with only "low effectiveness" and therefore also only "medium applicability to the United States". The differing estimation of the potential of cargo bikes by inner-city couriers doubtlessly reflects the substantial difference between American and European urban morphologies. Conway et al (2011) undertook similar research in the city of New York, more particularly for the Manhattan district. Freight distribution from an urban micro-consolidation centre was analysed and last-mile freight transport via human-powered or electrically-aided freight-tricycles was included in the research scope. This research mainly was based on European methodologies developed by Browne et al (2005) and Leonardi et al (2011), but came to a comparable conclusion on the competitiveness as Giuliano et al (2013).

Browne et al (2005), Leonardi et al (2011) and Dablanc (2011), primarily researched bicycle couriers as part of projects researching UCCs. These fall out of the scope of this research. This chapter is limited to the actual cycling operations in urban areas and does not focus on UCCs.

Straightsol, a 3-year EU-funded project, mapped effects of seven innovative urban freight demonstrations. First, Straightsol developed an impact assessment framework for measures applied to urban-interurban freight transport. Secondly, Straightsol facilitated a set of innovative demonstrations showcasing urban freight innovations. Third, it applied the impact assessment framework to the demonstrations and concluded with recommendations for future freight policies and measures. Demonstration project B was researching the project of TNT Express in Brussels. The CEP company used cargo bicycles for distributing freight in the city of Brussels. The demonstration project used its Mobile Depot[34]. This depot, based on a classic truck-trailer combination, was designed by TNT and the Dutch Delft University of Technology. It links the suburb-based depot and the last-mile transport services of the Brussel bicycle couriers (Kok, 2012; Straightsol, 2014). The project resulted, over a three-month test period in a 24% decrease in CO_2 and SO_2 emissions, a 78% decrease in NO_X emissions, a

[34] The Mobile Depot has a length of 14m and a width of 6.5 m. The trailer is extendable, has a loading ramp, toilet, office space and can as such serve as warehouse. It fits 4 large and 7 smaller cages (Kok, 2012).

decrease by 98% in PM_{25} and 22% in PM_{10} emissions. The delivery cost in the project was twice the cost of the traditional situation, which was (partly) accounted to the deliberately low loading degree of the depot of 40%. The sorting within the depot and the transport of larger parcels were two disadvantages of the concept (Straightsol, 2014).

Melo et al (2014) concluded that despite the increasing promotion of small sized electric vehicles (here electric LCVs are the main topic), there are still some reservations to its implementation. Moreover, due to the initial stage of experiments with electric cargo cycles and trikes, there are still some cautions from suppliers, which can only be diminished through risk sharing with public stakeholders and subsidizing policies. Operational and economic issues are supporting these reservations. They estimated nevertheless the effects of SEV when replacing vans to deliver parcels at the street, unit and city level coverage. The better scenario would be the 10% of market penetration, which confirms it to be still a niche of market. The advice to local policy makers is not to spend a significant amount of time and money for the limited positive effects.

Pilot tests in Germany provided the first detailed data

Gruber et al (2013) worked on a research project in Germany where the focus was exclusively on electric cargo bicycles. These were evaluated on characteristics and competitiveness. This distinctive research determines whether there is a potential market for electric cargo bikes (ECB), how the current market is organized, how electric cargo bikes are perceived by bike and car messengers, and what factors drive the willingness to use them.

Eight German courier companies, all among the three biggest market players in their home cities[35], provided quantitative data. One company based in Berlin was selected for an in-depth analysis of courier shipments. To analyse the messengers' willingness to use an ECB as a means of transport for their daily job, a detailed survey was conducted providing together with the pilot tests the first data on cargo cyclists operations, expectations and visions.

Based on the data collection, Gruber et al (2013) state that bike courier trips are mostly carried out inside the city perimeter. Their analysis showed that the spread of bike versus car courier services in six German cities is differing. The result of their research is shown in Figure 8 on page 58. Bike shipments are very concentrated in the urban core. The car shipments have a far larger delivery area (Berlin data illustrated via Figure 9 on page 58).

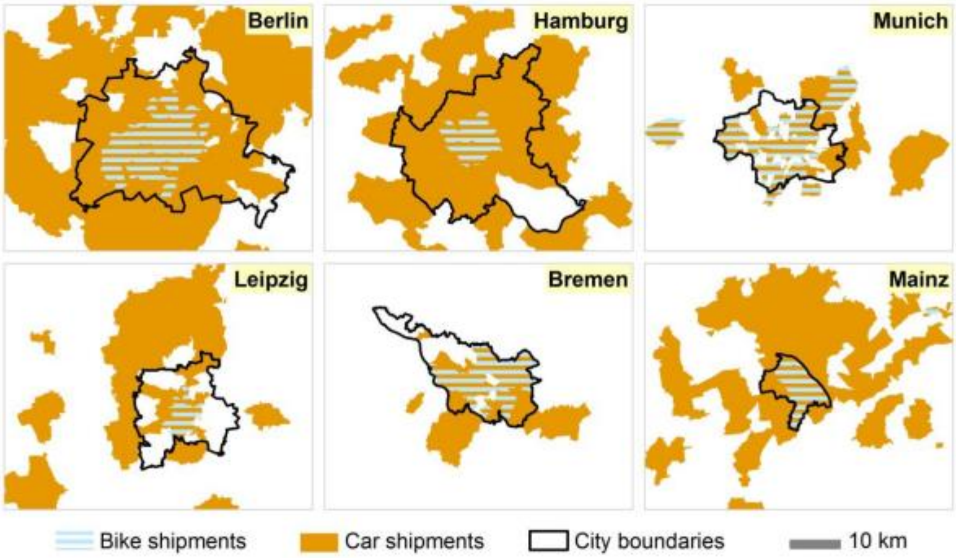
A more detailed analysis of shipments in Berlin showed that the demand for courier shipments is even more concentrated in specific inner-city areas.

- For Berlin, 83% of the pickup locations (origins) and 77% of the drop-off locations (destinations) are positioned within the inner city perimeter.

[35] Ranked according to size of the market: Berlin, Hamburg, Munich, Düsseldorf, Leipzig, Bremen, Nuremberg and Mainz.

- Bike shipments are more concentrated than car shipments: 85% of the bike shipments have origin and destination within the inner city, 11% link areas inside the inner city with other parts of Berlin and 4% of the relations are completely outside the inner city.

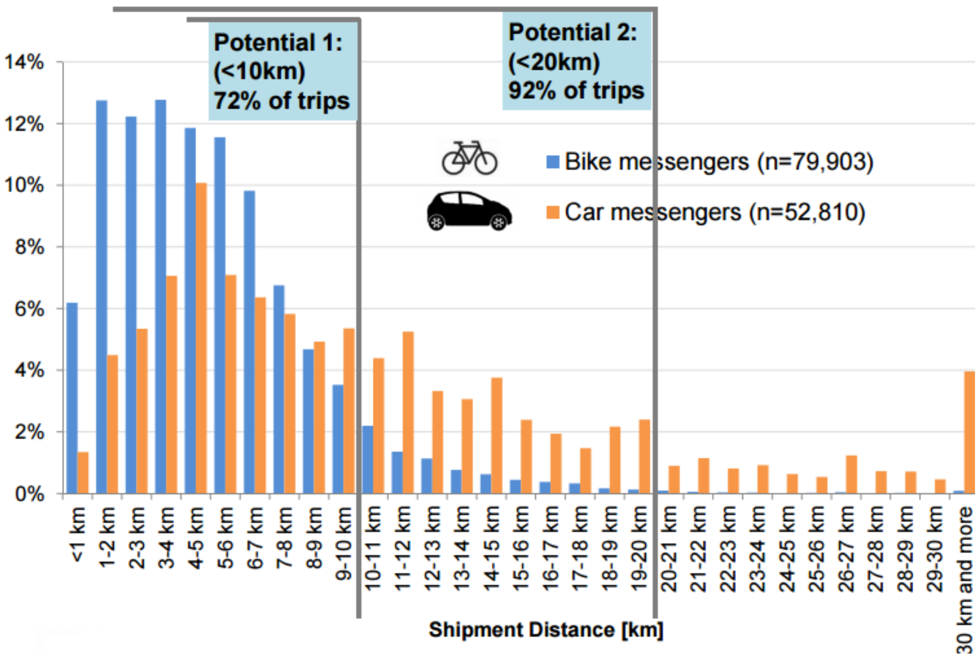
Figure 8: Spread of LCV versus bicycle couriers' services in six German cities



Source: Gruber et al, 2013

Contrary to express or parcel deliveries, the courier market in Berlin is characterised by a high share of short-distance trips. Mean distance for bike shipments in Berlin is 5.1 km, against 11.3 km for car shipments (Gruber et al, 2013). So, it can be concluded that shipments are concentrated in the inner core of the city, and that the outskirts of the city can be reached by bicycle but that the competitiveness decreases considerably.

Figure 9: Trip distance bicycle and car messengers in Berlin study



Source: Gruber, 2014

Hofmann, Assmann et al (2017) published a new simulation-based assessment tool integrating cargo bicycles in urban distribution systems. This paper started from a planning problem and lead to the developed of a GIS-based discrete-event simulation model and the coupled tour-planning algorithm. The tool is applied, evaluating the potential use of cargo bikes for B2B-deliveries in the medium size city of Grenoble (France). Applied to the case study, the tool revealed the potentials inherent in a two-level multimodal logistics scheme for B2B goods deliveries. bigger truck is used to supply these transfer points where goods are transhipped and then delivered to the shops using cargo bikes. It is assumed that on LCV should be replaced by two cargo bicycles.

Cycling logistics federation - professionalisation

The project Cycle Logistics project created at 21st of March 2014 the CycleLogistics Federation, providing a communal feeling between European cargo cyclists. Discussions with cycle based delivery companies across Europe has highlighted that there is no one group or professional body which represents and supports the needs of cycle logistics companies. The closing meeting in April 2014 in Nijmegen was coupled with the cargo bike festival, where many vehicles were shown and many cargo cyclists cycled from their hometown to Nijmegen (Cycling Logistics, 2014). This is a first step towards professionalism, as cargo cyclists organised workshops on business models and share experiences. Their 'Start-up Workshop' has been successfully delivered 16 times across cities in Europe reaching over 300 participants, while the 'Empowerment Workshop' aimed at city officials from municipalities and local authorities has been successfully delivered 11 times across cities across Europe reaching over 270 participants (ECLF, 2017).

A valuable instrument for professionalisation is the simulation tool originating from the PRO E-bike project. One of the project objectives was the development of an E-bike simulation tool for companies and public bodies wanting to better understand cargo cyclists. This tool enables potential users to simulate the impact of the use of E-bikes, and analyse the potential benefits in terms of costs and emissions. The tool reports a simple comparison between different technologies (Pro E-bike, 2017).

Synopsis of the business economic viability

The literature shows that the business economic viability of cargo bicycle transport is researched to a far lesser extent. International research on the delivery services by bicycle courier was often focused solely on the technicalities of delivering freight by bicycle, or on the environmental and social aspects (Maes and Vanelslander, 2012; Gruber et al, 2014; Maes, 2015).

The publications on the demand, i.e. the markets, the characteristics of supply and demand of bicycle courier delivery services, delivery costs, external effects (costs and benefits for society) and market behaviour are rather limited. Also Gruber et al (2013) stated that *"In all, however, there is hardly any knowledge regarding the potential and conditions of (electric)* *cargo bikes use in city-centre commercial transport today".* Research on bicycle transport as a solution for freight transport in urban areas can be considered a rather new and under-developed academic research stream, with pertinent knowledge imperfections.

International research on the delivery services by bicycle courier is focused often on technicalities of delivering freight by bicycle. The publications on the markets, i.e. the characteristics of bicycle courier delivery services, delivery costs, external effects and market behaviours are limited. Operational and economic insight are limited to Gruber (2013) and Riehle (2012). This view is shared and was the basis for further developing the knowledge on cycling logistics. PRO E-bike as an EU-funded project to promote electric bicycles and electric scooters is also focussed on extensive national and international dissemination.

Only Browne et al (2005), Leonardi et al (2011), Dablanc (2011), Giuliano et al (2013), Conway et al (2011), Conway et al (2011), Gruber et al (2013), Straightsol (2014) and Cycling logistics (2014) regard cycling logistics from an economic and operational viewpoint. But only some of the research publishes the economic insights retrieved, for example the number of parcels transported per cargo bicycle per day, the start-up and operational costs, the profit made or the average cost per parcel transported. PRO E-bike has developed a quick scan tool to estimate the benefits of shifting from LCVs to E-cargo bicycles, but does not disclose the data behind the tool.

Therefore, it was clear that further research into the topic was needed. The literature overview and the identified research gaps are the basis for the next section, developing the research scope and research questions.

1.4. Rationale, research scope, questions, process and Ph.D. structure

Given the challenges for urban freight transport discussed in this chapter, and the likely chances of cargo transport by bicycle, the research within this dissertation will focus on last- and first mile urban freight transport by bicycle. First, the rationale for this Ph.D. research is provided.

1.4.1. Rationale

After this introductory chapter, urban cargo bicycle transport was concluded to be most interesting to further research as a solution to attain more sustainable urban goods transport. Because of reasons found within the urban freight transport sector itself, the (immature) cargo bicycle transport sector, and the general trend of e-commerce growth and increased sensitivity of citizens for urban liveability challenges. Twelve main reasons are listed on the next page.

- ✓ The cargo bicycle transport companies developed within research and dissemination projects still exist, years after pilot testing. And many grew considerably since then.
- ✓ A revival of the use of bicycles is seen in Western-Europe, also in Belgium.
- ✓ Cargo bicycle sales and use is growing, also for the non-commercial usage.
- ✓ E-commerce is booming. The parcel volumes in Belgian grew by 24.3% between 2013 and 2015, reaching a 6% share in total mail volumes nonetheless contributing to 40% of the total mail revenue of the Belgian post market (BIPT, 2017).
- ✓ An average Belgian buys already 12.4 parcels a year (in 2015), a strong increase from 8.1 in 2010 and 9.8 in 2013 (BIPT, 2017).
- ✓ Most of e-commerce parcels are delivered at home, which is the preferred way of receiving good by customers (65%) (BIPT, 2017; Comeos, 2017).
- ✓ Many Belgians live in urban areas. Economic wealth is generated and spend in these regions. Expectation is that urban density will increase just as the demand for goods.
- ✓ It is believed that this almost-zero emission transport mode should be analysed on its economic and social benefits. The current literature is seldom focused on the economic aspects. Gaps exist in academic research.
- ✓ New IT tools allow different business models in logistics to flourish. Communication is easily accessible and cheaper for start-ups to develop.
- ✓ ODD and Crowd Logistics (Deliveroo is a very visible example) made the transport of goods via bicycles more accepted than before.
- ✓ Liveability of urban areas and the influence of freight transport thereon is a discussion topic in many of Europe’s cities, also in Belgium.
- ✓ The easy transferability to other urban areas, due to the limited capital investment costs, is an additional argument for further researching this innovation.

1.4.2. Research scope

The transport concept of cargo bicycles for urban freight transport will further be researched on economically and societal impacts as this was the main research gaps. In order to develop a comparison of cargo bicycles and current practices, some concepts need to be scoped first: the service structure (the supply of services), and the demand.

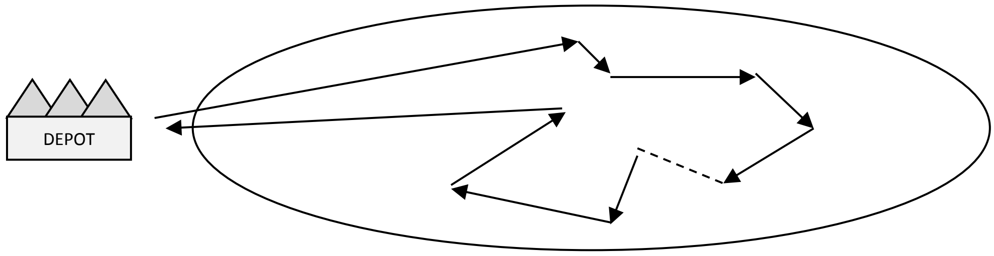
Service structure

This means last-mile and first-mile transport needs to be defined. Just as the structure of the delivery rounds in urban areas.

- Last-mile transport is the last trip to the final receiver, by a vehicle leaving a depot/ transhipment facility; i.e. the location where the last handling is undertaken (Gevaers, 2013).
- The first mile is the pickup of goods at the urban shipper’s premises, the transport within the urban area, and the delivery to the first handling location (often the same location as the depot/transhipment facility mentioned in the first bullet).

The last mile is also illustrated in the figure below, where the oval expresses the boundaries of the urban area or city. The scope of the research is limited to the transport services from the depot, to the final customer, without taking account of the depot cots, assuming these are similar for LCVs or cargo bikes docking there.

Figure 11: Service structure of the last mile within an urban area

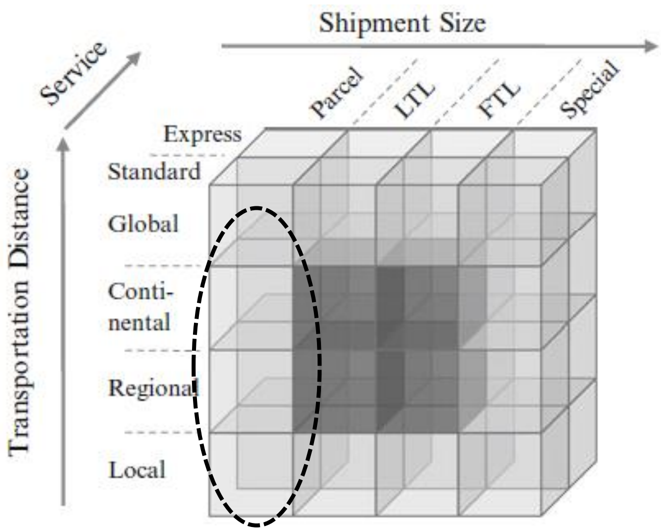


As discussed in this chapter, the market for urban goods transport consists of four flows (please refer to Figure 1 on page 8). Out of the four, only three flows are fitted for cargo bicycle transport: transport to, from or within the urban area (flows a), b) and c)). Trough-traffic is not fitting the characteristics of cargo bicycles. His is often long distance transport, organised best in LCV or HGV, or in a multimodal way.

Demand

Fleischmann (2008) distinguished three specific dimensions in transportation services: load sizes, transportation distance and transportation speed. These three dimensions allow distinguishing among the likely demand for urban goods transport by cargo bicycles. These are illustrated in the Figure 12. With regard to the first dimension, Fleischmann et al (2008) arguments that the "appropriate structure of a transport system mainly depends on the size of the single shipments." Standardized shipment sizes in the CEP market are letter and parcel consignments. Large global players in this market are DHL, UPS or FedEx.

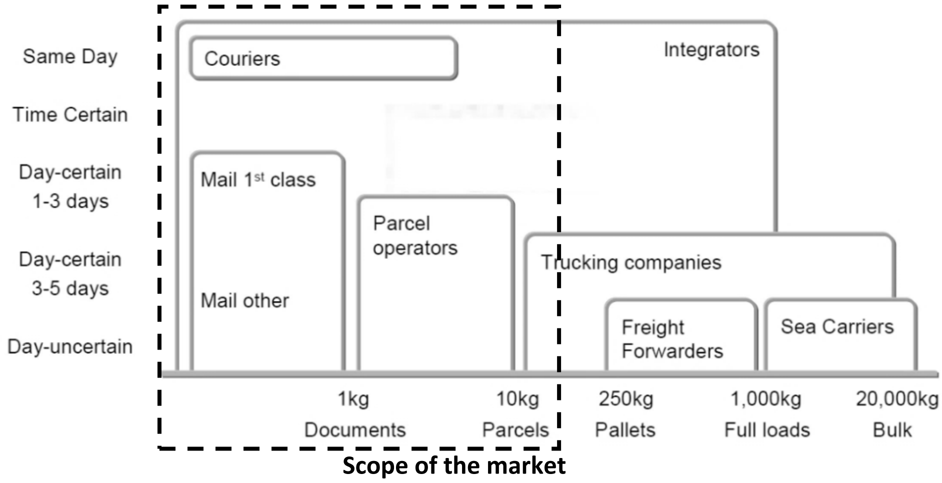
Figure 12: Structure of the transportation market



Source: Fleischmann et al, 2008

The dissertation mainly regards the local to continental market, and especially the parcel shipment sizes (CEP market). Regarding service level, both express and standard are relevant. The research in the dissertation will focus on the transport of goods towards the end receiver, located in an urban area. These cargo flows can be B2B as well as B2C types of shipments. Meals and food products are not in the scope of the research. The CEP market is only a small share of the total logistics market. The next figure sketches the market position. CEP is situated top left, with parcels below +- 10 kg (to fall into CEP category, the delivery employee should be able to lift the parcel without assistance).

Figure 13: Courier and logistics market divisions



Source: Based on TNT, 2010

Considering the expected growth of e-commerce, in spite of the economic situation, a growth in the number of parcels delivered per consumer per year can be expected. According to research from LET (Patier-Marque, 2002), the flow of goods in cities can be divided into three main categories i.e.:

i) establishment supply movements (40% of total goods distribution in the city);
ii) end-consumer commodity movements, home deliveries (50%);
iii) other flows, i.e. waste flows, removal activities, the building supply chain, home deliveries and post (10%).

CEP could be found in establishment supplies, home deliveries and postal activities (and even end-consumer B2Cs). Thus, parcel flows possibly will represent around 20-30% of the total urban goods distribution (TNT, 2010; Patier-Marque, 2002, Ducret and Durand, 2012).

- **E-commerce** Europe estimated the 2015 total EU GDP to have reached 17.6 tn EUR, with a share of e-commerce of 2.59% (2.45% in 2014); or in total 455 bn. EUR (402 bn. EUR in 2014) (ECommerce-Europe, 2015).
- Not all e-commerce transactions require transport. ECommerce Europe (2017) reports that only 52% of online sales represent goods. In turnover, the **European parcel and express market** (representing a considerable share of the total e-commerce market),

was estimated by DG MOVE at 42.4 bn. EUR in 2008 or 0.34% of the EU-27 GDP (MDS Transmodal, 2012). This aligns with market studies by AT Kearney, who estimated the 2013 market at 43 bn. EUR (AT Kearny, 2015).

- DG MOVE published that parcels accounted for about two-thirds of this market revenue, while express shipments represented one-third (MDS Transmodal, 2012). Copenhagen Economics (2013) reported **total shipments** of 6.4 bn units in the EUR, 56% of them B2C, 29% were B2B and 14% C2C & C2B. Domestic shipments were estimated to have a share of 85%, Intra-EU cross-border shipments are about 12% and Extra-EU cross-border shipments are only 3%.
- According to a study by Barclays (2014), **letterbox-sized packages** and small **parcels** (not larger than a shoebox) comprised 59.5% of online orders (Barclays, 2014).

The share of CEP in the total logistics market is not easy to estimate. French e-consumers buy around 13.5 parcels a year (Ducret and Durand, 2012). This is in line with Belgians, who ordered some 12.4 parcels a year (in 2015) (BIPT, 2017). Further research on the demand will be necessary.

1.4.3. Research questions

The main challenge for the urban freight transport sector is meeting the increased demand for parcel shipments while being confronted with urban road freight congestion and its elevated (in)direct societal impact of freight vehicles (expressed in among others rising external emission, accident and noise costs); mainly seen or at least felt in urbanised areas.

The research will explore whether cargo bicycles are able to act as an alternative mode to current *traditional* LCV fossil fuel-powered transport, and assisting to obtaining a more sustainable urban freight transport and urban liveability. The main research question is:

"Can cargo bicycles contribute to an enhanced economic/environmental/societal liveability of urban areas, and to what extent?"

This question is supported by four sub-research questions, depicted in Table 11. The research will regard the private and societal economic benefits separately. As such, a well-funded conclusion can be made on the societal impact increasing cargo bicycle use for urban freight transport. Also the magnitude of the societal and private business-economic impact will be quantified. The last sub-research question will define if and how policy can contribute to enabling cargo bicycle use for increasing urban liveability.

Based on research, the own definition of city logistics by bicycle is:

"the activities related to the professional delivery of goods in cities and urban areas by either (two-wheeled) bicycles or specialised cargo bicycles, which are characterised to be primarily pedal-powered and on occasion electrically aided. Activities include home delivery services and

the reverse flows of used goods as well as the supporting activities as ICT, handling and (short term) storage of goods, and the management thereof."

Table 11: Sub-research questions

1	In which economic constellation and political context do these cargo bicycle companies operate?
2	What is the magnitude of their private economic benefits/profits?
3	What is the magnitude of the societal benefit of an increased cargo bicycles use?
4	How can policy contribute to the sustainability and liveability of urban areas by enabling cargo bicycle use?

1.4.4. Research process

The Ph.D. was commenced as a researcher at the University of Antwerp's department of Transport and Regional Economics (TPR), embedded at the Faculty of Applied Economic Sciences. TPR develops research on transport and regional economics. City logistics became one of the spearheads from 2010 on. That year, on the 2nd of September 2010, a round table 'Cycling logistics' was organised in Brussels, which brought together a representative sample of Flemish and Brussels bike couriers. This round table resulted in Maes et al, 2011. All Belgian bike couriers were invited, of which a majority active at that moment took part in the discussion. The results of the beforehand shared questionnaire were used to structure the meeting. Before, an open questionnaire was prepared and sent to all bike couriers active in the region of Flanders and Brussels[45].

In parallel, a literature review was performed. This involved searching for publications in catalogues as ebsco host, research gate and google scholar. Keywords used were 'cycling logistics', 'cyclelogistics', 'Bike couriers', 'cycling messengers', 'urban freight transport', 'cargocycles', freight bicycles', 'bikes for urban freight', 'e-cargobikes'. The last search for new publications was undertaken in October 2017.

Then, Belgian market players were contacted, their websites were scanned, and consequently a market study was established. First contacts were made among others with the Belgian bike messenger company Pedal BXL. Subsequently, a meeting with Max Mobiel and start-up players Lunchbutler.be[46], Ecopostale, Bubble Post, Cargo Velo took place. Furthermore, separate discussions with major integrators and other logistics companies were organised, e.g. ASX-Ibeco and TNT Express.

[45] Flanders is a region in Belgium, and Brussels is the capital city of the country, and also a Belgian region.
[46] This company was at that time elaborating a Belgian logistics (IT) platform to connect bike couriers and their customers easier with each other. A meeting was organised in 2012.

Results were presented at an Expert Colloquium on Urban Freight Distribution organised at the University of Antwerp (4th of May 2012). Various experts were invited to discuss ideas and discuss the future for urban freight transport in general, and the policy aspects specifically, in a more informal way. Cargo bicycle transport was one of the discussion topics. The conclusions of this expert meeting were also published in a policy-supporting paper 'Expertenbijeenkomst Trends voor duurzame stedelijke logistiek' (Gevaers, Maes, Sys and Vanelslander, 2012). As a closing, an expert lecture was convened by Prof. Rosário Macário (IST Lisbon / TransportNET) on the state of practice and science for urban freight solutions.

The intermediate steps of the Ph.D. research were published in academic papers, and presented at various fora. The table below shows a selection thereof.

Table 12: Selection of presentations and publications Jochen Maes (2009 – 2017)

Activity
Presentation on Bivec 2009 - 27 May 2009, Brussels, BE **Maes Jochen**, van de Voorde Eddy, Vanelslander Thierry (2009). *Mapping bottlenecks in the Flemish logistics sector,* Proceedings of the BIVEC-GIBET Transport Research Day / Macharis, C. [edit.]; e.a. - ISBN 978-90-5487-580-2 - Brussels, VUB Press, 2009, p. 297-311
Presentation on Metrans National Urban Freight Conference 2009, Long Beach, USA **Maes Jochen**, Vanelslander Thierry (2009). *The use of rail transport as part of the supply chain in an urban logistics context,* Conference proceedings of Metrans 2009, Long Beach, USA
Presentation on ETC 2009, Harderwijk, NL **Maes Jochen**, van de Voorde Eddy, Vanelslander Thierry (2009). *Mapping bottlenecks in the Flemish logistics sector,* European Transport Conference 2009: proceedings, the Netherlands
Presentation on 12th World Conference on Transport Research, Lisbon, PT **Maes Jochen**, Vanelslander Thierry (2010). *The use of rail transport as part of the supply chain in an urban logistics context*, 12th World Conference on Transport Research, Lisbon, 11-15 July 2010
Publication **Maes Jochen**, Sys Christa, Vanelslander Thierry (2011). *Kunnen fietskoeriers een rol spelen in de Vlaamse logistieke sector?,* Antwerpen: Steunpunt Goederenstromen, 43 p.
Publication **Maes Jochen**, Sys Christa, Vanelslander Thierry (2011). *Noden van de Vlaamse logistieke sector,* Antwerpen: Steunpunt Goederenstromen, 49 p.
Presentation on BIVEC-GIBET Transport Research Day 2011, Namur, BE **Maes Jochen**, Vanelslander Thierry (2011). *The use of bicycle messengers in the supply chain? Moving slowly,* Proceedings of the BIVEC-GIBET Transport Research Day - Namur
Presentation doctoral Day University of Antwerp, BE **Maes Jochen** (2011). *The use of bicycle messengers in the logistics chain: Concepts further revised*, Paper for University of Antwerp : Doctoral Day 2011, 23 November 2011
Publication Author of a chapter in the book 'City Distribution and Urban Freight Transport' (edt. Macharis en Melo) **Maes Jochen** and Thierry Vanelslander (2011). *The Use of Rail Transport as Part of the Supply Chain in an Urban Logistics Context*, Edward Elgar Publishing ISBN 0857932748
Publication **Maes Jochen**, Sys Christa, Vanelslander Thierry (2012). *Vervoer te water : linken met stedelijke distributie?,* Antwerpen, Steunpunt Goederen- en personenvervoer, 59 p.

Publication after presentation Roel Gevaers, **Maes Jochen**, Sys Christa, Vanelslander Thierry (2012). *Expertenbijeenkomst: Trends voor duurzame logistiek*, Antwerp: Steunpunt Goederen- en Personenvervoer, 2012, Following 4th of May 2012 expertmeeting, Wettelijk depotnummer: D/2012/11.528/7
Presentation **Maes Jochen** (2013). *Cost Benefit Analysis to Evaluate an Urban Freight Project?,* Presentation on the METRANS International-Urban Freight Conferences 2013, Long Beach, 8-10/10/2013
Publication **Maes Jochen**, Vanelslander Thierry Procedia (2012). *The use of bicycle messengers in the logistics chain, concepts further revised*, Published in social and behavioral sciences - ISSN 1877-0428 - 39(2012), p. 409-423 Full text (open access): https://repository.uantwerpen.be/docman/irua/1ac0a9/5078.pdf
Presentation **Maes Jochen**, Sys Christa, Vanelslander Thierry (2011). *Low emission zones in Europe : their impact on sustainability and logistics*, Proceedings of the METRANS National Urban Freight Conferences 2011, Long Beach, 12-14/10/2011 - Antwerpen, 2011, p. 1-23 Full text (open access): https://repository.uantwerpen.be/docman/irua/5f283c/20c7c029.pdf
Publication Sys, C., **Maes, J,** Vanelslander, T. (2015). *City logistics by water : good practices and scope for expansion,* Transport of water versus transport over water : exploring the dynamic interplay of transport and water, Edt. Ocampo-Martinez, Carlos, Springer, ISBN 978-3-319-16132-7
Poster session Washington, USA **Maes Jochen** (2015). *Welfare economic evaluation of an urban freight distribution concept with cargo cycles,* 94th Annual meeting TRB, 11 – 15 January 2015, TRB Paper 15-4817

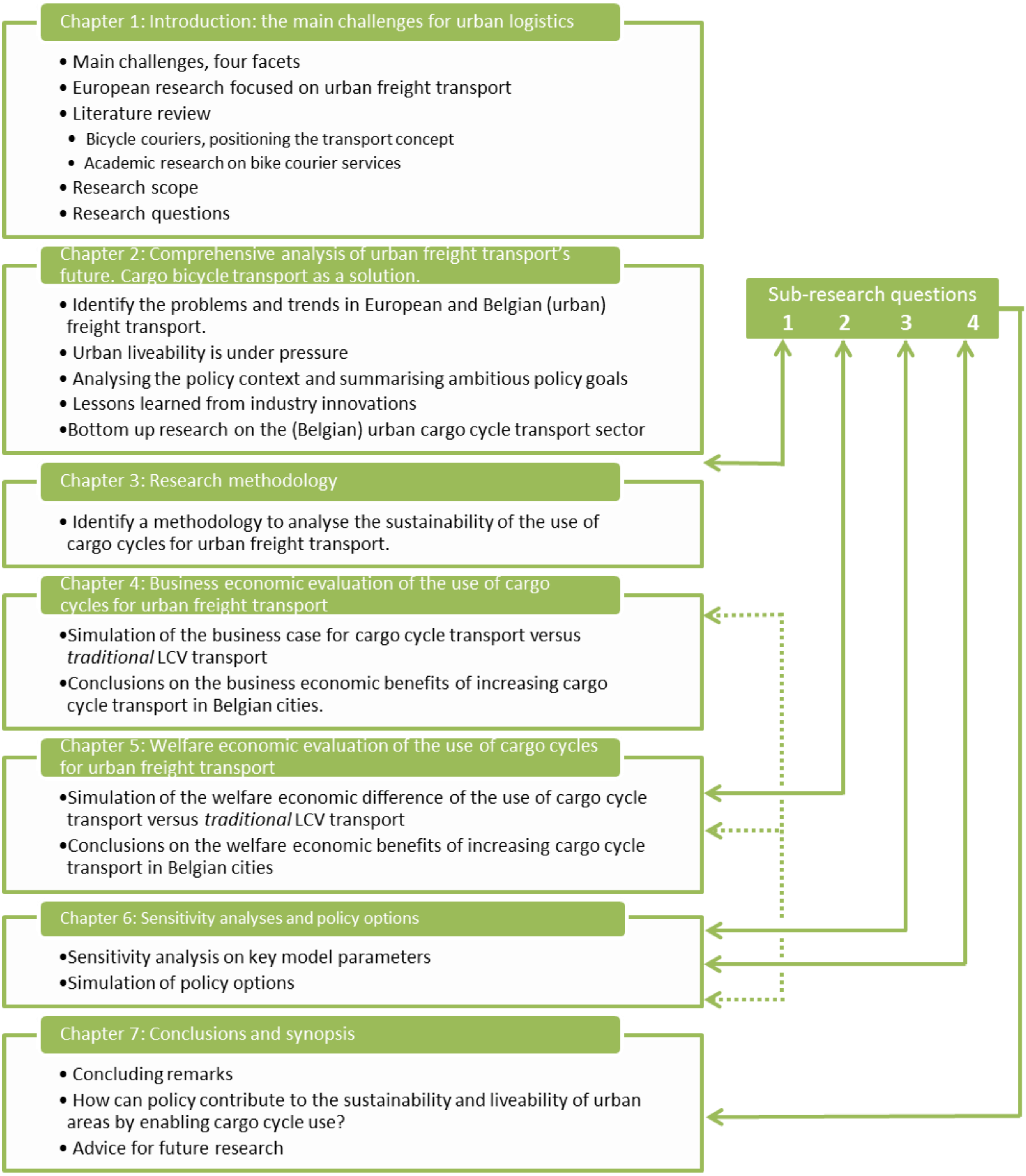
A close link with the bicycle freight market was maintained. Regularly, individual companies were contacted to be aware of new trends. Developments within the market were closely monitored.

All these steps resulted in a modelling exercise, analysing the competitiveness of bicycle transport vis-à-vis LCV use, and estimating the welfare-economic aspects of a modal shift from LCV to bicycle transport to fil the research gap of the limited number of academic papers about the specific or structural use of bike couriers in logistics. The dissertation aims to link seamlessly bottom-up data collection and research on Belgian bicycle couriers, with a thorough industrial-economic analysis and a welfare-economic impact assessment via an urban freight transport spreadsheet model. This model was developed in Excel, and offers the opportunity to simulate different input data for cost parameters, demand estimates, external cost indicators and for example price sensitivities.

1.4.5. Ph.D. structure

These research questions are answered via the following chapters. The structure is outlined in the next figure. **Chapter 1** provided a first overview of the challenges in urban logistics, the research gaps, policy intentions, innovations, pilot tests and research projects, the chances for cargo bicycle transport and the rationale for developing this Ph.D. research. The research questions will be used as a guideline in the other 5 chapters. The **second Chapter** provides a comprehensive analysis of the challenges, and develops own research on the Belgian bicycle courier market. Then, **Chapter 3** develops the methodological framework for comparing cargo bicycle transport with LCV transport. The framework serves as a basis for developing the Excel-based simulations. **Chapters 4 and 5** discuss the simulation outcomes, on the business economic aspects, respectively on the welfare economic outcomes. Chapter 6 closes the analysis with simulations on key parameter values of the model. The model is also used to simulate policy impacts. **Chapter 7** ends with conclusions on the research questions, and provides a synopsis in which advice is given for further research.

Figure 14: Structure of the research and connection to the sub-research questions



2. Comprehensive analysis of urban freight transport's future. Cargo bicycle transport as a solution.

What is urban liveability, and how can policy and cargo bicycle transport contribute thereto? These topics are discussed in this elaborate second Chapter. Figure 15 on the page 70 illustrates the Chapter structure.

In section 2.1 an overview is provided of challenges for urban freight transport and for the liveability of urban areas. Background is given on the trends behind the increased use of road transport. The challenges are quantified in 2.2, and distinction is made between external costs in general and (higher) external costs of goods vehicles in urban areas.

The first chapter already introduced the challenge of 'urban liveability', which can be regarded as an overarching problem for urban areas. Liveability has many features. It is not only related to the external costs depicted in 2.2, but captures as well expectations of residents and subjective feelings towards freight vehicles, noise and visual intrusion. Therefore, section 2.3 provides more information on indicator sets for measuring urban liveability, of which the 'Mercer quality of life' and 'European green capital awards' are two well-known examples.

Then, the policy context is outlined. Both objective and subjective urban challenges, are fuelling (European) transport policy (discussed in section 2.4). The developments in urban freight transport policy are introduced in a comprehensive way, and main policy objectives are summarised.

Industry innovated and developed some chanceful innovations for tackling the challenges. Chapter 1 already well-argued the rationale for researching cargo bicycle transport. This chapter adds via section 2.5 own research on the Belgian market for cargo bicycle transport, and the developments therein. The market segments are discussed, just as data on their operations and financials. Based on this analysis one business case is distilled.

Figure 15: Structure of Chapter 2

2.1. Data on the main trends and challenges in the European transport sector

- 2.1.1. The European transport sector grew after structural changes
- 2.1.2. Transport and logistics' importance for the European economy

2.2 External costs of transport are elevated

- 2.2.1. External congestion costs
- 2.2.2. External emission-, climate change-, noise-, urban effects and accident costs
- 2.2.3. Energy use
- 2.2.4. Emissions
- 2.2.5. Climate change
- 2.2.6. Noise
- 2.2.7. Accident costs

2.3. Urban liveability is regarded by citizens as under pressure

- 2.3.1. Measuring and benchmarking urban liveability
- 2.3.2. Measuring city sustainability
- 2.3.3. Measuring quality of life in metropolitan areas
- 2.3.4. DG REGIO's urban liveability index
- 2.3.5. The UN City Prosperity Index
- 2.3.6. The Public Spaces Wheel by PPS
- 2.3.7. European green capital award
- 2.3.8. Liveability parameters related to the analysis in this dissertation

2.4. (EU) policies to improve performance of urban freight transport

- Halve the use of 'conventionally-fueled' cars in urban transport by 2030;
- Phase them out in cities by 2050;
- Achieve essentially CO2-free city logistics in major urban centres by 2030.

2.5. Cycling logistics as a chanceful alternative for LCV transport

- 2.5.1. The Belgian bicycle courier services market
- 2.5.2. SWOT Belgian bicycle courier market
- 2.5.3. Defining representative business case for cargo bicycle transport

2.1. Data on the main trends and challenges in the European transport sector

This first section depicts the high-level trends in the European transport and logistics sector and serves as a background for better understanding the increased urban freight transport demand, and the impact this growth has on the sector and on urban (freight) transport. Transport in general is confronted with similar sector challenges, but urban freight transport's external costs are higher. This is depicted in sub-section 2.1.1. In its nature, transport is a supporting sector for the general economy. A catalyser for growth and wealth. Transport is not only a problem; it is in itself also an important sector for the economy, contributing to Europe's GDP and labour market. This is discussed in sub-section 2.1.2.

2.1.1. The European transport sector grew after structural changes

Reaching a free movement of persons, goods, capital and services were the key elements of the Treaty of Rome (1957) [48], founding the European Economic Community. The foundations laid with the Treaty were not specifically focused on freight transport. Therefore, years later, the 1992, the Treaty of Maastricht[49] reinforced the political, institutional and budgetary foundations for among others a Common Policy for Transport (CTP), finally allowing the European transport policy to be further concretized. The Commission's first White Paper on the future development of the common transport policy followed shortly after in December 1992[50], and put the accent on opening up the transport market(s). As a result, European road cabotage[51] was opened for competition, air safety standards in the European Union were set more ambitious and personal mobility increased.

In pursuing the goal of creating a Single European Transport Market, stepwise lots of National market boundaries were left behind. The single market for goods transport is noticed in practice by a deregulation effort focused on the respective sub-markets of the transport sector. Where in the past, free competition between European road transport services was hindered by for example tariff regulations, customs, licensing requirements and market access quota. Member States harmonized, under European influence, regulation and leveled market barriers. Cabotage activities of road transport operators are nevertheless still scarcely allowed[52]. In addition, the rail industry underwent structural changes, as competition between companies on national rail infrastructure networks was to a certain extent liberalized. Open

[48] The Treaty of Rome, Signed 25 March 1957

[49] Treaty on European Union (Treaty of Maastricht), Signed 7 February 1992

[50] The future development of the common transport policy, A global approach to the construction of a Community framework for sustainable mobility, COM(92) 494 final

[51] Cabotage, in a European context, is meaning the national carriage of goods for hire or reward carried out by non-resident hauliers on a temporary basis in a host Member State.

[52] Article 8 of the Regulation (EC) 1072/2009 provides that every haulier is entitled to perform up to three cabotage operations in a seven-day period starting the day after the unloading of the international transport.

access was created for freight transport services, but still market barriers and imperfections subsist. Whereas national and international rail freight transport is liberalized, passenger transport services are often still predominantly or solely with the incumbent rail operator[53]. In addition, the air transport industry was deregulated, limiting state aid and harmonizing regulation. As last, also inland shipping transport is now performing services in a more competitive setting[54].

In 2011, total goods transport activities in the EU27[55] are estimated to have amounted to 3,824 bn. tkm. This figure includes intra-EU air and sea transport but not transport activities between the EU and the rest of the world. Road transport accounted for 45.3% of this total, rail for 11%, inland waterways for 3.7% and pipelines for 3.1%. Intra-EU maritime transport was the second most important mode with a share of 36.8% while intra-EU air transport only accounted for 0.1% of the total. (European Union, 2016)

When putting the tkm and pkm data in a graph (Figure on the next page), a clear correlation with an elasticity larger than 1 could be derived between the European GDP and the transport sector growth. The growth in passenger transport had an elasticity to GDP lower than 1, the freight transport sector had till 2007 an elasticity exceeding 1. From then on, the tkm performed by the freight transport sector declined heavily. The crisis hit hard, and 2009 resulted in a transport sector's performance comparable to 2003 levels. After that, the volumes recovered but only gradually (Eurostat, 2017a; Eurostat, 2017b).

It cannot be stated yet whether this decline is structural, or temporary. The clear correlation between GDP growth and transport growth was in the past the basis of European transport policies. A decoupling of this growth in transport became of high importance as the sector gradually was confronted with increasing congestion, emissions and accidents. But when observing the trends since 2009, it seems that GDP picks up at a faster pace than transport in tkm.

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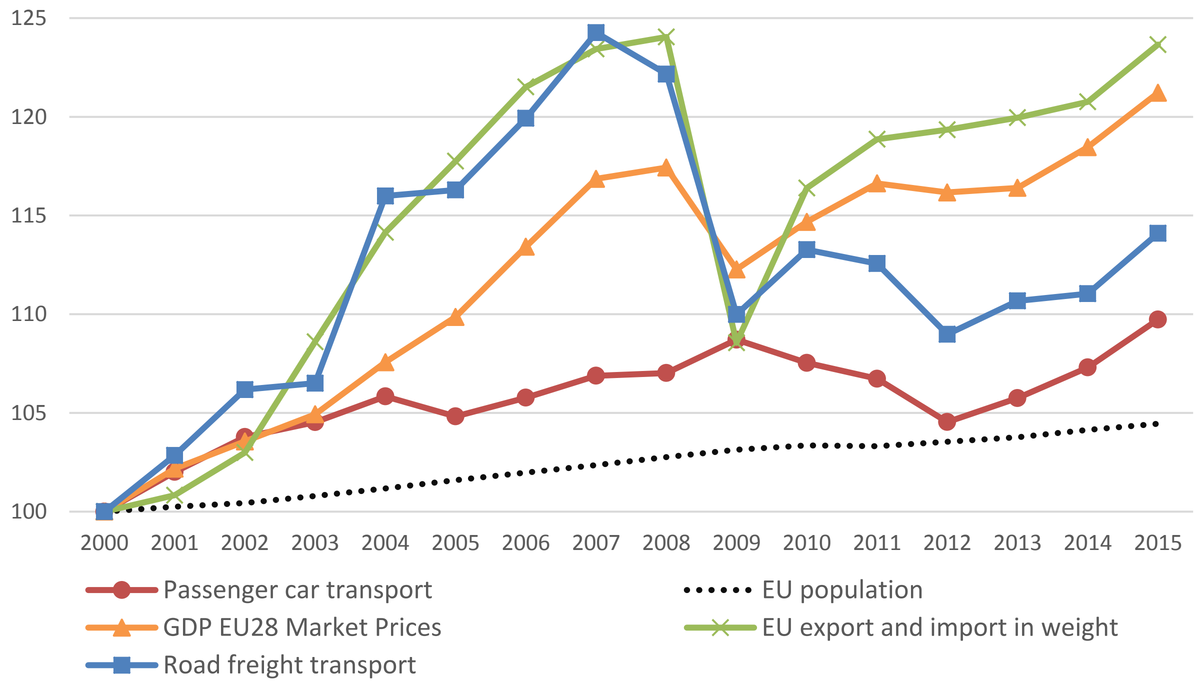
[53] A first breakthrough in the liberalization process came with directive 91/440 (29 July 1991). Then, via European rail packages, national and international rail freight transport was opened for competition. Since 2011, Europe focuses its policy on three broad axes: market functioning, infrastructure, and interoperability, based on the 2011 European White Paper. That White Paper gets execution in a Fourth Rail Package, that the Commission proposed early 2013, and which got approved early 2014, be it in a modified form. International passenger transport is open to competition; but national passenger transport by rail is still a protected market.

[54] Harmonisation of transport subsidisation policy, which began with Directive 70/1107, in the EU member countries has helped slow down the use of subsidies and stabilized the market for inland waterway shipping.

[55] In this dissertation, Europe will still be referred to as EU27. Croatian data are not yet available for all-time series yet.

Figure 16: Indices* of EU28 pkm, tkm, import & export, population and GDP



Source: Based on European Union, 2017 and Eurostat, 2017a and Eurostat, 2017b
*2000 = 100

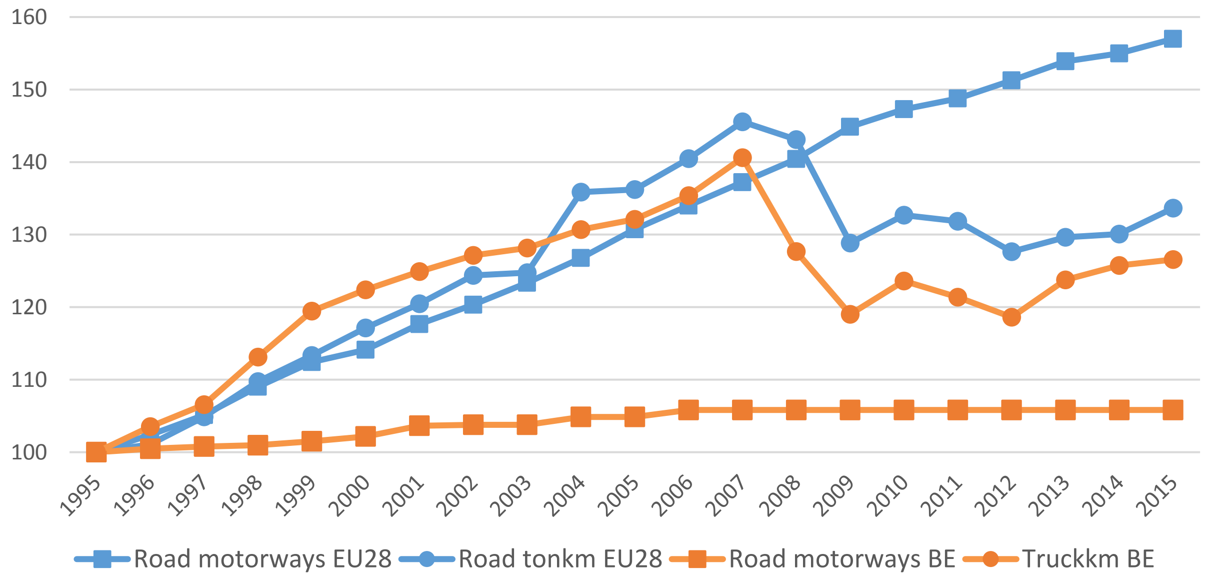
In contrast to the increase in freight transport demand, relatively little investments were made in the road infrastructure. Especially when looking at the highway infrastructure, a stabilised network expansion pace can be seen in Figure 17 (only data on main road infrastructure).

In the EU28, in the period 1995-2015, main road capacity increased by 57%. In the EU15, there was an equal 47% increase, while in the densely populated BeNeLux only 17% extra capacity was provided. In Belgium specifically, only 97 km of new highways were constructed in the last two decades, resulting in an increase of the already dense infrastructure network by no more than 6% (European Union, 2017).

Figure 17 o the next page shows the indexed growth (base year is 1995) for European and Belgian road transport. The infrastructure in the EU28 countries followed closely the road transport growth until 2007. The pattern was broken from then on, where infrastructure was still built and transport by road heavily declined. Belgian data show a different situation, where infrastructure hardly grew and road use increased considerably (Meersman, Van de Voorde, Vanelslander and Verberght, 2010; Eurostat, 2017).

The congestion problem is not only attributable to this growth in road freight transport. Additional to the demand for road capacity by the freight transport sector, passenger car use had a steep growth. The total increased demand for capacity was higher than the road infrastructure could handle. Belgian road demand increased by 26% over 20 years, by trucks alone, whereas the infrastructure only grew by 6% (FOD Mobiliteit, 2017; European Union, 2017).

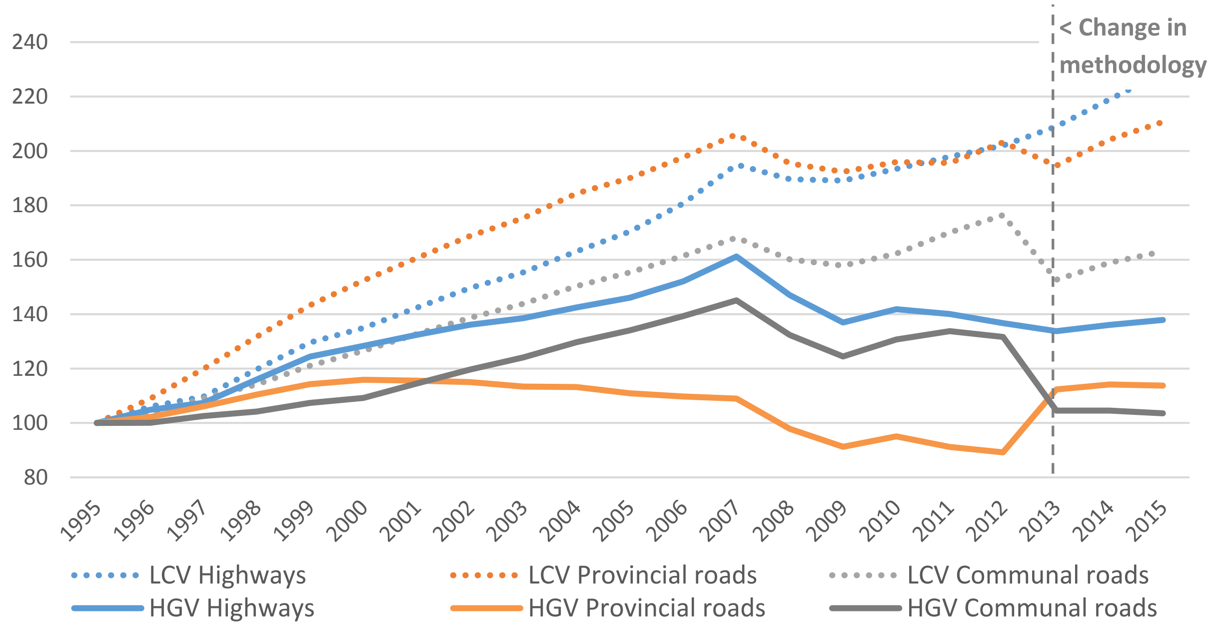
Figure 17: Indexed* growth road freight transport and infrastructure (EU28 & BE)



Source: Based on European Union, 2017
*1995 = 100

This increasing combined demand increase by freight vehicles and passenger cars hence will without doubt lead to increasing capacity concerns, i.e. increasing transport congestion. The next Figure 18 depicts data from FOD Mobiliteit (2017) showing the decoupling of LCV and HGV growth on Belgian roads. LCV transport on highways increased by 128% on 20 years, while HGV transport grew 37%. The trend after 2013 is based on another methodology, explaining the nod in the curve. But before 2013, the trends for LCV and HGV differ strongly.

Figure 18: Indexed* growth LCV and HGV freight transport on different road types (BE)



Source: Based on data FOD Mobiliteit, 2017
*1995 = 100

2.1.2. Transport and logistics' importance for the European economy

Given the growth of mobility and transport, the freight transport industry by now represents a considerable share of the general economy. The sector is not only responsible for the transport of goods, but also offers logistics services. SEALS (2009) estimated the value added of logistics in the EU to be 300 bn. EUR, representing 3% of the EU's GDP (2005 data). After this 2005 benchmark, it grew strongly. By 2015, according to the Statistical Pocketbook (European Union, 2017), the Gross Value Added of the European transport sector amounted to 651 bn. EUR (Table 13).

Table 13: Gross Value Added (GVA), of the provision of transport services (incl. storage, warehousing and other auxiliary activities) (GVA in bn. EUR)

	Gross Value Added	%GDP EU27
2006	400	4.2
2007	500	4.6
2008	520	4.6
2009	533	5.1
2010	540	4.9
2011	548	4.8
2012	562	4.9
2013	n.a.	n.a.
2014	633	5.1
2015	651	5%

Source: Consolidated data of Eurostat & European Union statistical Pocketbooks, 2013 - 2017

It is estimated that the transport share amounts to 4.5% of total GVA if postal and courier activities are not included. So the European Commission (2017) estimates the share of postal and courier activities at 0.5% of the Union's GDP. And these estimates only take account of the added value of companies whose main activities are the related to transport (and transport-related) services. Own account transport operations are not included (European Union, 2017).

Logistics is a separate industry, but heavily related to the transport sector. "*Logistics is the process of planning, implementing, and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods and related information from point of origin to point of consumption for the purpose of meeting customer requirements*" (Canadian Association of Logistics Management, 1998).

These services are often provided by the LSPs (logistics service providers) and transport companies; however, large manufacturers or retailers often take care of such activities themselves. According to Kille and Schwemmer (2013) the total European logistics market is consisting mainly of transportation (44%), warehousing (24%), capital costs (22%), order processing (6%) and administration work (4%).

While SEALS (2009) estimated the total employment in 2005 at 7 million people, by 2010, the transport and storage services industry together (including postal and courier activities) in the EU27 employed around 11.1 million persons. This represents 5% of the total workforce. Modal differences exist since around 52% of them currently work in land transport (road, rail and pipelines), 3% in water transport (sea and inland waterways), 4% in air transport and 25% in warehousing and supporting and transport activities (such as cargo handling, storage and warehousing) and the remaining 16% in postal and courier activities (European Union, 2017).

2.2. External costs of transport are elevated

The growth of mobility and transport, as discussed in the former section(s), results in increasing societal impacts, of which the problem of road congestion is the most visible. The problem is especially perceivable in the Western part of Europe, where road transport grew without an equally large increase in capacity of the road networks. Thus, the road transport sector, accounting for the largest growth numbers, is firstly facing a rise in costs (expressed first in time loss and second in higher operational costs of fuel and vehicle use) and secondly imposes a rising impact on society (which are expressed in external costs terms). The external costs of the European transport industry, i.e. the costs a transport user is causing, but for which he or she is not fully paying, are elevated. The non-Internalisation of external costs is even stated to be the fundamental cause of excessive growth in traffic and mobility (Blauwens, De Baere, Van de Voorde, 2016).

These external costs can be categorized in congestion, emissions, infrastructure wear & tear and accident costs. Next to these, noise, up- and downstream effects and climate change effects exist. Not all are encountered in every mode (see Table 14). Section 2.2.1 deals with external congestion costs. Then, emissions, energy use, noise and accidents are discussed.

Table 14: Relevant external cost categories per transport mode

	Car	Truck	Water	Cycling	Bus	Train	Tram	Metro
Wear &tear	X	X			X	X	X	X
Climate	X	X	X		X	X	X	X
Air pollution	X	X	X		X	X	X	X
Noise	X	X			X	X	X	X
Accidents	X	X		X	X	X	X	X
Congestion	X	X			X			
Up-downstream[57]	X	X	X		X	X	X	X

Source: Based on van den Bossche, Schroten et al (2012).

[57] Climate change and air pollution costs of energy consumption and GHG emissions of up-stream (extracting raw materials) and downstream processes (processing materials collected during the upstream into a finished product); i.e. the energy needed for the generation of energy (e.g. fuel pumps, excavation of coals, transport).

Ricardo-AEA (2014) presently published the newest estimates. Still, CE Delft, INFRAS and Fraunhofer ISI (2011) data will be used, when data that is more specific is of added value.

2.2.1. External congestion costs

Congestion on transport networks occurs when the network's capacity cannot handle the demand fully. As a result, transport users lose time in traffic. This time loss is expressed in external congestion costs, costs an additional transport user is imposing on the other users as he or she causes the network to congest. Congestion secondly surges a negative impact on the environment since it results in increased air and noise pollution as congestion generates "stop and go" movements. These also lead to higher fuel consumption. Congested urban traffic requires frequent short journeys which increases fuel consumption by 30% compared to free-flowing longer journeys (EEA, 2013). Volvo Truck corporation even states that HGVs fuel consumption increases more strongly if vehicles have to stop very often. With five stops on a distance of 10km; a vehicle's fuel consumption can increase up to 140% (BESTUFS, 2006a; BESTUFS, 2006b).

European transport network congestion is mainly found on the road transport network and is concentrated in a number of densely populated Western-European countries. According to Inrix, supplier of road traffic data, congestion levels of Belgium, The Netherlands and Germany are among the highest Europe-wide. Belgium, and its main cities are as well the worst performers where road congestion is concerned. While the average number or lost hours per user in 2015 was countrywide totalling to 44, the number of lost hours in the Brussels and Antwerp urban area are more elevated: respectively 74 and 70 lost hours; Belgian cities are not performing well. Inrix's annual reports (2012 - 2015) show that the top 20 of most congested cities includes with Brussels, Antwerp and Ghent no less than three Belgian cities. Congestion in metropolitan and city regions is a larger challenge than road congestion on national road networks.

CE Delft, INFRAS and Fraunhofer ISI (2011) investigated congestion costs across the 27 European Member States, shown in the table on the next page. It was found that, in total, yearly social road congestion costs range between 146,214 million and 243,192 million EUR (i.e. 1.1 to 1.8% of the EU's GDP). And 28.8% of the congestion costs are attributable to goods transport. Congestion costs on other transport networks are less important. The total deadweight loss caused by congestion-related market failures leads to figures from 23.6 to 39.2 bn. EUR (0.2% to 0.3% of the EU's GDP) (CE Delft, INFRAS and Fraunhofer ISI, 2011).

Table 15: Total social losses and delay costs from road congestion in Europe in Mil. EUR (2008) EU27

	Total costs Mil. EUR/year (2008)	
	Max.	**Min.**
Light Commercial Vehicle (LCV)	27.63	13.83
Heavy Duty Vehicles (HDV)	42.66	26.7
Total freight transport	**79.29**	**40.52**
Total freight and passengers transport	**243,194**	**146,214**

Source: CE Delft, INFRAS and Fraunhofer ISI, 2011 I Data is published in 2011, but only range to 2008 estimates.

Within freight transport's share, the large truck-trailers are responsible for the highest freight transport congestion costs. Recent estimates show that truck-trailers, per vkm, are having almost four times the external congestion costs of cars (Ricardo-AEA, 2014).

Striking is that a large difference is seen among metropolitan, urban and rural roads. External congestion costs for trucks for example range between 41.5 EURct per vkm on rural and 361.4 EURct per vkm on metropolitan roads. This vkm indicators do not take into account the loading capacity of these vehicles. Expressed in tkm, car use (in the Ricardo-AEA study (2014) equal for LCV) is much less efficient per tkm (Table 16). Then, trucks transport is the vehicle type which has the lowest external congestion cost.

Table 16: External congestion costs in EURct per vkm (2010) EU28

	Metropolitan		Urban		Rural	
	Main roads	**Other roads**	**Main roads**	**Other roads**	**Main roads**	**Other roads**
Car	168.5	190.2	58.0	166.3	21.8	50.1
Rigid trucks	320.2	361.4	110.3	316.0	41.5	95.2

Source: Based on Ricardo-AEA, 2014 I Data is published in 2014, but only range to 2010 estimates.

Urban congestion problem is a bigger challenge, which is reflected in the external congestion costs for transport in urban areas[58] shown in the next table. Traffic on roads in urban areas, reaching its maximum capacity utilisation, has much higher costs than traffic on roads in metropolitan areas or in rural areas. The car's external costs for urban roads are ranging between 75.8 and 230.5 EURct per vkm (for roads over capacity). On roads in metropolitan areas, the costs are estimated to be between 61.5 EURct and 242.6 EURct per vkm. On rural roads, these are only 30.8 to 139.2 EURct per 1,000 vkm (Ricardo-AEA, 2014).

The transport of freight in urban areas has increasing external congestion costs when larger vehicles are used on non-main urban roads. For HDVs on main roads in urban areas, external

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[58] Here, metropolitan: cities with population > 250,000 people; Urban: population > 10,000 people; All other areas are considered rural. (Ricardo-AEA, 2014)

congestion costs are higher with 144.1 EURct per vkm. Articulated trucks (in urban areas) have costs which range from 219.9 to 668.6 EURct per vkm (Ricardo-AEA, 2014).

Table 17: Metropolitan, urban and rural external congestion costs EU28 (2010)

	Region	Road type	Free flow (EURct/vkm)	Near capacity (EURct/vkm)	Over capacity[59] (EURct/vkm)
Car	Metropolitan	Motorway	0.0	26.8	61.5
		Main roads	0.9	141.3	181.3
		Other roads	2.5	159.5	242.6
	Urban	**Main roads**	**0.6**	**48.7**	**75.8**
		Other roads	**2.5**	**139.4**	**230.5**
	Rural	Motorway	0.0	13.4	30.8
		Main roads	0.4	18.3	60.7
		Other roads	0.2	42.0	139.2
HDV	Metropolitan	Motorway	0.0	50.9	116.9
		Main roads	1.8	268.5	344.4
		Other roads	4.7	303.0	460.9
	Urban	**Main roads**	**1.2**	**92.5**	**144.1**
		Other roads	**4.7**	**264.9**	**438.0**
	Rural	Motorway	0.0	25.4	58.4
		Main roads	0.8	34.8	115.3
		Other roads	0.4	79.8	264.5
Truck-trailers	Metropolitan	Motorway	0.0	77.6	178.4
		Main roads	2.7	409.8	525.6
		Other roads	7.2	462.5	703.5
	Urban	**Main roads**	**1.8**	**141.1**	**219.9**
		Other roads	**7.2**	**404.4**	**668.6**
	Rural	Motorway	0.0	38.8	89.2
		Main roads	1.2	53.1	176.0
		Other roads	0.6	121.9	403.8

Source: Ricardo-AEA, 2014 I Data is published in 2014, but only range to 2010 estimates.

In the Annexes on page 279, Table 70 shows Belgian estimates originating from Ricardo-AEA (2014). This table shows even substantially higher external costs for the Belgian case, also for urban road freight transport. For HDVs on main roads in urban areas, external congestion costs are 171.9 EURct as opposed to the average of 144.1 EURct per vkm for the EU28. Truck-trailers in urban areas have external costs ranging from 262.3 to 797.3 EURct per vkm instead of 219.9 to 668.6 EURct per vkm for the EU28 (Ricardo-AEA, 2014).

While Inrix (2014) states Belgium to be on top of the most congested countries in Europe, four Belgian cities i.e. Brussels, Antwerp, Ghent and Charleroi individually rank a lot higher on the index. The same conclusion can be drawn when observing the external congestion cost

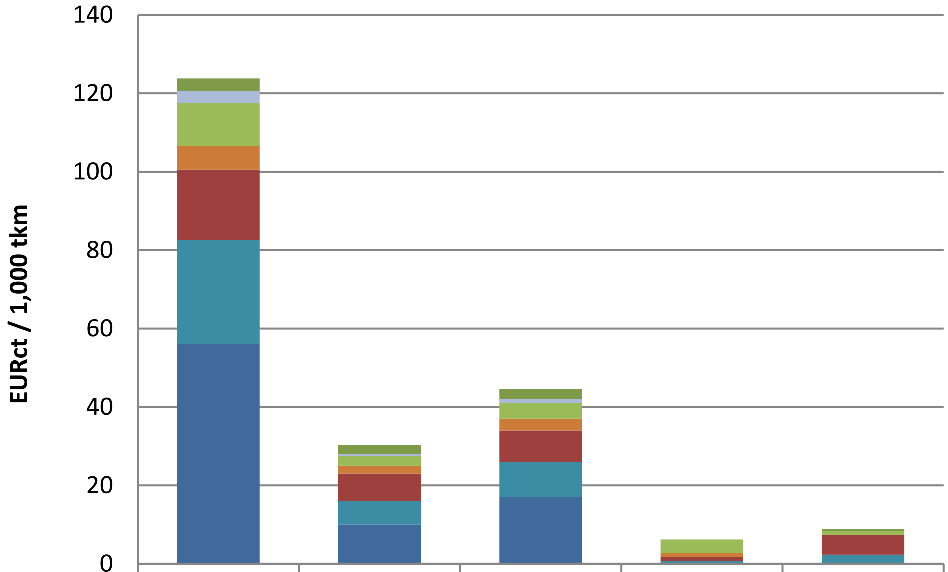
[59] Capacity utilisation is, in the used 'FORGE output model', defined as a ratio of demand vs. the supplied capacity of the infrastructure. Indicator value 1 is at capacity, over 1 is over capacity (Ricardo-AEA, 2014).

estimates of Ricardo-AEA (2014). The congestion costs in urban areas, certainly of traffic on non-main roads, are much higher than on roads in metropolitan and rural areas. Belgian estimates for external congestion costs are also deviating considerably from the EU average.

2.2.2. External emission-, climate change-, noise-, urban effects and accident costs

External The figure below offers an overview of the external costs additional to the external congestion costs. In this section, only emissions-, climate change, noise-, urban effects and accident costs are regarded. Besides these, nature, up- and downstream effects and infrastructure wear and tear exists. In this setting , these are less relevant.

Figure 19: Average external costs for EU27 (2008) EUR per 1.000 tkm



	LCV	HDV	Road total	Rail freight transport	Water-borne transport
Nature/ Biodiversity/ Soil and water	3,3	2,3	2,5	0	0,5
Urban effects	3	0,5	1	0	0
Up- and downstream average	11	2,5	4	3,5	1
Noise	6	2	3	1	0
Air polution	18	7	8	1	5
Climate change average	26,5	6	9	0,6	2,3
Accidents	56	10	17	0,1	0

Source: CE Delft, INFRAS and Fraunhofer ISI, 2011 I Data is published in 2011 but only range to 2008 estimates.
Note: External costs excluding congestion and infrastructure tear and wear

Differences between freight transport modes are prominent. Freight transport by road is accountable for a very large societal impact. LCV transport in particular is accounting for over 120 EURct per 1,000 tkm. HDVs are more efficient (per tkm) with an external cost of 30 EURct per tkm. Nevertheless, external costs of road freight transport are on average the five till sevenfold of external costs of transport by rail or over water (CE Delft, INFRAS and Fraunhofer ISI, 2011).

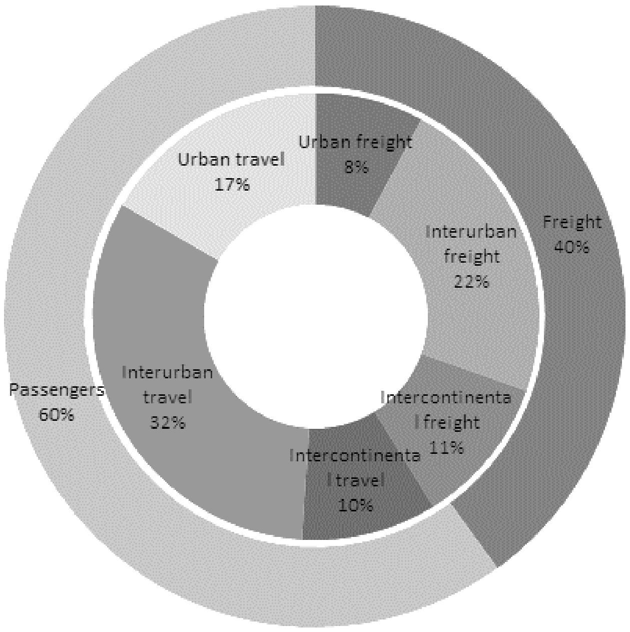
BESTUFS (2006) found that total urban freight transport accounts for only 14% of the vehicle kilometres while it is responsible for 19% of the energy use and 21% of the CO_2 emissions in urban areas. Transiting HGVs travelling through the area add another 4% of the vehicle kilometres, 12% of the energy use and 10% of the CO_2 emissions (BESTUFS, 2006a; BESTUFS, 2006b). Urban mobility accounts for 40% of all CO_2 emissions of road transport and up to 70% of other pollutants from transport (European Commission, 2015). The problem of transport emissions is greatly pertinent. The 2017 Air quality in Europe report (EEA, 2017) states that in 2015, 19 % of the EU28 urban population was exposed to PM_{10} levels above the daily limit value. And approximately 53% was exposed to concentrations exceeding the stricter WHO Air quality guidelines (AQG) value for PM_{10}. Regarding $PM_{2.5}$, 7 % was exposed to levels above the EU limits, and approximately 82% was exposed exceeding AQG values (EEA, 2017). Public health is influenced negatively, 70% of cancerous substances find their origin in traffic emissions (Silva and Ribero, 2009). In view of a statement of IARC[61], the specialised cancer agency of the WHO, which officially classified outdoor air pollution as carcinogenic to humans, this pollution problem needs political attention (IARC, 2013), and action!

But to what extent is urban (freight) transport contributing to this pollution problem? The formerly discussed congestion cost differences between urban areas and other areas are as well reflected in the share of urban freight transport in the total transport emissions. Urban areas are, because of their density and as well because of increasing congestion, representing a large share of 23% of all transport emissions.

The environmental impacts of urban logistics operations can be high, contributing to air and noise pollution and greenhouse gas emissions. indicates that about a quarter of transport's share in urban areas is related to urban freight, while urban transport of freight only represents a small share in the total transport sector. In general, urban freight is approximately accountable of 6% of all transport emissions (European Commission, 2013).

[61] International Agency for Research on Cancer

Figure 20: Share in European transport emissions freight vs. passenger



Source: Based on EU Urban Mobility Package 2013: COMMISSION STAFF WORKING DOCUMENT, A call to action on urban logistics, Brussels, 17.12.2013 SWD(2013) 524 final

In the following tables, external emission costs for freight transport in differently populated areas are shown. shows the external emission costs for HDVs on urban, suburban and interurban roads and on motorways. First, it is clear that emission costs drop over generations of vehicles. The Euro 0 [62] category of HDVs are polluting much more than the most recent Euro VI vehicles. Secondly, it is clear that urban trajectories account for a larger external cost value. The urban emission factors are almost double of interurban trajectories (Ricardo-AEA, 2014).

Table 18: Marginal external air pollution costs HDV EU28 (2010) in EURct/vkm

	Category	EURO-Class	Urban *(EURct/vkm)*	Suburban *(EURct/vkm)*	Interurban *(EURct/vkm)*	Motorway *(EURct/vkm)*
HDV	<=7,5 t	Euro I	8.5	4.8	3.8	4.1
		Euro II	6.9	4.6	3.8	4.1
		Euro II	**6.1**	**3.7**	**2.9**	**3.1**
		Euro IV	3.8	2.5	2.1	2.1
		Euro V	3.7	2.3	1.2	0.8
		Euro VI	1.7	0.6	0.3	0.2
	7,5 - 12 t	Euro I	13.0	7.6	5.7	5.6
		Euro II	10.5	7.2	5.8	5.7
		Euro II	**9.1**	**5.9**	**4.5**	**4.3**
		Euro IV	5.4	3.9	3.2	3.0
		Euro V	5.2	3.6	1.8	1.2
		Euro VI	1.8	0.7	0.3	0.3

[62] European emission standards define the acceptable limits for exhaust emissions of new vehicles sold in Member States. The standards are defined in a series of regulations (Directive 2007/46/EC and Commission Regulation (EU) No 214/2014 for example).

	>32 t	Euro I	29.8	18.1	12.5	10.5
		Euro II	23.7	17.0	12.5	10.6
		Euro II	**19.9**	**13.9**	**10.1**	**8.4**
		Euro IV	10.9	8.7	6.8	5.8
		Euro V	8.5	6.3	3.4	2.3
		Euro VI	2.1	0.9	0.5	0.4

Source: Ricardo-AEA, 2014 I Data is published in 2014, but only range to 2010 estimates.
Note: Here Urban = population density of 1,500 inhabitants per km^2 , Suburban = population density of 300 inhabitants per km^2 , Interurban population = density below 150 inhabitants per km^2

The external emission costs per vkm of LCV transport are lower than those of HDVs. Values shown in are retrieved from the recent study of Ricardo-AEA (2014), estimating air pollution costs for LCVs. For a Euro 3 diesel LCV, external emission costs in urban areas are 4.6 EURct per vkm, while these of LCVs in interurban areas are only representing a value of 1.1 EURct per vehicle kilometre (Ricardo-AEA, 2014).

Table 19: Marginal external air pollution costs LCV EU28 (2010) in EURct/vkm

	EURO-Class	Urban *(EURct/vkm)*	Suburban *(EURct/vkm)*	Interurban *(EURct/vkm)*	Motorway *(EURct/vkm)*
LCV diesel	Euro 1	5.3	2.4	1.4	1.3
	Euro 2	5.9	2.5	1.4	1.3
	Euro 3	**4.6**	**2.0**	**1.1**	**1.1**
	Euro 4	3.2	1.5	0.9	0.8
	Euro 5	1.4	0.8	0.6	0.6
	Euro 6	1.1	0.5	0.3	0.3

Source: Ricardo-AEA, 2014. I Data is published in 2014, but only range to 2010 estimates.

Nonetheless, when taking into account the loading capacity of the vehicles, much higher emission costs per tkm are found for LCVs; especially when compared with HDVs. Estimates for the Euro 3 type below 7.5t for HDVs range between 0.6 and 1.6 EURct/tkm, and for LCVs, they are at 1.6 EURct/tkm.

Combining this difference with the fact that urban freight transport is increasingly executed by smaller vehicles like cars and LCVs, the external cost problem increases. BESTUFS (2006) estimated the cars and LCV share in urban freight transport to range between 56 and 58%, while truck-trailers only account for 4 to 13% of urban freight transport vehicles. No European data exist, but in 2006, the annual vkms of LCVs in London was estimated to be 2,226 million vkm, compared to the 887 million vkm by HGVs[63] (BESTUFS, 2006). There is a clear LCV overweight. More detailed tables in the Annexes on page 280 show the difference when costs are expressed in tkm. Then, these of LCV transport increase to 1.6 EURct per tkm for Euro 3 vehicles, while these of 7.5 - 12 t vehicles decrease to 0.9 EURct per tkm (in urban areas).

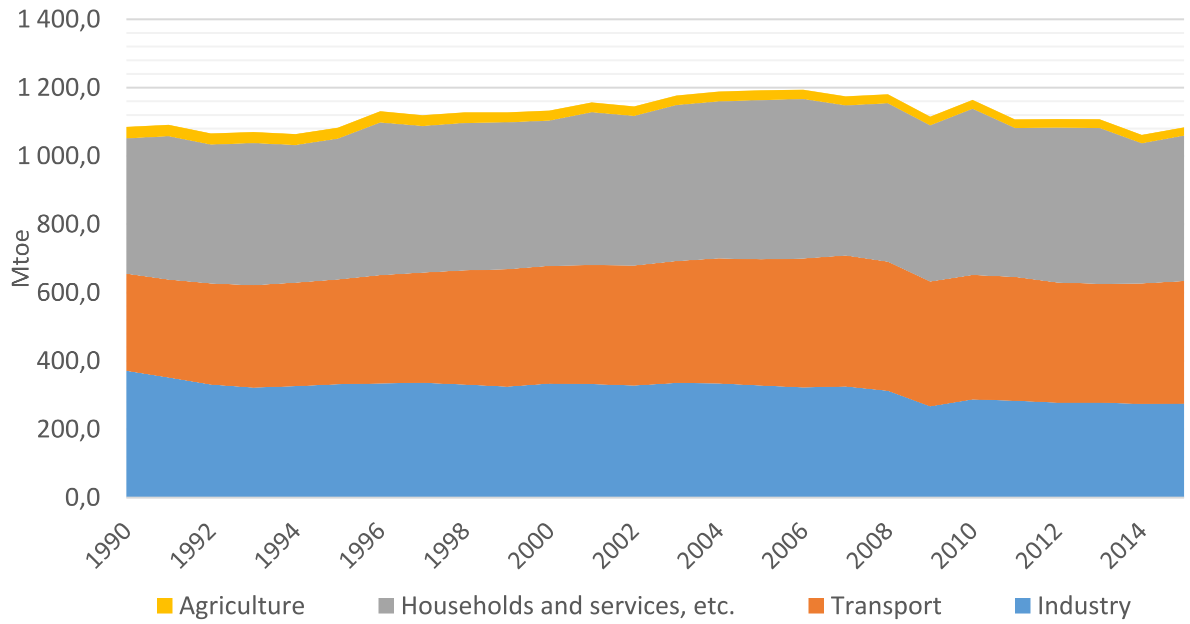
[63] This data was collected by surveying vehicle operators about all the trips they made in the UK (including London trips) for several days, but is still an estimation (BESTFACT, 2006).

The first conclusion is that emission levels in urban areas are higher as traffic is more concentrated and congested. These emissions influence more people negatively as urban areas are more densely populated. This is clearly shown in the external cost values of emissions. Secondly, external emission factors for freight differ quite significantly between type of vehicles and Euro norms of these vehicles. The LCV is in general less efficient per tkm and has higher external emission values than HDVs, certainly compared to the >32t types.

2.2.3. Energy use

As road congestion rose, also emissions of road transport activities rose. In total, the European energy consuming sectors is clustered in four categories. The category 'households and services', using 425.9 Mtoe (tons of oil equivalent[64]), represent a share of 39%. Secondly, the transport industry is using 358.6 Mtoe, a share of 33%. The majority within this sector is being used for road transport activities. Industrial production is the third-most consuming sector with 274.4 Mtoe in 2015 (European Union, 2017).

Figure 21: EU28 Energy consumption per sector (1990 – 2015)



Source: European Union, 2017

2.2.4. Emissions

This high energy demand is reflected in the emission levels of transport (on the next page). The total GHG emissions from transport in the EU27 evolved rapidly. Between 1990 and 2000, a 21% increase was seen. This growth moved up more strongly from 2000 on. By 2007, the

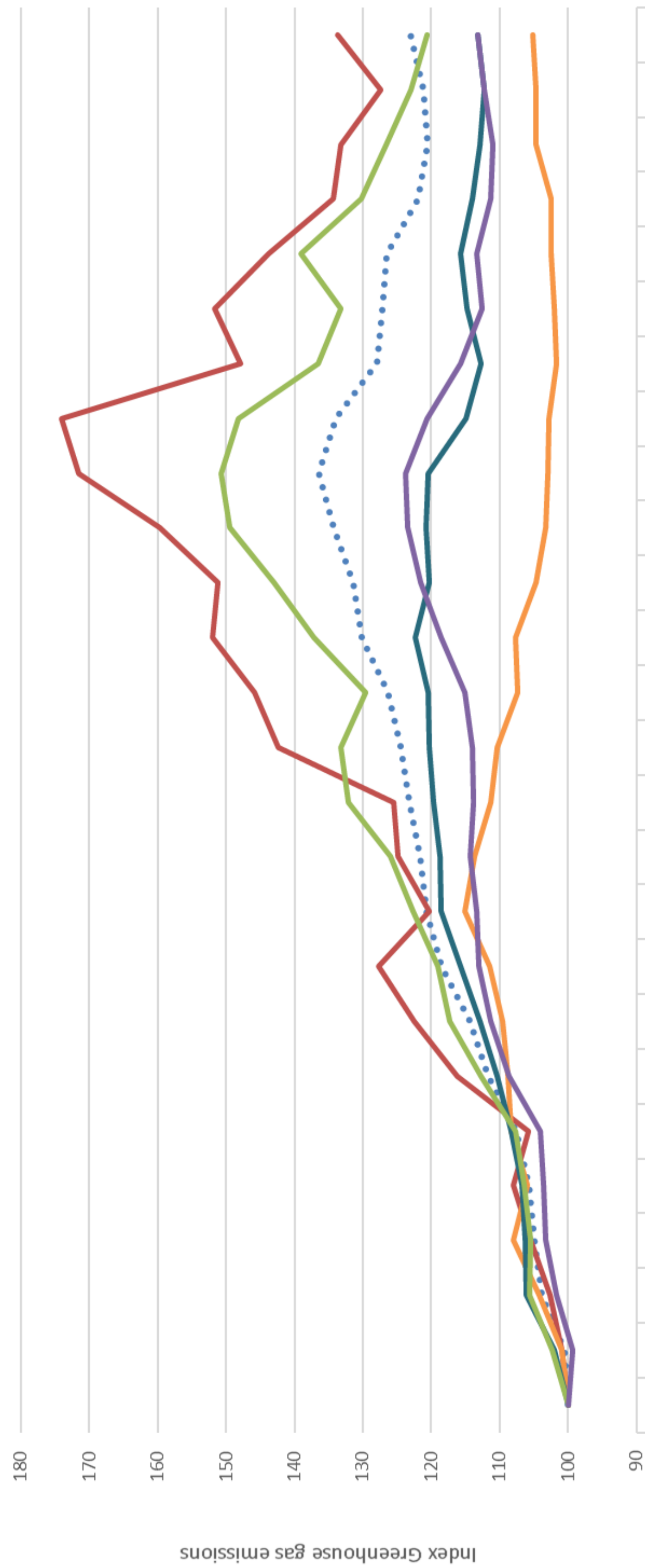
[64] Tonne of oil equivalent is a conventional standardised unit for measuring energy, defined on the basis of a tonne of oil with a net calorific value of 41 868 kilojoules/kg. 1 ktoe = 1 000 toe; 1 Mtoe = 1,000,000 toe

sector emitted 36% more compared to the 1990 levels. From then on, a decrease is seen. Still, in 2010, emissions from transport were 27% higher compared to the 1990 levels. The Member State data show different emission trends. According to those data, the emission levels in Belgium and The Netherlands rose faster than the EU average; an increase is seen of 34% and 35% respectively. The levels in Germany and France rose less sharply. Levels in Germany even stabilized to a 2% increase over 20 years (European Union, 2013).

In total, emissions from transport in the EU28 consolidated in 2015 to 1,182 Mil. tonnes of CO_2 equivalent while Belgian transport activities emitted 48,7 Mil. tonnes CO_2 equivalent. This is a steep drop after peak of 63.5 Mil. tonnes CO_2 equivalent in 2007. Belgium and The Netherlands increased emissions, stronger than the EU28 did. The emissions in Germany France and the UK rose less than 10% in 15 years time.

The largest emitting country in absolute numbers is Germany though (192.4 Mil. tonnes of CO_2 equivalent), followed by the UK (158.7 Mil. tonnes of CO_2 equivalent), France (155.7 Mil. tonnes of CO_2 equivalent) and Italy (121.4 Mil. tonnes of CO_2 equivalent) (European Union, 2017).

Figure 22: Growth in freight transport emissions 1990-2015 (index)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
EU-28	100	101	104	105	106	108	112	114	119	121	122	123	125	126	130	131	134	136	134	128	127	127	122	121	121	123
BE	100	101	103	106	108	106	116	122	128	120	125	126	142	146	152	151	160	172	174	148	152	144	134	133	127	134
DE	100	101	104	108	106	108	109	110	111	115	114	111	110	107	108	105	103	103	103	102	102	103	102	105	105	105
FR	100	102	106	106	107	108	110	113	116	118	119	120	120	120	122	120	121	120	115	113	115	116	114	113	112	113
NL	100	102	106	105	106	108	113	117	119	123	126	132	133	130	137	143	150	151	148	136	133	139	130	127	123	121
UK	100	99	102	103	104	104	109	111	113	113	114	114	114	115	119	122	123	124	121	116	113	113	111	111	112	113

Source: Based on European Union, 2017

Note: Emission index 1990 = 100; based on values in tonnes CO_2 equivalent

2.2.5. Climate change

In 2007, about 19.5% of total greenhouse gas (GHG) emissions in Europe were emitted by transport (CE Delft, INFRAS and Fraunhofer ISI, 2011). This increased to 26.6% in 2015 (European Commission, 2017). This is also expressed in the external costs of transport. These external cost differ very much per vehicle type (as depicted in Table 20). LCV transport has the highest external - climate change - cost, and freight transport's external costs are in general much higher than those of rail and water transport.

Table 20: Average external freight transport climate change costs EU27 (2008) in EUR per 1,000 tkm

	LCV	HDV	Total road freight transport	Rail freight transport	Water freight transport	Average freight transport
High scenario	44.5	9.8	**14.9**	0.9	3.6	**2.1**
Low scenario	7.6	1.7	**2.6**	0.2	0.6	**2.1**

Source: CE Delft, INFRAS and Fraunhofer ISI, 2011 I Data is published in 2011, but only range to 2008 estimates.
Note: Data include the EU27 with the exemption of Malta and Cyprus, but including Norway and Switzerland.

With the very high uncertainties in climate costs, it would be misleading to give a single cost estimate. Therefore, CE Delft, INFRAS and Fraunhofer ISI (2011) presented two scenarios. The lower one was estimated on the avoidance cost estimates for meeting the 2020 EU GHG target (estimated to be at least 25EUR per ton of CO_2). The higher climate cost estimate is based on the cost for meeting the long-term targets in order to keep global temperature rise below two degrees C° (i.e. 146 EUR per ton of CO_2) (CE Delft, INFRAS and Fraunhofer ISI, 2011).

2.2.6. Noise

With regard to external noise cost, also LCV transport scores the highest value (Table 21). The values for rail and water transport are fairly low (CE Delft, INFRAS and Fraunhofer ISI, 2011).

Table 21: Average external freight transport noise costs EU27 (2008) EUR/ 1,000 tkm

Road freight transport			Rail freight transport	Water freight transport	Average freight transport
LCV	HDV	Total road freight transport			
6.2	1.8	**2.5**	1.0	0.0	**2.1**

Source: CE Delft, INFRAS and Fraunhofer ISI, 2011 I Data is published in 2011, but only range to 2008 estimates.
Note: Data include the EU27 with the exemption of Malta and Cyprus, but including Norway and Switzerland

2.2.7. Accident costs

The number of yearly fatalities in the European transport sector is problematic. Road transport activities are almost exclusively accountable for this large number. In Europe, road fatalities are high, even though a major decrease was realised in the last decade. The number of fatalities in the EU28 Member States attributable to road transport was in 2010 totalling to 31,506 persons, and then decreased to 26,134 by 2015. In 2010, 840 left their life on Belgian roads, which also decreased to 732 by 2015 (European Union, 2017). The number of fatalities in other modes is significantly lower. Rail transport in the EU28 resulted in 27 fatalities in 2015. A drop, compared to the last decade's average where the number of fatalities was 57. Air transport fatalities are even lower. In 2016, 6 persons left their life in a EU28 accident. The average number of fatalities in the air sector in the last decade was 30 (European Union, 2017).

This difference per mode is as well expressed in the external accidents cost values. Table 22 illustrates the total external accident costs of freight transport. These are high (summing up to 38,352 million EUR per year) and are linked in essence to road transport alone.

Table 22: Total external freight transport accident costs EU27 (2008) in Mil. EUR/year

LCV	HDV	Rail freight transport	Water freight transport	Total freight transport	Of which road freight transport related
18,677	19,604	71	0	**38,352**	**38,282**

Source: CE Delft, INFRAS and Fraunhofer ISI, 2011

Note: Data include the EU27 with the exemption of Malta and Cyprus, but including Norway and Switzerland.

This is also reflected in the average external accident values expressed in EUR per 1,000 tkm (Table 23). On average, the external accident cost sums to 13.4 EUR per 1,000 tkm. The value of LCV transport is particularly high. LCVs are having a parameter value fivefold the value of HDVs and fourfold the average for freight transport activities.

Table 23: Average external freight transport accident costs EU27 (2008) in EUR per 1,000 tkm

LCV	HDV	Total road freight transport	Rail freight transport	Water freight transport	Average freight transport
56.2	10.2	17	0.2	0	**13.4**

Source: CE Delft, INFRAS and Fraunhofer ISI, 2011

Note: Data include the EU-27 with the exemption of Malta and Cyprus, but including Norway and Switzerland.

Next to emissions and congestion problems, road safety in urban areas is under pressure. The number of transport fatalities in the EU remains high. Road freight transport is responsible for 99.87% of all 2015 transport related fatalities. Freight transport can be a key contributor to road injuries, with HGVs responsible for over 42 % of cyclist deaths in London (Keigan, Cuerden and Wheeler, 2009) and 23% of Belgian deadly cycling accidents (between 2003 and 2007) involved an HGV (BIVV, 2007). Of the 756 bn. EUR external accident costs, road transport's share is 30%. Of the total, freight transport is likely responsible for 14% (Ricardo-AEA, 2014).

More in particular, the urban areas account for 38% of all road fatalities. Table 24 shows the most recent data (2014) by the European safety road observatory, who counted a staggering 9,923 fatalities in urban areas. Vulnerable users like cyclists and pedestrians are particularly exposed. In the decade before, the number or urban transport fatalities reduced by 39%, while the total transport fatalities reduced by 42%. The EU aims, according to the 2011 White Paper on transport, to halve the number of fatalities by 2020 and reduce it to zero by 2050, ensuring that it is a world leader in transport safety (EC, 2011a). The current data show that the EU is far from reaching this target.

Table 24: Number of urban road transport fatalities per year 2001 – 2014

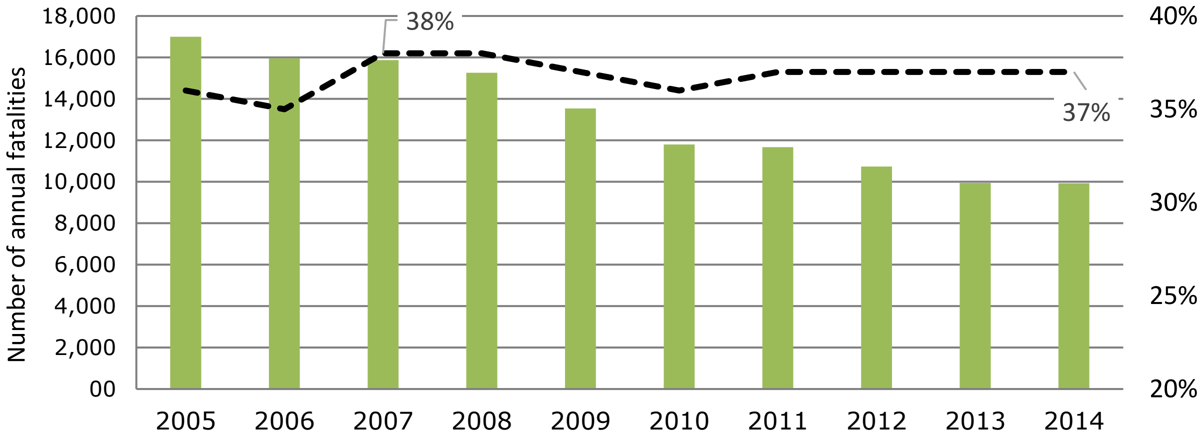
	2001	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Trend
EU	n.a.	16,997	15,964	15,867	15,263	13,535	11,802	11,667	10,733	9,939	9,923	▼
BE	453	255	265	275	274	257	246	281	213	179	188	▼
DE	1,726	1,471	1,384	1,335	1,261	1,225	1,011	1,115	1,062	977	983	▼
FR	2,277	1,664	1,346	1,359	1,235	1,252	1,133	1,096	1,027	932	993	▼
NL	335	254	283	270	243	277	199	233	208	201	158	▼
UK	1,448	1,302	1,326	1,178	1,087	1,000	597	648	632	553	631	▼

Source: European road safety observatory, 2016

Note: Retrieved from CARE data base; based on data available in May 2016

Most EU member states achieved a decrease in fatalities. The EU average decreased too. Still, the pace of making urban roads more safe does not follow the total road transport network's trend. In percentages of the total transport fatalities (Figure below), the share of urban areas stays high, exceeding 35% of total fatalities for a consecutive number of years.

Figure 23: Share of urban road fatalities in total transport fatalities (EU)



Source: European road safety observatory, 2016 (more recent than 2014 not available)
Total = x '000 on left axis, share = in% on right axis

This trend is of course also reflected in the external accident costs. Recent estimates by Ricardo-AEA (2014) for external accident costs for the EU28 and Member States show differing values for motorways, non-urban roads and urban roads (see Table 25).

In the case of Belgium, cars and HGVs on urban roads have respectively 0.4 and 0.9 EURct per vkm external accident costs. For the EU average, urban accident costs of cars are three times higher in urban areas compared to (non-urban) highways.

For the calculations, the information on the number of fatalities and the number of injuries from the European CARE database (years 2005-2010) will be used (Ricardo-AEA, 2014).

Table 25: External accident cost estimates in EURct/vkm (2010)

	Car			HGV		
	Motorway	**Other non-urban**	**Urban road**	**Motorway**	**Other non-urban**	**Urban road**
EU28	0.1	0.2	0.3	1.2	0.8	1.1
BE	0.3	0.3	0.4	3.0	1.5	0.9
DE	0.2	0.4	0.6	2.4	1.3	1.5
FR	0.1	0.2	0.2	0.4	0.5	0.7
NL	0.0	0.1	0.1	0.3	2.3	1.2
UK	0.1	0.1	0.2	0.9	0.5	0.3

Source: Ricardo-AEA, 2014

2.3. Urban liveability is regarded by citizens as being under pressure

The former section leads to the conclusion that the impact of urban mobility and urban freight transport in particular on the urban area is elevated. Aside the urban congestion, local air quality and greenhouse gas emissions and a pertinent road safety problem, several other (negative) impacts are noticeable. Noise in urban areas is a challenge, next to wear and tear of the public domain (by for example HGVs). Cities and urban areas can curb mobility, but cannot restrict access too much as passenger and freight transport are required given the areas are concentrating economic activities (offices, super markets, measure activities, tourism etc.).

Transport brings value to the economy. The value added and the employment generated by the transport sector is important. More than 5% of the EU population works in this sector. This is no surprise. All economic activities also those in urban areas need supplies, need to transport their products to clients and need to get rid of their waste. As such, economic activities need freight transport to subsist: transport is a derived demand (Maes, Sys, 2012).

The challenges are quantifiable to a certain extent. The pressure of goods transport on the wellbeing and quality of life of urban residents increased. This leads increasingly to stakeholders identifying these challenges and proposing solutions on how to turn the situation around. Cities are confronted by groups of inhabitants stepping up against the local mobility policies. These people are identifying their problem often in a narrow way by means of slogans like 'The liveability is under pressure!', 'I fear the safety of our children!'', 'Freight vehicles should be restricted to access the city', 'Large trucks should be forbidden', or 'Our quarter is no longer liveable with this increased traffic!'. The statements have often-subjective elements, even though they express a feeling, the challenges are also observed in the quantifiable data.

Nevertheless, how can liveability of urban areas then objectively be defined? Should only the external costs be regarded, and what is the influence of non-transport activities on liveability of urban cores? Up till now, only quantifiable arguments stating the challenges were discussed. As well the attitude and feelings of the general public towards urban mobility challenges are important to take account of. A recent special Eurobarometer survey[73] concluded for example that a strong majority of EU citizens consider congestion, and the impact of urban mobility on health and the environment as an important problem. Moreover, many respondents were rather pessimistic regarding expected improvements in their city's traffic situation (TNS Opinion & Social, 2013). Indeed, citizens in developed economies understand mobility as a right, especially in large cities where congestion and pollution make private transportation more inconvenient and expensive (Albalate and Bel, 2009).

Based on a general review of Kramers Woordenboeken (1984), Van de Wardt and de Jong (1997), van Dorst (2002) van Dorst (2005), Schofer (2010) and Van Dale (2012), Maes & Sys (2012) concluded on the definition of urban liveability as: *"Urban liveability is a diffuse estimation of a variety of parameters by stakeholders on the urban environment, together forming and index. This index is a snapshot estimation at a given moment in time, partly objective but largely subjective. The underlying parameters of the index are related to economic, social, ecological and institutional factors"*

Therefore, the next section aims at giving insight into the quantifiable and qualitative aspects of urban liveability vis-a-vis urban freight transport.

2.3.1. Measuring and benchmarking urban liveability

Urban liveability, urban sustainability and urban attractiveness all express a judgment on the quality of life of living in an urban area, working in the area, commuting towards the region etc. The judgment is qualitative and subjective in nature.

Meers, Buldeo Rai et al (2015) indicated that urban indicators are not a new field of research. The same authors refer to Parris and Kates (2003) at the time already identifying an 'indicator industry'. Meers et al (2015) propose to map the judgment on liveability, attractiveness of sustainability via composite indictors, which then group data on a variety of aspects. These

[73] Eurobarometer survey number 406

composite indicators then form various indices, shifting with the focus of the weighing of the underlying indicators. Meers et al (2015) started developing an index for measuring urban freight transport sustainability. The authors regard four aspects, or four indicator clusters. These are profit, people, planet and policy. This approach is aligned with the earlier defined definition by Maes and Sys (2012), where it was judged to define the liveability index on four aspects. Profit aspects are measured by modal split, efficient use of vehicles, congestion, bottlenecks etc. Planet is measured for example by energy consumption and emissions. People aspects are measured by e.g. safety, accidents, security, employment and noise. Policy aspects are proposed to be measured by financial resources, public participation and the presence of sustainable businesses.

The indices are then often used to benchmark performance. Huggins (2010) defined three types of benchmarking needs. The first one is performance benchmarking, when a set of prescribed indicators are used to benchmark characteristics of a region. The second type is process benchmarking, when structures and systems constituting practices and function of regions are compared. The third use is policy benchmarking, then types of policy that influence the area's practices and characteristics are compared with each other. This implies the need to measure at least twice the performance, preferably even several times to define time series. Especially the last use is relevant for this dissertation.

2.3.2. Measuring city sustainability

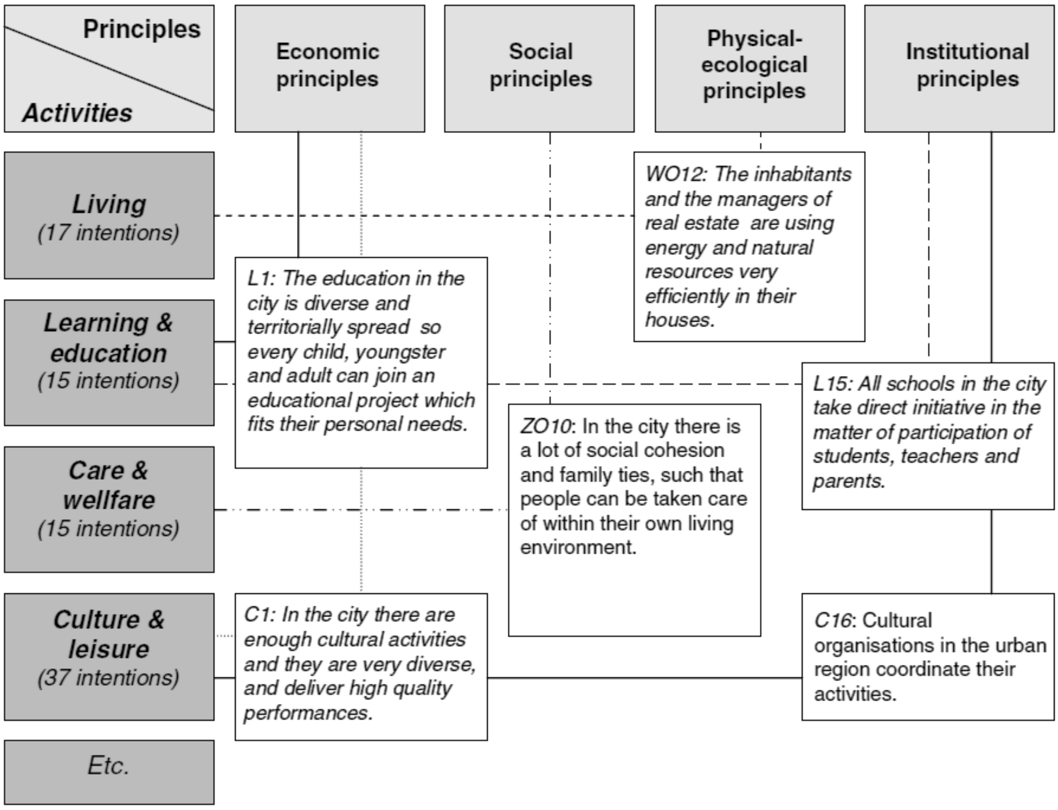
This section highlights the main aspects of various existing liveability indicators or indices. The section concludes with wrapping up main lessons learned from this analysis.

Van Assche, Block and Reynaert (2010) defined an index for liveability as a sub-index of a larger index for measuring *sustainability*. The index maps different indicators. The long term effect of a certain policy or measure, implemented in an urban environment or in general, can be evaluated in the long run (sustainability) and the short run (liveability). This parallel was also seen in Evans (2002), who identified liveability as having a two faces: livelihood and sustainability.

The quantified aspects of urban mobility and freight transport in particular are according to Van Assche et al (2010) only one source of information for estimating an area's liveability. This is also sketched in their liveability matrix, shown in Figure 16. The matrix consists of several parameters, needed for analysing a weighted index of liveability.

The index is not transport-oriented. Urban road freight activities are then taken account of in the different activity layers, on the left hand side of Figure 24. These are then evaluated on economic, social, physical-ecological and institutional principles.

Figure 24: Matrix of parameters influencing liveability



Source: Van Assche et al, 2010

Van Assche's et al (2010) index's relevance for measuring transport effects in urban liveability is that it takes account of economic, social, physical, ecological and institutional aspects. However, urban freight transport is not regarded separately and clear defined indicators for transport lack.

2.3.3. Measuring quality of life in metropolitan areas

A similar measuring approach is seen in the methodology for determining 'Quality of life in metropolitan areas' of Sufian (1993).

This quality-of-life ranking was made on the basis of 10 criteria: public safety (murders per 100,000 people), food cost (% of income spent on food), living space (persons per room), housing standard (% of homes with water/electricity), communication (telephones/100 persons), education (% of children in secondary school), public health (infant deaths per 1,000 live births), peace and quiet (levels of ambient noise), traffic flow (miles per hour in rush hour), and clean air (alternate pollution measures). Each of the 10 indicators was assigned 10 points, and an index of urban liveability on a 100-point scale was developed. A city with a low murder rate, low food cost, more living space, etc. scored high on the index- close to 100[74]. So, Sufian

[74] The scores of the cities ranged from a high of 86 (Montreal, Canada; Melbourne, Australia; and Seattle, US), to a low of 19 (Lagos, Nigeria). The cities were then divided into four groups according to their index values: very

(1993) also touched on the aspects described above: traffic flow and clean air. Nevertheless alike Van Assche et al (2010), the scope of measuring liveability is also much broader than on mobility aspects only.

These evaluation matrices, like the one of Van Assche et al (2010) and Sufian (1993), are used in several rankings of 'most liveable' cities in the world. The rank is then often used for promotional and touristic initiatives of the well-ranked cities. Nevertheless, these more and more become a policy evaluation measure. Does a certain city outperform on liveability criteria? And which criteria should be tackled by the local administration?

The most known indices of liveability are the *Mercer Quality of Living Survey* and the *Economist's World's Most Liveable Cities*. In the latter, Brussels is the only Belgian city featuring in the lists. Ranked first in 2017, and for a consecutive number of years, is Vienna. Zurich is ranked second, also since years. Brussels is not ranked in the Top-20, and appears only on place 27 (Mercer, 2017).

Mercer's index is based on the following categories: consumer goods, economic environment, housing, medical and health consideration, natural environment, political and social environment, public services and transport, recreation, schools and education and last the socio-cultural environment. The Mercer ranking consists of different sub-parameters. In the 2010 *Eco-City ranking*, measuring among others the access to and quality of water, waste collection, sewage, air pollution and congestion on the road, Brussels scored even lower with a 41st rank (Mercer, 2017).

These 'most liveable' indices take account of economic parameters (goods, economic environment, housing), social parameters (medical, health, social and socio-cultural environment), environmental aspects (natural environment) and the institutional aspects (political environment and public services) alike the index of Van Assche et al (2010). Also transport, recreation, schools and education are added specifically, while urban freight transport is not regarded.

2.3.4. DG REGIO's urban liveability index

Also the EU, by means of DG Regional Policy, scores urban liveability (Eurostat, 2014). In total, 258 large and medium-sized cities are compared in the EU Urban Audit on 300 underlying parameters (these are high level with for example mobility, unemployment, emissions and population growth). Data collection currently takes place every three years, with an annual data collection for a smaller number of targeted variables. For Belgium, Antwerp, Brussels, Bruges, Charleroi, Ghent, Liege and Namur are evaluated. The evaluation is not meant to rank

good (75 and above, 21 cities); good (60-74, 23 cities); fair (44-59, 26 cities); and poor (43 and below, 28 cities) Sufian (1993).

cities like the Mercer Quality of Living Survey and the Economist's World's Most Liveable Cities: the database is more regarded as a policy tool.

This study resulted in the 'Flash Eurobarometer 419', for which 79 European cities were surveyed at the request of the Directorate-General for Regional and Urban Policy. The survey was carried out by the TNS Political & Social network. Some 40,798 respondents from different social and demographic groups were interviewed via telephone (DG Regio, 2016). Main conclusions:

- At least 80% of the respondents say that they are satisfied to live in their city. Compared with the 2012 survey, the level of satisfaction is stable.
- People feel safe, and appreciate the availability of retail shops and public spaces. The cities allow to find jobs, schools and healthcare.
- Air quality is the aspect on which views diverge the most. In 61 cities, a majority of respondents are satisfied with air quality, and at least 50% are dissatisfied in 20 cities. There are nine EU capitals among the 20 least satisfied cities.
- More than half of respondents are dissatisfied on the noise level in 17 cities. There are 10 EU capitals among the 20 least satisfied cities.

Even though the perception of the increasingly negative influence of road (freight) transport on liveability in apparent, it is not only mobility and transport which should be considered when measuring a certain city's liveability. The estimation should according to literature and best practices of liveability indicators be measured on economic, social, ecological and institutional factors. To conclude: DG Regional Policy's index on liveability tackles a wide variety of parameters from an economic, social, environmental and institutional nature. Mobility is a separate indicator, and urban freight transport is not regarded separately.

This lesson will be taken into account further in this dissertation. The next section designs a new Urban Liveability Index dedicated at measuring urban freight transport's impact.

2.3.5. The UN City Prosperity Index

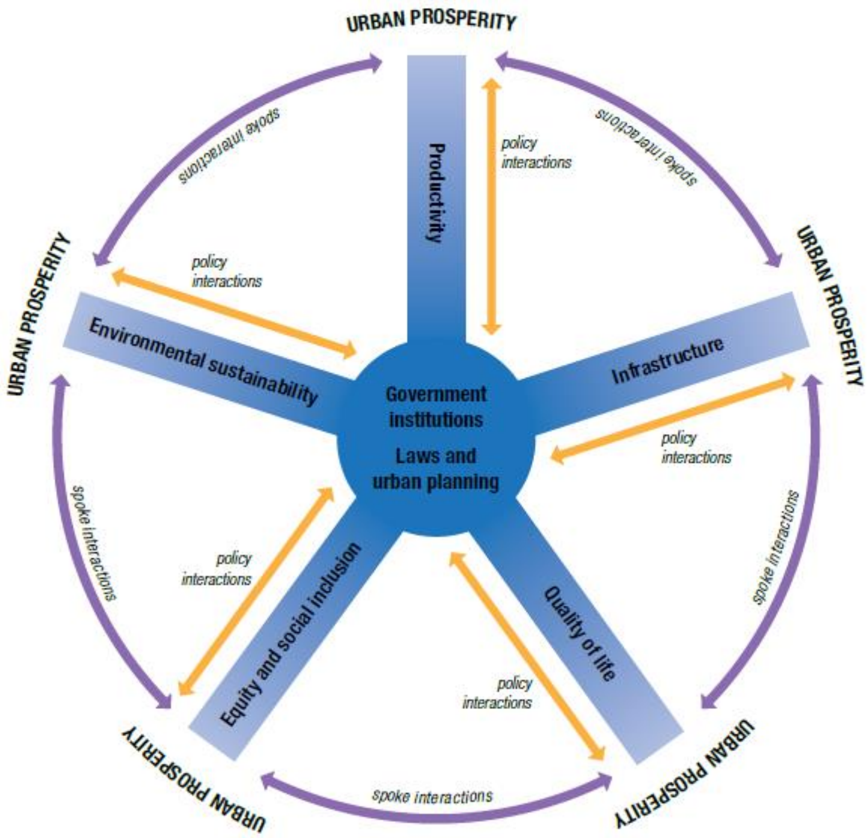
The UN-Habitat[75] also developed in 2012 an urban liveability index. In its 'City Prosperity Index', around 67 cities are compared. The index is targeted to mayors, non-government organizations and the civil society in general. The index is consisting of a benchmark process. The index defines 'prosperity' as "*well-balanced, harmonious development in an environment of fairness and justice*" (UN-Habitat, 2012).

[75] The United Nations Human Settlements Programme (UN–Habitat), established in 1978, is the United Nations' agency for human settlements and sustainable urban development. It promotes socially and environmentally sustainable towns and cities with the goal of providing adequate shelter for all.

The index allows cities to achieve a shift away from the "current dominant perspective, which is outdated and unsustainable on many grounds with its combination of cheap fossil fuel, heavy dependence on the motor car, highly segmented urban forms, socially and economically segregated spaces, endless urban peripheries that consume land, resources and in many cases natural protected areas – and all largely steered by private, not public interest".

Prosperity, as defined by UN-Habitat, is a broader, wide-ranging social typology. It builds on objective conditions and has to do with a well-balanced, harmonious development in an environment of fairness and justice. The UN-Habitat's notion of prosperity groups all urban functions clustered around five main categories: productivity, infrastructure, quality of life, equity and environmental sustainability. The 'wheel of prosperity', shown in Figure 25, symbolizes the well-balanced development of the five dimensions which is measured through the City Prosperity Index (CPI). UN-Habitat suggests that it is for the city of the 21st century to pursue shared, integrated prosperity, keeping the 'wheel' well balanced with mutually reinforcing spokes through a dynamic hub.

Figure 25: UN-Habitat's wheel of prosperity



Source: UN-Habitat, 2012

The classification by CPI values results in regional brackets with various cities in the developed world featuring solid prosperity factors (CPI: 0.900 or higher), with a majority of African cities with very weak readings constituting the last two groups (0.600 or below). In between, a large number of Asian and Latin-American cities make up the third and fourth groups (0.700–0.799 and 0.600–0.699 respectively).

To conclude: the UN-Habitat's index, shaped in the wheel of prosperity, is based on quality of life, equity and social inclusion, environmental aspects, productivity and infrastructure aspects. Mobility and urban freight transport are not regarded separately.

2.3.6. The Public Spaces Wheel by PPS

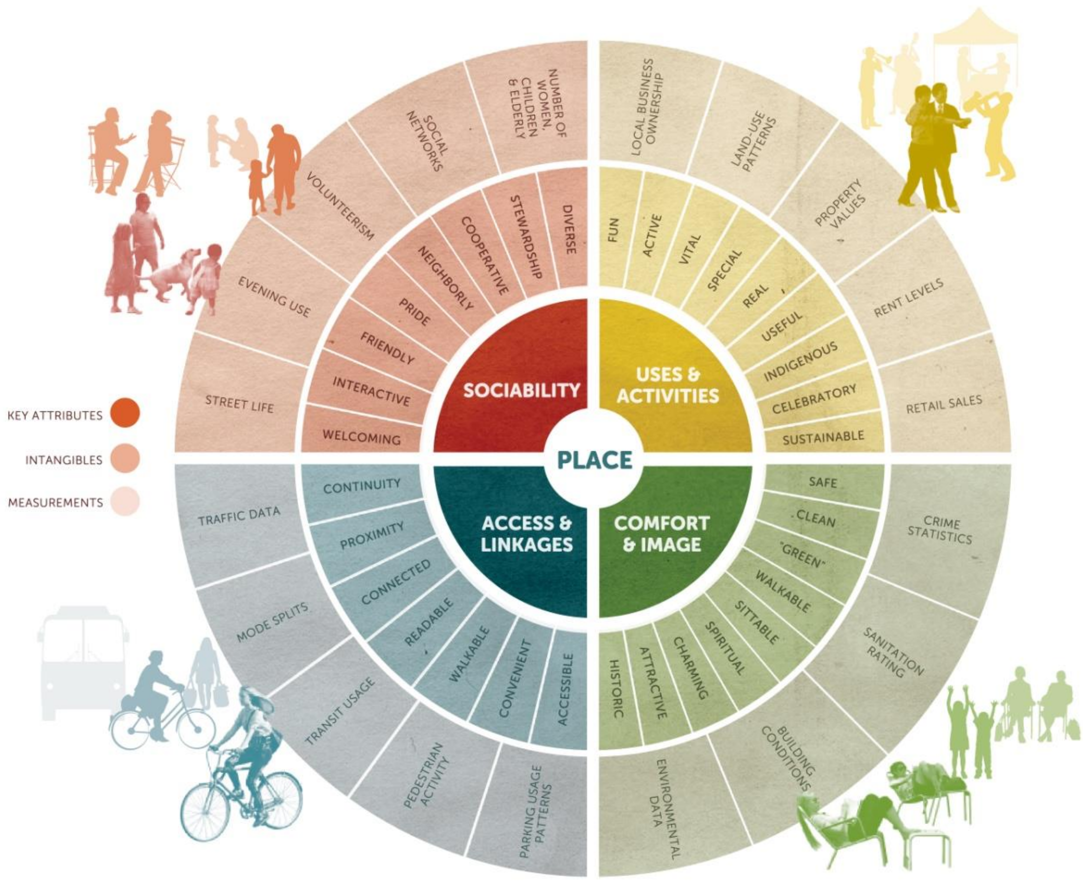
Project for Public Spaces (PPS) is a non-profit planning, design and educational organisation dedicated to helping people create and sustain public spaces. PPS was founded in 1975 to expand on the work of William (Holly) Whyte, author of The Social Life of Small Urban Spaces. The central concept is 'Placemaking'. This approach is a movement that tries to inspire people to collectively reimage and reinvent public spaces. As both a theoretical idea and a hands-on approach for improving a neighbourhood, city, or region, Placemaking has the potential to strengthen the connection between people and the places. It is a collaborative process based on urban design, paying particular attention to the physical, cultural, and social identities of an area (Project for Public Spaces, 2017).

Placemaking was launched in the mid-1990s while the theory was developed the 1960s when urban planners like Jane Jacobs and William H. Whyte introduced ideas of designing cities for people, not just cars and shopping centres. Their work focuses on the social and cultural importance of lively neighbourhoods and inviting public spaces. Jacobs encouraged citizens to take ownership through the idea of "eyes on the street," while Holly Whyte outlined key elements for creating vibrant social life in public spaces.

The approach involves eleven principles[76] offering guidance to help communities to integrate diverse opinions, translate that vision into a plan and program of uses, and to ensure the sustainable implementation of the plan. "The Place Diagram" (Figure 26) is one of the tools PPS has developed to help communities evaluate places. The inner ring represents a place's key attributes, the middle ring its intangible qualities, and the outer ring its measurable data.

[76] The idea behind this concept is that places thrive when users have a range of reasons (10+) to be there. These might include a place to sit, playgrounds to enjoy, art to touch, music to hear, food to eat, history to experience, and people to meet. Ideally, some of these activities will be unique to that particular place, reflecting the culture and history of the surrounding community. Local residents who use this space most regularly will be the best source of ideas for which uses will work best.

Figure 26: Public spaces wheel by PPS



Source: Project for Public Spaces, 2015

To conclude: the PPS' wheel, shapes the index in four aspects: sociability, uses and activities, comfort and image and access and linkages. As such, quantitative social/environmental/ economic and qualitative aspects are regarded.

2.3.7. European green capital award

The European Green Capital Award is an award for European cities, and is based on its environmental record. The award was launched in 2018. The first award was given to Stockholm for the year 2010. The selection for the title is assessed on the basis of twelve (mainly) environmental indicators: climate change: mitigation, climate change: adaptation, sustainable urban mobility, sustainable land use, nature and biodiversity, air quality, noise, waste, water, green growth and eco-innovation, energy performance and governance (EGCA, 2017).

The cities applying for the award are asked to describe the present situation, the measures implemented over the last five to ten years, the short and long term objectives for the future and proposed approach to achieve these. As such, the award looks at past policy, results thereof and future plans.

The city of Oslo's application for the 2019 round reveals their view on urban mobility indicators (EGCA, 2017). These are public transport-oriented, and deal with the share of bus and rail use in mobility, the share of electric cars, EURO IV busses, private car use, public transport etc.

2.3.8. Liveability parameters related to the analysis in this dissertation

To conclude this liveability section, the lessons learned from performance indices is translated and applied to the context of this research. The appraisal in this dissertation will focus on the quantifiable aspects of urban freight transport.

The previous sections on liveability indices lead to lessons learned on measuring liveability. For measuring all aspects of urban liveability, it is clearly necessary to assemble an index consisting of underlying objective and subjective parameters. The parameters are to be related to economic, social, ecological and institutional/political factors. However, a one size fits all approach will not exist, as different stakeholder views and expectations were seen by Balm et al (2014) and Meers et al (2015). The first differentiated five main stakeholder groups are: logistics service providers (LSPs), shippers, local authorities, receivers and citizens. The latter expressed the need for four clusters of indicators. Based on the former sections, a wide-range index is distilled. The next table shows the majority of objective and subjective aspects that can be regarded when measuring urban liveability related to urban freight transport activities.

Table 26: Urban freight transport linked to urban liveability indices

	Quantified aspects	**Qualitative 'subjective' aspects**
Economic Urban freight transport has an economic impact on entrepreneurs and citizens. Impacts are both measurable and qualitative.	• Turnover/profits of urban businesses (EUR) • Turnover/profits of LSP (EUR) • Turnover/profits delivery at home (EUR) • Margins (EUR) • Transport tariffs (EUR) • Number of deliveries in the urban area (Stops) • Number of delivery vehicles in the urban area • Accessibility of receivers (number of urban kms needed)	• Vital and active urban area • Attractive environment for businesses • Diverse retail landscape • Offer of home deliveries • Ease of pickup of freight in urban area • Ease of delivering freight to receiver freight in urban area • Level of transport service

Social Urban freight transport has a large impact on social criteria; indicator values are only minor quantitative in nature.	• Jobs (Number of) • Accidents (Number of fatalities) • Road congestion (Time lost) • Road occupancy	• Welcoming and friendly urban area • Attractive environment for citizens • Urban planning to human scale • LSP's employee satisfaction
Ecological Urban freight transport has a large impact on the ecological values of an urban area.	• Emissions (CO_2, PM, NO_X) • Accidents (fatalities) • Noise (dB) • Road occupancy	• Green • Sustainable • Attractive • Peace and quite
Institutional Urban freight transport is influenced strongly by the institutional framework.	• Wear and tear of infrastructure • Availability of infrastructure for urban freight transport activities • Innovations • Policies on emissions • Policies on innovations • Policies on modal shift	• Innovative businesses • Regulatory framework for businesses • Incentive system for good behaviour

Source: Own composition

The indicators regarded in this Ph.D.'s conclusions are summarized in the next table, and were distilled form the long-list in Table 26, which was built on sections 2.3.1 till 2.3.7. They consist of economic, social and ecological aspects. For measuring all aspects of urban liveability, it is necessary to assemble an index consisting of objective and subjective parameters. This short-list captures the main indicators. The operations have and economic, ecological, social and an institutional impact.

Table 27: Urban freight transport indicators taken account of in this dissertation

	Quantified aspects
Economic Urban freight transport has an economic impact on entrepreneurs and citizens. Impacts are measurable via data or are qualitative.	• Turnover/profits of urban businesses (EUR) • Turnover/profits of LSP (EUR) • Turnover/profits of delivery at home (EUR) • Margins of LSPs (EUR) • Transport tariffs for urban deliveries (EUR) • Number of deliveries in the urban area (Stops) • Number of delivery vehicles in the urban area • Accessibility of receivers (number of urban kms needed)

Social Urban freight transport has a large impact on social criteria. Company and societal values are only minor quantitative in nature.	• Jobs (Number of) • Accidents (Number of injured and number of fatalities) • Road congestion (Time lost)
Ecological Urban freight transport has a large impact on the ecological values of an urban area.	• Local air pollution: emissions: PM, NO_X • Greenhouse gas emissions: CO_2 • Noise (dB)
Policy impact Impact of urban freight transport on policy needs, and policy impact on urban freight transport practices.	• Enforcement of current policies • Policy measures for stimulating economic, social and ecological aspects of urban freight transport's practices

2.4. Policies to improve performance of urban freight transport

In light of global warming and political concerns on the tailpipe emissions of transport, policies were developed targeting the challenges, increasing urban freight transport's performance, limiting vehicle emissions and decreasing the economy's fossil fuel dependence. Annex II details the policy developments at the European, and regional Flemish level, relevant for urban freight transport activities. An outline of policy developments, mainly at the European level, is given in this section.

Since 1992, the European Union sets distinct financial incentives to improve environmental performance of the European transport system and to foster sustainable freight transport services as a key element of this policy. A key policy initiative was the **Gothenburg Summit** in June **2001** where EU leaders launched the first EU sustainable development strategy (European Commission, 2001a). In the transport policy area, the Council declared that shifting the balance between the transport modes was the central element of this approach, which became the core principle for the policies following this summit.

In **2001**, the European **White Paper on transport** (European Commission, 2001b) policy updated, outlined and analysed problems faced by the European transport system. It was the starting point of a development process of several specific policy instruments to achieve in the long term a sustainable European transport system. Guidelines proposed 60 concrete measures to promote the use of less polluting modes and less congested networks and prepare the way for new types of infrastructure financing.

Still, no urban (freight) transport specific policy was defined until the European Commission published, in **2007**, the **Green paper "Towards a new urban mobility culture"** (EC, 2007a). The Green paper first focused on an integrated policy on different aspects influencing urban mobility. Internalising external costs was proposed in the Green paper as a way of optimizing mobility and transport. The Green paper illustrated limits as the right to act of the European policy level is limited by the principles of conferral[77], subsidiarity[78] and proportionality[79]. The challenges that European towns and cities face cannot be solved easily at the local nor the European level alone (EC, 2007a).

After issuing a Communication on Freight Transport Logistics in Europe (EC, 2006) in June 2006, the European Commission asked for action on the logistics policy initiatives in **2007**. The **Freight Transport Logistics Action Plan**, abbreviated FLTAP (EC, 2007b), focused on six European logistics-related action domains, of which urban freight transport was one. There, the basis was laid for the future Urban Transport Action Plan (EC, 2007b).

In **2009**, the Commission's Communication "**A sustainable future for transport: Towards an integrated, technology-led and user-friendly system**" (EC, 2009a) identified urbanisation and its impacts on transport as one of the main challenges in making the transport system more sustainable. It called for effective and coordinated action to address the challenge of urban mobility and suggests a framework at EU level to make it easier for local authorities to take measures.

The **European Action plan on urban mobility** was only published in **2009** (EC, 2009b), drawing on the former policy initiatives and following the Green Paper. This Action plan set out a framework for EU initiatives in the area of urban mobility, while respecting the principle of subsidiarity (EC, 2009b). The action plan was foreseeing a policy framework and action 19 of the plan showed the Commission's intention to guidance help on how to optimise urban logistics efficiency, including on improving the links between long-distance, inter-urban and urban freight transport, aiming at ensuring efficient 'last mile' delivery (EC, 2009b).

(Transport) policy guidance was given by publications of among others the IPCC (2007), stating the need for a reduction of greenhouse gases (GHG) emissions by 50 to 80% by 2050 to avoid dramatic and irreversible climate changes. In 2008, the **Europe 2020** strategy (EC, 2010b) for "**A smart, sustainable and inclusive growth**" was adopted. To be less dependent on energy import, the EU should according to the Europe 2020 targets decrease the harmful climate change emissions by at least 20%. These were later reflected in the Commission's Communication of **2011** in the "**Roadmap for moving to a competitive low carbon economy in 2050**". As a result, the EU needs to reduce emissions by 80-95% below 1990 levels by 2050. The Commission showed that while deeper cuts can be achieved in other sectors of the economy, a reduction of at least 60% of GHGs by 2050 with respect to 1990 levels is required from the transport sector. By 2030, the goal for transport will be to reduce GHG emissions to

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[77] The problem should be linked to at least one article of the Treaties and the objectives they contain, which is the basis for Union's right to act.

[78] Subsidiarity means that it is (legally) necessary for the EU to check whether the Member States would be better in place to take action on the issue than the EU level.

[79] Any Community action should not go beyond what is necessary to achieve satisfactorily the objectives which have been set.

around 20% below their 2008 level. Given the substantial increase in transport emissions over the past two decades, this would still put them 8% above the 1990 level by then (EC, 2011b).

In **2011**, a new **European transport White Paper** was published, listing the present transport and mobility problems. The document, just as the Green paper, devotes specific attention to the urban transport challenges[80]. The gradual decrease of fossil fuel-powered vehicles in urban areas materialised through the ambitious targets "Ten Goals for a competitive and resource-efficient transport system". The principal urban transport-related targets are:

- ✓ Halve the use of 'conventionally-fueled' cars in urban transport by 2030;
- ✓ Phase them out in cities by 2050;
- ✓ Achieve essentially CO_2-free city logistics in major urban centres by 2030.

These three targets are ambitious, and influence city logistics directly. Initiative 33 of the White Paper details the expected approach.

The Commission adopted in **2013**, the "**Clean Power for Transport Package**", which is constituted by a Communication (EC, 2013b), an LNG action plan and a legislative proposal[81]. The initiative will guarantee the deployment of alternative fuels infrastructure, in particular electric recharging stations to contribute to the 'zero emission' target for urban freight logistics in major urban centres by 2030. (EC, 2013a)

In **2013**, the Commission launched the COM(2013) 913 final "**Together towards competitive and resource-efficient urban mobility**" (EC, 2013c) and aimed at reinforcing the support to European cities for tackling urban mobility challenges. The Communication sets out how the Commission will strengthen its actions on sustainable urban mobility in areas where there is EU added value (EC, 2013a). How the Commission sees these actions is framed in in Annex 2.

The Communication was published with an accompanying **Commission Staff Working Document** "**A call to action on urban logistics**" (EC, 2013a) detailing the actions. These are detailed in on page 282 in the Annexes as they shape the future urban logistics policy.

The Commission will also prepare, with experts, guidance documents that provide practical assistance on how to improve urban logistics performance: e.g. urban logistics definitions, data collection and evaluation methodologies, recommendations and best practices for including urban logistics in Sustainable Urban Mobility Plans (SUMPS), treatment of urban logistics in access restriction schemes, Delivery and Service Plans, implementation of

[80] In the 2011 White Paper

[81] Proposal for a Directive of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, COM (2013) 018 final. This package is accompanied by a Staff Working Document on Actions towards a comprehensive EU framework on LNG for shipping.

consolidated local urban delivery schemes, reducing CO_2 emissions from urban logistics for cities and operators, and ITS solutions supporting city logistics (EC, 2013a).

As last, and exceptionally, the Commission points directly to the Member States for taking action. "*Member States should consider ensuring that urban logistics are given proper consideration in their national approaches to urban mobility and in Sustainable Urban Mobility Plans. Member States should also consider ensuring creating platforms for cooperation, exchange of data and information, training, etc., for all actors of urban logistics chains*" (EC, 2013a).

The European level is as well working on an internalisation of external costs strategy. In 2006, the European Parliament asked the Commission to present "a generally applicable, transparent and comprehensible model for the assessment of all external costs to serve as the basis for future calculations of infrastructure charges" (EC, 2014). This policy is framed within the "**Directive on the charging of Heavy Goods Vehicles in the EU"[82]** (EC, 1999) which lays down certain rules defining the conditions under which user charges ("Eurovignette") and tolls may be applied. This Directive was followed by a Communication in 2003 (EC, 2003), with a proposal for a Directive amending 1999/62/EC. The Commission also prepared a second Communication in July 2008 (Greening transport package) which provided a general framework of reference for the internalisation of external costs in the transport sector (EC, 2008). Based on an IA, a proposal for Directive was published, which wanted to give Member States the possibility of varying tolls according to a number of factors like distance travelled, place, infrastructure type and speed, vehicle characteristics, time of day and congestion level. The proposal for Directive was proposed to stretch the former Eurovignette directive to include LCVs below 12 tonnes (from 3.5 tonnes loading capacity). The proposal was followed by Directive 2011/76/EU (EC, 2011c), summarised in Annex on page 282 of which point 5 if highly relevant for future road freight transport.

Directive 2011/76/EU allows Member States to **levy external costs** of road **congestion, emissions and noise**[83] to freight vehicles over 3.5 tonnes (EC, 2011c). This external cost concern has led to the "**Handbook on the estimation of external costs in the transport sector**", updated recently by Ricardo-AEA (2013). Also an Internet consultation has been carried out to get a feedback on the general principle of internalisation and on the various policy options. The consultation ended in December 2007 and the Commission has presented its main findings at a high level stakeholder conference in 2008[84]. A Commission SWD

[82] The "Eurovignette" Directive

[83] Maxima for air pollution and noise are included in the annex of the Directive, and make a distinction between suburban and interurban roads. Emission costs are ranging between 0 EURct/vkm for EURO 6 till 16 EURct/vkm for EURO 0. Noise costs range between 0.2 and 1.1 EURct/vkm.

[84] Stakeholder conference on the internalisation of transport external costs, Brussels, 31 January 2008

summarizes the existing internalisation of external costs in freight transport (Report as a result of Article 11 (4) of Directive 1999/62/EC) (EC, 2013d).

The Commission's **Communication on e-commerce and online services** (EC, 2011e) identified the improvement of the delivery of goods purchased online as one of the top five priorities to boost e-commerce by 2015 – most of these deliveries are in urban areas, just as the Communication on the "Coherent framework for building trust in the Digital Single Market for e-commerce and online services" (EC, 2011d). There, first- and last-mile (urban) transport services are identified as important for the future e-commerce growth.

Meanwhile, other measures like the Euro-norm scheme, setting step by step more strict emission maxima for newly-produced vehicles, forced the car manufacturing industry to innovate (amendments to the original Directive 70/220/EEC, like for instance regulations and directives 715/2007/EC, 98/69/EC, 2002/80/EC, 2002/51/EC and 2006/120/EC).

Local policies

Some of the policies at a European level resulted in local actions. One to highlight is the Dutch initiative of '**Zero Emission Stadslogistiek'** or 'Green deal ZES', pilot testing various logistics innovations for achieving CO2-free city logistics in major urban centres by 2030.A pilot 'Living Labs Fietskoeriers' supports, disseminates and monitors Fietskoeriers.nl, the first countrywide cargo bike service. It is delivering parcels in 30 cities in the Netherlands, with 18 local collaborators and the company therefore received the Dutch prize for most innovative e-commerce initiative' in 2017. The company developed a state of the art Track & Trace-system, allowing customer to change their delivery location flexibly. This lead to a 98% first attempt success (Zero Emission Stadslogistiek, 2017).

After the adoption, in 2008, of the 2020 EU Climate and Energy Package, the European Commission launched the Covenant of Mayors to endorse and support the efforts deployed by local authorities in the implementation of sustainable energy policies. A new **Covenant of Mayors** for Climate & Energy was launched by the European Commission on 15 October 2015. The covenant aims for action on a local level to prevent and mitigate climate change: mitigation, adaptation, and secure, sustainable and affordable energy are key targets. Signatory cities pledge action to support implementation of the EU 40% greenhouse gas-reduction target by 2030 and the adoption of a joint approach to tackling mitigation and adaptation to climate change. Mayors committed to submitting, within two years following the date of the local council decision, a Sustainable Energy and Climate Action Plan (SECAP) outlining the key actions they plan to undertake (Covenant of Mayors, 2017). The city of Antwerp signed, among many other Belgian cities, the covenant. This resulted in a first action plan, in which city logistics was included in the policy actions. The plans include researching off-peak transport and urban consolidation centres.

In recent years Flanders, a Belgian Regional policy level, initiated and guided some urban logistics projects, of which PIEK (I and II) and cargo bicycles were the most prominent. Flanders

Logistics was the framework in which actions were taken. This resulted in pilot testing silent off-peak deliveries (PIEK) by main retailers, and resulted in positive outcomes. Fuel consumption decreased by 15%, time gained was 35%, and no complaints were received by residents. The pilots and research by University or Antwerp resulted in a guidance document for local policy makers 'Wegwijzer voor een efficiënte en duurzame stedelijke distributie in Vlaanderen', providing an overview of possible actions, policy measures, do's an don'ts and further reading. The document and pilots were supported by University of Antwerp's Policy Research Centre on commodity Flows.

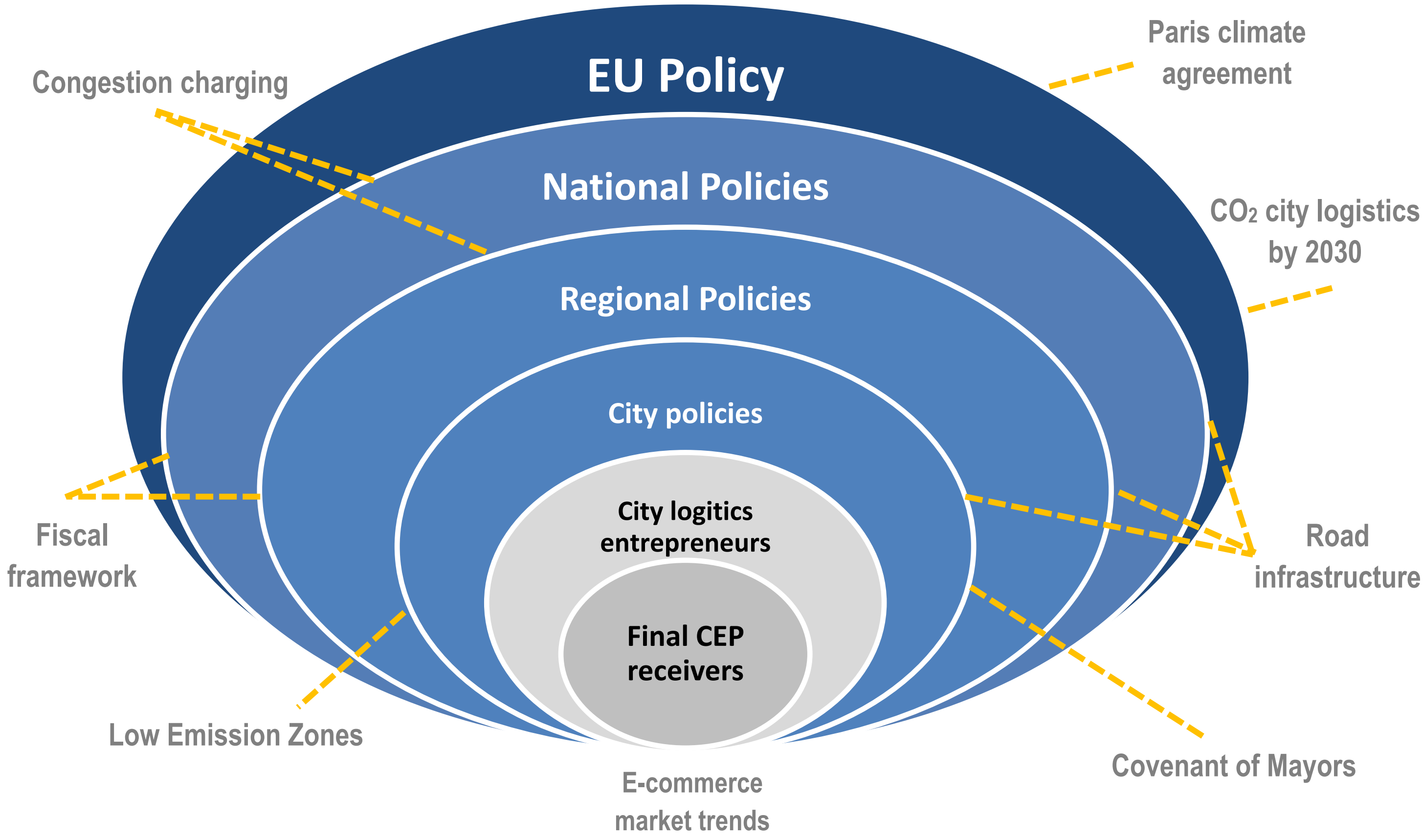
Synopsis: Policy context

European transport policy, developed from the 1950's on, focused first on international cross-border freight transport only; the free movement of freight across the Union was one of the spearheads of the Union's existence. The sub-sector of urban freight transport and urban logistics was never really a separate policy focus; urban transport is hardly ever cross-border so therefore not a core competence of the Commission. Nonetheless, given the increasing challenges for pushing the freight transport industry to a more sustainable and innovative level, the Commission gradually started implementing policies tackling by coincidence or specifically urban freight transport challenges. The changed viewpoint on the scope of its core competence also shifted due to an increasing demand at city level for European guidance and coordination. With 2007 and 2009 being two decisive years in which this shift established.

The Green Paper 'Towards a new mobility culture' of 2007, was the first step towards urban freight transport policies. It was recognised officially for the first time that the challenges faced at local level couldn't be solved alone by towns or cities. In 2009, the 'European action plan on urban mobility' further translated this shift in the core competence's scope. The EC set out several actions, also specifically referring to last-mile and urban freight transport (e.g. Action 19). The path was further developed in the 2011 White Paper setting strict ambitions for the local level, of which 'CO_2 free city logistics in major urban centres by 2030' is most essential.

At the same time, local policy levels started implementing mobility policies for persons, and for goods transport. The most visible being Low emission Zones, and Congestion Charging. This in reaction to road congestion, local air quality and urban livability concerns. CO_2 free city logistics was later added as a policy objective. Cities became active in EU projects as CIVITAS, BESTUFS etc. in order to research via pilot test urban freight innovations, while receiving EU funding. City logistics policy making is therefore quintessential a stacked policy approach (Figure 27).

Figure 27: Stacked policy levels and competencies



The execution of many of urban freight related policies and the responsibility for reaching the ambitious targets set by the European level, is a core competence of the local policy levels and local businesses. The EC may have changed the scope of its core competence regarding urban freight transport, the definite path towards reaching the policy targets (e.g. reducing emissions) is less strongly designed nor implemented.

2.5. Cycling logistics as a chanceful alternative for LCV transport

The analysis showed a multi-facet problem for urban areas' sustainability and liveability. The increased road transport allowed cities to grow and develop economically.

First, general transport policies were set, and recently, policy makers want to tackle urban challenges via setting urban freight transport policy objectives. Consequently, the sector is now confronted with an ambitious policy goal: by 2030, the use of 'conventionally-fuelled' cars in urban transport should be halved. The end goal is to phase them out in cities by 2050.

"The logistics goal is to achieve essentially CO_2-free city logistics in major urban centres by 2030" (EC, 2011 White paper on transport).

Bicycle couriers are often found in central business districts of metropolitan areas. Very likely, these couriers work on a small scale, collecting packages and distributing these quickly throughout the area. Reliability, almost continuously offered as they are, compared with conventional urban freight transport modes, not hindered by road congestion, allows offering better and more stable transport times in congested urban areas. Regardless of weather conditions, traffic jams, peak or off-peak times, strikes in public transport and so on, predictable transport times can be offered all year round (Maes et al, 2011).

The next research steps build further on the published literature on these particular transport services, and adds knowledge on the Belgian market.

Nowadays, bike couriers are perhaps first perceived as students riding for apps like Deliveroo and UberEATS. Before recent this boom in the 'gig-economy'. Before, these couriers were seen as small idealistic entrepreneurs delivering packages, letters, contracts, etc.. Shippers were 'cool' frontrunners, with among others advertising agencies, law firms, notary and banking administrations as key customers. They shared the client characteristic to put a strict pressure on delivery companies to deliver things fast, from A to B as soon as possible, and only for them. Some of these clients worked with couriers because then they showed a preference for a 'green' and 'cool' way of delivering (Maes et al, 2011). These bike couriers rode on 'fixies'[85].

Though, besides these well-known bike transport users, other less obvious goods can and are already transported by bike too. These flows are (still) niche markets. The distribution of heavier boxes or palletised goods is for instance seen more and more as a common practice for cargo cyclists. Provided they have a special cargo bicycle.

In essence, bicycle couriers have a strong focus on city deliveries. Their distributed freight characteristics are i) small, ii) low weight and iii) time pressure. Clients are found in urbanised areas. This while traditional logistics networks, and especially those of integrators, are expanded and optimised at a regional, national, European and - in most cases - a global scale. The latter are less focused on the specific urban level, and are increasingly confronted with congestion and cost challenges. Therefore, a cooperation between these *two worlds* of logistics might be an option. They show potential to become an important local partner for these logistics companies, which do endure more and more urban congestion and see an increased customers' awareness for sustainability (especially city inhabitants). In terms of distance, this first and last mile stretch is representing a limited share of the total mileage logistics companies are doing, but it is not negligible in terms of costs and emissions. Then, this first- and last mile transport becomes considerably significant. Bike couriers, with their local focus and often to a certain extent idealistic nature, might be seriously in conflict with the modern global logistics organisation though.

[85] A fixed-gear bicycle or fixed-wheel bicycle, commonly known in some places as a fixie is a bicycle that has a drivetrain with no freewheel mechanism. This means if the rider does not peddle, he brakes. It is also possible to cycle backwards.

The very local urban transport, historically developed by couriers, e.g. transport from one part of the city to another part (A to B), is a relatively small share in the total transport market.

This section further develops the opportunity to link long distance transport to urban areas with local urban goods transport by bicycle. It is a question whether the app-based delivery services are an added value to the traditional bicycle couriers or not. This section is analysing these first observations, with a Belgian emphasis. The aim is to define the current service market and the trends therein. Thereafter, in Chapters 4 and 5, the most chanceful market will be further developed and modelled.

2.5.1. The Belgian bicycle courier services market

A bottom-up approach was chosen to map the Belgian market give that only a limited number of publications on Belgian cargo cycling are available. This section is based on own desk research and field visits.

In 2010, a round table 'Cycling logistics' was organised in Brussels, which brought together a representative sample of Flemish and Brussels bike couriers. This round table resulted in Maes et al (2011) and serves as a basis for this section. All Belgian bike couriers were invited, of which a majority active at that moment took part in the discussion. The results of the beforehand shared questionnaire were used to structure the meeting. Before, an open questionnaire was prepared and sent to all bike couriers active in the region of Flanders and Brussels.

Then, a selection of Belgian market players were contacted separately. Their websites were scanned on information on prices and operations. First contacts were made among others with the Belgian bike messenger company Pedal BXL. Subsequently, meetings with Max Mobiel and start-ups Lunchbutler.be[86], Ecopostale, Bubble Post, Cargo velo were organised. Furthermore, separate discussions with major integrators and other logistics companies were undertaken, e.g. ASX-Ibeco and TNT Express. The next paragraphs deepen out the empirical results achieved during this research steps. Due to confidentiality, limited direct references to specific companies will be made.

Six market facets are regarded: size and employment, organisation and markets, offered transport services, innovations and financials.

[86] This company was at that time elaborating a Belgian logistics (IT) platform to connect bike couriers and their customers easier with each other. A meeting was organised in 2012.

I. Size and employment

The number of bike courier companies active in Belgium shows that the supply side of the market is modest. In the period December 2010 - October 2017, a total of 38 bicycle transport companies were identified, several of which one-person firms. Twelve already stopped activities or merged. Three work(ed) in the framework of a larger logistics company (e.g. TNT Express, UPS and FedEx), two are part of a not-for-profit organization (one of these stopped) and the other ones are small independent companies. A considerable amount of firms has started operations less than five years ago. Bubble post was the biggest player, and was taken over by bpost in summer 2017.

Table 28: Belgian bike couriers, regional presence and details

Name	Region	Details	Stopped activities
ASX Ibeco**	Antwerp	A larger logistics company using scooters and opting for bikes to do urban deliveries of (maritime) documents in Antwerp. Does consider using more cargo bicycles.	
Brussels Bike Courier	Brussels	A courier in Brussels using a motorbike.	x
Bubble Post	Ghent and many other cities (also abroad)	Bike taxi that changed its business orientation towards freight transport. Employs in the meanwhile many people and rapidly expanded to Belgian and European cities. Also performs non-bicycle courier services; e.g. electric vehicles and logistics. Was taken over by bpost in summer 2017.	
Cargo pedalo	Bruges	Delivers in Bruges and surroundings. Small start-up.	x
Cargo velo	Ghent	Start-up (end 2012) as bicycle courier service, which expanded to the heavy lift and CEP transport.	
Corpco Urban Bike	Brussels	Part of a bigger company (Corpco - Euro-Sprinters). Luc Heyvaert is one of the most experience cargo cyclists in Belgium.	
CycloXpress	Ostend	Start-up in the Ostend region. Mainly active in local deliveries for bakeries, print, flower shops etc.	
De fietskoerier *	Antwerp	Dolf Kok was more than 10 years active as cycle courier pioneer. New generation took over in 2014.	
De fietspost *	Aalst	Start-up in Aalst in 2013.	x
Deliveroo	Belgium	App-based cargo cyclists. Antwerp, Mechelen, Ghent, Leuven, Brussels and growing.	
Dioxyde de gambettes	Brussels	Small start-up in Wallonia. Active in Brussels. Can carry heavy loads.	
Eco-express	(east) Brussels	Small start-up. Delivers east Brussels communities.	
Ecokoerier	Antwerp	2014 start-up (stopped).	x
Ecokoeriers	Mechelen	'ECOkoeriers Mechelen' is a cooperative idea between social entrepreneurs, city hub Mechelen (ODTH) and bubble post. Support by city Mechelen and Province of Antwerp in framework of Cycling Logistics Ahead.	

Ecopostale **	Brussels	Active for years. Fast growing company in the Brussels market. Cooperated with TNT Express.		
Fast bike delivery	Brussels	Recent start-up (2014).		
Fietskoerier Kortrijk	Kortrijk	Small start-up (end 2013). Stopped activities in 2016.		x
Fiets-Licht	Schorisse	Small start-up delivering in rural East-Flanders.		
Flits	Ghent	Exists since 1999 in Ghent. Bike taxi, bike shop as well as bike rental activities. Activities were taken over by Cargo velo.		x
Green company	Brussels	2015 start-up (stopped).		x
Vlam Koeriers *	Antwerp	Antwerp courier. Can organize Belgian shipments as well. Merged with 'de Fietskoerier' in 2012.		x
Le Coursier Montois	Mons	Start-up delivering around Mons. Merged with Coursier Mosan to Coursier Wallon.	New name: Coursier Wallon	
Le coursier Mosan	Namur	Small start-up (end 2011). Merged with Coursier Montois to Coursier Wallon.		
Max Mobiel */**	Ghent	Social project thet employed cycle couriers; supported by the city of Ghent. Refocussed on transport of people.		x
New customer services (NCS) *	Brussels	A logistics actor employing one cycle courier. Possibly longest active cargo cyclist on the Belgian market.		
OOVelo	Antwerp	Start-up 2015. Handles also special cargo (laboratory samples, flowers etc.).		
Pakfiets	Mechelen	Small start-up (2013).		x
Parcify	Growing	App-based cargo cyclists. Antwerp, Amsterdam, Ghent, Brussels and growing.		
Pedal BXL */**	Brussels	Active for years in Brussels (since 2009). Cooperated for a while with FedEx and with couriers in San Sebastian and Barcelona. Real bike adepts.		
Snel & Wel	Aalst and Oudenaarde	Social inclusion project employing cargo cyclists.		
Snelbinder	Antwerp	Small start-up in the Antwerp region.		x
Stadskoerier	Ghent	Started in 2009 in Ghent.		x
Transpire Transport	Brussels	Small start-up (2014).		
UberEATS	Belgium	App-based cargo cyclists. Antwerp, Brussels and growing.		
UPS	Leuven and Mechelen	UPS started a same-scale pilot test with cargo bike deliveries in Leuven, which expanded to Mechelen recently (UPS, 2017).		
Veloxpress	Hasselt	Small start-up in Hasselt.		x
Via Velo	Deinze	Small start-up (beginning 2015). Cooperates with GLS and delivers fruit to offices.		
Vit-tes *	Leuven	Can organize (inter)national shipments. Long history.		

* These companies were present at the round table discussion.
** These companies were cooperating with an individual interview.
Last update October 2017.

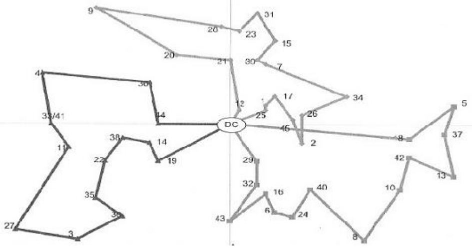
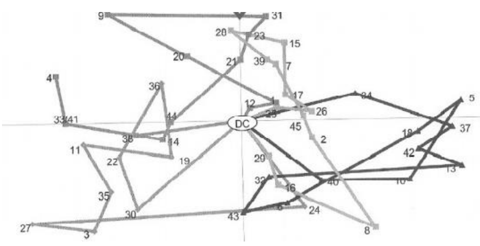
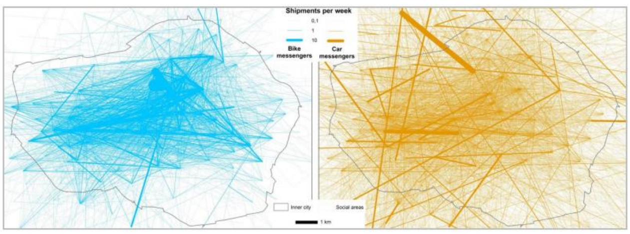
Although employment opportunities are far from enormous, bike couriers indicated at the round table and in the interviews to find employees easily. This at least is not a hurdle to develop their business. The reason why only a limited number of bike couriers are employed can be found in the fact that companies cannot employ for a longer period as the current market demand is not stable.

Fluctuating volumes per day are common. According to the owners, Belgian taxes on labour are a burden to employ new couriers, as one needs a big and stable volume of deliveries to make the business profitable. On the other hand, bike couriers have a physically tough job which is sometimes causing people to quit. But as stated, replacement can easily be found. Only a minority employ more than 10 cyclists: Ecopostale and Bubble post. And to a certain extent also UberEATS and Deliveroo.

II. Organisation and markets

The bicycle courier market delivers quite a lot of different services. The transport activities which bicycle couriers are performing in the urban environment can be divided into two organisations, as shown by the Table below. On the one hand, the bikers transport a very limited number of parcels (mostly one) for one client from one location in the city to a location in the same city. This is called the A-B market. Furthermore, one can discern a second market of bigger volumes for one client shipping things to several addresses in the city. This type of market is called 'the routed deliveries'. The shipments are mainly originating from out of the city core.

Table 29: Difference between A-B shipments and routed deliveries

Routed deliveries
Fixed routes – Volumes – First- and last mile
 
A-B shipments
Express – On call – Small volume – More expensive
 

Source : Own composition based on Boyer, Frohlich & Hult (2005) and Gruber et al (2013)

These organisations, are linked to the market segments they serve. In general, six markets are distinguished: the Post & CEP market, Courier services, Delivery services, Service vehicles, UCC partnerships and the gig-economy.

Figure 28: Market segments for cargo bicycle transport

The businesses differences, clients and vehicles will be depicted in the market developments of the company types, and reflects on the potential growth paths.

Courier services

These are the grassroots for bicycle transport. These riders are idealistic bikers offering backpack services for decades, just like their American counterparts. Belgian examples are Pedal BXL (Brussels), Vi-tes (Leuven) or de Fietskoerier (Antwerp). These are doing limited volumes. In addition, there are the state-owned projects, which were set up with a social purpose rather than with a business perspective (e.g. Snel & Wel in Aalst and Oudenaarde).

The courier companies have different clients in different sectors. The volumes are not big nor stable. On the other hand, many clients see an increasing awareness for sustainability issues, with increasing volumes as a result. This unique selling point combines well with the increasing congestion, which hinders traditional LCV transport in urban areas.

The future market for A-to-B transport: the A-B market on a local/regional scale, and the round trips on a city scale. This second market is a niche within the bigger logistics network, where bicycles do the first and/or last mile of longer transport services and is found in the Post & CEP market segment. Several sub-sectors, or sub-flows, of A-B transport can be identified: administrative documents, medical shipments, food (mainly lunches and catering), flower deliveries and lastly the short mile market.

- **Administration**: The promising administrative freight flows most often consist of letters and small parcels under time pressure. Letters however are typically sent by post and an increasing digitalization of information flows is to be expected.

- **Advertisement sector**: An important sector, certainly in the Brussels region, is the advertisement sector. Companies see bike couriers as a fast and reliable service for sending very urgent packages. The sustainable and sportive image helps.
- **Food**: A growing sector for bike couriers is the delivery of lunches. Consumers can order local food. The lunch is delivered by the bike courier, a fast and reliable alternative to sandwich bars' delivery van. Sustainability can be of large importance to market the services. But this marker is captured by the gig-economy market segment.
- **Medical sector**: Doctors, pharmacists and bike couriers could be working together to collect prescriptions from and deliver to elderly people. The flows are matching important characteristics: parcels are small, delivery speed is of high importance and the value is high which means that the tariff of the courier is a small percentage of the total sales price. More and more pharmacists sell prescription-free medicines online, easy to deliver at home or work by a bike courier.
- **Flowers**: A last and promising sector is the delivery of flowers. These shops can send flowers by bike couriers as a present. The image helps increase the experience.
- The **short mile**: The short mile is a specific market which is actually very small and disorganized. Due to the financial and economic crisis of the late 2000s, a trend of local urban production and local consumption is seen. Knitting and self-mending broken appliances is gaining increasing interest. Instead of going to restaurants, young city people cook by themselves and share their cooking results with others (Cordon coffee, 2013; Repair café, 2013, and Thuisafgehaald.be) These locally produced and consumed products and services are transported by the consumer or local producer themselves, often by bike or public transport. This is more and more linked with ODD.

The round table and interview indicated that the market organization as well as the organization of the individual companies leaves room for professionalisation. But, as most bikers are employed in small companies of maximum three people in total and are not connected to the national nor international logistics network, growth, investments and professionalisation is hard to achieve. The lack of financial stability is a real hurdle for investing. The (start-up) companies are often undercapitalised and have a step-by-step approach towards scale increase of their operations.

At the round table, only some entrepreneurs stressed that being part of an (inter)national logistics network was their main goal to start their activities. In contrast, the majority started from an idealistic viewpoint, whereas only some saw it as a business opportunity.

They ride regular bikes, often fixies, and some invested in bullit-type of cargo bikes. In essence, they use two-wheelers and can be recognised as backpack cycling couriers.

The majority of the cycle couriers organize daily tasks (making phone calls, route choice, contacting possible new clients etc.) from the bike itself. The administrative part, mainly invoicing, is done after the working hours. Although companies are small, some express a will to invest in innovative technologies to make every-day work more efficient. First on the list of tools is track-and-trace technology and routing devices.

Based on the market analysis, current Belgian employment in this market lies between 20 and 50 FTE.

Post & CEP

These are companies delivering bigger volumes. These cargo bicycle couriers are mainly using two and three-wheeled cargo bicycles, and with exemption general bikes. Bpost is the general example. The universal post deliverers (UPU) in Europe have a tradition of using two-wheeled bicycles for post deliveries. But as the post market declines, and the parcel marker booms, the vehicles become less appropriate. Other companies originate from this parcel market, and found in cargo bicycles a new niche product for urban deliveries.

In this respect, one start-up company in the city of Brussels is worthwhile to highlight. The logistics company 'Ecopostale', active since 2010 with cargo bicycles, managed to bring together increasing volumes. The company developed a close cooperation with the express operator TNT Express, and was the final delivery partner in the Straightsol projects (see page 29). Cooperation still exists with FedEX. Some of these integrators outsource the shipments for the central zone of the city to Ecopostale's cargo bikes, in their own livery or in Ecopostal's. This company uses bicycles, cargo cycles and electric vehicles

A second company to highlight in this market segment is Bubble post. The company rapidly expanded from Ghent to cities not only in Belgium but also to The Netherlands and Spain. It offers a logistics product to various clients, employing over 100 own cyclists by 2017. The company is innovative in the fact that the services were expanded not only in one city (like for example the couriers and Ecopostale) but also to a network of cities. This allows then to talk to bigger clients, and taking over their last mile deliveries in various cities. The fleet of vehicles was expanded from standard three-wheeled cargo cycles to heavy lift vehicles, and even cooled trailer (see page 41). The company grew from 2012 on at a rapid pace, requiring frequent capital rounds. The business was heavy lossmaking. As a result of new investment partners, the founders saw their share diluting and stepped out. This resulted in a takeover by bpost in summer 2017. Bpost has the necessary volumes to further develop efficiency and can try to make bubble post profitable.

First, a short parallel is made to the more general last-mile CEP market. Last mile parcel deliveries can theoretically be divided in different markets, as shown in Table 30. These are the main CEP transport service providers in Belgium (KPMG, 2017). Only some can offer the whole range of services, standard or express delivery and/or pick-up points. The customers are or B2B, B2C or C2X (consumer and small business parcels market).

Table 30: Standard, express and pick-up points for B2C, B2B and C2X in Belgium

	Services			Customers		
	Standard	Express	Pick up points	B2C	B2C	C2X
Asendia	x	x		x	x	
bpost	x		x	x	x	x
BPS	x			x		
Ciblex		x		x		
DHL Express		x	x	x	x	x
DHL Parcel	x		x	x	x	x
DPD (Belgium) NV		x	x	x	x	x
Euro Sprinters		x		x	x	x
FedEx Belgium		x		x	x	x
GLS Belgium NV		x	x	x	x	
Kariboo!	x		x	x	x	
Kiala4	x		x	x	x	x
Mikropakket	x			x		
Mondial Relay	x		x	x	x	x
PostNL	x		x		x	
TNT België		x		x		
United Parcel Service		x	x	x	x	x

Source: KPMG, 2017

The CEP market is shaped as a pyramid. The lowest slice of the market pyramid is the 'mass market'. This market consists predominantly of the shipment of letters and small parcels delivered by big (often former) nationalized UPUs [87], known as standard postal services. Volumes are big and recurring, the preference for fast delivery and willingness to pay is to a certain extent low. The middle slice is the 'intermediate market', and is having a bigger time pressure, an average willingness to pay and customers demand extra services. Track-and-trace options are standard. Higher security and reliability are asked. Bigger parcels and envelopes are the main shipments. The top, the 'high-end market' is characterised by a high time pressure, higher willingness to pay and strict customer requirements. Shipments should be fast, reliable and relatively expensive. A global network is needed (Gevaers and Hassler, 2011).

UPS has already developed own cargo bicycles services in Leuven and Mechelen, as pilot tests. The bullit-type cargo bikes handle some of the urban delivery volumes (UPS, 2017). This unlike the foreign test of UPS, where three-wheeled cargo bikes were deployed. No data on volumes is shared separately.

[87] The Universal Postal Union or UPU is known by the EMS (Express Mail Service) express postal services, offered by UPU members, like Bpost in Belgium. The EMS Cooperative founded in 1998 within the UPU to promote the harmonization and development of postal services offers in more than 190 countries worldwide.

The top of the pyramid is the former express CEP segment, which was in the past only offered to B2B customers. The main players are the bigger integrators like FedEX, TNE Express and DHL. Prices are high, and service is fast. Some of these integrators shifted focus to a broader market, and started also delivering B2C.

TNT Express tested with Ecopostale if urban volumes in Brussels could be delivered by cargo bicycle. The trial period was funded by the Straightsol project, which involved also the first use of the own-developed mobile depot. This pilot was not deployed as further and the integrator shifted back to LCVs.

DHL deploys cargo bicycles in the Netherlands, but not yet in Belgium.

In the past, contacts were made between some bike couriers and bigger logistics companies. Often, from the logistics companies, no interest was shown to co-operate with a small bike courier. The tariffs formerly offered were often below the courier's cost level, so negotiations often ended unsuccessfully. Ecopostale and Pedal BXL are the only ones having a more intense relation with a logistics player, respectively TNT Express and FedEx (De fietskoerier, 2010; Ecopostale, 2010; Asx-ibeco, 2011 and Hietbrinck, 2011).

Based on the market analysis, current Belgian employment in this cargo bicycle market size is estimated between 50 and 150 FTE.

Delivery services

This market is the own account transport market. In the jargon of the logistics industry, 'own account' refers to businesses that operate a fleet of their own vehicles to carry out their deliveries. The trend towards outsourcing of services means that there are fewer own account operations now than there used to be, but for some sectors it still makes sense to keep this work in house (TfL, 2009). Own-account transport operations are those carried out by own employees or by a non-profit-making body for the transport of its members in connection with its social objective provided that[88]:

- the transport activity is only an ancillary activity for the undertaking or body,
- the vehicles used are the property of that company, have been the subject of a long-term leasing contract and are driven by its staff.

It is observed that pizza shops, sushi shops, bakeries and other SME's are replacing their LCV or scooters with electric cargo bikes. From a financial point of view, cargo cycles have the potential to realise savings not only on time lost due to congestion, but also fuel costs (which are rising), and depreciation (by allowing the LCV fleet to be cut back) (TfL, 2009).

[88] Council Regulation (EEC) No 684/92 of 16 March 1992

Based on the market analysis, current Belgian employment in this market is unknown. This market size is estimated between 20 and 50 FTE.

Service vehicles

Another market for cargo cycles are commercial service suppliers, tradesmen and artisans such as window cleaners, electricians, builders, chimney sweeps, locksmiths, painters, repairmen, carpenters, gardeners, plumbers, scrap dealers, photographers, musicians, street and market vendors, distributors of magazines, newspapers and advertisements, and so on (Cycle logistics, 2014). During the first half of the twentieth century, almost every profession made use of cargo cycles, which were specially designed to carry the tools of their trade. These were both commercially available models as well as self-adapted vehicles. Also local authorities are another target group for cargo cycles. The vehicles appropriate tools for maintenance of city infrastructure such as parks and roads, for repairs.

Home bicycle repair is another example. In Brussels, 'De Velofixer' comes at your home to maintain or repair customer's bikes. 'Tuub' and 'Velovelo' followed this example and started mobile repair services in Ghent. The service is extremely valuable for the courier services and CEP cargo cyclists. If they break down, they need repairs as soon as possible.

The cargo bikes allows them to start a business with a much lower investment, and to operate it at considerably lower costs. No motorised vehicle is required, and even a shop is not a necessity. The cargo cycle can thus indirectly bring more (self-employed) jobs (Cycle logistics, 2014).

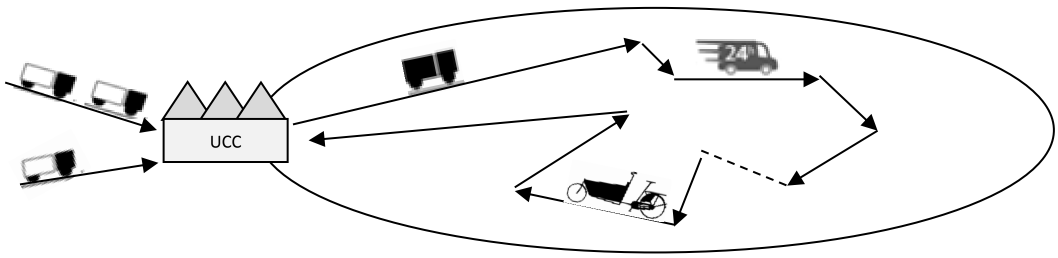
This type of services, which have been operating in many large cities for some years now, often use vans/LCVs. During the first half of the twentieth century, almost every profession made use of cargo cycles which were specially designed to carry the tools of their trade. These were both commercially available models as well as self-adapted vehicles. Based on the market analysis, current Belgian employment in this market size lies between 1 and 10 FTE.

UCC partners

Some Western-European cities and/or private parties invested in UCCs. These set up warehouses at the outskirts of the city with the aim of delivering freight to the urban area from different logistics companies and shippers, in a consolidated way. Transhipment takes place from less-than-full trucks originating from outside the city, towards full trucks for the last mile. This last mile transport is seen as a service to the receivers in the city core as well as to the distributing companies. Furthermore, these warehouses can offer added logistics such as labelling, repacking or cross-docking. Reverse logistics is taken into account.

For example Binnenstadsservice.nl has developed several branches in the Netherlands and City Depot initiated UCCs in Hasselt and 9 other Belgian cities. The first developed into Goederenhubs.nl, and the second was taken over by bpost in 2015.

Figure 29: Service structure of the last mile within an urban area with an UCC



As depicted in Figure 29 above, from the UCC a fully loaded truck can leave to the inner city, limiting the number of moves in the city, lowering the transport cost as well as the related pollution. The concept of bike couriers fits here as well. Bike couriers are able to take the smaller packages, meeting the previously-defined freight characteristics (small, low weight, time pressure) and distribute them as little ants in the city towards the final destination.

Gig-economy

The real boom of cargo cyclists in urban Europe started less than five years ago as a result of two changes: the rapid development and accessibility of the app-based economy, and the flexibilisation of labour markets. This new market was labeled On Demand Delivery (ODD) or Crowd Logistics.

The ODD market results of a delivery concept which has been implemented since late 2014 by new start-up companies like Deliveroo, UberEATS, Take Eat Easy and Foodora. E-shoppers can order products using apps on their smartphones, and receive their orders at home in less than two hours. These goods, often food, are predominantly delivered by couriers using their own bicycles or by exception by cars.

These companies are using their technological platform and for the services, they rely on an extended network of independent delivery couriers. By using these services, local retailers can establish home deliveries to serve their urban customers without developing their own technological platforms and logistics solutions. Couriers can find a job via installing the app. In general, they provide their own vehicle and smartphone.

Based on the market analysis, current Belgian employment in this market size lies above 100 FTE, of which many work part-time as self-employed couriers.

III. Offered transport services - characteristics

As almost all Belgian bike couriers work on a city scale, price structures are quite similar. Research of the current offer shows that differentiation is mostly made on three characteristics of the shipment: speed, distance and weight. The characteristics are shaped in matrixes, to define prices. The table below shows price discrimination by the mentioned cycle couriers on the three parameters. The line below gives extra information on the tariff details.

- Available prices depend on delivery speed and volume. On average, these go from about 5 up to 30 EUR per parcel delivery.
- Some couriers also offer companies to collect mail and bring these to the postal office. However, these services do not belong to their core business.
- Price differentiation exists on speed and distance and based on geographical zones. Limitations on package size are based on size or on weight

Table 31: Service structure, criteria for tariff differentiation by Belgian bike couriers

	Criteria for tariff differentiation		
Bike courier	**Speed/time**	**Distance**	**Weight**
Vi-tes fietskoerier (Leuven)	x	x	x
	<u>Criteria for price differentiation:</u> Weight: standard price up to 10 kg, otherwise surcharge of 2 EUR on standard tariffs. Above 20 kg, extra surcharge of 1.5 EUR per 10 kg excess weight. Service areas: Prices for inner city Leuven, outside Leuven, Belgium Time : Delivery within 45, 90, 180 minutes, today, 24h or 48h Tariffs: Start at 5 EUR for urban delivery within 48h		
De Fietskoerier (Antwerp)	x	x	No
	Weight : Not restricted, but clearly aims for light goods (courier type), size 30 x 40 x 10 cm. Time: Within 1 (express) or within 3 hours (standard) Service areas: Prices for inner city Antwerp and 4 more zones Tariffs: Start at 9 EUR for urban delivery within 3h - up to 26 EUR for zone 5 (and 32 EUR for zone 5 Express = within one hour) Express: standard price + 6 EUR		
New Custom Service (Brussels)	x	x	x
	Weight : Maximum 2 kg Service areas: Brussels postal codes : 1000 - 1210 - 1030 - 1040 - 1050 – 1060 No further price details published		
Pedal BXL (Brussels)	x	x	x
	Regular and bullitt cargo bikes: maximum 250 kg. The classical bike has volume restrictions of 35 x 45 x 20 cm (and max 5 kg). Service areas: Several regions in Brussel (5) Time: Exclusive = within 1 hour, Green = within 3 hours.		
Dioxyde de gambettes (GO2) (Brussels)	No	x	x
	Service areas: Four distance categories, all 19 communities of Brussels. Nine weight categories (maximum 80 kg) A 3 EUR surcharge for same day service		
Ecopostale (Brussels)	x	x	x
	Ecopostale picks up and delivers at integrators, their larger volume brings discounts Tariffs not public.		
Cargo velo (Ghent)	x	x	x
	Service areas: Ghent and surroundings Services: courier, CEP, heavy load Tariffs: from 6 EUR for 10 kg in Ghent. Surcharge for heavy shipments		

Le coursier Wallon	x	x	x
	Services: express, parcel, heavy load Tariffs not public. Advertising opportunity on the bicycles is offered		
Via velo (Deinze)	x	x	x
	Service areas: four Tariffs: start at 6 EUR for max 10 kg and max 20 x 20 x 40 cm. -10% when ordering 10 deliveries. Maximum 150 kg. Offers advertising for 180 EUR per month.		
Bubble Post	x	x	x
	Prices start between 5 and 8 EUR per delivery. The cargo bikes can handle at maximum 300 kg or 2 m³. Parcels max. 30 kg, and max 170 cm combined length, depth, and height. Fast expansion from Ghent to Antwerp, Brussels and further abroad.		

Source: Company websites and direct contact with cargo bicycle company owners (update October 2017)

IV. Innovations

IT is the driver for efficient urban deliveries. Handhelds, track-and-trace and routing software was mentioned in the round table and interviews to be critical for success. In the end, making all contacts by phone makes the work inefficient. When volumes increase, the chance of making mistakes could increase equally. Customer service then will need professionalization. At the round table, an interest in electric scooters or electric vans was expressed by one courier, but criticized by others. Batteries used to power the vehicles would not be environmentally friendly enough for their market. In the meanwhile, many have bought electrically assisted cargo bikes. These are not electric vehicles, but given the payload weight up to 250 kg, the small battery gives the necessary boost in the first meters.

A sector-wide logo to stress sustainability, and so to convince companies to use non-petrol powered transport in an urban context was proposed. This could prove useful in communication with customers. Ecopostale and Bubble Post shows on invoices the emission difference between bike transport and fuel-powered transport. Frequent Ecopostale customers can register on the website to see their avoided emissions. Others, e.g. Bubble post, developed their own IT platform for urban deliveries. This platform allows customer contact, track and trace, vehicle routing optimisation and CO_2 calculation.

Regarding investments in rolling stock most indicated at the round table to further invest in bikes. There the real difference in the courier and Post & CEP markets is seen. Some invest in new lightweight cargo bikes that can carry up to 250 kg without losing the advantages of biking in the city. E.g. Ecopostale uses 'Cyclocargo', a French cargo bicycle. Others, like Pedal BXL, Cargo velo, Via velo, Vi-tes invested in so-called Bullitt Cargo bikes of the Danish manufacturer Larry vs. Harry.

V. Financials

One conclusion that can definitely be made is that the Belgian market for these services is very small. The couriers together employ between 20 and 50 FTEs, the Post & CEP companies between some 50 - 150 and the gig-economy between some 100 - 200 FTEs.

A turnover figure (roughly calculated) of the couriers and Post & CEP markets would be some five certainly less than 10 million EUR. An average annual estimation for the active companies, employing roughly 125 full-time equivalent (FTE) bike couriers delivering on average 5 to 50 packages a day at an average shipment tariff of 10 EUR.

Maybe, some addition should be made for the round trips made for one customer (for example posting flyers locally for a new business). These may add a small amount to the turnover, but not a great number, as tariffs are low.

Data on the turnover in the gig-economy is not public. Looking at the number of Deliveroo and UberEATS couriers in Belgian cities, they have created a large new market. The experience of Take Eat Easy revealed though that they are likely not profitable.

If these *guesstimations* are compared to the overall courier market in Belgium, the turnover numbers are negligible. The market - sector 53.200[89] completed with UPU bpost (only the parcel division) covers 10,082 companies providing courier services. These were in 2016 adding up to a total turnover of roughly 2.1 bn. EUR (Belfirst, 2017). As shown in Table 30, the Top-15 CEP service providers represent together a 2016 turnover of 1,64 bn. EUR.

It is noticeable that the employees directly on the payroll are very low. For example 'Post NL' has only 61 FTEs. According to Belfirst (2017), the total courier market is concentrated. The Top-15 companies (ranked on turnover) jointly represent over three-quarter of the market, while the top-3 represents already 50.43% of total turnover.

Table 32: Belgian courier market – Top 14 + bpost's parcel division (2016)

Name	Number of employees	Turnover 1,000 EUR	Market share in Top 15	Cummulative market share Top 15	Last available year	Mother company name
Bpost (parcel division)	n.a.	379,400	23,2%	23,2%	2016	n.a.
United parcel service Belgium	676	251,469	15,3%	38,51%	2016	United Parcel Service inc.
Federal Express Europe inc & co	412	195,414	11,9%	50,43%	2016	Fedex corp.
DHL international	644	193,878	11,8%	62,27%	2016	Deutsche Post AG
TNT Express Bel.	584	184,350	11,3%	73,52%	2015	Fedex corp.
DPD (belgium)	316	114,848	7,0%	80,53%	2016	France

[89] NACE activity code in Belgium for 'Other postal and courier activities'

G3 worldwide (belgium)	66	57,580	3,5%	84,04%	2016	n.a.
Nippon express (belgium)	94	39,696	2,4%	86,46%	2016	Nippon express co ltd
PostNL pakketten belgie	61	39,672	2,4%	88,89%	2016	PostNL N.V.
DHL parcel (speedpack)	106	36,005	2,2%	91,08%	2016	Deutsche Post AG
Bdd nv	n.a.	32,916	2,0%	93,09%	2016	Fentener van Vlissingen family
Dupuis logistic services	39	31,355	1,9%	95,01%	2016	Stichting cultuur en gezin
World Courier Belgium	36	30,256	1,8%	96,85%	2016	W C international ltd.
UPS scs (belgium)	95	26,562	1,6%	98,47%	2016	United Parcel Service inc
Dematra	66	24,996	1,5%	100,00%	2016	El cazador
TOTAL	**3,206**	**1,638,397**				

Source: Belfirst (2017) activity code 53.200 'Other postal and courier activities' + bpost's parcel division

According to the bike couriers themselves, their product is hardly known in Belgium. The market is therefore relatively small, but shows potential for growth. Table 33 on the next page shows data, for so far available of the bicycle couriers who incorporated their activities.

Many did not report financial details. The bigger companies, 'Ecopostale' and 'Bubble post' published their accounts until 2015. The first showed very negative results. The year 2014 was closed with an operational loss of - 128,974 EUR. In 2016, activities were suspended and the company was declared bankrupt on 21st of March 2016. Then, new 'ECOPOSTALE' was founded taking over the delivery activities. The accounts of 'Bubble post' show a similar pattern. In 2013, operational loss accumulated to - 152,969 EUR. This further worsened until - 2,382,465 EUR in 2015.

Smaller couriers are or not incorporated, or lack public data on their accounts. 'De Fietskoerier' in Antwerp made minor losses in 2014 and 2015, but made profit of 3,849 EUR in 2016. 'Fast bike Delivery' was only incorporated in 2014 and made a minor loss in the first year (-527 EUR in 2015), and a larger loss in 2016 (- 10,441 EUR).

The gig-economy players made considerable losses, - 1,004,029 EUR for 'Parcify' in 2015, and - 4,079,825 EUR for 'Deliveroo' in 2016.

'Max Mobiel' is a larger company, where courier was only a small part of the turnover. The profit is not representative for the cargo bicycle activities, which were only a small share of total turnover. These activities were stopped last year.

Table 33: Financial details Belgian bicycle courier market – 2013/2014/2015/2016

			Total of balance				Own equity				Profit / loss on exploitation			
Commercial name	Started	Stopped	2013	2014	2015	2016	2013	2014	2015	2016	2013	2014	2015	2016
De fietskoerier	10/01/2008		16 965	14 965	8 790	16 051	909	7 328	2 340	6 189	274	-1 525	-4 988	3 849
Ecopostale	22/06/2010	21/03/2016	128 122	67 884			-188 966	-317 047			-63 926	-128 974		
ECOPOSTALE	11/05/2016													
Viavelo	5/01/2015													
De Fietskoerier	1/04/2015													
Vi-tes fietskoerier	21/12/2014													
Cargo Vélo	14/07/2017													
Bubble Post	13/04/2016		321 189	773 921	1 866 869		11 223	277 358	159 307		-152 969	-333 776	-2 382 465	
Fietskoerier Kortrijk	18/11/2013	16/11/2016												
OOvelo	30/06/2015													
Parcify	24/08/2015				1 149 830				1 050 965				-1 004 029	
Max Mobiel	15/01/2007		1 273 596	1 308 947	1 367 415	1 690 400	809 268	709 708	754 550	1 122 005	661 997	678 214	697 600	969 805
NCS	28/02/1991		880 154	773 157	751 867	697 818	320 203	383 255	322 738	322 902	1 090	198	2 535	19 714
Flits Koerierdienst	30/03/2009		372 654	398 533	397 831		20 589	-3 837	-17 171		-30 107	-13 334	-24 426	
Dioxyde de Gambettes	29/06/2015				45 114				22 816				-1 384	
Coursier Wallon	31/01/2017													
Fast Bike Delivery	21/11/2014				14 543	2 675			11 873	1 431			-527	-10 441
Transpire transport	1/07/2014													
Cycloxpress	6/10/2014													
Fietskoerier Roeselare	5/05/2014	1/04/2017												
Deliveroo	9/07/2015					2 718 848				-4 226 040				-4 079 825

Source: Kruispuntbank ondernemingen and National Bank of Belgium, 2017

Empty cells = no data available

2.5.2. SWOT Belgian bicycle courier services market

This section analyses the strengths, weaknesses, opportunities and threats based on own research: a round table discussion with Belgian bicycle courier services, a survey in the Belgian market, individual contacts with bicycle couriers and internet search on their websites.

Table 34: SWOT analysis of the bicycle freight market

S	W
- Bicycle transport is environment-friendly (little emissions, noise etc.) - In a congested urban environment cycles are as fast or faster than trucks - The impact on the streets is less - The same volume of packages generates more employment	- The market is not professionally developed - Companies are small and cannot handle bigger volumes (yet) - The start-up companies are undercapitalized - The volume for the companies is not stable - The bicycle transport companies do not have a Flemish or Belgian association, making it difficult to address the market by among others policy makers - Idealistic bicycle couriers have limited experience in negotiating with logistics companies - Safety of a bicycle driver is perceived to be lower than for truck drivers
O	**T**
- The use of bicycle couriers employs more people for the same market - The awareness of sustainable transport among shippers grows - Congestion on the road increases - Cities in Belgium and the EU have an increased interest in cycle policies - The bicycle couriers have a good image regarding fast and sustainable transport - Logistics last mile operators often have set sustainability criteria themselves - Bicycles do not need to pay for parking - Bicycles easily find parking - The rising fossil fuel prices bring an advantage for non-fuel using modes - Public and policy support is high - Cheap labour via app-based models	- The market prices for bike transport nowadays are not always competitive - The bike transport market is not professionally developed - The market players need financial stability to be able to grow - The image of the market regarding their level of professionalization is not good - The cost per delivered item needs to be competitive with traditional transport by Light commercial Vehicle (LCV) or truck. These work at lower tariffs - The app-based market works with (false) self-employed employees

Source: Own composition

Many important advantages exist: no fossil fuels are needed to power the vehicles, therefore it is a very sustainable transport mode. The limited dimensions make it a vehicle that is easy to steer in narrow urban centres. Nevertheless, it has a limited loading capacity, which might increase cost. The mode employs more people per volume of parcels, making it a socially advantageous mode on the one hand, however making it an expensive option.

Because of the identified strengths and opportunities, the following section of this chapter will investigate in-depth some development paths for the nearby and far distant future. These are at first bike couriers operating with volumes in the city, as can be called the traditional cycle courier activities. Second, the relation to city hubs is discussed. As last the most interesting path of integration within the logistics industry is developed.

Limited (business/social) economic research on the Belgian bicycle freight transport was made. The empirical research resulted in some conclusions on the market. Freight transport by bicycle is unknown and the market is therefore small. Several bicycle entrepreneurs have set up a company on a micro scale. All perform transport activities in urban areas, only some work with larger volumes. Most stick to the traditional A-B transport, characterised by the bicycle back-pack combination. However, many believe that growth can be achieved as traditional truck transport for urban purposes is criticised and costs are increasing due to urban road congestion and fuel price increase. Therefore, research on this development is worthwhile.

Is an integration into the worldwide logistics network even possible? The individual companies highlight that bike couriers are hardly connected to the global network. Most operate on a small regional or city scale and pick-up and deliveries are limited to one city. One is operating at an international scale but has 89% of its volume at a city level. For this company, 10% of packages are sent nationally, only 1 % is international in nature.

The bicycle couriers are strong in delivering freight, meeting three characteristics: the freight is being packed in small parcels, has a limited weight and is to be delivered under time pressure. Furthermore, the freight is originating from the city or is coming from the last-mile operations from (inter)national shipments. The strengths do have extra advantage in dense congested areas.

The answer to the question whether Flemish and Brussels' bike couriers are cooperating in the operations of internationally organized integrators like DHL, FedEx, TNT Express, etc. is negative. Although some hand over packages to have them dispatched internationally, except for the larger bicycle couriers like Ecopostale, Bubble post and Pedal BXL, real co-operation does not feature. The bike courier thus is one of the many daily customers of the bigger logistics companies. As the awareness among possible customers, and the general public, about the product 'bike delivery' is limited, this market therefore currently seems to be small.

Furthermore, it is particular that only UPS directly self-employs multiple cycle couriers. If cycling couriers are used in the last mile operations, these services are sourced in from the smaller independent cycling couriers.

2.5.3. Defining a representative business case for cargo bicycle transport

This section, defines a realistic business case for applying a SCBA analysis. The biggest market identified in the round table, and in the literature overview is the CEP market.

- ✓ The Top-15 of Belgian CEP couriers + bpost's parcel division jointly have a turnover of 1.64 bn. EUR (Belfirst, 2017).
- ✓ E-commerce sales are rising, parcel demand in urban areas grows. The parcel volumes in Belgian grew by 24.3% between 2013 and 2015, reaching a 6% share in total mail volumes nonetheless contributing to 40% of the total mail revenue (BIPT, 2017).
- ✓ 79% of Belgian e-shoppers usually choose to be delivered at home (DPD, 2016).
- ✓ In 2015, an average Belgian ordered 12.4 parcels per year, a strong increase from 8.1 in 2010 and 9.8 in 2013 (ERGP, 2016; BIPT, 2017).

The business case developed in this dissertation therefore aims at a close cooperation between cargo bicycles and the globally organised logistics sector, earlier defined in Figure 28 on page 115 as the Post & CEP market segment.

This business case makes a bridge for cargo cyclists to other more *traditional* last mile logistics services. Is it viable to integrate bicycle services with for example globally active integrators? There seems to exist a cultural gap between the two worlds, so negotiations and co-operations between the two modes are rare. An increasing growth in volume at an affordable tariff could be a step towards the real professionalization of bike freight transport services. It was said by the entrepreneurs that for bike couriers, extra volumes add up to the income without increasing operational costs considerably. This was stated by the entrepreneurs individually; their statements will be checked in Chapter 4 with a business case simulation.

The empirical results give insight in the current market. Current bicycle messenger services in Belgium are working in the high-end market with tariffs and services of the mass till medium market. Speediness and reliability is offered. Track-and-trace technology, high security levels and an international service network is lacking. A match between these worlds seems possible, but not straightforward as shown by Ecopostale and TNT Express who went their ways after the Mobile Depot pilot test. Efforts are necessary (Ecopostale, 2010 and Gevaers et al, 2012).

Cooperation with the globally organized logistics sector is where the short term growth for bicycle freight transport can be found.

First step: only difficult urban locations can be outsourced. Locations that can be reached only with great difficulties by LCVs can be handed over to the bike transport. Here, one can think of zones in the urban area where traffic congestion arises more than on average. In addition, zones where no parking space is available are interesting. Savings are possible: on parking fines, fuel and time. This is a market fit for cargo bicycles.

Time-sensitive deliveries can be outsourced to bike couriers. The hours where urgent deliveries take place are conflicting with the peak periods on the road network. The advantage of bike couriers can be maximized. This is a market for the real backpack couriers, less for the cargo bicycles.

A **second** step: part of the volume with destinations located in the central business district is sorted out for the bike courier. The bike courier can be responsible for the pick-up as well as the deliveries. This is possible if integrators adapt the sorting system. This is a market fit for cargo bicycles.

Offering green transport options is a niche market. In several ways, integrators and other logistics companies offer an optional surcharge for green transport already. Then the surcharge paid by the customer is invested in compensation systems (offsetting emissions). But they could consider to really deliver in a more sustainable way too. By transporting with a bike courier a green option can be provided.

3. Research methodology

The preceding two chapters introduced the rationale to research cargo bicycles chapters. The problem analysis of a likely decreasing urban liveability as a result of negative impacts of freight transport activities, along with the likely positive effects of alternative urban freight transport solutions (both identified in Chapter 2), gave a first insight in the effects that need to be taken into account when evaluating urban transport innovations.

The literature overview lead to four research questions, regarding the impact of cargo bicycles and their impact on the economic/environmental/societal liveability of urban areas.

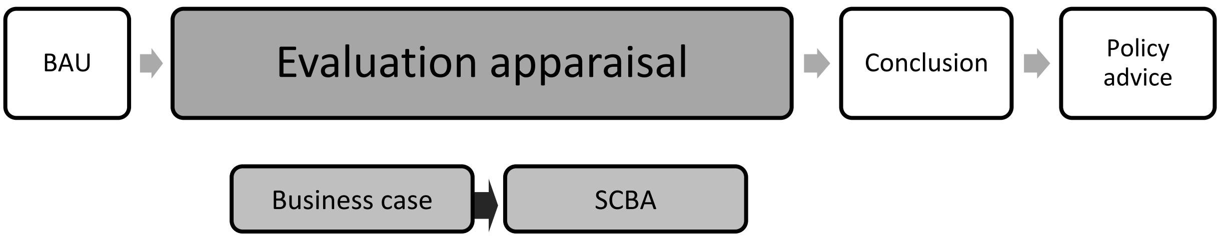
To make sound conclusions on urban freight transport innovations, a consistent evaluation method structuring the evaluation and making the results of different evaluations comparable is needed.

In the second chapter, an overview of the Belgian cargo bicycle marker was presented. The market consists currently of six segments, of which 'Post & CEP' was concluded to be the most chanceful to further mature. The research questions indicated the need to evaluate not only business but also welfare-economic impact. The use of cargo bicycles in this market segment will therefore be analysed on its economic benefits in Chapter 4, and on its welfare economic impact in Chapter 5. This chapter develops the methodological framework and impact analysis steps.

The chapter's first section (3.1) outline the research framework and methodology. The second section (3.2) makes conclusions on practical implications and looks frontward to Chapter 4.

The evaluation is split into four main parts, of which part two is split into two sub-analysis steps. The structure is presented in Figure 30 below.

Figure 30: Evaluation framework for urban freight transport innovations (Chapter 3)



Main steps are:

(i) In order to acquire a clear impression on the benefits of an alternative transport solution, one first needs a good description of the solution, and the present circumstances, for defining its likely impact, concerned players etc.. This first step of the analysis is named: mapping the **Business As Usual** (BAU) situation.

(ii) The second step is focused on the **evaluation appraisal** itself. It first sets up a business case, which is the research framework for analysing the economic effects of implementing a project. The second step within the evaluation is expanding the pure business-economic view towards a societal evaluation. This 'social cost benefit analysis' methodology and its rehabilitation can be seen as the centre of the political debate, which is having the last decade more interest in social-environmental impacts of policies. To take into account these impacts, policy makers and academics often want effects of policies to be quantified in ex-ante or pre-feasibility studies.

(iii) The appraisal's third step ends with the **conclusions**. These are framed within a STEEP analysis. Different stakeholder groups will be regarded in the conclusions.

(iv) Last, this framework will be translated into a research-based policy advice.

3.1. Getting insight in problem analysis and Business As Usual

This subsection develops the methodology to map the current situation, meaning the circumstances in which the project is implemented. This first step is not only referring to the current state, but also takes account of existing trends. Will the freight transport sector grow/decline? Which average growth can one estimate without implementing the project?

First, there is a need to map the current sectorial behaviour, or the baseline scenario. Here, a challenge arises as researchers and policy makers have little data on the operations of freight vehicles in urban areas. And for estimating the current behaviour, data (e.g. on costs, prices, volumes and operational characteristics etc.) is needed.

Different data collection methods exist: e.g. surveys, traffic counting and camera observation. These were developed years ago, but are still applied rather limitedly throughout Europe. According to Balm (2014), Allen, Ambrosini et al (2014), EC (2013a), Macário (2012b) and BESTUFS (2006) the data gaps on European (urban) freight transport are still substantial.

Already in 2001, Newton (2001) indicated the urgent need for better data collection on urban freight transport. Allen & Browne (2008) confirmed this need later on, plus added that operational data is to a large extent only available at company level, and due to confidentiality concerns hardly shared with the urban freight transport research community.

Both Ambrosini & Routhier (2004) and Crainic, Ricciardi & Storchi (2004) expressed their concerns on good survey techniques in urban freight data collection appraisals as well as on data comparability between cities and certainly between countries, as the definition of urban freight transport differs significantly from country to country. Allan, Ambrosini et al (2014) reconfirmed this limited comparability of data. So, Allen and Browne (2008) and Allan, Ambrosini et al (2014) concluded that quite often local mobility surveys are undertaken, but indicated a general too narrow focus area and general low representativeness.

Researches like Dablanc (2009) then referred to the option of modelling urban road freight operations based on hypotheses and narrowed down data collection methods. This possibility was explored in France by LET (Laboratoire d'Economie des Transports) at the University of Lyon via developing their FRETURB[90] model.

But new technologies offer opportunities for data collection. Cherrett et al (2012) suggested to many cities having road traffic counting infrastructure (like counting loops in the road lanes and/or via camera's), to use this infrastructure as a basis of developing road freight transport models.

Gonzales-Feliu and Pluvinet et al (2013) and LET (2000), proposed a GPS-based data collection method for urban freight route characterization using a smartphone application. The application of those GPS-based techniques to urban freight transport is less extended that on people (mainly car) transport but is tested on usability (for example McCabe, Roorda et al, 2008; and Greaves and Figliozzi, 2008). GPS data collection is a challenging field in urban goods movement and can give access to important information with a lower cost, but the use should still be developed to reach maturity (Gonzales-Feliu, Pluvinet et al, 2013).

It are mainly European and Japanese researchers who developed urban freight data collection methods: traffic surveys, research projects and experimental deployments were seen from the 1980's on. In the beginning, researchers relied solely on surveys. This approach was however time- and money-consuming, still it gave insight in urban freight logistics (showing low load factors of urban freight vehicles and a high number of empty trips) (Coopers and Lybrand, 1991; Ambrosini and Routhier, 2004; Patier-Marqué, 2001 and Dablanc 2007).

In the **Japanese** research community, the focus is more on theoretical vehicle routing research. These researchers (e.g. Taniguchi, Thompson, Russell, Yamada but also Van Duin, 2008 and 2013; Pillac, Gendreau, Guéret and Medaglia, 2011) deal with operations research including or not including time slots, dynamic flows, terminal location models and models combining vehicle routing and Intelligent Transport Systems (ITS) (Thompson and Taniguchi, 2003; Ambrosini and Routhier, 2004). This theoretical approach is not developed enough for transferring the knowledge to urban freight transport to cargo bicycles nor does it have direct applicability yet to Western-European historic cities.

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[90] The FRETURB software (V3) is constructed by LET for analysing urban freight transport behaviour and is based on surveys. First, it was focused on estimating the road capacity occupation of urban freight vehicles. Secondly, it was used to simulate the evolution of this occupancy.

European research papers better fit the scope of the research dealt with in this dissertation. In France, research projects on data collection are mainly set up in Paris and Lyon, as a result of the National Governmental Programme *marchandises en ville*[91]. Other, mainly smaller, **French** cities joined European research projects like Civitas[92]. So, joined La Rochelle in the electric LCV transport project ELCIDIS (2002-2005) and the French city of Nantes set up a project to improve the local freight regulation (CIVITAS MOBILIS, 2005-2009). This way, both cities got insight in the urban freight transport operations in their area. As a result, researchers Patier et al (2008, 2009) and Dablanc (2009) devoted many of their publications on French data collection.

According to the OECD (2003), **Italian** urban goods transport consumed more than 7% of the total energy consumption by the transport sector. LDVs, counting for 40% of the total vkm's, are utilized for less than 30% of their capacity. In Rome, where the city centre only accounts for 1.1% of the entire urban area, it accounts for 33% of the freight regardless policies on night deliveries and incentives like using low emission vehicles. Road space occupied by freight vehicles is over 20%. In Italy, Nuzzolo et al (2012) mapped urban freight transport behaviour in Rome.

In **The Netherlands**, cities are expected to do a quick scan of their urban freight transport when implementing a LEZ[93] (Maes, Sys, Vanelslander, 2011). Locally, data exists, based on surveys and traffic counts. However, Vleugel (2006) expressed at the time concerns over the representativeness of traffic counting as freight vehicles are mixed with other road user categories (for example LCVs and large passenger vehicles).

To implement LEZ's in the Netherlands, a quick scan on urban freight movements was demanded. As such, the implementation of policies was based on data collection. The interest to urban distribution policies grew, as such the national level installed an 'ambassador urban logistics' (NVVP, 2002). This ambassordarship stopped, but was recently followed by Green Deal Zes (Zero Emission Stadslgistiek), a cooperation and dissemination network of almost 100 dutch companies aiming at CO_2 free city logistics by 2030.

In **Belgium**, insight from cities in the local distribution is limited. Antwerp commissioned a study in 2012. No results are publicly available. Ghent and Hasselt joined the D-via research programme, mapping urban freight transport rules in both cities. For Ghent, surveys were conducted to get a view on the logistics activities (D-via, 2011). These results are not published

[91] A '93 French national research plan on urban freight, focusing on data collection.

[92] Civitas is a European initiative where cities are at the core. The initiative is run by cities and was launched in 2002 to redefine transport measures and policies in order to create cleaner, better transport in cities.

[93] A LEZ was defined by Maes, Sys, Vanelslander (2011) as a geographical zone where for reasons of liveability local governments, preferably within a national framework, put in place a restrictive policy on road transport users with the goal of limiting road transport's negative impact within this zone (for example emissions and noise).

publically as well. De Langhe et al (2012) researched, in close cooperation with the Flemish Association of Cities and Communities (VVSG), the willingness of local authorities to collect data. A stunning 90% indicated not to reserve resources for data collection on urban freight transport, while indicating the need for data for supporting policy decisions (De Langhe et al, 2012).

Despite all the good recent developments regarding urban freight data collection, the collected data often makes no distinction between the flows of delivery trucks, palletized transport, mail services and for example express couriers. Nor does it give insight in the routing and loading degrees. If further research would be undertaken, a categorisation of freight vehicle types would provide extra information. Still, it will be difficult to differentiate. The LCVs can be driving into the city with numerous purposes. The 'standard white' delivery LCV can transport parcels, building materials, hospital supplies, and many other commodities. To filter out express services based on just the type of vehicle is extremely difficult.

Data collection is often locally steered, so even if some cities in a region take action to get insight in the urban freight transport in the region, methodologies between cities or even countries do not match. Moreover, the surveys are irregular or very time-specific, making it difficult to draw historical analyses and projections (Heuer, 2003; OECD, 2003; Dablanc, 2009). Based on this literature review, it can be concluded that urban freight represents 10 to 15% of vehicle equivalent kms travelled in city streets and 2 to 5 % of the employed urban workforce. But a city is not only a location to receive goods, but is also an origin of shipping goods. So, apparently 20 to 25% of all truck-km in urban areas are outgoing freight, while 40 to 50% is incoming freight. The rest (25 - 40%) originates from and is delivered within the city (the short mile) (BESTUFS, 2006; Ogden, 1992; LET, 2000; Figliozzi, 2007). Comparability between studies and cities is very difficult due to methodological differences.

In the research of BESTUFS (2006), Ogden (1992), LET (2000), Figliozzi (2007) and Macário (2012), it was indicated already a little on the volumes that an urban area on average generates and attracts. However, the volumes differ locally from country to country, region to region and city to city. Therefore, other methods are necessary.

- Urban freight data collection is undertaken in Europe and Japan, less in the US;
- Data collection methods are numerous but many methods are time-consuming;
- Data collection results have an absence of comparability.

Despite the critique on data collection on urban freight transport, Dablanc (2009) saw encouraging changes in the research field. Governments, especially in Europe, have set up major programs to provide a set of statistics and impact assessments. Data at operational level will certainly be available at the freight transport companies, however does not find its way to decision makers at cities, regions or countries, mainly due to their contractual and hence confidential character.

3.1.1. Listing pros and cons of diverse data collection techniques

Different methods, four types in total, can be distinguished to collect data on a specific market. This section gives an overview of the collection methods.

The first one is the grass roots method. This method starts collecting information from the street, where loading and unloading activities take place.

In the grass roots method, shippers and receivers are interviewed on their use of logistics services via surveys. Estimates on frequencies, volumes, prices and lead times can be asked. However, they might not be known or shared by the interviewee. Data collection in surveys can ask for shipper/receiver data, trip data, vehicle data, tour details and freight volumes (Holguin-Veras and Jaller, 2013). Most data is to be collected from scratch.

PRO: The method gives real insight in the flows. Extra information on local situations and behaviour is obtained. By smartly choosing one submarket of the urban freight transport, interviews can deliver good data regarding the volumes and prices within that sub-sector.

CONTRA: This is a time-consuming method asking for manpower, therefore demands an extensive budget. Only a small share of the market can be surveyed.

Via physically counting the vehicles on certain points on the urban road network, the number of used freight vehicles in one urban area can be roughly estimated.

PRO: The method gives insight in the number of vehicles at one point or entering a certain well-defined zone.

CONTRA: This is a time consuming method. Only a small share of the market and/or city region can be surveyed.

Based on data availability of certain sectors like for example households, offices, retail (for example supermarkets, fashion, electronics and other) and pharmacists, an estimation on the freight attraction and generation can be made. When then looking at the share these activities in the city represent, a fictitious number of freight vehicle trips can be obtained (Gevaers, Maes, Sys, Vanelslander, 2012).

PRO: The method gives insight in the number of vehicles at one point or zone. When the sub-market is defined well, good insight is gained into one market.

CONTRA: This is a time-intense method. Only a small share of the market can be surveyed.

A second data collection method is based on technology use. Cameras can be used to scan vehicles on the urban road network. Via intelligent ANPR (Number plate reading camera's) camera's trucks and vans can be scanned when passing a certain point in the road network.

PRO: The system then tells something about the number of vehicles and route.

CONTRA: The method is not giving insight in the route and content of the vehicles. The camera based bounces often on privacy issues. The infrastructure to set up the data collection is highly expensive.

A third kind of intelligent method is using smart phone and/or track and trace data. Vehicle drivers can be equipped with this tracking technology. By collecting data on the basis of individual vehicles, insight is gained on routes and delivery/pick up behaviour.

PRO: If the driver matches the delivery/pick up points with freight data (number of parcels and characteristics of parcels), the researcher has detailed insight in a (small) share of the market.

CONTRA: This method says a lot more than the method of counting (physically or automatically) vehicles but requires cooperation of the vehicle drivers and logistics companies. The equipment to set up the data collection is highly expensive.

A fourth and last method is to obtain data via industry, e.g. via the numerous large logistics companies. The market of delivering parcels in urban areas is highly consolidated. When combining the data of companies like TNT, DHL, UPS and FedEX, one would have a great idea of the volumes, routes and commercial tariffs. Though private data of these companies is also a small share of total logistics on Europe's road network. Nevertheless, these data will not be openly available not even when the data of one region or city is asked to the companies mentioned above. Therefore, this method is not feasible.

All these four methods can be used when drafting an urban freight transport profile of one city or urban area. All have advantages and disadvantages. These were briefly mentioned by the pros and cons.

For the current research, the first approach, using surveys and interviews, can be used relatively easily. The other approaches require a considerable investment in infrastructure and/or vehicle tracking equipment and technologies. This investment budget is not found within this Doctoral research. But the first method has an additional disadvantage of being time consuming, but delivers some insight in the shipped volumes and prices. Therefore, this method is chosen frequently, habitually combined with interviewing or a survey. Hitherto, limited research projects published data on transport costs and - volumes.

When data is not publicly available, or difficult to collect, researchers work with proxies, indicators and scenarios for freight transport demand. When these scenarios are combined with price elasticities of the demand, a representative demand curve can be constructed without obtaining all the detailed data. This was already concluded by discussing Boardman et al's Option 1 in the introduction of this section. This approach of estimating the demand curve, is discussed in the next section.

3.1.2. Data collection leads to estimating the urban freight demand curve(s)

The data collection methods could lead to a transparent market overview (prices, volumes, elasticities etc.). The analysis of these data collection methodologies however gave already the limits of the methodologies. Therefore, researchers should often rely on estimates of demand curves, based on incomplete data or on indicators.

According to Boardman et al (2001), one has three possible situations to estimate the demand curve of a specific market.

- The **first** situation occurs when the researcher knows one point on the demand curve. Then the researcher can rely on former research on the matter which defined the elasticity of the slope of the demand curve for that product.
- In the **second** situation, a few points of the demand curve are known by the researcher. These points can then be used to find a concrete point of relevance for the evaluation of for example a policy measure.
- The **third**, and last possibility, is the easiest one of the three. This situation occurs when a sufficient number of observations are known by the researcher, so that the demand function is easily obtainable. In this third situation, prices and quantities are transparently available. The researcher has sufficient reliable data on the current market behaviour.

Based on section 3.1.1., the absence of reliable/comparable research data on urban freight transport places researchers likely in the first situation. But before jumping to conclusions, all three options and how to deal with the demand curve estimation in every option, are briefly discussed below.

I. First, what if demand elasticities and one point on the demand curve are combined?

For the first possibility ,only one point of the demand curve is needed. For the research of chapter 4 it is clear that different urban freight transport 'markets' and different 'demand curves' can be distinguished.

The market of urban freight transport is first divided in a 'freight' and 'parcel/postal' market. The real freight market, with for example palletised flows, is not falling into the scope of the bicycle transport market and is therefore not further looked at.

Boardman et al's option 1 gave a clue on the outcomes of extensive research on urban freight transport price sensitivities. Condition 2 of the first situation proposed by Boardman et al (2001) is fulfilled. Literature like Robinson (2006) and Estupiñan and Rene (2011) has a history on estimating the elasticities for these services. But the first condition, the need of one point on the demand curve (price and quantity of actual urban freight transport in one city or region), is not really fulfilled. Data is lacking, but these indicators give guidance.

II. Second, what if a few points of the demand curves are known?

This option proposed by Boardman et al (2010) is for the research in chapter 4 not applicable as option 1 already bounced on the second condition, the lack of data on the actual demand curve for urban freight transport services. Not even a few points are known. Option 1 is preferred above option 2.

If a few points of the demand curve would be known, the researcher does not need elasticities from the literature to construct the demand curve. The researcher can draw a straight line through these points. Comparing the elasticity of this self-drawn curve with literature results can however increase the credibility of the results.

III. Third, what if an adequate number of observations are known?

This third option proposed by Boardman et al (2010) is for the research in chapter 4 not applicable as Option 1 and 2 already bounced on a lack of data on the actual demand curve for urban freight transport services. To conclude, option 1 is the preferably option out of the If many points are known, the curve drawn by the researchers will be more credible than the one of situation 2, where linearity is used to simplify the framework. A situation with abundantly available data on one specific market would be the best of the three to be in, for a researcher.

Data collection. Conclusions and way forward

In short, current prices and volumes in the urban freight transport sector are not openly shared by the major express operators nor by smaller companies, both by reason of confidentiality.

Second, data is locally differentiated and differentiated to different markets (for example the express, day+1 and economy shipments have very different market characteristics). This implies that just using published data from the market players is not always possible, although preferable. As such, academic estimates found in literature should be consulted to identify current volumes, prices and price elasticities.

Result, as there is a lack of reliable data on Belgian urban freight transport, the use of indicators retrieved in literature is currently the second best, but sensible option left to acquire a realistic idea on volumes and prices in the urban freight transport sector. The evaluation step will therefore take account of conclusions in academic literature first rather than building data collection methods and will complement these by conducting field research to a certain extent.

A few academic papers on urban freight data collection give insight in indicators: the number of freight vehicles per city are linked to economic and demographic parameters. Although researched for specific regions and specific situations (BESTUFS, 2006; Ogden, 1992; LET, 2000; Figliozzi, 2007), indicators on urban freight estimates converge. The papers are representative on the freight demand in cities in developed countries.

Thus, according to BESTUFS (2005), Ogden (1992), LET (2000), Figliozzi (2007), TURBLOG (2011) and Macário (2012) a city generates:

- 0.1 deliveries or pick-ups per inhabitant per day;
- 1 delivery or pick-up per job per week;
- 300 to 400 truck trips per 1.000 people per day;
- 30 to 50 tons of demand for goods per person per year.

And urban freight represents (Turblog, 2011):

- 10 – 15% of vehicle equivalent miles travelled in city streets;
- 2 - 5% of the employed workforce;
- 3 - 5% of the urban land is devoted to freight transport and logistics.

These indicators are originating from studies on urban freight transport in Paris and were compared later with findings by other European researchers (for example BESTUFS (2005), Ogden (1992), LET (2000), Figliozzi (2007) and Macário (2012)). Despite, the limited comparability of scattered urban freight data, as already noted by Macário (2013)[94], indicators converged.

Projecting the findings of BESTUFS (2005), Ogden (1992), LET (2000), Figliozzi (2007) and Macário (2012) on Belgian cities gives an idea on the number of freight movements and pick-ups/deliveries without local surveys. These indicators are used in relation to local demographic and economic data.

The estimates will be cross-checked with current CEP data. The proxies were established me years ago. And since then there was a strong increase of transport of e-commerce goods towards the final consumer’s address. In general, parcel volumes in Belgian grew by 24.3% between 2013 and 2015. In 2015, an average Belgian ordered 12.4 parcels per year, a strong increase from 8.1 in 2010 and 9.8 in 2013. In 2010, demand was only 8.1 on average (ERGP, 2016; BIPT, 2015, Comeos, 2017 and BIPT, 2017).

[94] The figures presented in this research were as well compiled from different individual sources: Rodrigue (2006), Stantchev and Whiteing (2006), START (2008), Visser van Binsbergen, and Nemoto (1999), BESTUFS (2008), BESTUFS (2002), ECOTEC et al (2007), FHA (2009) and TURBLOG (2011).

These proxies will be used as demand estimates for the base year 2016. The base year 2016 is a starting point. The scope will be extended to a 25 years period.

3.2. Evaluation appraisal

The insight gained via the data collection methods discussed in section 3.1 will be used as the methodological basis for comparing urban freight supply chain changes with.

According to Turcksin et al (2011), today five commonly used methods of evaluating transport projects are used. All can reconcile tangible and intangible criteria and can take into account different conflicting objectives. Besides the (social) cost benefit analysis, they defined the private investment analysis (PIA), the cost effectiveness analysis (CEA), the economic effects analysis (EEA) and the multi-criteria analysis (MCA). For this, an MCA and certainly a MAMCA[95] analysis becomes useful. One of major value of a MAMCA analysis is that it is allowing researchers to analyse alternatives and to rank these on different weighted criteria, for different stakeholders (Nijkamp et al, 1990; Turcksin et al, 2011). The MAMCA has already proven its applicability on several transport-related decision problems. The method has a three-step approach in which different alternatives are defined; criteria are sets by which the alternatives are ranked (Taniguchi, 2003).

Thomson and Hassal (2005) and the TIDE[96] project highlighted the weaker points of multi-criteria techniques. The correct specification or derivation of weighing factors is a large challenge. Numerous approaches are used, but there is no generally accepted preferred method. In the evaluation methodology of this dissertation, it is not the goal to assign these weights. For this, in-depth research is needed consulting stakeholders and consulting them on preferences and sensitivities. It is believed that the MAMCA results of Balma, Macharis, Milan and Quack (2014), based on extensive research, identified correctly the stakeholder types for the further analysis. These are: LSPs, freight shippers, local authorities, freight receivers and citizens. The conclusions will feed into the STEEP framework.

This section builds further on the theoretical as-is situation, and deals with the core methodology of the evaluation framework, consisting out of two research phases: the business case (in section 3.2.1.) and the SCBA (in section 3.2.3.).

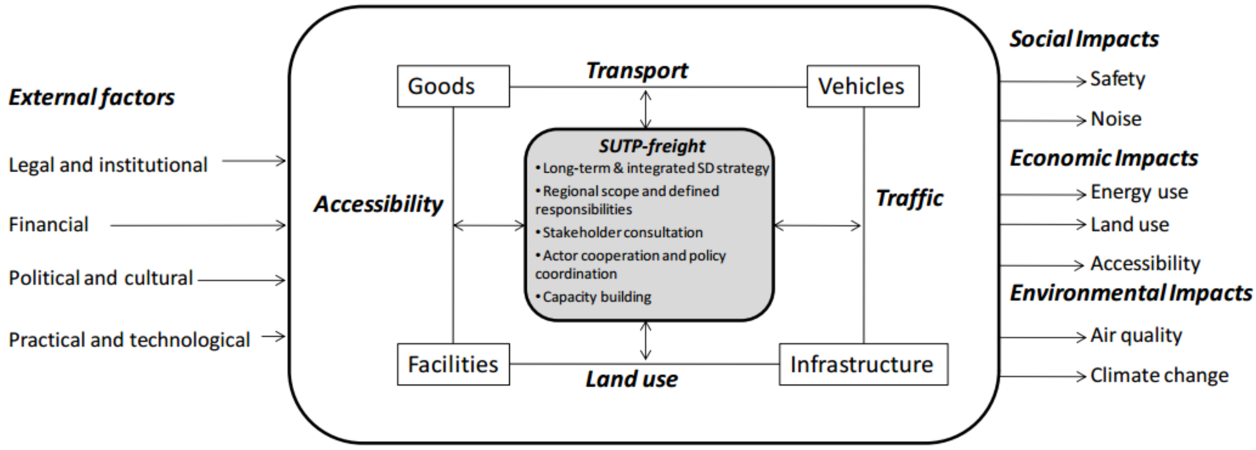
[95] Abbreviating Multi-Actor Multi-Criteria Analysis

[96] TIDE (Transport Innovation Deployment in Europe) was an EU funded project (7th framework programme) on 'Methodologies for cost-benefit and impact analyses in urban transport innovation'.

3.2.1. Business case

Research of Lindholm and Behrends (2012), shown in Figure 31 below, gives transparency on the sustainable urban freight transport market. The figure, originally created by Sjöstedt in 1996 then amended by Lindholm and Behrends (2012), gives a great understanding of the complexity of urban transport, urban logistics, scarce urban infrastructure capacity and moreover adds a link to land-use aspects. This system-oriented framework serves for defining the business characteristics and the SCBA.

Figure 31: The relationship between factors affecting Sustainable Urban Transport



Source: Lindholm, Behrends, 2012

The general framework of sustainable urban freight transport operations is according to both Sjöstedt (1996) and Lindholm and Behrends (2012) consisting of four basic elements: the facilities where the economic activities take place, goods that demand transport to and from these facilities, vehicles that provide transport services and infrastructure. Moreover, these elements do interact in four different subsystems: accessibility, land use, transport and traffic. The performance of the transport system in general is influenced by these subsystems which are influenced on their specific parameters separately. A change in the urban transport sector will as such result in a change in one of the four basic elements (facilities, goods, vehicle and infrastructure) and additionally on one of the subsystems.

Accessibility of the goods and vehicles to the facilities is key to make the (sustainable) transport system work efficiently. Therefore the facilities (e.g. warehouses and terminals) are mainly found on strategic locations, often in the vicinity of commercial centres and transport infrastructures. Land-use is a crucial factor for the accessibility of the transport infrastructure and is defining the location of these facilities. The traffic system should be matching the demand for goods movement to and from the facilities by the transport services, if not congestion arises. These physical movements of goods and vehicles via infrastructures and facilities are happening on physical networks, but need steering via external impacts (legal and institutional; political and cultural) (Sjöstedt, 1996; Lindholm, Behrends, 2012).

The negative impacts of urban freight transport are mainly perceived on the streets, the infrastructure, but are according to the research of Lindholm and Behrends (2012) resulting from the inefficiently sub-optimal organized interaction of the four subsystems. Therefore, the researchers advised to solve urban freight transport's inefficiencies by focusing on all elements, not on one specific element.

> "*Integration is at the core of any promising approach aiming at reducing the impacts and achieving a sustainable urban freight transport system".* (Lindholm and Behrends, 2012)

The analysis in this dissertation will focus specifically on the transport effects, logistics effects and the operations. Others, like the *land use* aspect of urban freight transport or the effects on *facilities*, are regarded as of little importance. Maybe in the long run, or for specific cases (like the analysis of UCCs), it can be of value to include their adaptation costs and effects in the analysis. In the short run, urban freight transport's impact on land use is largely limited to loading and unloading activities. And furthermore, the warehousing activities do take a distance from the urban core (Dablanc, 2007; Rakotonarivo, 2010). Including these effects will have limited impact on the conclusions, while it makes calculations unnecessarily complicated.

Hence, the main factors of urban freight transport are:

- I. Vehicles and goods.

For efficient operations, these need:

- II. Infrastructure and facilities.

In addition these are under external influence of following aspects:

- Legal and institutional-,
- Financial-,
- Political and cultural- and
- Practical and technological aspects.

A good organization of all these parameters will result in social-, economic- and environmental impacts. After identifying the urban freight transport aspects, indicators/parameters need to be identified per aspect. First vehicles and goods are discussed. Then also the aspects of infrastructure and facilities are touched upon.

3.2.2. Vehicles and goods

To estimate the transport costs of a certain transport system, regardless of the vehicle type deployed, one can distinguish two main types of parameters: time and distance costs.

I. Time costs

Time costs are accruing quite simply with the passing of time. These accumulate even if the vehicle is standing idle, during loading and unloading and in case of congestion. The total transport costs are often heavily related to the amount of time staff is working, as working hours represent a significant percentage in the total cost structure. Distance costs are superimposed on time costs. These arise when the vehicle is moving, not when standing still. (Blauwens et al, 2016)

Time costs are as well-related to wages of staff and the insurance premium for vehicles. These accrue even when standing still. They are as well-related to fixed costs which automatically should be met in order to maintain a certain capacity. These include for example the rent of storage space, rent of garages and as well general administrative costs (Blauwens et al, 2016).

II. Distance costs

Distance costs will include fuel use, to power vehicles, which varies according to the covered distance. Furthermore, regular maintenance costs, mileage allowance to staff, fines, damages and liabilities are depending largely on distance (Blauwens et al, 2012).

Litman and Doherty (2009) gave a clear overview of the different cost parameters, shown in the next table. These of the vehicle's business case are internal (the first two rows). The parameters are depending or time (T), distance (D), time & distance (T+D) or Volumes (V).

Table 35: Vehicle cost parameters; basis for the appraisal

	Variable	**Fixed**
Internal vehicle cost parameters	Fuel (T+D) (LCV only) Short term parking (T) (LCV only) Maintenance (T+D) (LCV and Bike) User time & stress (T+D) (LCV and Bike) Crash risk (D) (LCV and Bike)	Vehicle purchase Vehicle registration Insurance Long-term parking Vehicle maintenance (LCV and Bike)
Internal operational cost parameters	Labour (T) (LCV and Bike) Track-trace software (V) (LCV and Bike) Personnel insurance (T) (LCV and Bike)	Start-up costs IT system Website Advertisement Office costs Office insurance (LCV and Bike)
External vehicle and operational cost parameters	Road maintenance (wear and tear)(T+D) Traffic services (T+D) Insurance disbursements (T) Congestion (T) Noise costs (D) Environmental impacts (emissions and climate change) (D) Uncompensated crash risk (i.e. accident costs) (D)	Road construction Subsidized parking Traffic planning Street lightning Land use impacts Social inequity

Source: Based on Litman and Doherty, 2009

Blauwens et al (2016) further identified costs not really fitting the strict division defined above. First, some are not really time- and/or distance-related. These tolls include port dues, crew expenses and others. Second, some are by nature both time- ánd distance- related, for example depreciation costs. These can be fully attributed to time costs, or can be split between time and distance costs. A method more difficult to calculate is to link the depreciation costs with the vehicle replacement policy of the company. The replacement policy can be linked to time or to kms or both. Depreciation as well heavily depends on the resale value of the vehicles.

With these parameters, the business case will construct estimates for Total Transport Costs (TTC), Average Transport Costs (ATC) and Marginal Transport Costs (MTC). The table shows the applicability of these costs categories on LCV and Bike transport.

Logistics parameters

'Transport costs in logistic chains' are a separate academic research subject. Not only the vehicle transport costs are vital (time and/or distance correlated costs), but also service criteria mind (these are partly quantitative, but also qualitative in nature). Especially in mode choice decisions, these can be of large influence for the final decision to opt for unimodal road transport or multimodal transport. Decision criteria are used to opt for a certain supply chain.

Many different decision criteria were identified in research: cost/price/rate, lead-time performance, loss and damage, flexibility, infrastructure availability and capacity, regulation/legislation, controllability/traceability, social/environmental considerations, etc. (Blauwens et al, 2010). Not all of these decision criteria can be expressed in monetary terms. But, using a decision framework with various parameters offers the opportunity to sketch the magnitude of the costs/benefits of a certain supply chain.

The transport time and distance costs link to logistics inventory costs. When transport services become more reliable and faster, inventory costs of the shippers reduce (Baumol and Vinod, 1970; Blauwens et al 2016) developed a model including four logistics characteristics: transportation costs, loading capacity, average lead time and variance of lead time.

Moreover, the supply chains have six additional parameters: annual volume, average daily demand, variance in daily demand, value of the goods, holding cost and the service level required by the receiver.

Table 36: Parameters for the calculation of total logistics costs

Goods flow parameters		Transport mode parameters	
Annual volume (units)	R	Transportation costs (/unit)	TC
Average daily demand (units/day)	D	Loading capacity (units)	Q
Variance of daily demand (units²/day)	d	Average lead-time (days)	L
Value of the goods (EUR/unit)	v	Variance of lead-time (days²)	l
Holding costs (% per year)	h		
Safety factor	K		

Source: Blauwens et al, 2006

Based on these parameters Blauwens et al (2016) calculated the Total Logistics Costs (TLC) as follows:

$$\mathrm{TLC} = \mathrm{TC} + \left(\frac{1}{R} \times \frac{Q}{2} \times v \times h\right) + \left(L \times v \times \frac{h}{365}\right) + \left(\frac{1}{R} \times v \times h \times K \times \sqrt{(L \times d) + (D^2 \times l)}\right)$$

The TLC is consisting of the Transportation Costs (TC), being referred to as the out of pocket costs for the shipper. Then, adding the cycle stock, inventory in transit and the speed and reliability of the transport mode expands these to the scope of logistics costs (Blauwens et al, 2006).

In the application, only the first and last mile will be regarded. Therefore, the applicability of the TLC is low. Value of time, reliability and safety can be included in the appraisal via indicators. These are detailed in the next section.

Value of time and reliability

The majority of the costs like vehicle operating costs, investment costs etc., will be valued in monetary terms. The better parameters are valued, the more reliable the S(CBA) will be. The valuation must be consistent, which leads to a big challenge because many other aspects like the value of time (VOT) and safety-related aspects are only indirectly valued in monetary terms. In principle, all dimensions can be covered by the users' WTP (Blauwens et al, 2016) or by the account-based approaches where one identifies the direct, time-dependent costs associated with transport production factors (for example the driver costs and fuels) (Tavasszy, 2008).

Two forms of unexpected delays exist (Ritsema et al, 2004). On the one hand, there is the daily variability affecting travel time for trips undertaken at the same time each day. One can plan these delays. On the other hand there are the occasional, catastrophic delays as a result of incidents. Unexpected delays in freight transport may according to De Jong, Kouwenhoven et al (2009) lead to:

- Greater than expected decline in the value of the goods (especially important for perishable goods) and capital tied up in the goods longer than anticipated;
- Missed connections at transhipment points;
- Waiting time for staff at the receiving end, or even missing out on the delivery window and having to deliver again at the next delivery interval;
- Missed opportunities for applying JiT (Just-in-Time) to physical distribution, production (delays leading to disruption of the production process, because of unavailability of critical inputs), and the management of stocks (a more reliable transport system can make it possible to reduce inventories and use fewer warehouses and distribution centres).

Values of reliability are often derived from Stated Preference (SP) models via which reliability is defined as the standard deviation of transport time distribution (Significance et al, 2012). The variation between studies is vast (Tavasszy, 2008). Therefore, and give the CEP market works with same-day deliveries and not with express demands, the value of time is equal for LCV and bike transport.

Most literature is devoted to travel time in road transport (Mackie and Nellthorp, 2001). A specific distinction is made for travel in working/leisure and freight travel time. For *working time,* the labour market approach comes handy, as this market is directly giving values to the researcher (an approach is the gross wage). For *leisure time*, values are different. Both stated preference and revealed preference methods have been used for obtaining values for travel choice situations; including route and mode choice. The VOT is influenced by among others income, socio-economic characteristics, journey purpose, length etc. (Blauwens et al, 2016; Mackie and Nellthorp, 2001; Wardman, 1998).

A consortium of Significance (De Jong et al), VU University (Koster et al), John Bates, TNO (Tavassy et al), Nea, TNS NIPO and PanelClix (2012), approached by the Dutch Ministry of Infrastructure & environment, provide recent values of time and travel time reliability (variability) for passenger and freight transport by mode to be used in cost-benefit analysis (CBA) of transport projects. Questionnaires have been designed for interviewing travellers, shippers and carriers. Freight transport stakeholders were asked to trade[97] between waiting times (for a lock or bridge or to be loaded or unloaded at a quay), reliability of these waiting times and the total transport costs.

The research resulted in Dutch values of time and values of reliability for freight transport. Carriers are in the best position to give the VOT that is related to the costs of providing transport services. If the transport time decreased, vehicles and staff would be released for other transports, so there would be vehicle and labour cost savings. Shippers which contract out are most interested in another VOT: the VOT that is related to the goods themselves. This

[97] So, estimates were derived via Stated Preference methods

includes the interest costs on the capital invested in the goods during the transport time. Shippers with own account transport can give information on both the VOT that is related to the costs of providing transport services and the VOT that is related to the goods themselves. Data is shown in Table 37 below.

Table 37: Values of time and reliability road freight transport (EUR/h per vehicle, 2010 price level)

	Value of time	Value of reliability
Container	**(2 - 40t truck)**	**(2 - 40t truck)**
	59	4
Non-container	**(2 - 15t truck)**	**(2 - 15t truck)**
	23	34
	(15 - 40t truck)	**(15 - 40t truck)**
	44	6
	(all non-container)	**(all non-container)**
	37	15
All	**(20 - 40t truck)**	**(20 - 40t truck)**
	38	14

Source: Significance, VU University et al, 2012

Values differ for container and non-container transport and differ significantly for different vehicle loads. On average, the value of time was set at 38 EUR per vehicle per hour, while the value for smaller trucks (below 15t) is significantly lower with 23 EUR per vehicle hour. The value of reliability is estimated at on average 14 EUR per vehicle per hour, while the small trucks there have an upward differing value of 34 EUR per vehicle hour (Significance, VU University et al, 2012).

Value of safety

Regarding the *value of safety,* changes took place from the mid-80's. Since then, monetary values derived from the WTP to avoid accidents were used. Before, the values were more based on the monetary values of lost output - the average reduction in GDP per loss of an individual worker -. Sometimes "human costs" of grief or pain were added. The newer theory was set out by Jones-Lee (1992). Recently, Ricardo-AEA, updated the cost of human fatalities. These are in the EU on average 1.9 mil. EUR per fatality.

Other costs related to casualties like material damage, insurance costs, legal issues and costs of fire and police interventions can be high compared to the casualty costs. Especially with light accidents, these are disproportional (Mackie and Nellthorp, 2001). Recent data from Ricardo-AEA (2014) was already touched upon in Chapter 2.

Last mile cost function including impacts of new technologies

In 2010, research by Gevaers (2013) resulted in an extended and updated costs function for estimating last mile transport costs. The cost function, shaped on the literature of Blauwens et al (2010), was expanded with impacts of new consumer buying patterns and new technologies such as parcel boxes, dynamic ordering and track-and-trace equipment. A new aspect in this cost function is the aspect of not-at-home deliveries (a delivery attempt, when the consumer is not at home). These are mainly encountered at the B2C market and might increase logistics costs significantly.

The logistics costs function of Gevaers (2013) includes aside time and distance costs, newer aspects like :

- STOP = average number of stops (addresses) per delivery route per driver / day;
- Q, the average number of products per parcel;
- SHF, extra handling costs like e.g. insurance;
- W, the time window coefficient;
- R, the reverse logistics coefficient;
- Cp, collection point coefficient;
- p, the pooling of parcels coefficient;
- …

III. Infrastructure and facilities

Ultimately, when actually implementing a change in urban supply chains, *investment costs* occur. These are derived from need to reengineer or redesign supply chains, requiring investments in infrastructure and facilities. In urban logistics, the use of infrastructure is often uni-modal and road transport-based.

Multi-modal urban logistics concepts, as discussed in chapter 2, are less likely to be competitive to the current state of affairs. Nevertheless, transhipment might become necessary when consolidating smaller volumes of freight, even for urban transport. Then, an urban transhipment platform might be needed for consolidating freight at the city boundaries, as such optimizing the long haul transport and transhipping shipments to urban vehicles (e.g. EV or cargo bicycles).

In order to allow cargo bicycle transport to flourish within the global logistics networks, the services need a transhipment platform located in the vicinity of the urban core . As such the cargo bicycles can fully play their role on the short distance while the long distance can be optimised as well.

3.2.3. Social cost benefit analysis (SCBA)

The social impacts of urban freight transport gained importance, as the general public awareness for their negative effects increased (Lindblom, Behrens, 2012; Maes, Sys, 2013). In order to develop comprehensive policies on new transport solutions, integrating external costs in the simulation will add value to the policy makers' decisions. This indicates the need to expand the former *business case* evaluation (section 3.2.1.) to a *social cost benefit analysis* (SCBA), as it will not only take account of the individual entrepreneur's costs and benefits, but also of the impact on society. This section discusses the second aspect of the appraisal, as shown in Figure 30. The theoretical basis for the evaluation methodology of urban freight innovation has already been developed (Tsamboulas & Kapros 2003; Patier & Browne 2010) but needs to be tailored to this research topic.

As deepened out in Chapter 2, the main external costs in freight transport can be categorised in: congestion, emissions, infrastructure wear & tear and accident costs. Next to these main categories, noise-, up- and downstream effects and climate change impacts exist. Research estimated a major external cost increase in urban areas. The local tail-pipe emissions are causing higher external costs due to the high density of activities and people in the urban area. Also, vehicles in urban areas emit much more per km, certainly in rush hours. Aside these costs, value of time aspects and impacts on supply chain reliability will be added.

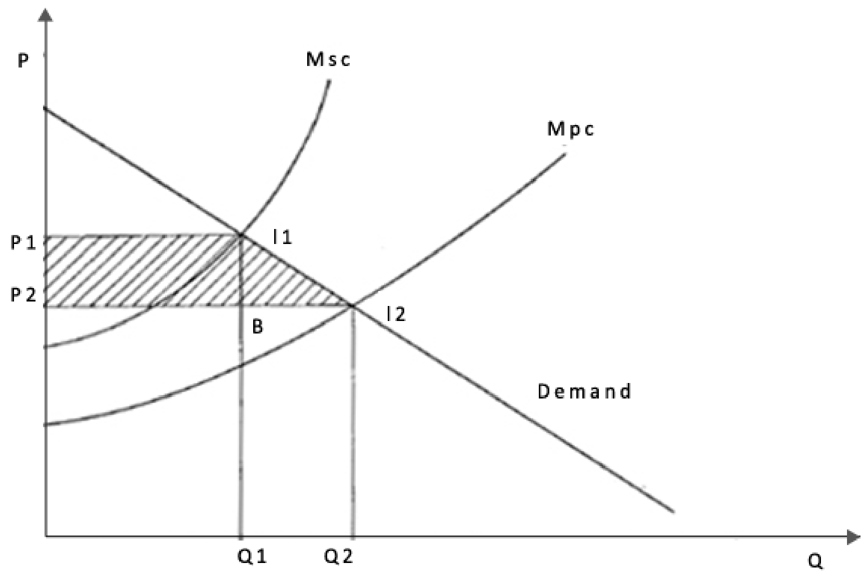
Internalising these into the business case will lead to the social cost estimates: Social Total Transport Costs (STTC), Social Average Transport Costs (SATC) and Social Marginal Transport Costs (SMTC). The latter are obtained when taking the derivative from the Total Social Cost. These are most important as these will become the basis for defining the market's supply curve. The Marginal Transport Costs can be split into the Marginal private costs (Mpc) and the Marginal social costs (Msc).

After estimating the supply curve (i.e. the long run Marginal Transport Cost curve) and the Demand curve, a Cost Benefit Analysis can be commenced. The costs and benefits of a new solution are scattered among the stakeholders. It is important to define the stakeholder types benefiting, or contrary, seeing their costs rise with the implementation of a supply chain/policy change. (Balm et al, 2014)

The Marginal private costs graph is situated below the one of Marginal social costs, as shown in the drawing in Figure 32. The Marginal cost curves serve as the supply curve for the market. Also the Demand curve is shown, characterized by a decreasing slope. The slopes should be estimated within an appraisal for revealing the consumer surplus effects.

Research of among others Jones (1977), Blauwens (1986), Blauwens (1988), Mackie and Nellthorp (2001) and the TIDE project stated that for a variety of considerations, cost benefit analysis is a suitable methodology for evaluating freight transport impacts as it allows including external costs in one framework.

Figure 32: Marginal private and marginal social transport cost framework



Source: Based on Blauwens, Van de Voorde, 1986

A cost benefit analysis is the specific branch of an appraisal. Appraisal is the generic term for the process of weighing up the impacts, positive and negative, of a project or policy action, so as to inform the decision makers. Key characteristics are that the analysis is conducted from an overall societal viewpoint rather than that of any particular stakeholder/agent, and different to the MAMCA[98] (Turcksin et al, 2011; Mackie and Nellthorp, 2001). These researchers clearly advocate that the effects, when relevant, need to be quantified/monetised where feasible and valid.

Key features of an SCBA are:

(i) It is a process undertaken from a social perspective, considering **all relevant costs and benefits for all stakeholders.** Practical reasons for including certain effects can lie at the basis for the level of detail.

(ii) It takes individuals' willingness-to-pay (WTP) as the starting point for the monetisation. The **monetary valuation of effects** being the result of negative externalities is not a straightforward procedure since many of the effects have no market value. Here, a key difference is seen between the cost-benefit analysis and other types of appraisal like MAMCA. Whereas the latter hold back from monetary valuation, cost benefit approaches rely on individual values and preferences. Values for time, safety and environmental impacts are implicit markets or based on revealed-preference and stated-preference research methods, as discussed above on page 148 (e.g. Louviere et al, 2000).

[98] Main difference is that this technique uses monetary values, applies weights and values to various impacts when being relevant for the decision process.

(iii) A correction from pure **WTP** values, for social reasons, is possible in a cost benefit analysis. This way, income differences can be included.

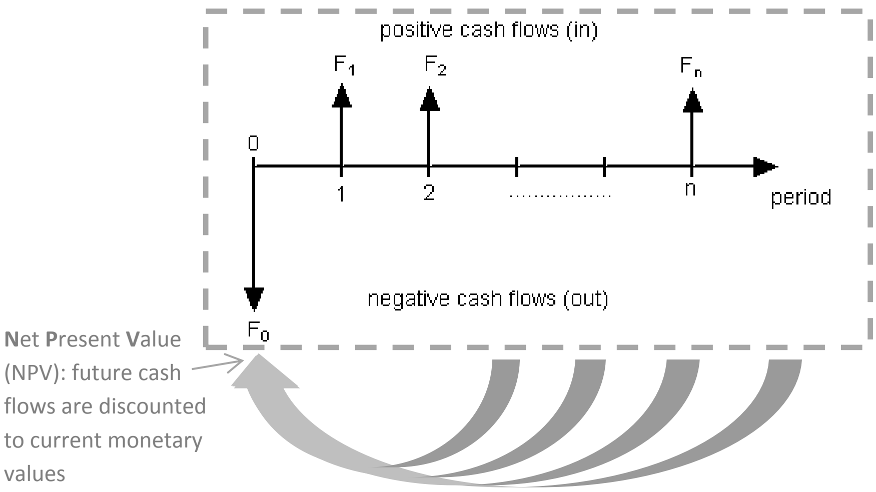
(iv) The evaluation can take place in a **consistent** manner. This means that prices and values must be consistent throughout the **appraisal** and all benefits and costs need to be valued either at market prices or at factor costs. Market prices are gross, **factor costs are net of indirect taxes.** The more usual approach has been to use the factor costs basis, however the developments of public-private partnerships tend to favour market price use.

(v) One of the **strengths** and at the same moment weaknesses of CBA is the **monetisation of the effects**. Some effects are only fairly quantifiable, leaving the researcher with effects and impacts that are qualitative in nature. The different levels of detail in various CBA appraisals make conclusions less comparable. Some studies go for an extensive quantification, while others develop a quick-scan CBA leaving various impacts un-quantified, or estimated via proxies.

(vi) The procedure involves summing up **benefits and costs over a longer time period**, as projects have a life cycle. So in different points of time, effects can be expected. A social **discount rate** is regularly necessary, especially for projects having a very long life span (road, rail or port investments), irreversible issues (habitat, biodiversity etc.) or accumulating effects (like global warming or acid rain). Some feature in transport sector applications[99] (Mackie and Nellthorp, 2001; Segalou et al, 2003). In the case of urban freight transport, long-run costs have to be taken account of in the case of for example multimodal solutions and urban transhipment platforms (warehouses etc.).

The next figure illustrates the cash flow of a project, where in the first period a negative cash flow is generated (investments in new vehicles for examples), which in their turn result in income (transport services) and savings (les fuel use of new vehicle compared to old ones).

Figure 33: Cash flow in cost benefit analysis and Net Present Value



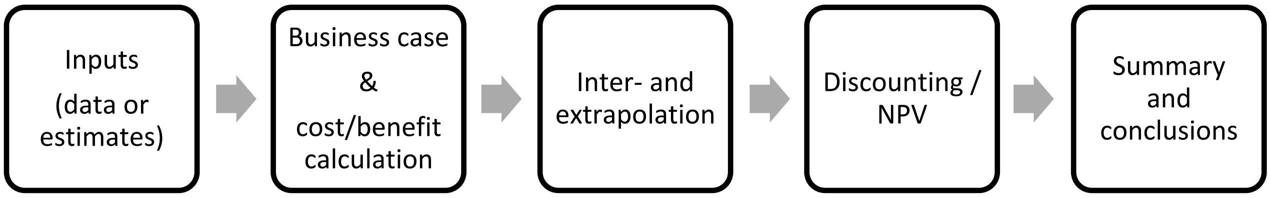
[99] (i) till (vi) are all found in transport appraisals, and will become useful in the upcoming analysis.

IV. SCBA applied to urban freight transport

The method of SCBA was already applied in different settings. This section explains the practical approach distilled from the literature and adapts the approach to the urban freight transport research setting.

The main steps in the process are shown in the Figure 34. It goes from an as-is situation, listing the current situation, while approaching changes in a quantitative way. The data for each parameter will be based on Belgian (business) costs & external cost indicators.

Figure 34: Main steps in a (social) cost benefit analysis appraisal



The summary of all steps usually ends with the calculation of the net present value (NPV), where the benefits, investments and costs in year *t*, are calculated with a social discount rate *r*, for *n* years. As in the industry, the available capital often is limited, the projects with the highest rank on the benefit/cost ratio should be prioritized. Policy makers do value other parameters more than others: e.g. social impacts. It is to the researcher to evaluate these objectively; as Florio (2006) and Mackie, Nellthorp (2001) suggested. The presentation of the results can be shown briefly by the NPV and benefit/cost ratio.

The next two chapters will assess the impact on liveability in urban areas of increased cargo bicycle transport via the (S)CBA methodology.

As noted in Chapter 2, it is not possible to make definitive comments about the data collection strategy one needs when studying urban freight transport. These will vary depending on the issues concerned, the planning and policy framework in which the issue is researched, and the availability of previously collected data. In the current literature, several authors have investigated the methods used for collecting data (Ambrosini and Routhier, 2004; Dasburg and Schoemaker, 2006; Browne et al, 2007; BESTUFS, 2008; Allen and Browne, 2008; Holguín Veras and Jaller, 2012). Only a few of them have investigated the transferability of their results (Browne et al, 2007).

In ‘98, the Dutch Ministry of Transport, Public Works and Water Management, installed a commission for developing and specifying a shared approach for ex-ante transport infrastructure investments (Eijgenraam et al, 2000). The method was baptized the ‘OEEI’ methodology (Onderzoeksprogramma Economische Effecten Infrastructuur). The cost-benefit analysis was used as the proper evaluation method as the commission argued that investments by governments should be evaluated from a welfare economics point of view

(O'Connel, 1982). However, being with a large rate of success of use in infrastructure investment decision processes, the technique is able to deliver support to local governments and municipalities as well. Van Duin et al (2008) saw this potential and started adapting this methodology for large infrastructure projects to make it useful for the evaluation of freight problems in smaller cities. Their research focused on urban distribution centres. Effects on stakeholders were the main focus. CBA is a method coming from the infrastructure field. However, research is exploring evaluation possibilities of operational concepts more and more. Following the OEEI example in The Netherlands, in Flanders, Rebel Consulting was awarded by the Flemish Government a study for defining guidance on CBA parameter values.

V. Concrete SCBA steps in this dissertation (iii)

The appraisal itself starts with defining the research topic, its scope and the needed research questions. Here also identifying the stakeholders is undertaken. The steps are shown below and will be used in chapter 4.

i) Inputs from transport data collection, analysis and forecasting

Step I consists of researching the current situation, sketching context. Moreover, an analysis is made of the availability of data, which is then used to forecast future volumes for urban freight transport. This appraisal starts with a case study approach (discussed in 3.1).

ii) The user and societal benefit estimation

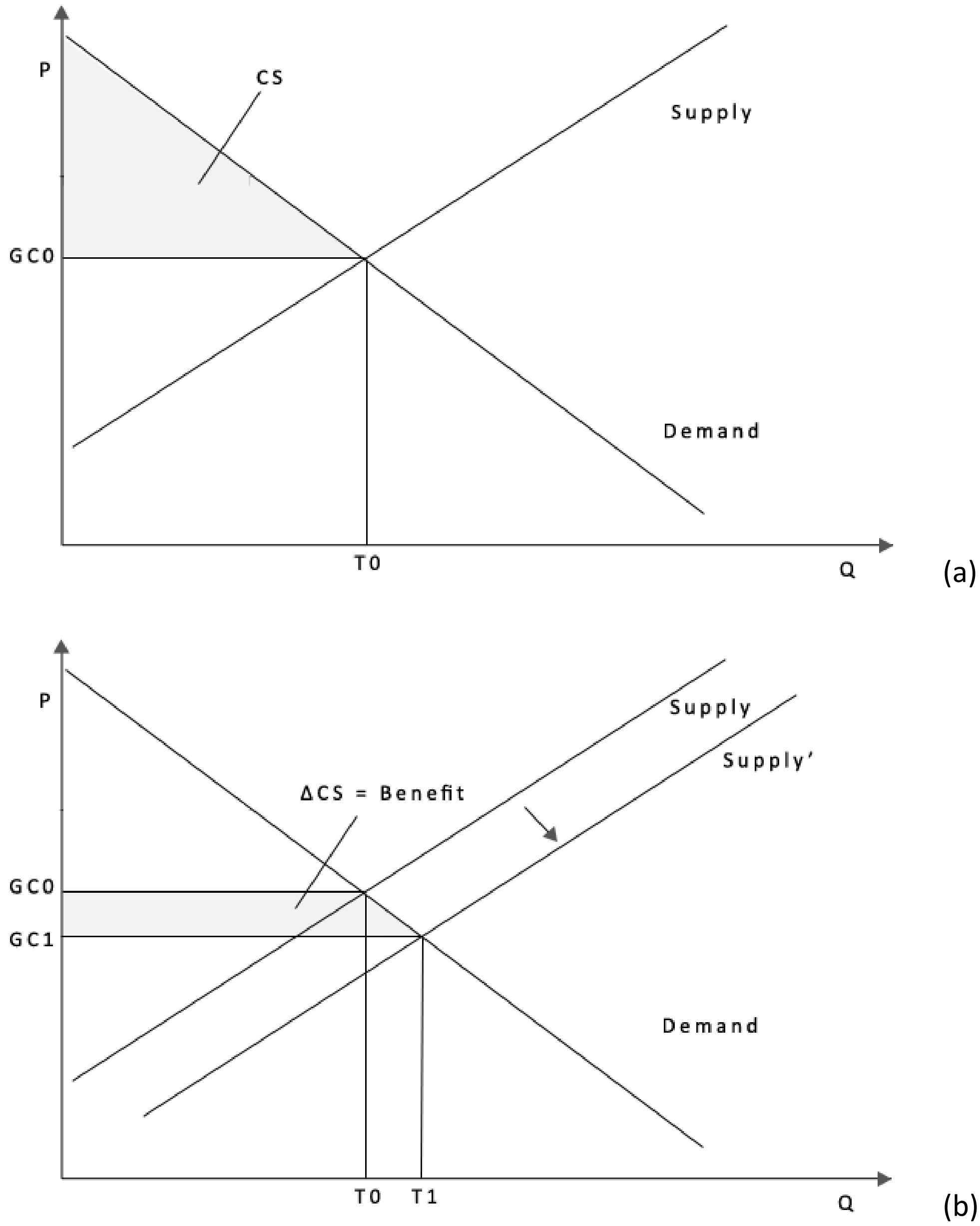
Step II is the core of the research, as it will define the business and societal benefits. For the first, the business case is defined. For the latter, external costs and benefits are taken account of.

Estimating the *user benefit* is the main motivation for starting up the cost benefit analysis process. Before deciding on a project, policy or solution, the changes for stakeholders should be known. Often, conditions, faced by transport users, should improve in order to gain interest for the project. These user benefits can be defined in different ways. One can see three fundamental concepts: willingness to pay, the consumer surplus and the generalized cost. WTP is the maximum amount a consumer individually is willing to pay to make a trip from *i* to *j* by mode *m.* Second, the *consumer surplus* (CS) is another way of calculating the excess WTP.

This CS is the excess WTP compared to the set tariff. In cost benefit analysis, it first is interesting to calculate the consumer surplus of all individuals, and second to see how this CS changes when a project or policy change is implemented. One can see the CS in Figure 35 (graph (a)) as the triangular shape between the downward sloping demand curve and the horizontal line from the price GC_0 indicating the level where the supply curve crosses the demand curve. (Jones, 1977; Glaister, 1981; Blauwens, 1986; Blauwens, 1988; Mackie and Nellthorp, 2001; Liedtke et al, 2005). Figure 35 (b) indicates a change in policy. When the supply increases, giving the same demand, the curve moves right.

Operationalising this approach in transport appraisals can bounce on practical difficulties. The vertical axis indicates price. But in transport not only price is important. Price is only a part of the structure of transport costs, which are incorporating matters as time spent, access time to (public) transport, discomfort, perceived risk of safety and many others. The confined aspect of transport costs is therefore better to be replaced by the *generalized transport cost* (Blauwens, 1986; Blauwens, 1988; Department of the Environment, Transport and the regions, 2000; Liedtke et al, 2005).

Figure 35: Consumer surplus



Source: Based on Mackie and Nellthorp, 2001

This *generalised cost* is the amount of money representing the overall cost and inconvenience when choosing a transport option, when a consumer for example is travelling from origin *i* to destination *j* by a mode *m*. All aspects should be included. In Figure 35, the WTP is expressed by the downward-sloped demand curve. The supply of the transport mode is represented by the upward sloped curve. The intersection between the two is then representing the equilibrium generalized cost (Blauwens, 1988; Mackie and Nellthorp, 2001; Liedtke et al, 2005).

In practice, the analyst using cost benefit analysis is rarely possessing all the necessary information. Forecasting in the form of matrices of trips, times and costs of the network is in transport research a common approach. Then it is often assumed that the demand curve is linear. As such the change in user benefit (the triangle below the demand curve and the GC) is then estimated by the function below, known as the rule of a half (RoH).

$$\int_{GCO}^{GC1} D(GC)dGC \sim \text{rule of a half} = \frac{1}{2}(GC_O - GC_1)\ (T_0 - T_1)$$

In Figure 35 (b) above, the RoH is equal to the area indicated as *benefit* (between T_0, GC_0 - GC_1 adding the triangle T_1- T_0 and GC_0 – GC_1). The rule is acceptable except in cases such as estuary or mountain crossings, where cost changes may be considered “large” (Mackie and Nellthorp, 2001).

However, practice proved that the RoH collapses in certain settings. For example, the introduction of completely new modes (a high speed rail or light rail link for ex.). Then the generalized cost is the not defined yet. Or when new attractors and generators of trips which do not feature in the *i-j* matrix (again a problem of non-defined costs) (Mackie and Nellthorp, 2001).

There is no strict way of attributing the user benefits between modes or between *i-j* pairs. Breaking down the total user benefit in proportion to the change in generalized cost on each mode is an appealing solution (Sugden, 1999; MVA Consultancy et al*,* 1994). In the disaggregate cost benefit results, the user benefits can then be presented split by mode, as well as by purpose (Mackie and Nellthorp, 2001). But the GC components vary by mode. Public transport users pay a fare and give up time but do not pay for the vehicle operating costs (VOCs). The car user and own account freight transport company give up time, may be asked to pay an infrastructure charge or toll and pay for their fuel and VOCs. This is a fundamental difference.

The *total benefits*, composed by breaking down the components of generalized costs, can be found by applying the RoH on each component separately. According to Mackie and Nellthorp (2001) the formula for time savings, VOC savings and benefits from lower user charges are as follows:

$$RoH_{time} = ½ [(H_0 – H_1) \times VoT] (T_0 + T_1)$$

Where H is the travel time per trip in hours, and VoT is a value of time in EUR or hour.

$$RoH_{VOC} = ½ (VOC_0 – VOC_1)(T_0 + T_1)$$

The VOC are in currency units per trip. Subscripts are added for different vehicle types.

$$RoH_{user\ charges} = (U_0 – U_1)(T_0 + T_1)$$

U is the user charge in currency units per trip.

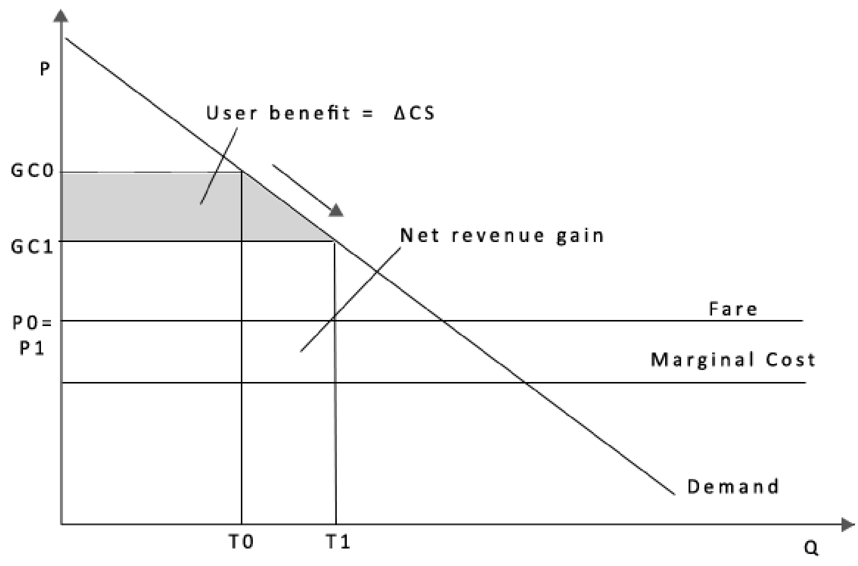
For safety costs, the RoH is not applicable. The safety costs are calculated differently than the user benefits. These costs are typically treated as a random, occasional cost per trip. Accidents and causalities are arising from the transport system which can be evaluated by applying unit values per accident and per causality. The calculation is a multiplication of forecast accident numbers (by severity) with the costs of accidents (by severity).

Revenues and costs

Subsequent to user benefit estimation, an analysis of revenues and costs can be undertaken. The cost-benefit analysis is not only concerned with the consumer surplus, but regards the total social surplus. This includes also the *producer surplus* (PS). The project is profiting for the value p x Q.

The Producer Surplus is found via the total surface below the demand curve and the GC/P. Figure 36 below illustrates the effect of a situation where the fare for a service is higher than the marginal costs. This indicates the equilibrium to shift left, as lower demand will be seen for this higher fare.

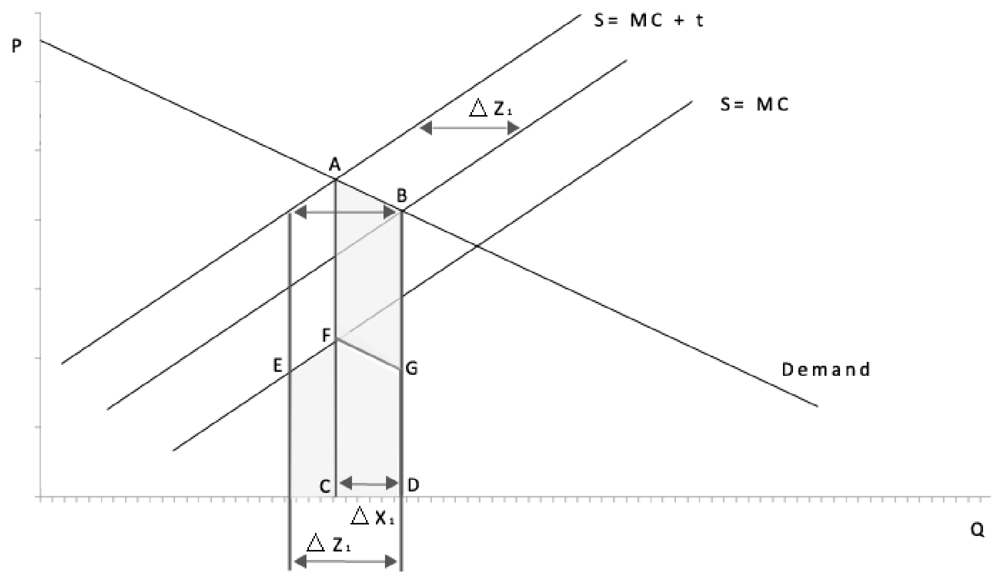
Figure 36: User benefits and revenue effects



Source: Based on Mackie and Nellthorp, 2001

In this respect, Harberger's approach, seeking second best optima, becomes valuable as this approach translates general theory to the internalisation of external costs. The approach is illustrated in Figure 37 below. A project where one good is produced is taken as an example in the next figure . Several suppliers are active on this market. Their marginal costs are shown on the graph by curve S = MC (the producers supply at marginal cost, so this is the market supply). However, the market is distorted by a tax or monopolistic margin *t*, above the marginal cost value. This *t* can as well be an internalized external cost, as of use in this chapter. This curve MC+*t* is situated above the MC curve. The market equilibrium is then found at A, demand and MC+*t* intersection (Blauwens, 1988).

Figure 37: Harberger's approach



Source: Based on Blauwens, 1988

When a new mode or vehicle type is added to the market (for example a mode with lower transport and/or external costs), the Supply curve makes a shift downwards, for the value of the benefit (which is indicated as Z_1). The market equilibrium shifts consecutively from point A to B. The price drops and the total demand increases from C to D (Blauwens, 1988).

Harberger's rule then calculates the welfare increase as the shaded area. The area under E, F and G is calculated first. Second, the area ABGF is added. This approach will be used in the assessment further on.

iii) Inter- and extrapolation

Step (iii) follows the analysis of user benefits and societal impact and extrapolates the results to a higher level and simulates a long term growth path.

The business case for a single business entity (LCV or cargo bicycle operator) will be used to define the market behaviour of these actors. However, for an SCBA, it is needed to extrapolate the simulation to a regional or national scope. Therefore, the approach discussed in section 3.1.2 will be used.

The second step in extrapolating is moving the SCBA from an annual to a multi-annual scope. The time horizon will be expanded to 25 years, as advised by European Guidelines on SCBA (EC, 2008). The horizon starts counting from the base year of the data, i.e. 2016. As such, the SCBA expands up till 2041.

Moreover, the current estimates on urban freight transport demand will need to be aligned with the forecast growth, as it was shown in chapter 2. In pursuing the goal of creating a Single European Transport Market, stepwise lots of national market boundaries were left behind.

When plotting ton and pkm data in a graph (see for example Figure 16 on page 75), a clear correlation can be derived - with an elasticity larger than 1 - between the European GDP and the transport sector growth . The passenger transport had an elasticity to GDP lower than 1, while the freight transport sector had till 2007 an elasticity exceeding 1. From then on, the tkm performed by the freight transport sector declined heavily. The crisis hit hard, and 2009 resulted in a transport sector's performance comparable to 2003 levels. Then, the volumes recovered but stabilized (European Union, 2017).

It cannot be stated yet whether this decline is structural, or temporary. The clear correlation between GDP growth and transport growth was in the past at the basis of European transport policies. A decoupling of this growth in transport became of high importance as the sector gradually was confronted with increasing congestion, emissions and accidents. In the figure above, transport demand has an elasticity with GDP of +1.

iv) Discounting

The costs and benefits are then discounted, in step IV, by a discount rate of 4% [100]. The next step in the appraisal then defines cost and benefit impacts per stakeholder. With the aim for structured conclusions, a STEEP framework will be used.

After expanding the scope to the regional market and the time horizon to 25 years, it is needed to discount the impacts to one Net Present Value (NPV). The NPV is the difference between the present value of cash inflows and the present value of cash outflows. It calculates current monetary value of future cash flows (illustrated in Figure 33).

[100] As defined by Rebel Consulting (2013) in the Flemish SCBA guidance documents.

v) Presentation of results, defining effects per stakeholder

The NPV assessment results in quantified conclusions. However, it is often needed to add information. Direct costs and benefits are in urban freight transport mainly related to fuel, rolling stock, IT and the internal costs. Vehicle emissions, congestion, infrastructure wear and traffic safety are examples of external costs. However, urban freight transport solutions can have qualitative benefits as well, like better services, better image for the transporter and increased awareness of the public of sustainable logistics for example, quantified if possible.

The analysis will also make use of a STEEP framework. Beria, Maltese and Marioti (2012) and Browne and Ryan (2011) just as Balm et al (2014) defined many stakeholders involved in urban freight transport, each having different priorities. Due to the conflicting priorities, it is necessary to spend attention to the differing impacts of the project on the actors.

After the conclusion for the stakeholders specifically, it will be analysed whether enabling increased use of cargo bicycle transport contributes to an improved urban liveability and whether, and how, policy makers can stimulate the use of these vehicles.

- First and most importantly, the **average transport cost** (ATC) for both the bike as well the LCV operations will be calculated.
- Second, the total cost graph will give insight in the cost structures. The **Total Transport Cost** (TTC) of the LCV-based solution will be compared to the one of the TTC_{Bike}.

So, the simulation will give a good insight in the competitiveness of two companies, choosing different vehicles to operate an urban freight transport service. At first, external costs are not taken into account yet, so the simulated costs only represent a share of the social transport costs. Emissions, congestion and other external costs are surely relevant to be taken into account as for example congestion and urban emissions are noteworthy. These services feature in an already congested and densely populated and built area, where citizens are more vulnerable to emission particles. Second, congestion hits mainly the economic centres of the countries: the cities. The external costs are therefore included in the simulation in Chapter 6.

VI. Conclusions

The research questions indicated the need to evaluate not only business- but certainly also welfare-economic effects to make sound conclusions on urban freight transport innovations like cargo bicycles. Therefore, this chapter developed a methodological framework for upcoming research and the appraisal in Chapters 4 and 5.

The evaluation is split into four main parts, and part two is split into two sub-analysis steps.

i) To obtain a clear idea on the benefits of an alternative transport solution, one first needs a good description of the solution, and the present circumstances, for defining its likely impact, concerned players etc. This first step of the analysis is called: mapping the ‘as-is’ or ‘business as usual / BAU’ situation. This section will be elaborated in Chapter 4.

ii) The second step is focused on the evaluation appraisal itself. It first sets up a business case, which is the research framework for analysing the economic effects of implementing a project. The second step within the evaluation is expanding on the pure business-economic view towards a societal evaluation. This step is developed in Chapter 4.

iii) The appraisal’s third step ends with preliminary conclusions. These are framed within the STEEP analysis. Different stakeholder groups will be regarded in the conclusions.

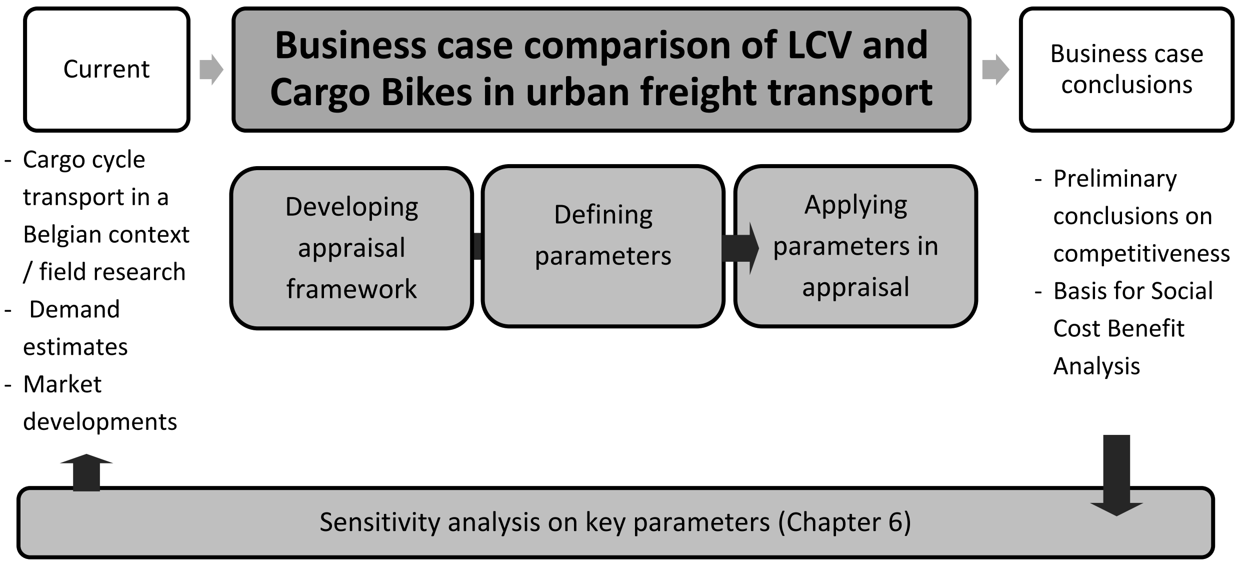
In Chapter 5, external costs are integrated. The steps of the methodological framework are recalibrated for societal effects of shifting from LCV to cargo bike transport.

4. Business-economic evaluation of the use of cargo bicycles for urban freight transport

Bicycle couriers were identified in Chapter 3 as fitted as an alternative to LCVs to pick up/deliver CEP shipments by cargo bicycle . Compared to, as can be called the *conventional* white van or LCV, bikes do suffer less from and contribute less to challenges like road congestion, local emissions and road unsafety. It can even be stated that the more urban areas are faced with congestion, the more these types of freight transport services have a competitive plus. Delivery times by bike are often shorter.

This chapter focuses on the bike couriers' logistics potential and the economic effects of the use of bicycle cargo instead of LCVs. The evaluation framework developed in Chapter 3 will be applied, ultimately leading to research-based policy advice. The cost simulation is organised in an Excel spreadsheet, allowing to test parameter values for simulating different scenarios. The structure of the Chapter is depicted below. A sensitivity analysis is completed in Chapter 6, just as a policy simulation.

Figure 38: Structure of business case urban transport by cargo bicycles (Chapter 4)



4.1. Simulating the use of different vehicles in an urban setting; clarifying assumptions

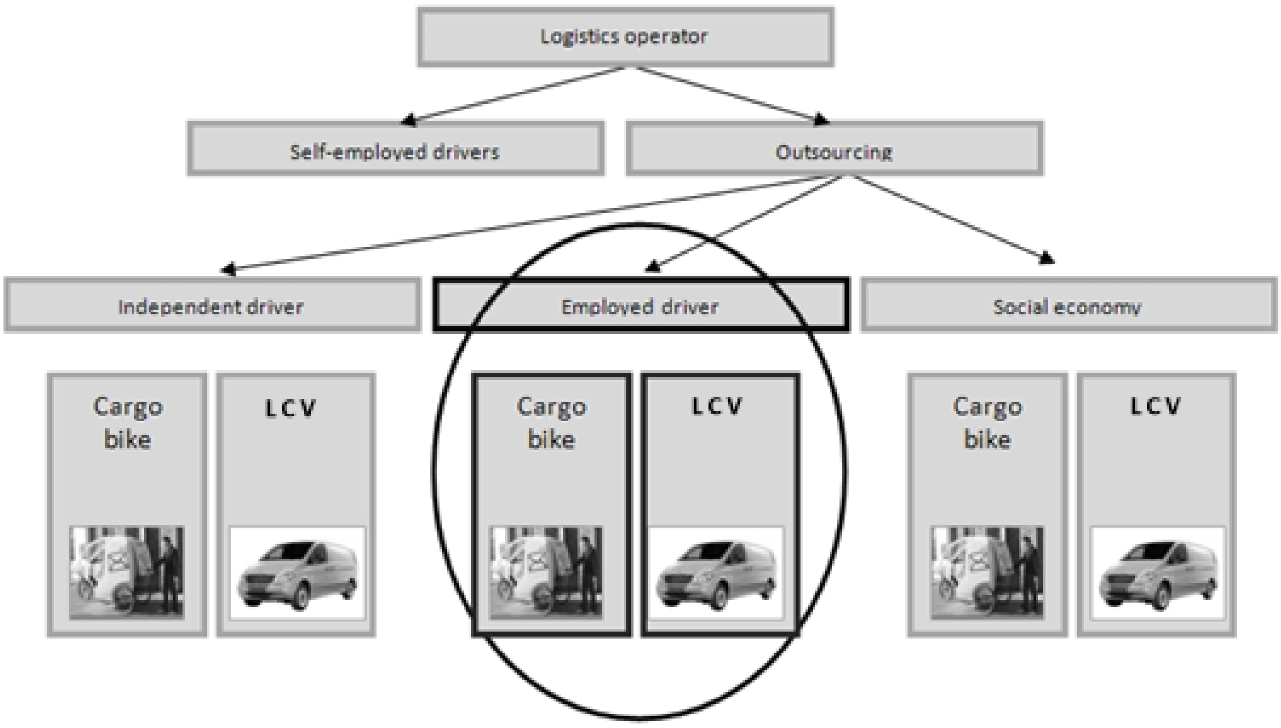
The 'Post & CEP' market segment is characterised by transporting light parcels to residents and businesses in urban areas. First, this research setting is made more concrete in order to compare the two vehicles (LCVs and cargo bicycles) in a fairly similar service structure.

Both are considered to pick up and deliver (pud) parcels and envelopes in an urban area. The starting point of the cost simulation is the moment shipments leave the final depot or hub, thus the moment where the last handling is undertaken. For this appraisal, it is assumed that depot costs are not influenced by vehicle choice. Consequently, they are assumed fixed. The appraisal will simulate transport costs of last mile delivery and as such leads to a business case comparison the competitiveness of the two vehicle types.

Services

The logistics operator is assumed to outsource the last-mile delivery to an independent last mile transport company, as shown in Figure 39. Based on the interviews undertaken for the second Chapter, it is a realistic starting point. Discussions with logistics operators in Belgium identified a preference in the market to outsource last-mile deliveries to SME's. As far as last-mile deliveries of integrators in Belgium are concerned, the majority of routes is outsourced to subcontractors.

Figure 39: Organisational setting



Vehicles

Every vehicle type has specific characteristics, e.g. cost, vehicle fuel consumption, taxes, operational specificities etc. For the simulations, two entirely different delivery vehicles are assumed (illustrated in Figure 40). For the cargo bicycle transport, a simulation is made with a three-wheeled electrically assisted 'cyclo cargo' [110]. This type of cargo bike is in use in the current Belgian market, presents inspiring results and shows potential fort the Post & CEP market segment, as it is able to carry a goods volume of one m³ or a max payload of +- 250 kg. For the LCV, an average commercial white van (LVC) with a maximum payload of 3.5 tonnes is considered. For the LCV simulation, leased standard vehicles are realistic.

Figure 40: Compared vehicle types

Routing

The vehicles leave from a depot and then deliver their parcels in a routed structure. The route is planned upfront. This unlike the bicycle couriers, which were characterised to do mainly unplanned A to B trajectories for a consecutive number of customers. Regarding the urban routing, four hypotheses are made.

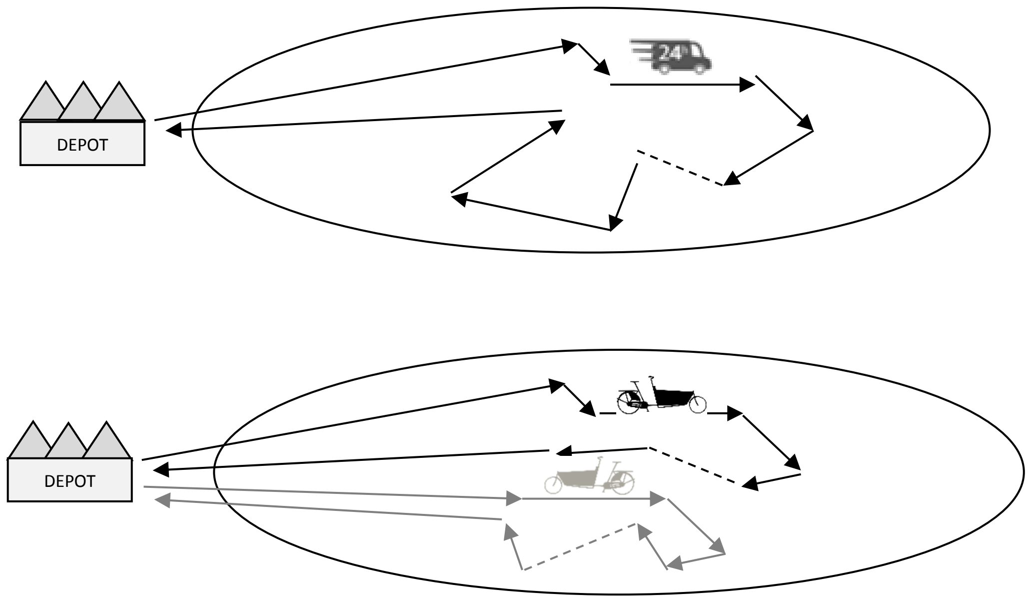
i) It is assumed that regarding service criteria, outside delivery speed and emission levels, outsourcing the urban delivery of parcel deliveries is not making any difference compared to the service quality of the self-employed drivers. As outsourcing of activities is mostly done to small independent operating companies already, small cargo bike operators are considered to be able to deliver an equally good service.

ii) The vehicles are considered to have an almost fixed delivery route per day.
   - It can reasonably be assumed that a cargo bicycle can do two delivery rounds a day, which means in practice that the vehicles are reloaded one time during the day at the depot (as a result of the lower loading capacity; 250 kg / one m³ for the cargo bike and 3.5 tonnes for the LCV). The LCV is assumed to do one delivery round per day. The structure is shown in below.

[110] It is not an electric bicycle, but has an electrical assistance for uphill rides.

- The LCV has a higher loading capacity and as such does not reload during the day. For the vehicles, leasing is assumed.
- The cargo bicycles follow as well a routed delivery path, but can avoid certain streets by doing local detours. The pre-planned route is not expected to change during the day. Nor do the vehicles flexibly visit additional pickup and delivery locations, not closely located on the pre-planned route. Otherwise, the research would be heading towards an optimal routing appraisal, which is not the scope of the research.

Figure 41: Service structure of the LCV and cargo bicycle route



iii) Some players in the Belgian bicycle courier market work within a specific fiscal system of social economy[111]. This noble system of employment for the weaker in society is relying on government support. This possibility is not taken into account here: it falls out of the scope of the simulation, which is constructed within a competitive market.

iv) Belgian social and fiscal laws are considered. The outsourced company employs people under a normal Belgian fiscal regime (Specifically PC 140.03), which means all labour costs are fully burdened with taxes and social security contributions.

[111] For some companies, achieving a social objective is central to their mission statement. These organisations make up what is known as the 'social economy'. They carry out a variety of economic activities but differ from ordinary private companies in that they see maximizing profits not as their primary goal and are mainly committed to democratic governance and sustainable development.

Dealing with differing vehicle capacity restrictions

The maximum operational volume per day per vehicle, because of the limited physical carrying capacity per vehicle, is set arbitrarily lower for the bicycle than for the LCV. To be able to handle a certain amount of parcels per day, taking into account the restrictions on volume and weight, additional drivers and vehicles will be needed to pick up and deliver all parcels within the limited time window per labour day. In practice, the maximum time widow for same day deliveries is defined by the general office hours[112].

This means that for every certain volume, a certain number of vehicles (which will be abbreviated by parameter H) and drivers (which will be abbreviated by parameter L) will be needed to deliver the service. This reasoning is applicable to the two modes. In short: the number of vehicles and the number of drivers per company is a function of the expected average daily volume. For the bike this link is expressed by parameters H_{bike} and L_{bike}, for the LCV this link is expressed by parameters H_{LCV} and L_{LCV}. Moreover, there is a capacity restriction in the short run. The number of vehicles in the short run cannot be changed flexibly, shown by their fixed parameter values. For example, decisions regarding the fleet composition cannot be taken every working day as these would result in a change of the capital structure which is a long-term decision.

From interviews with cargo bicycle transport companies, it can be concluded that the three-wheeled cargo bicycle has a restricted carrying capacity, limited in both weight (a maximum payload of 250 kg in total) and volume (approximately limited to 1 m³). More concretely, this means that a cargo bicycle is able to do two round trips per day, delivering at maximum 500 kg or 2 m³ per labour day.

The bike does two trips per day. As the bike is fast in doing the defined urban trajectory, a reloading operation during noon can be planned into the route structure. The cargo bicycle might not take all the shipments in one go. Cargo bicycle users expressed that a cargo bicycle in an urban route can handle around 45 stops per day. However, an entrepreneur will not wait till the maximum capacity is reached, to engage a supplementary driver and vehicle. Therefore, for the simulation, the vehicle is at first considered full from an average of 40 stops per vehicle per day. This is illustrated in Figures 42 and Figure 43 on the next page.

LCVs have a higher loading capacity but are also limited by its low urban delivery speed. Based on interviews it is assumed that LCVs can deliver a 65 stops (Q = 65) per day in one round. The LCV does not have the flexibility to reroute to the depot during noon, but has an advantage as the cargo area is bigger and as the loading limit exceeds the 250 kg of the cargo bicycle easily.

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112 These values are retrieved from the contacts made during the research on the Belgian bicycle transport market (Chapter 2). The cargo cycle maximum daily capacity in a routed structure are based on services delivered by the Brussels cargo cycle operator Ecopostale.

Figure 42: Capacity use of cargo bikes

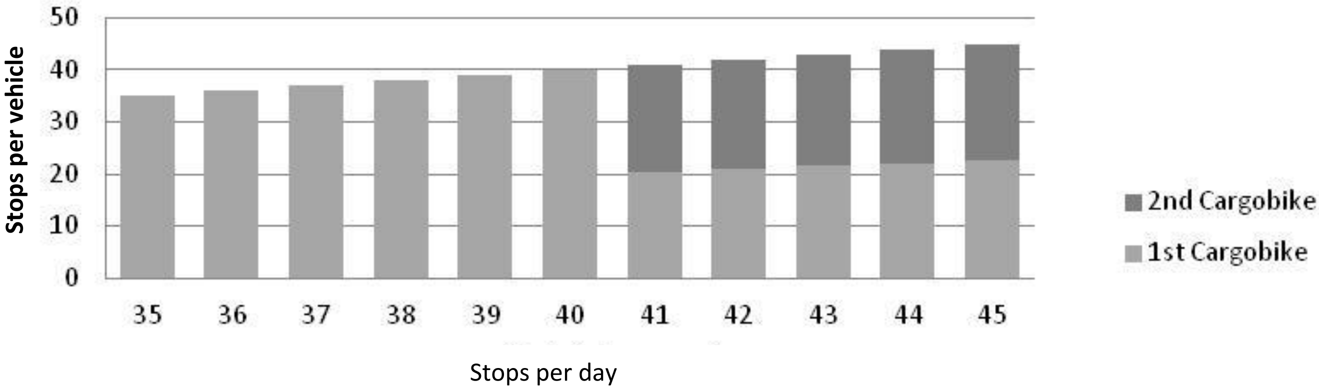
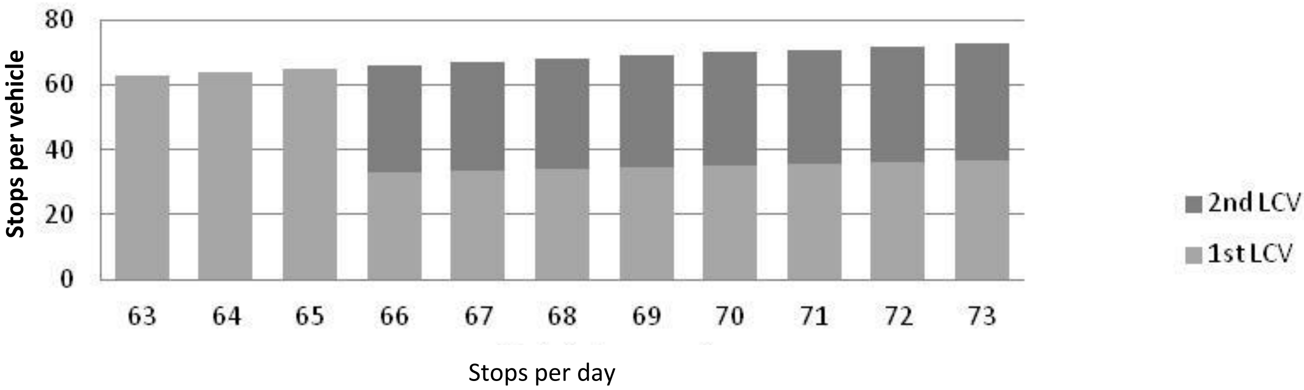


Figure 43: Capacity use of LCVs

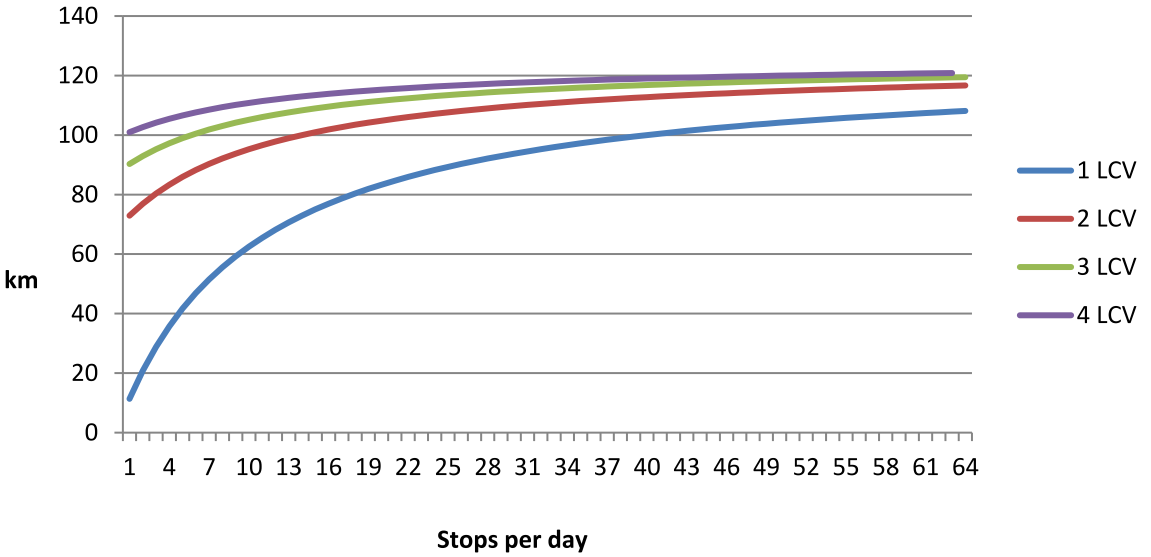


Parameter D, which is the indicator for the distance driven per day per vehicle is evidently depending on the number of stops. A fully loaded LCV is expected to perform a route of maximum 125 km per day. And 100 km is the real-life maximum per day for a cargo bicycle. This is the maximum distance, which is for 1 parcel on average 10 kms and which gradually increases as shown in the next two figures.

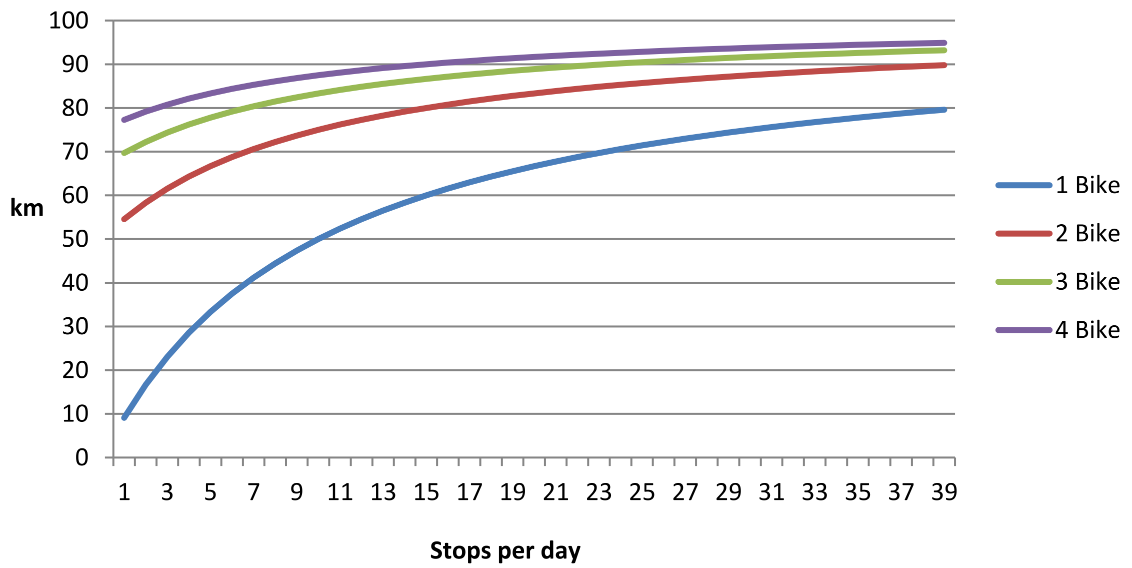
The first figure shows the average distance per vehicle based on the number of stops. The blue line depicts the driven kilometres in relationship to the number of stops. E.g. when only 10 stops per day are undertaken, the total number of kilometres driven is expected to be around 60 km per LCV. If volumes grow, e.g. till 61 stops per day, the number of driven kms per 1 LCV is expected to amount up to 110 till 120 km. A scale advantage is realised, more stops allow the route to be optimised. Extra stops in a 100 km route can be organised at a marginal cost, where on extra stop on a route for 10 stops can increase the distance driven significantly. The red line in Figure 44 depicts the situation where LCV 1 is fully loaded, and where one additional vehicle is needed to respond to the demand. The red line shows the average distance driven by LCV 1 + 2 conjointly. Then the first vehicle performs a fully loaded route, the second accumulates additional distances as shown in the blue LCV line. This means they conjointly drive some 90 km for some 65 + 10 stops per day; 65 by LCV 1 and 10 by LCV 2

Figure 44: Cumulative kms driven (i.e. parameter D) of fleets deployed in relation to value parameter Q (i.e. number of stops/vehicle/day)

LCV



Cargo bikes



Direct effect of vehicle capacity restrictions on the assessment

The short term perspective defines that the entrepreneur chooses a number of vehicles and drivers, and that this number is considered fixed. This results in a vehicle fleet based on the predicted average number of stops per day.

This implies that a cost calculation should be executed for every single company model with a fleet of x, x+1, x+2,... etc. vehicles. In the short run, the fleet cannot be changed. The capital is fixed[113]. In a range of for example an estimated average of 0-65 stops per labour a day, an entrepreneur will start-up the business with one or two cargo bicycles or with one LCV. When an average of 110 stops is expected, the entrepreneur will start his or her business with or 3 cargo bicycles or 2 LCVs.

This leads to	H_{bike} = 1 for q x Q > 0 and <= 40
	H_{bike} = 2 for q x Q > 40 and <= 80
	H_{bike} = 3 for q x Q > 80 and <= 120
	...
and that	L_{bike} = 1 for q x Q > 0 and <= 40
	L_{bike} = 2 for q x Q > 40 and <= 80
	L_{bike} = 3 for q x Q > 80 and <= 120
	...
This means as well that	H_{LCV} = 1 for q x Q > 0 and <= 65
	H_{LCV} = 2 for q x Q > 65 and <= 130
	H_{LCV} = 3 for q x Q > 130 and <= 198
	...
and that	L_{LCV} = 1 for q x Q > 0 and <= 65
	L_{LCV} = 2 for q x Q > 65 and <= 130
	L_{LCV} = 3 for q x Q > 130 and <= 198
	...

4.2. Business-economic cost parameters for bike and LCV transport

Before detailing the cost function of this simulation, one needs to define the diverse cost parameters. This costs parameter structure is based on the theoretical background discussed on page 144 in Chapter 3 where Blauwens et al (2012) and Litman and Doherty (2009) were considered. The simulation will result in the out-of-pocket transport costs for both modes. External effects are not taken into account yet, but will be explained and integrated into the equation, from Chapter 5 on.

All equations using these parameters are modelled in a spreadsheet. The cost parameters therein are defined in Table 38. The parameters are grouped by their characteristics as retrieved in literature: main parameters, distance-based costs, time-based costs, other costs. Here, the start-up costs are added.

[113] LCV vehicles are, at least in the short run perspective, not easy to obtain. For the competitive bicycle, this assumption is equally credible as this simulation discusses cargo tricycles with a closed loading space. These are even less easy to obtain than LCV's.

Table 38: Cost parameters in equations and model

	Parameter abbreviation	Unit of measurement	More information
Cost parameters	L	Number of drivers	L = a function of (Q / max. capacity per vehicle)
	H	Number of vehicles	H = a function of (Q / max. capacity per vehicle)
	W	Number of labour days per year (in days)	260 days a year
	Q	Average daily volume (vehicle stops, in number)	Capacity caps are applied, see page 172 for more details.
	q	Average number of parcels per vehicle stop (in number)	/
Distance based	f	Number of litres per 100 km per vehicle	Fuel and lubricants. Multiplied by the fuel price per litre (in EUR) + the oil consumption)
	D	Distance per vehicle per day (in km)	Distance influences fuel costs.
Time based	l	Labour cost for the employer (in EUR)	Fully burdened with taxes and social security contributions, per worked hour
	U	Average number of worked hours per labour day (in hours)	8 hours per day maximum.
	i	Insurance cost per driver per hour (in EUR)	This is higher for bike than for LCV transport.
	t	Vehicle tax per year (in EUR)	Fixed taxes, registration etc.
Other	p	Cost of illegal parking fines per year (in EUR)	LCVs get parking fines quite often. Interviews led to including this parameter.
	h	Depreciation costs per vehicle per year (in EUR)	Purchasing price - residual value; then divided the number of years in use (i.e. 6)
	z	Overhead costs per year per company (in EUR)	/
	zS	Start-up costs per company (in EUR)	Costs depreciated over 5 years

The parameters defined above result in the construction if the simplified equation simulating total transport cost (TTC) **[1]**. This equation is equal for both urban last mile operations. And consists of energy use, labour costs, vehicle and other costs.

[1]

$$\text{Total Transport Cost} = \underbrace{((f \times D) \times H)}_{\textbf{Energy use}} + \underbrace{[((l + i) \times U) \times L]}_{\textbf{Labour cost}} + \underbrace{(((h + t) \times H) / W)}_{\textbf{Cost/vehicle}} + \underbrace{(p + z + z_S/5)/ W}_{\textbf{Other costs}}$$

Note that both H and L are a function of the average daily volume of the vehicles (Q). This then results in the equation for simulating the simplified average transport cost (ATC) **[2]**.

[2] $$\text{Average Transport Cost} = \frac{((f \times D) \times H) + [((l + i) \times U) \times L] + ((h + t) \times H) / W) + (p + z + z_S/5) / W}{(q \times Q)}$$

4.2.1. Defining the parameter values

Table 39 on page 174 provides the values of the different parameters which were introduced earlier in Table 38.

The values of the parameters are based on a Belgian transport case employing drivers for a cargo bike and for LCV vehicles complying with Belgian law and Belgian fiscal legislation. This then results in an absolute minimum full **labour cost**, in 2016 prices, of 22 EUR per hour[117]. This minimum labour cost includes all legal obligatory surpluses for these employees, borne by the employer.

The parameter f (for diesel **fuel**) is calculated on the basis of a fuel consumption of 13 litres of diesel per 100 km at 1,2236 EUR[118], for the LCV. The fuel consumption in urban areas is considerably higher than on highways. For the cargo bike, the parameter value for *f* is obviously zero, as the bikers do not use any fuel. The cargo bikes require a charge of maximum 250 W per day. Considering the energy price of on average 20 EURct per Megawatt, this cost is deemed neglectable.

The **insurance cost per driver** (parameter L), is set higher for a bicycle driver than for an LCV driver. The parameter is set following interviews with cargo bike entrepreneurs arbitrarily at 1.25 EUR/hour for the cyclist and 1 EUR/hour for the LCV driver.

The **fixed costs per vehicle** (parameter *h*) for the cargo bike are calculated on the basis of a purchase of a cargo bicycle at the vehicle producer (Cyclopolitain vehicules, 2017). This option was chosen to be comparable with the LCV. The cost of 8,500 EUR purchase price is lowered by the estimated residual value of 1,000 EUR. The vehicle is depreciated over 4 years. For the LCV, a similar cost estimation took place. The yearly depreciation cost of a standard van is set at 6,800 EUR[119].

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[117] These are calculated with the full labour cost, equal to ((10.64 + 1.2155 + 1)x 1.08) x 1.4925. The gross wage of courier services drivers including ARAB allowance and (social security) levies paid for by the employer.
[118] Based on Belgian data. The value represents the average Belgian diesel fuel price for 2016 (FOD Economie data). The Belgian Diesel price consist of 4 parts: the CIF or pure product price (35%), the mark-up margin for the distribution (13%), the additional taxes (e.g. for strategic supply of fuel; i.e. 1%) and the fuel taxes (51%).
[119] An LCV has an estimated sales price of 35,000 EUR. Depreciated over 5 years with a residual value of 10,000 EUR.

The **fixed costs per year**, or *z*, (e.g. general overhead costs like office materials) for operating a pick-up and delivery round in a city centre are set at 2,000 EUR for the cargo bike and 2,500 EUR for the LCV.

Besides the fixed costs on a yearly basis, starting up a business requires **initial start-up costs** (administrative costs like the notary for example). These were estimated at 3,000 EUR per year, equal for both modes. The start-up cost is depreciated over 5 years, as this is a general accounting practice.

The urban freight transport market is considered a market with **limited diseconomies of scale**. Only when bicycle transport grows till a major modal share in urban transport, congestion due to bicycles hindering each other and other related inefficiencies will grow. Therefore, this congestion effect of bicycles in the city is not considered.

Value of time (VOT) parameters, as described in earlier, are not considered yet. The two last-mile modes are as comparable in delivery speed, as these deliver both at the same day. The minutes in time difference have no effect on the value of the shipment. Increasing urban congestion will influence the delivery speed negatively, but in the appraisal will be reflected in a lower efficiency (less deliveries per working day). The delivery speed is of paramount importance in the A-B courier market. This other type of market segment was discussed before but was evaluated as a 'niche market' development. Here, a round trip model is simulated with parcels and mail being delivered in narrow urban time window of one office day, regardless the preceding trajectory length.

The average number of parcels per stop is first set initially at 1 (as such q x Q = Q; one stop = one parcel). After the simulations with this base scenario, a number of sensitivity analyses, with an increasing average number of parcels per individual stop will be developed.

Table 39: Cost parameters values bike and LCV transport (input sheet model)

		Cargo bike	LCV
	Parameters		
Maximum volume per vehicle		40	65
H	Number of vehicles	L = f (Q/max. volume per vehicle)	L = f (Q/max. volume per vehicle)
L	Number of drivers	L = f (Q/max. volume per vehicle)	L = f (Q/max. volume per vehicle)
W	Number of labour days per year	260	260
Q	Total daily stops	ranging from 1 - 2500	ranging from 1 - 2500
q	Average parcels per stop	1	1
	Distance-based		
f	fuel price per km (based on # litres per 100 km per H x fuel price per litre (in EUR))	/	0,16
	Fuel consumption per 100 km	0	13
D	Average distance per vehicle per day in vkm	100	110
	Time-based		
l	Labour cost for the employer (per worked hour)	22	22
U	Average number of worked hours per labour day	7.6	7.6
i	Insurance per driver per hour	1.25	1
	Fixed costs		
h + t	Costs per vehicle per year (< 6,800 + 125 taxes)	1,875	6,925
	Investment bicycle (4 year depreciation)	7,500	/
	Depreciation costs per LCV per month (5 years depreciation)	/	577
p + t	Fixed costs per year < 2,000 + parking fines for LCV	2,000	2,500
z1	Fixed costs year 1 are 2,500 (5 year depreciation)	3,000	3,000
	Other costs		
Diesel	Price per litre (CIF+MAR+ADD+TAX)	/	1.22
p	Cost of parking fines per year	0	500
T&T	Vehicle tax per year	0	125

I. Short or long term perspective?

Graphs will be made with the earlier defined cost equations, using the parameter values defined above. These equations result in estimated total, average and marginal costs when running a daily urban freight transport service with a routed nature. With the total transport costs divided by the average number of stops per day, the average cost[120] per stop is simulated. Nevertheless, a difference is seen depending on the short term and long term perspective.

i) Nearly all parameters are fixed, at least in the short run, as all short run capital costs are fixed. An example: the total fleet composition cannot be changed on an hourly, nor daily basis. The entrepreneur starts up a business with a number of vehicles, and then tries to optimise the commercial utility of the fleet to maximize revenues. The entrepreneur has only in the long run the flexibility to adapt the fleet composition and the fleet characteristics. When the entrepreneur starts up a business with a certain number of vehicles, the costs per stop are only influenced by the average number of stops the vehicle fleet executes[121].The short-run costs are at the lowest possible point when reaching the maximum capacity utilisation of the current entrepreneur's fleet.

ii) A second difference is seen in the fuel consumption. This cost is a variable cost factor. But as the bicycle fleet does not use fossil fuels, the parameter value for this vehicle is permanently zero. The fuel cost per stop is variable for the LCV though, as its value is on the one hand to a great extent influenced by the density of pick-up and deliveries and on the other hand by the order (or disorder) of the route design. If all pick-ups and deliveries are well-planned in one lean route of consecutive stops, the fuel cost per stop is lower than when all orders are illogically and dispersedly located around the city. Because then, the average number of kilometres per stop increases, as the average fuel cost per stop. The correlation between the number of deliveries and the fuel cost is not linear. One could even state that the parameter 'cost' is almost fixed, as the urban delivery route is more or less fixed. Extra pickup and delivery stops *en route* do not increase the total driven kms considerably. Changes in number of stops are of high importance for the fuel cost per stop.

iii) Some parameters which can be identified as 'variable in the short run' for example the labour cost: expressed by the number of staff and the total of worked hours by this staff. As well for this parameter, the entrepreneur's short run flexibility is

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[120] For reasons of clarity, in the first steps if this quantification, the average number of parcels per stop (q) is kept at 1. This means the number of stops (Q) and number of parcels is equal to 1. Therefore, the X-axis only shows Q.

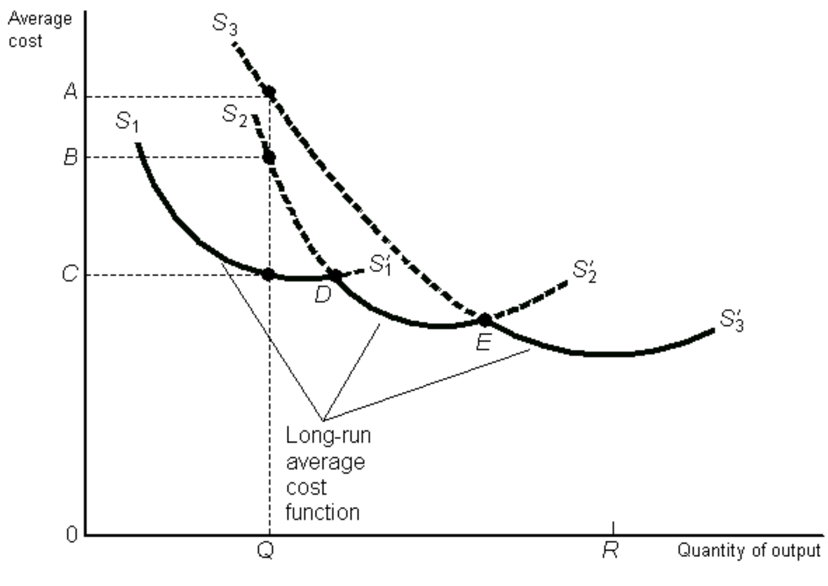
[121] Ranging from 0 stops for X vehicles, when the entrepreneur has no shipments at all, till the maximum defined by the combined capacity of the x vehicles.

limited. One can for example not employ a driver/cyclist for one hour in the morning and one hour in the evening[122]. Pick-up and delivery peaks are obviously to be expected in the morning and late afternoon of a business day. But these demand peaks are not predictable by the hour, leaving the entrepreneur with a need to employ people even if these are just waiting for new delivery orders.

Theoretically, the difference between short run and long run can be explained via the average transport costs, depicted in Figure 45 below. This graph drafts the envelope curve of short run average costs, and will be used to explain the main differences.

In the short run, the entrepreneur is fixed to a certain capacity i.e. a certain fleet size and composition, which is expressed by a number of vehicles (which is in return correlated to the number of drivers). The Short Run Average transport Costs (abbreviated as SRAC) follow a U-shaped path within the available capacity range. At a certain point on the path, the SRAC will reach the lowest possible value, named “the optimal capacity”. Thereafter the costs incrementally increase again. This effect can be attributed to the concept of diseconomies of scale. The SRAC decreases till the point where the optimal business scale is reached. From there on the slope increases as inefficiencies, gradually grow.

Figure 45: Envelope curve of short run average costs, consolidating to the long run average cost curve

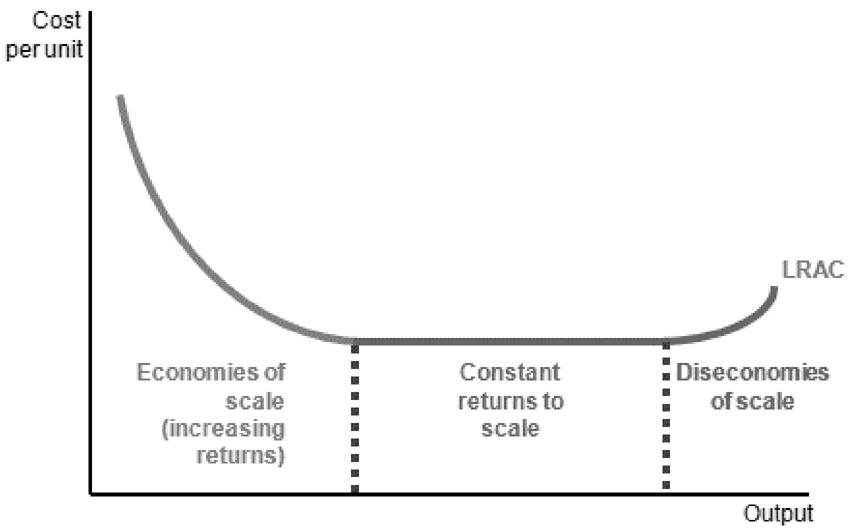


For logistics appraisals, this envelope curve is not always applicable, as maximum capacity restrictions in delivery services (due to for example the vehicle’s maximum payload) do not allow the entrepreneur to go beyond the optimum capacity. When the capacity of the vehicle is fully used, the average costs are at the lowest. At that moment the company is required to

[122] Current IT platforms allow more flexible labour though. Platforms as ‘deliveroo’ or ‘just eat’ employ couriers on a very flexible way, without them being entitled to a fixed or minimum number of hours.

stop offering services, as capacity does not allow the company to distribute more. This is in contrast to the theoretic Figure 45, applicable to for example industrial production assessments. On that ground, the upward sloping parts are shown by dotted lines, as these do not occur in the appraisal of this chapter. To increase capacity beyond the optimum capacity, fleet characteristics need to be changed, which are investments. These are catalogued as long run decisions. Consequently, in this appraisal, SRACs do not increase beyond the optimal point. The LR A(T)C will first decline, then stabilise and at a given point increase again. The first is economies of scale; the last is the effect of diseconomies of scale. This effect is depicted in Figure 46.

Figure 46: LRA(T)C – economies or diseconomies of scale



In the simulation discussed in this chapter, the short run costs do not go up U-shaped but flatten out gradually till reaching the maximum capacity[123]. This is the point where full capacity is used. Due to the capacity restriction, the SRAC cannot go up from that point (e.g. where there are constant returns of scale) as the small business is then working at full capacity. This capacity restriction will have a major influence on further cost simulation steps.

Based on the SRACs, one can construct the envelope of all short run curves to obtain the long run cost curve (LRAC). This long run perspective indicates the freedom of the entrepreneur to optimally plan the business scale based on the average production q x Q. Changing the business scale implies decisions on among others large scale investments i.e. a change in capital costs (for example investing in bicycles, storage and office space). These decisions can only be taken in the long run. These costs will be simulated with a long-term perspective, resulting from a variabilisation of all parameter values. In the long run, all parameter values can be tailored to the economic circumstances and the transport demand. The first graphs will

[123] The maximum capacity was defined as Q = 40 and Q = 65 for respectively the bicycle and the LCV.

be indicating the short run, and should be seen as the start of an envelope of all individual LCV/Cargo bicycle businesses.

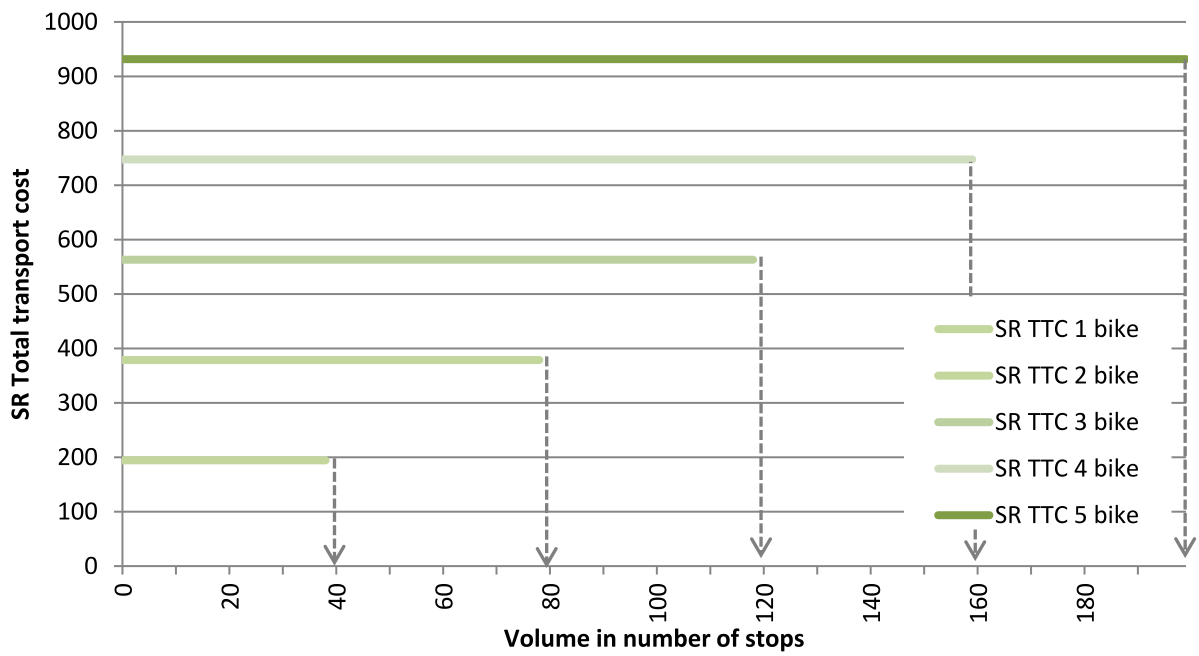
4.3. Simulation of Short Run Transport Costs

All following sections and accompanying graphs result from the initial total transport cost equation. At first, the short-term perspective will be continued. This perspective principally limits the entrepreneur in flexibility to adapt the business parameters (like its fleet choice). When a certain number of vehicles and accompanying staff is chosen, within the short-term perspective, he or she has to stick to this number.

4.3.1. Total Transport Costs in the Short Run

Figure 47 below on the Total Transport Costs (TTCs), shows the result of equation **[1]** with the parameter values of Table 39 on page 174. The x-axis depicts the total number of stops per day, while resulting SR TTCs are shown on the Y-axis. In these graphs, the denominator q x Q is still equal to Q, as the number of parcels is seen as 1 q per stop Q.

Figure 47: Short Run Total Transport Cost in EUR / day - Bike



A similar increase for every supplementary vehicle is seen in Figure 48 showing the SR TTC_{LCV}. A fleet of 1 LCV costs for example 194 EUR per day. This operational cost increases in a stepwise manner. Operating a fleet of four vehicles will cost 888 EUR a day, while deploying a fleet of 5 costs around 1,107 EUR per day (all costs as e.g. fuel, labour, insurance, depreciation and start-up costs included).

Figure 48: Short Run Total Transport Cost in EUR / day - LCV

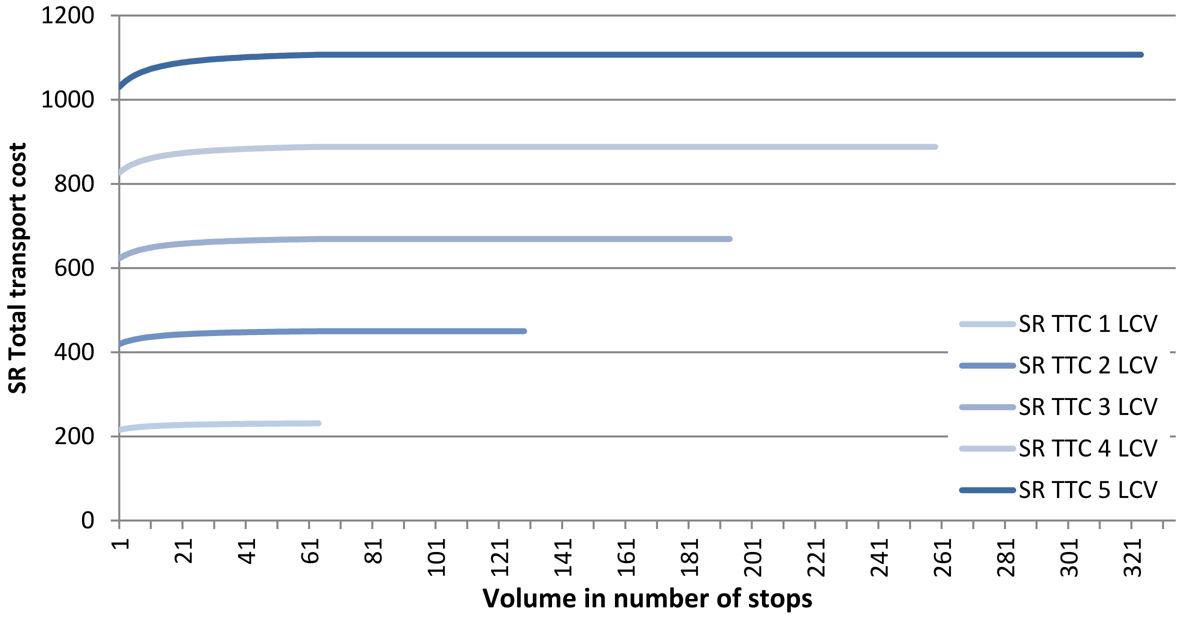
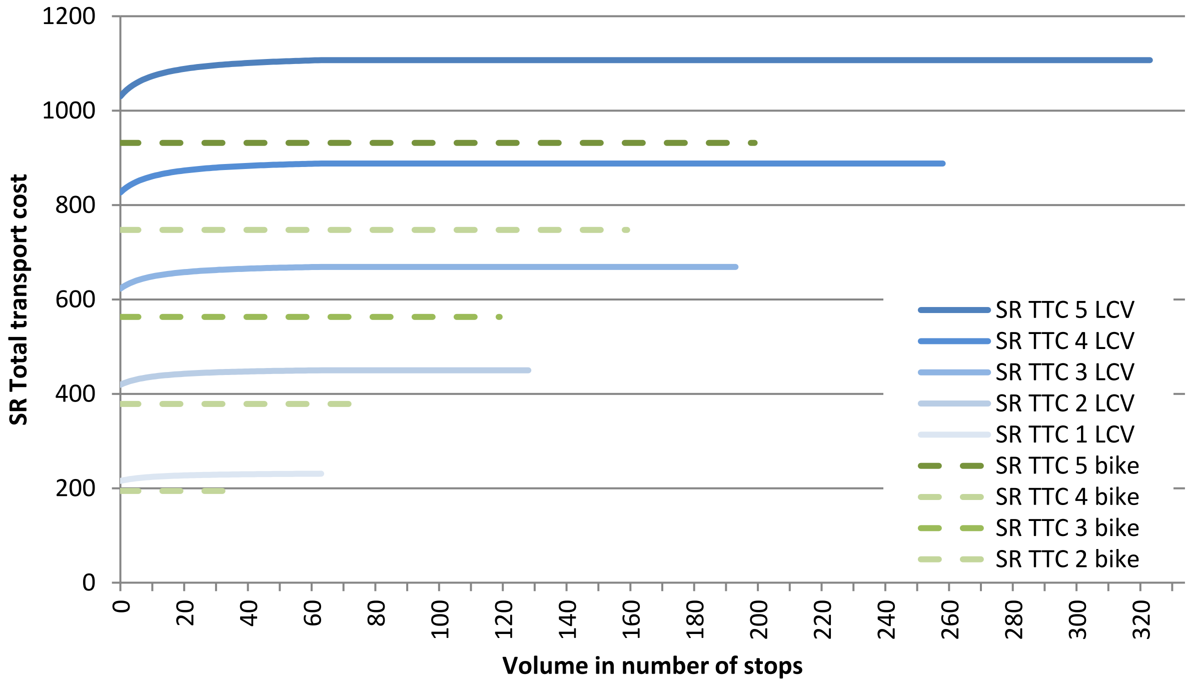


Figure 49 provides a clear view on the TTC developments for both vehicles. Estimates for Bike and LCV are combined in one graph. It is clear that the TTC for cargo bicycle transport surpasses easily the TTC for LCV transport. The LCV cost is depending on the increasing spending on fuels as more stops mean more kms driven (see parameter D). The cost per parcel with bicycles are lower only in a small range of the market (between 60-80 stops). The pattern of the vehicle fleet composition is noticeably visible. When the maximum capacity of 40 Q for one bicycle is fully utilised, a second vehicle will be engaged, and as such the cost for the 41th stop goes up with the TTC of 1 bicycle while the LCV can still organise this service with 1.

Figure 49: Short Run Total Transport Cost simulation EUR / day - bike and LCV



The entrepreneur deciding on the fleet before starting up a business will, when for example expecting an average demand between 160 and 200 stops per day, choose a fleet of 1-3 LCV or 1-5 bikes. This states the business needs respectively 3 or 5 FTE staff members.

Table 40: Short Run Total Transport Cost simulation results / day - bike and LCV

	SR TTC 1 Bike	SR TTC 2 Bike	SR TTC 3 Bike	SR TTC 4 Bike	SR TTC 5 Bike
EUR	194	379	563	747	932
	SR TTC 1 LCV	**SR TTC 2 LCV**	**SR TTC 3 LCV**	**SR TTC 4 LCV**	**SR TTC 5 LCV**
EUR	231	450	669	888	1107

4.3.2. Average Transport Costs in the Short Run

The Figures in the previous section showed TTCs for both modes. These first results reveal already a little on the competitive position of bike versus LCV transport. When the simulated TTCs are divided by the average number of stops , one can obtain the Average Transport Costs (ATCs). The parameters shown in Table 39 are used as input for equation [2], which results in Figures 49 till 53, showing the ATCs for LCV and bike services. This for companies with a fleet of 1 to 5 vehicles. Figures 51 and 53 are an extract of the graph, zooming in on the low ranges of 0 - 200 stops and 0 till 15 EUR for bikes plus 0 – 320 stops and 0 till 15 EUR for LCV.

Figure 50: Short Run Average Transport Cost EUR / day - simulation Bike

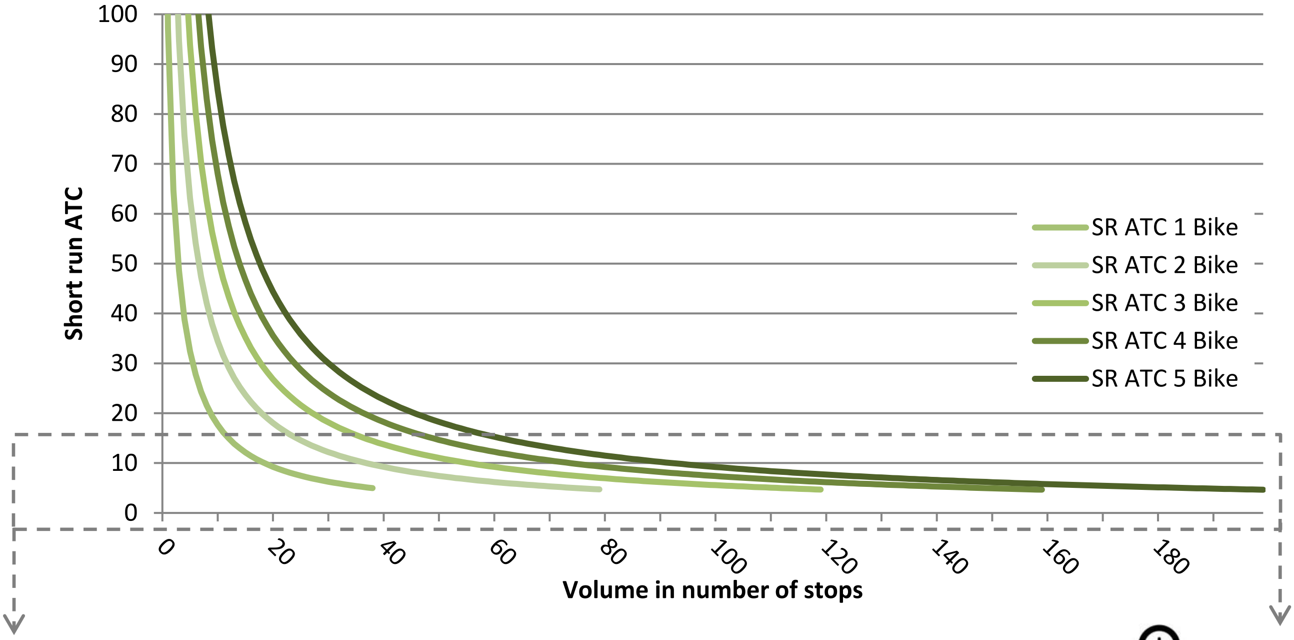


Figure 51: Extract - Short run Average Transport Cost simulation EUR/day - Bike

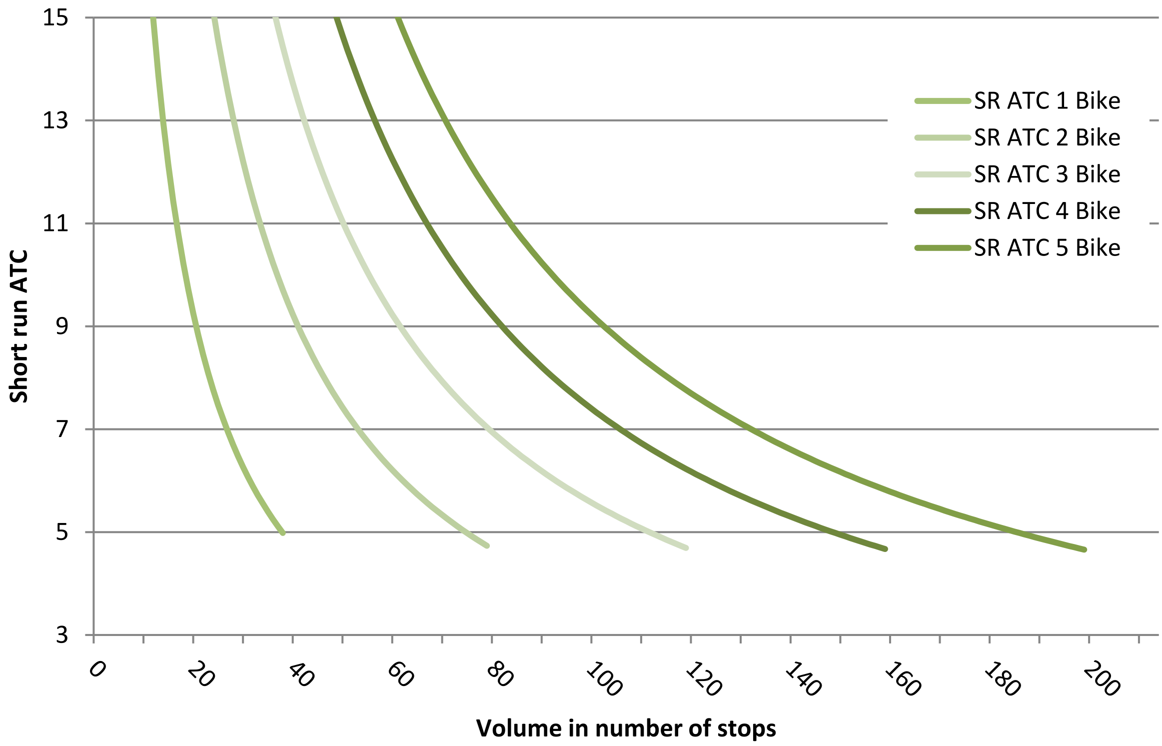


Figure 52: Short Run Average Transport Cost EUR / day - simulation LCV

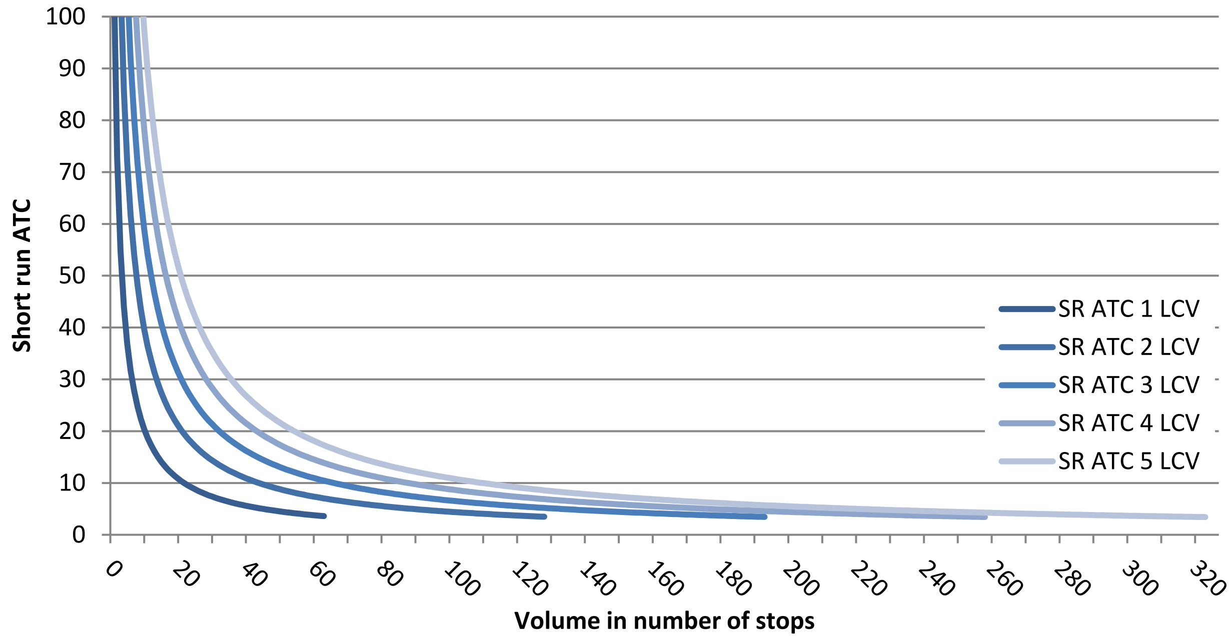
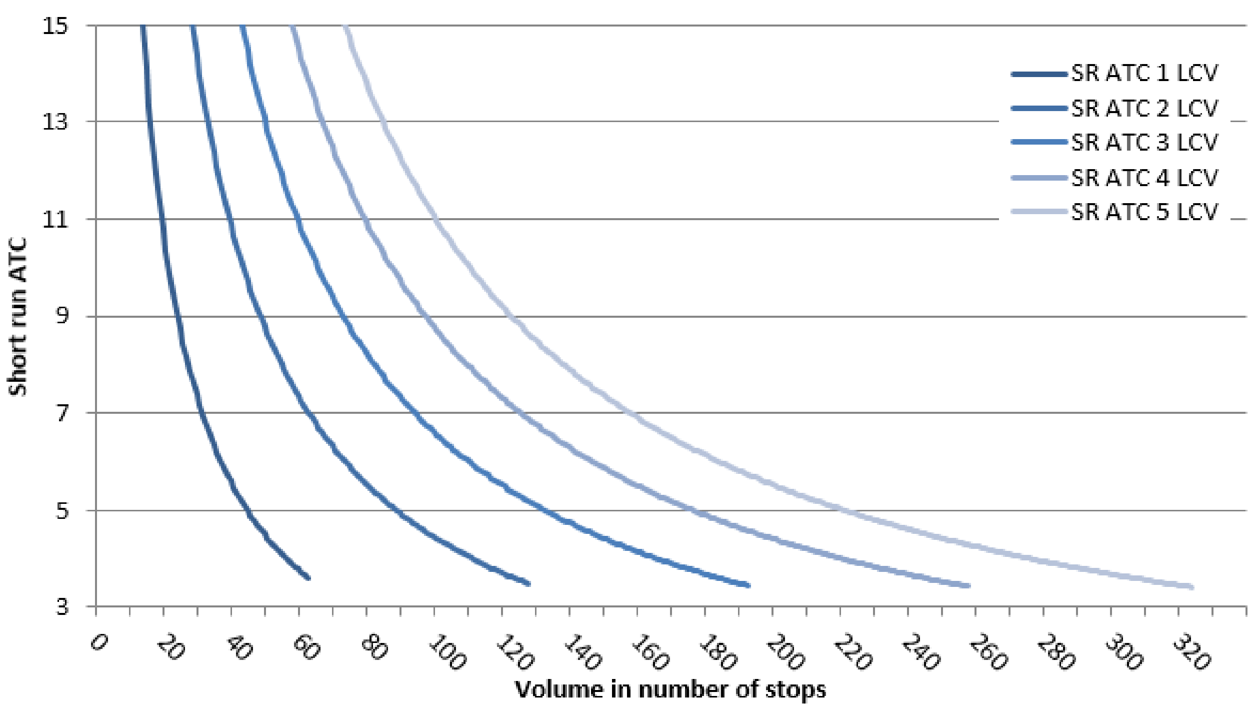


Figure 53: Extract - Short run Average Transport Cost simulation EUR / day - LCV



From the figures above is clear that a low occupancy rate of *larger* fleets (4 or 5 bicycles) results in very high transport costs. E.g., if a fleet of 5 LCVs is deployed for only 20ish stops per day, than costs per stop are around 50 EUR. These ATCs decrease considerably when the maximum capacity of the vehicle is almost reached (above some 35 stops per day per LCV, the costs decrease below 5 EUR. Data behind Figures 50 and 51 is presented in Table 41.

Table 41: Short Run Average Transport Cost simulation in EUR / stop - Bike

Q	SR ATC 1 Bike	SR ATC 2 Bike	SR ATC 3 Bike	SR ATC 4 Bike	SR ATC 5 Bike
1	194.33	378.66	562.98	747.31	931.64
2	97.16	189.33	281.49	373.66	465.82
3	64.78	126.22	187.66	249.10	310.55
4	48.58	94.66	140.75	186.83	232.91
5	38.87	75.73	112.60	149.46	186.33
…	…	…	….	…	….
36	5.40	10.52	15.64	20.76	25.88
37	5.25	10.23	15.22	20.20	25.18
38	5.11	9.96	14.82	19.67	24.52
39	4.98	9.71	14.44	19.16	23.89
40		9.47	14.07	18.68	23.29
…	…	…	….	…	….
76		4.98	7.41	9.83	12.26
77		4.92	7.31	9.71	12.10
78		4.85	7.22	9.58	11.94
79		4.79	7.13	9.46	11.79
80		4.73	7.04	9.34	11.65
…	…	…	….	…	….
116			4.85	6.44	8.03
117			4.81	6.39	7.96
118			4.77	6.33	7.90
119			4.73	6.28	7.83
120			4.69	6.23	7.76
…	…	…	….	…	….
156				4.79	5.97
157				4.76	5.93
158				4.73	5.90
159				4.70	5.86
160				4.67	5.82
…	…	…	….	…	….
196					4.75
197					4.73
198					4.71
199					4.68
200					4.66

The values of Figure 51 on the ATC_{LCV} are shown in Table 42. Low occupancy rates of the slightly larger fleets (4 or more LCVs) results in very high transport costs, even higher than these of bicycle transport. These decrease however considerably, and more than for bicycle transport, when the maximum capacity is approached (above 60 stops per vehicle, the costs decrease structurally below 4 EUR).

Table 42: Short Run Average Transport Cost simulation EUR / q x Q (results LCV)

Q	SR ATC 1 LCV	SR ATC 2 LCV	SR ATC 3 LCV	SR ATC 4 LCV	SR ATC 5 LCV
1	215.58	419.23	622.88	826.54	1030.19
2	108.54	211.12	313.69	416.27	518.85
3	72.78	141.59	210.40	279.21	348.02
4	54.86	106.74	158.62	210.50	262.37
5	44.08	85.77	127.46	169.15	210.84
…	…	…	….	…	….
61	3.78	7.37	10.96	14.55	18.14
62	3.72	7.25	10.79	14.32	17.85
63	3.66	7.14	10.62	14.09	17.57
64	3.61	7.03	10.45	13.87	17.30
65		6.92	10.29	13.66	17.03
…	…	…	….	…	….
126		3.57	5.31	7.05	8.78
127		3.54	5.27	6.99	8.72
128		3.51	5.23	6.94	8.65
129		3.49	5.19	6.88	8.58
130			5.15	6.83	8.51
…	…	…	….	…	….
191			3.50	4.65	5.80
192			3.48	4.62	5.77
193			3.47	4.60	5.74
194			3.45	4.58	5.71
195				4.55	5.68
…	…	…	….	…	….
256				3.47	4.32
257				3.45	4.31
258				3.44	4.29
259				3.43	4.27
260					4.26
…	…	…	….	…	….
321					3.45
322					3.44
323					3.43
324					3.42
325					

The graphs and tables above give a first insight in the simulated TTCs and ATCs for both modes. The short run ATC graphs on bike transport show the same pattern as for LCV transport. The two are combined in the next two Figures. The lower ranges, between 0 and 120 stops per day, result in a differing optimal ATC for bike and LCV transport in very narrow ranges. For example, when the number of stops per company per day (Q) is 75, it is advisable to choose a fleet of two bicycles rather than 2 LCVs. But when Q would increase to 85, it is advisable to opt for 2 LCVs than 3 bikes. Above 120 stops per day per company, it is optimal for the entrepreneur to opt for a fleet of LCVs.

Figure 54: Short run Average Transport Cost simulation EUR / day - Bike and LCV

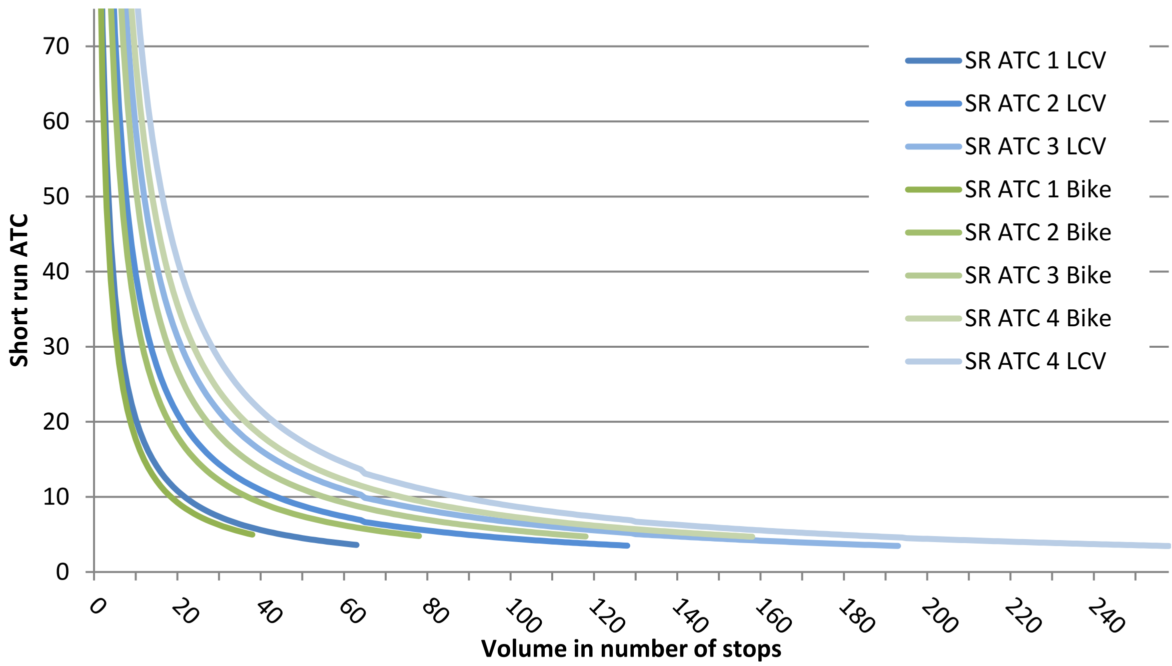
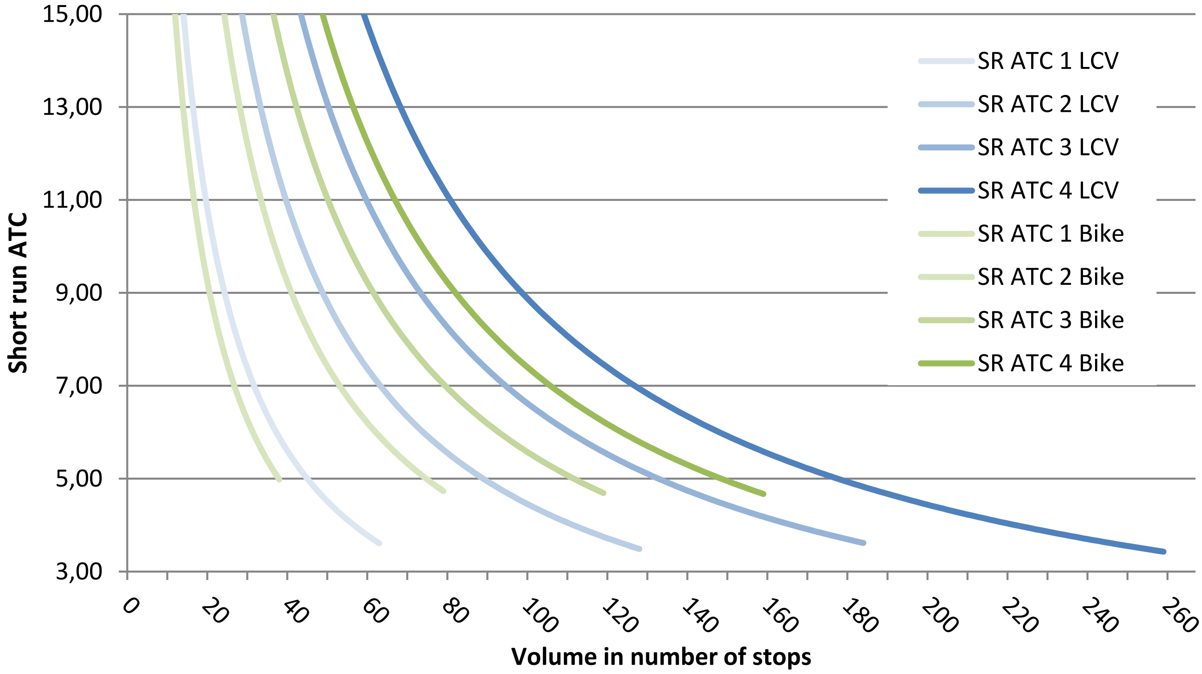


Figure 55: Extract - Short run Average Transport Cost simulation - Bike and LCV



It is concluded that the ATCs of both last mile solutions show a similar flattening trend. At first, in the section with a limited market volume shown on the left hand side of the graphs (roughly from 0 till 125 stops per day), the average transport costs for both modes increase. As soon as the average daily volume grows, the average transport costs go down to about 4 up to 5.5 EUR per stop. Nonetheless, in some specific intervals (60 to 80 stops for example), the ATC_{LCV} overrun these of the ATC_{Bike}.

However the trend shows a slightly less high ATC_{LCV} than ATC_{Bike}. The cost per stop is fluctuating heavily when operating low volumes. Higher volumes lead to a more stable estimated ATC, comparable for bike and LCV transport[124].

More important than the actual cost, which is still indicative, is the cost by higher volumes and the influence future developments will have on these costs.

4.3.3. Marginal Transport Costs in the Short Run

In order to estimate the supply function for the market, the marginal cost function needs to be estimated[125]. In the short run, all parameters are considered to be fixed. The marginal cost (related to the flat SR TTC) for an extra parcel or extra stop can then be considered close to zero. These can partially be attributed to the routed nature of the pick-up and deliveries. This assumes that the extra parcel does not add significant costs to the TTC curve. This is a simplification. There is still the maximum capacity restriction for the entrepreneur's fleet. Within its fleet, the MTC is zero. The entrepreneur cannot handle more stops.

At the point of breaking through the boundary of the fixed fleet restriction - which is considered a long term decision as it involves changes to the parameters and/or capital investments, the MTC will not be zero. This scenario is developed more meticulously in the next section. E.g. short term contracts and renting of vehicles, provides in real life more flexibility than now assumed.

4.4. Simulation Long Run Transport Costs

The preceding sections showed the simulation of transport costs, preserving a theoretical short-run perspective. This perspective was resulting in a setting where all parameter values were assumed fixed. The business case simulation compared the two options an entrepreneur has when founding an urban last mile delivery service. In the short run, the entrepreneur cannot change the parameters and their values flexibly. He or she starts up a business with a

[124] Only business' private costs, excluding external effects, which will regarded in the welfare economic analysis later on in Chapter 5.

[125] A competitive firm's supply curve is the portion of its marginal cost curve that lies above minimum average variable cost.

number of vehicles, and should then try to optimize the utility of this fleet to maximize revenues, i.e. the capital cost is fixed.

In the long run, in contrast to the short run, all parameter values (e.g. the fleet and number of drivers), can be adapted to the expected economic situation, the demand.

This section will therefore pay attention to the differences between the long and short run. The former short run cost curves will form the basis for constructing the long run total transport cost curves (LR TTC). The focus on the two modes will be alike, but the entrepreneur is considered to be able to move freely in defining among others the optimal fleet composition, labour agreements and short term rent of vehicles; i.e. assuming the fixed parameters are *variabilised*.

4.4.1. Total transport costs in the Long Run

The LR TTCs will be simulated on the basis of equation **[3]**, where costs are expressed as a result of the total Pick Up and Deliveries (PUDs) during one business year. The x-axis represents then the average yearly number of stops (or q x Q x W).

[3] $$\text{Transport Cost}_{LR} = ((f \times D) \times H) \times W + [((l + i) \times U) \times L] \times W + ((h + t) \times H) + (p + z + z_S/5)$$

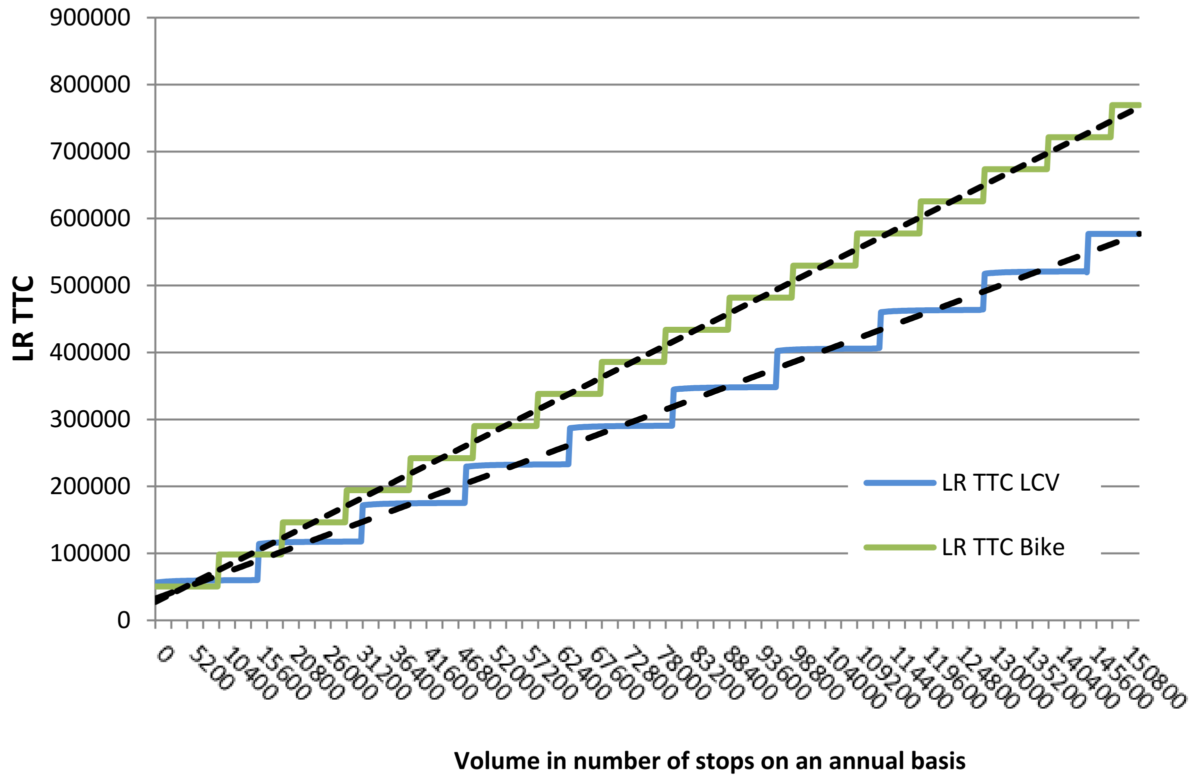
Intermediate step: demand driven supply – partly variabilisation of parameters

When the supply of services is closely following market developments, i.e. services are only offered as a reaction on the market demand, then, the TTC curves show a stepwise increase of TTCs. Fleets will be optimally planned in relation to the demand. The ultimate variabilisation of all costs will finally result in the trend line through the short run TTC curves.

To make the differences between the short and long run understandable, an intermediate step is shown. First, the LR TTCs are shown without variabilising every single parameter. In this first step, decisions on vehicles and labour forces are limited to the magnitude of one vehicle and one FTE cyclist/driver. So in this intermediate step, the entrepreneur is not able to rent additional vehicles and does not employ people with a less-than-full-time contract.

The first graph on the next page, depicts this intermediate step in the Long Run Total Transport Cost simulation. The use of a cargo bicycle is, for a large range of the volumes more costly than an LCV. The tipping point between the two modes, in the advantage of LCV transport, is already found in the low ranges.

Figure 56: Long Run Total Transport Cost simulation in EUR - Intermediate step



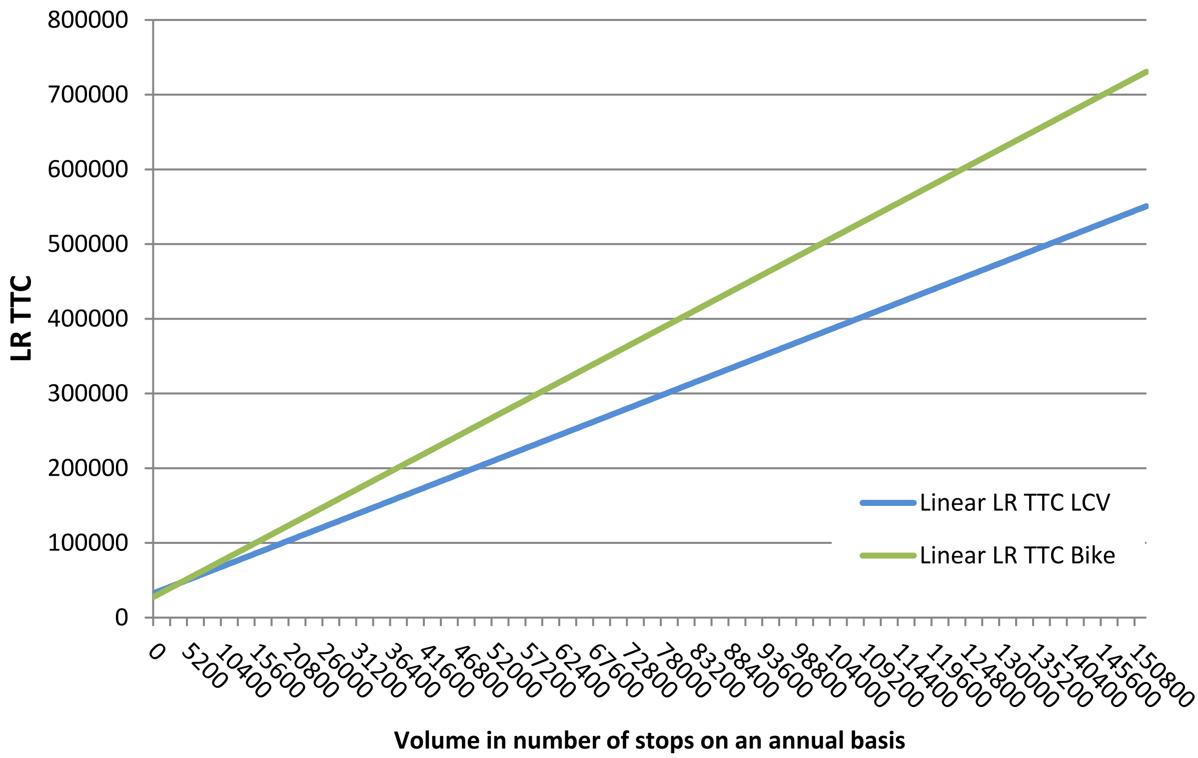
Second intermediate step: demand driven supply - full variabilisation of parameters

The long run total transport cost curves show a different pattern than the one above. In the long run, all parameters are variable.

In the long run perspective, the entrepreneur is able to fully adapt the operational costs to the demand. The number and use of vehicles and labour are flexibly adapted to the need of that moment. Instead of employing every day a number of drivers, he or she could opt for flexible contracts allowing the company to employ people less than full time and/or with less fixed working hours. Some European countries like The Netherlands and the UK among others allow zero hour contracts for example. The employee has to be stand by for a certain period, however is not guaranteed a job nor a salary.

Regarding the vehicles, the entrepreneur can go for short-term renting contracts and/or short-term lease to cover some busy periods during the week or even during the day. If for example historic pickup and delivery data show a considerably bigger volume on Monday morning, the entrepreneur can opt for a rental agreement for x-vehicles for Mondays. As such he or she saves compared to a fully owned vehicle or long term rental agreement. Nevertheless, parameter z, the fixed business cost per year, is an exemption. These are fixed per company (for ex. administrative costs like an accountant or a fixed local business tax).

Figure 57: Long Run Total Transport Cost simulation EUR / day



The LR TTCs show an increasing slope, which is larger for the bicycle than LCV transport. This indicates that the LCV is more competitive in the long run.

4.4.2. Average Transport Costs in the Long Run

From the LR TTCs, the LR ATCs are derived. Figure 58 below shows the simulations. The average transport costs are calculated on the basis of equation **[4]**, where costs are expressed as a result of the total transport cost divided by the volume per year. The X-axis shows the average daily volume per business day multiplied by the number of working days a year (i.e. q x Q x W).

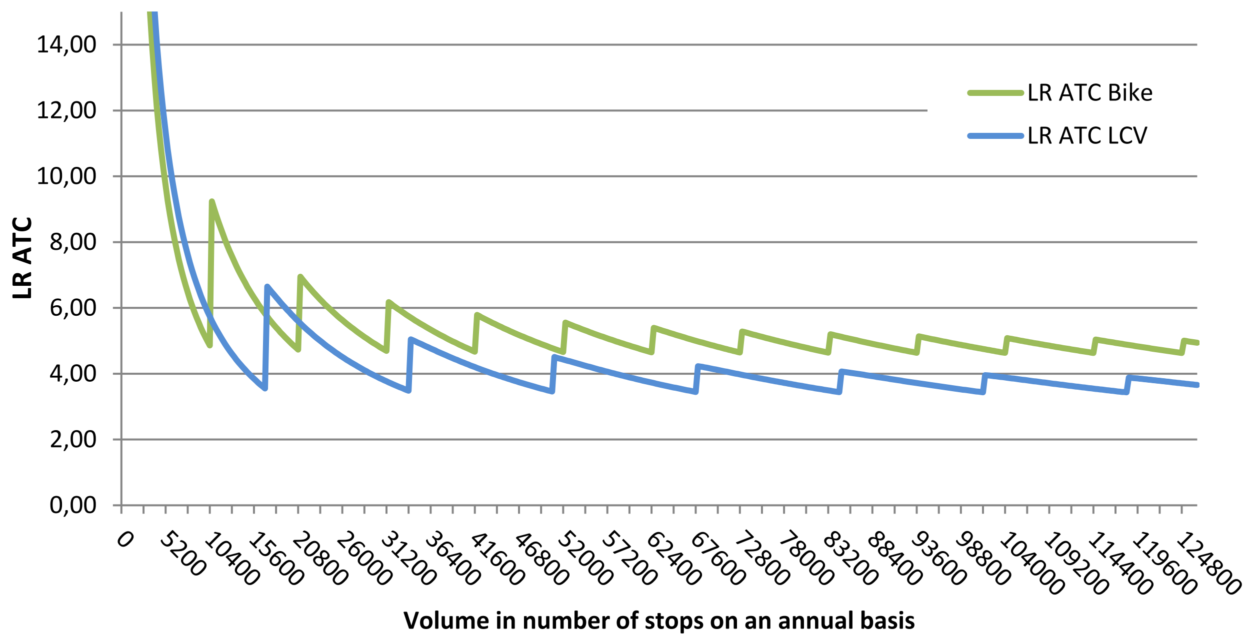
[4]

$$\text{Average Transport Cost}_{LR} = \frac{((f \times D) \times H) \times W + [((l + i) \times U) \times L] \times W + ((h + t) \times H) + (p + z + z_S/5)}{q \times Q \times W}$$

Intermediate step: demand driven supply – partly variabilisation of parameters

The Long Run (LR) ATCs for both businesses, each using one of the two modes, show a decreasing saw tooth trend. The range of low volumes (from 0 to roughly 25,000 stops on an annual basis) highlight a strong tendency for economies of scale. The larger the volumes, the easier start-up costs are spread on a larger base. From the tipping point on, the ATCs level out. These show a *saw tooth* pattern, but with less steeply decreasing ATCs.

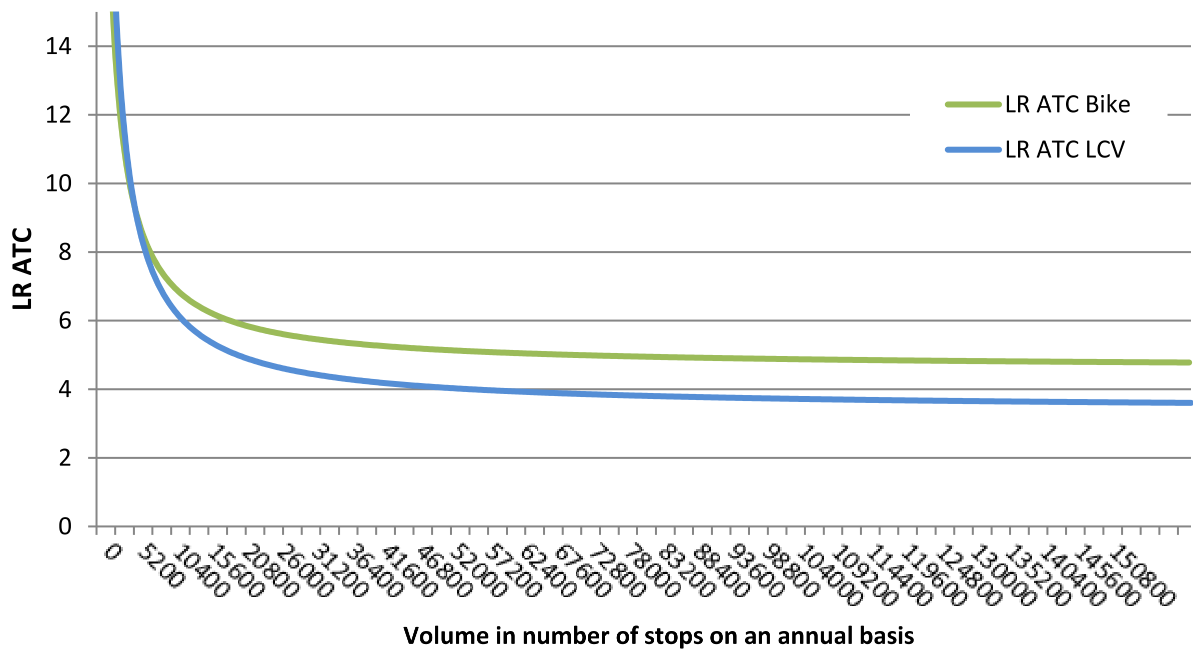
Figure 58: LR Average Transport Cost simulation EUR/day - intermediate step



Second intermediate step: demand driven supply - full variabilisation of parameters

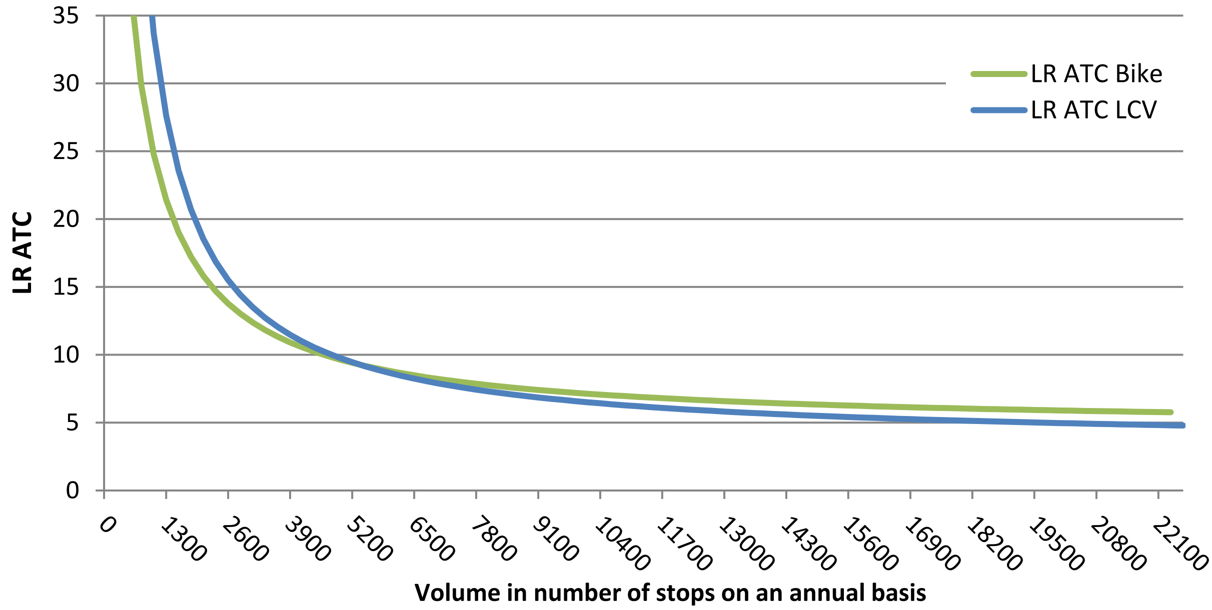
The long-run total transport cost curves show a slightly different pattern than the one above. In the long run, all parameters are variable. Only parameters z, the fixed business cost per year, is an exemption. These are fixed per company (for ex. administrative costs like an accountant or a local company tax).

Figure 59: Long Run Average Transport Cost simulation



It can be observed that the cargo bicycle option is highly competitive in the market range with lower volumes per day; less stops per day per vehicle. The graph below shows that the market equilibrium is found at 5,720 stops on an annual basis. Then, the cargo bicycle option is as favourable as the LCV. The market below 5,720 (an average approximately 22 stops per day) is then better organised via cargo bicycles. For example, own account transport could consider on this basis to deploy cargo bicycles instead of an LCV.

Figure 60: Extract - Long Run Average transport cost simulation



4.4.3. Marginal Transport Costs in the Long Run

The Long Run Average Transport Cost differ from the ATCs in the short run as the entrepreneur can then change the capital structure. He or she can freely choose the optimal fleet composition, service structure and labour agreements, aligned with the demand and expected yearly output. The LR ATC is high in the ranges with low volumes, but stabilizes rather fast. From an average daily output of 180 shipments (q x Q) [126], the SR ATC for both modes flattens out. The $ATC_{Bike\ LR}$ is almost always higher than the $ATC_{LCV\ LR}$. Also the Marginal Transport Cost will differ between the Long and the Short Run. This Long Run MTC is discussed below.

The marginal cost curve of both last mile solutions can be estimated, based on equation [1] describing the TTC in the short run. The marginal transport cost equation is similar for LCV as bike transport, but will use different parameter values. The derivative of the TTC equations to Q will result in equations for the Marginal Transport Cost of bicycle transport (MTC_{bike}) and LCV transport (MTC_{LCV}).

[126] Or roughly an average of 145 stops per business day per courier. Remember that parameter q is still equal to 1, making q x Q equal to Q.

Based on the bottom-up research in section 4.1, the hypothesis was made that every bike can handle at maximum 45 stops per day, and that the entrepreneur will engage a supplementary driver and vehicle from the moment the average volume grows till magnitudes of 40. It was estimated that the LCV can do a route of 65 stops on average. This indicates that the long run number of vehicles (H) and the long run number of drivers (L) are a function of the volume Q.

- H_{bike} = f(Q/max. volume per vehicle) = f(Q/40);
- L_{bike} = f(Q/ max. volume per vehicle) = f(Q/40);
- H_{LCV} = f(Q/ max. volume per vehicle) = f(Q/65);
- L_{LCV} = f(Q/ max. volume per vehicle) = f(Q/65).

Obtaining the Marginal Transport Cost results asks for rewriting equation [1] (the initial equation on the Short Run TTC) in order to obtain the Long Run TTC. Second, the derivative to Q of this rewritten equation, will be taken to obtain the MTC equations.

First, the MTC is derived for bicycle transport by replacing parameters H and L by respectively H_{bike} and L_{bike}. Second, due to the LR focus, the rewritten TTC_{SR} is multiplied by W to obtain the TTC_{LR}. Third, the equation is derived to Q.

[5]

$$\text{Total transport cost}_{SR} = ((f \times D) \times H) + [((l + i) \times U) \times L] + ((h + t) \times H) / W + (p + z + z_S/5) / W$$

Taking the derivative to the number of stops, i.e. Q[127], results then in the Long Run Marginal Transport Cost of bicycle transport ($MTC_{Bike\ LR}$) **[6]**:

[6]

$$MTC_{Bike\ LR} = \frac{[\,(W^2 \times f \times D) + (W^2 \times (l+i) \times U) + (W \times (h + t))\,]}{40 \times W^2}$$

Performing the same three steps on [1] for LCV transport, with variables H_{LCV} = f(Q/65) and L_{LCV} = f(Q/65), results then in the LR Marginal Transport Cost of LCV transport ($MTC_{LCV\ LR}$) equation **[7]**:

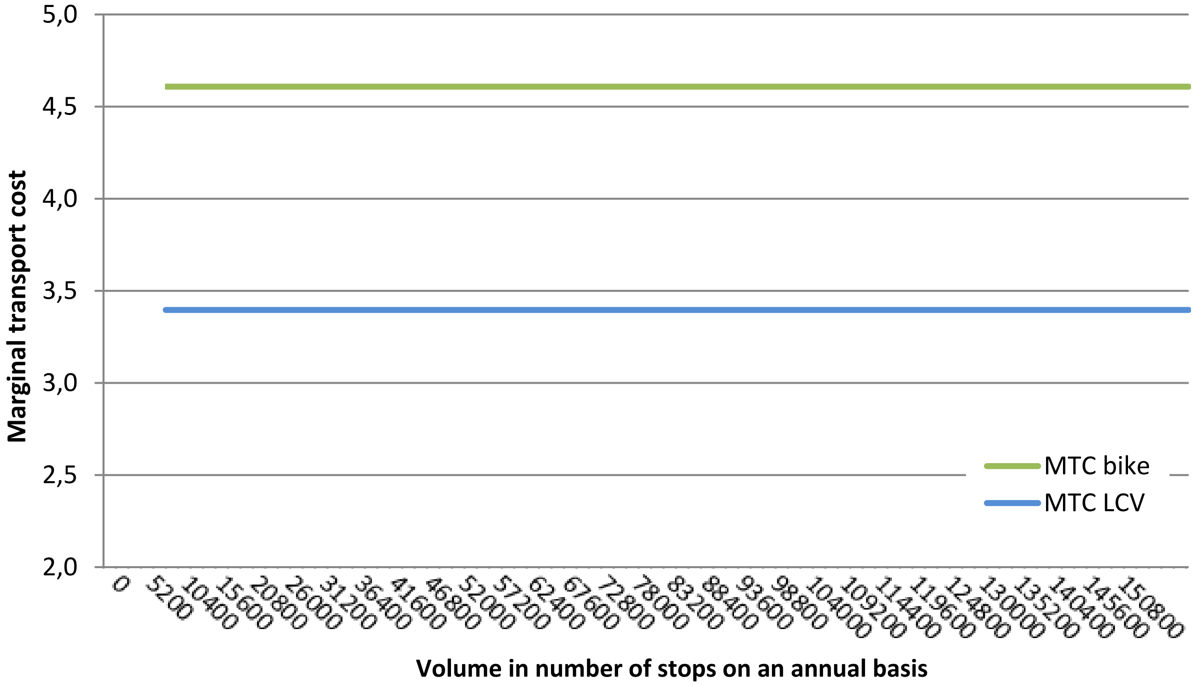
[7]

$$MTC_{LCV\ LR} = \frac{[\,(W^2 \times f \times D) + (W^2 \times (l+i) \times U) + (W \times (h + t))\,]}{65 \times W^2}$$

[127] The derivative to Q of this equation can as such be seen as the derivative of the trend line trough the TTC equation. In the long run, all parameter values are variable. The long run as such does not indicate a pure time related change, but a change in the capital structure of the company.

Using the data of Table 39 in the equations [6] and [7] results in the next Figure 61 illustrates the simplified MTC, showing the derivatives to Q of the LR TTC equations. MTC of bicycle transport is higher than for LCV transport. This was also seen in the LR ATC, which is exemplary for the MTCs. This simplification builds further on the hypothesis of no dis/economies of scale. This would otherwise lead to increasing costs (as illustrated in Figure 46 on page 177).

Figure 61: Long Run Marginal Transport Cost simulation – Bike and LCV



Note: These simulations do not include the external effects

The Long Run MTC graphs of both modes differ. $MTC_{bike\ LR}$ of delivering an urban parcel by bicycle in this theoretical setting is 1.21 EUR more costly per stop. Still, in this simulation result, no external effects are taken into account for simulating this price level.

4.5. Synopsis: Business case for CEP deliveries by cargo bicycle is challenging

Based on of the business case simulation, using the own developed cost estimation tool, depicted in section 4.1. and 4.2., and applied in 4.3. and 4.4. intermediate conclusions can be drawn. Three aspects are to be regarded in particular: Average Transport Cost of both modes, the Total Transport Costs and the main cost drivers. In addition, some weaknesses of the current analysis are touched upon and the link is made to Chapter 5 where these result will be analysed further on the welfare-economic aspects.

- First and most importantly, when looking at the **Average Transport Costs** for both Bike as LCV operations, the conclusion can be made that the Bike option is in a share of the market segment 'Post & CEP' the more expensive choice.

In some smaller intervals of the market demand, the bike solution is less costly than traditional transport. These intervals are mainly found in the situation where there is a lower daily demand; the left hand side of the X-axis. This indicates the niche position of cargo cyclists. Found in the markets characterised by lower volumes per day, e.g. own account transport. Especially below 20 stops a day, the costs per delivery go sky-high, for both modes. In the broader range, being above 250 stops a day, transport costs stabilise. There, the intermediary conclusion is as founded on that LCV transport is in general cheaper than bike transport. As LCVs have a higher load capacity, it is easier to recover fixed costs.

- Second, the **Total Transport Costs** give insight in the cost structures. The costs go up with increasing demand, originating from the need for supplementary vehicles in the total company fleet when a certain average number of stops per day is reached (the tipping point per bike was set at 40 tops per route, whereas for LCV the cap of capacity was set at 65). at these specific points, the volume goes up by one whereas the costs go immediately up by one extra driver and one extra vehicle.
- Third: the **main cost parameter** is the labour cost. The simulations and cost functions show that the vehicle cost is relatively less important. The fuel consumption is as well less relevant than expected, so is the diesel price. A full sensitivity analysis follows.

Hence, this simulation gives an insight in the competitiveness of two companies, each choosing different vehicles to operate an urban freight transport service. There are some elements that are not yet considered. At first, there is the issue of external costs. These are not taken into account yet. Emissions, congestion and other external costs are in the above-defined scenarios not identified nor internalised. And as shown in Chapter 2, these are surely relevant to be taken into account as for example congestion and urban emissions are noteworthy. Therefore, this current setting will be elaborated in the next Chapter, incorporating external effects (mostly costs, some benefits) in the cost simulation.

Not taken into account, is the routing problem from depot to city. This is of the scope of this modelling appraisal. A totally new research setting is encountered if the depot location is far from the city centre. The cargo bike will be slower compared to the LCV that is able to use highways. Also the higher LCV capacity is as such influencing the depot location. A solution could be to have the depot in the city outskirts. As Dablanc (2007) concluded, a city is a complex, costly and constrained place that is only used for loading and unloading. Freight has no location in the city, as other location factors are more important.

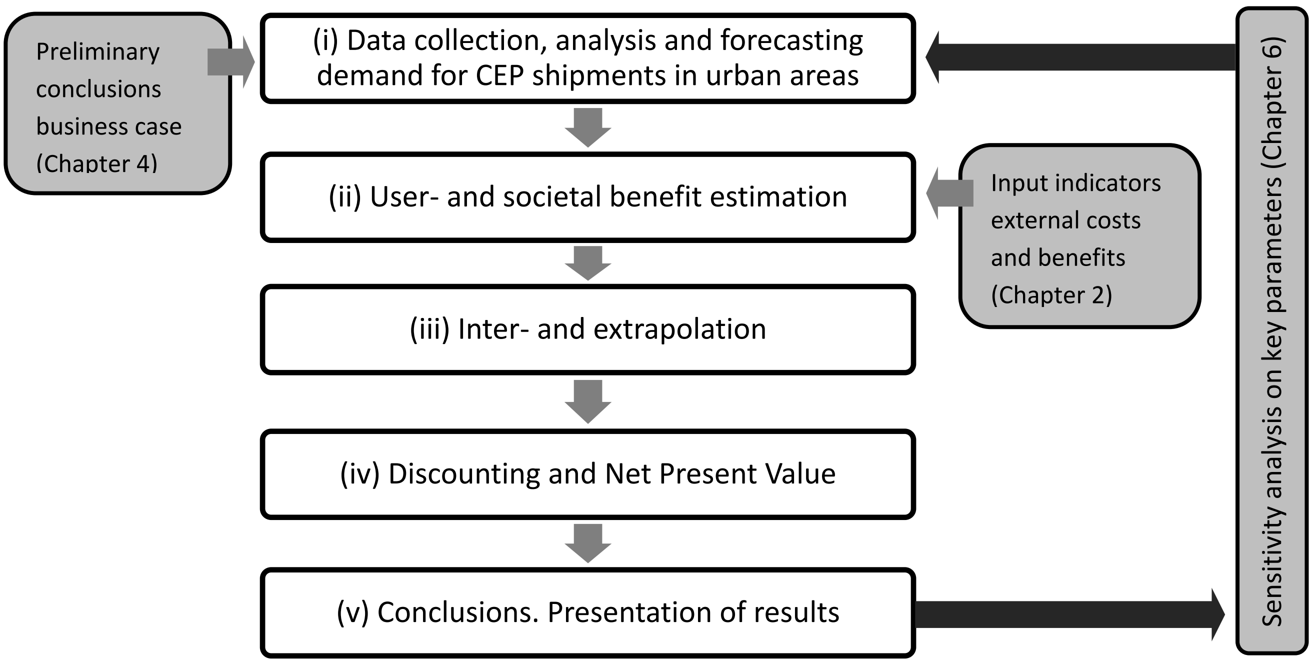
In Chapter 4’s setting, the depot was theoretically considered to be near the city centre. One of the hypotheses is that the link between the last-mile solution (being an LCV or bike based transport operation) is the same for both. One can already see a problem if the hub is located far from the city centre. This aspect is not regarded in Chapter 5 either, as otherwise comparability between the chapters would be lost.

5. Welfare-economic evaluation of the use of cargo bicycles for urban freight transport

Chapter 4 developed a introductory business case simulation, after which the conclusion is made that Bike transport in the CEP setting defined for this Ph.D. is not yet competitive to LCV transport. Bikes have sustainability characteristics, which are worth will to regard too. This chapter will elaborate the research on the competitiveness via a welfare-economic analysis.

This indicates the introduction of external costs in the equations and the simulation model. This will lead to conclusions on the societal (dis)advantages of the use of cargo bicycles. Internalising external costs in the simulated prices will likely alter the competitiveness of the two considered transport modes (Chapter 2 indicated vast external cost difference between motorised and non-motorised vehicles). The welfare-economic approach follows the methodology depicted in Chapter 3, and is briefly summarised in Figure 62 below. Just as for the outcomes in Chapter 4, a sensitivity analysis on the conclusions is organised in Chapter 6.

Figure 62: Five steps in cost benefit analysis process Chapter 5



5.1. Data collection, analysis and forecasting demand for CEP shipments in urban areas (i)

Data collection on urban freight transport is one of the main challenges for researchers in this field. EU proxy data exists, and will be used as an approximation of CEP demand. The literature overview in Chapter 2 showed that according to BESTUFS (2005), Ogden (1992), LET (2000), Figliozzi (2007) and Macário (2012a), a city approximately generates: 0.1 pick-ups or deliveries per inhabitant per day; one delivery or pick-up per job per week; 300 to 400 truck trips per 1,000 people per day or 30 to 50 tons of goods per person per year.

Projecting these research findings on Belgian cities provides an approximation of the number of freight movements and pick-ups/deliveries, without organising own time-consuming nor trustworthy surveys. These indications are used with regard to Belgian demographic data. Table 43 shows the estimates using these research proxies, for the 14 main cities in Flanders. As a basis, 2016 population data is used (Statbel, 2016). The column of the total inhabitants per Belgian city (on 1/1/16) is multiplied by 0.1 (the proxy average of pick up and deliveries - PUDs - per inhabitant per day) multiplied by 260 workdays.

Table 43: Approximated number of freight movements in Belgian cities (2016 data)

City	Inhabitants 1st Jan 2016	Estimated (un)loading activities / year	Mil. freight vehicles		Mil. tons / year	
			Min.	Max.	Min.	Max.
Aalst	84.329	2.192.554	6.58	8.77	2.53	3.37
Antwerp	517.042	13.443.092	40.33	53.77	15.51	20.68
Bruges	118.053	3.069.378	9.21	12.28	3.54	4.72
Genk	65.691	1.707.966	5.12	6.83	1.97	2.63
Ghent	65.691	1.707.966	5.12	6.83	1.97	2.63
Hasselt	76.685	1.993.810	5.98	7.98	2.30	3.07
Kortrijk	75.506	1.963.156	5.89	7.85	2.27	3.02
Leuven	99.288	2.581.488	7.74	10.33	2.98	3.97
Mechelen	84.523	2.197.598	6.59	8.79	2.54	3.38
Oostende	70.600	1.835.600	5.51	7.34	2.12	2.82
Roeselare	60.999	1.585.974	4.76	6.34	1.83	2.44
Sint-Niklaas	75.208	1.955.408	5.87	7.82	2.26	3.01
Turnhout	42.965	1.117.090	3.35	4.47	1.29	1.72
Brussels region	1.187.890	30.885.140	92.66	123.54	35.64	47.52

Source: By use of EU proxy methodology of BESTUFS (2006), Ogden (1992), LET (2000), Figliozzi (2007)., Macário (2012a); and based on Statbel (2016) data

Of course, not all PUDs are related to (the market segment of 'Post & CEP' transport. General freight transport (palletised goods for example) is an important share of this approximation. The CEP market is only a small share of the total logistics market (Patier-Marque, 2002; Ducret and Delaitre, 2013). When based on Patier-Marque (2002), the specific CEP transport market is estimated to amount to up to 50% of the total number of PUDs, the yearly number of PUDs is approximately 6.72 million PUDs per year in Antwerp, and for Brussels the approximation is 15.44 million PUDs per year (see two left columns in Table 44 below).

CEP transport demand is currently largely fueled by e-commerce sales. Current data on the Belgian Post & CEP market can be used to crosscheck the approximations. In 2015, an average Belgian ordered 12.4 parcels per year (ERGP, 2016; BIPT, 2015; BIPT, 2017). Based on this data, and the number of inhabitants in 2016, the yearly number of CEP PUDs for Antwerp would accumulate to 6.41 million. And for Brussels the approximation is then 14.73 million PUDs per year (see two right columns in Table 44 below). Given that parcel volumes in Belgium grew by 24.3% between 2013 and 2015, the slightly higher outcomes than the 2016 approximations of 6.72 and 15.44 million PUDs are plausible.

Table 44: Approximated total parcel pick up and deliveries in Antwerp and Brussels on EU proxy data and BIPT data (in 2016)

	EU proxy data used on Belgian inhabitant data		Cross-check with parcel demand data 2015 (BIPT, 2017)	
	Number of inhabitants 1/1/16	Average PUD estimate per year	2015 estimated parcel demand per inhabitant	Estimates CEP per city per year
Antwerp	517,042	6,721,546	12.4	6,411,321
Brussels region	1,187,890	15,442,570	12.4	14,729,836

This demand hypothesis is used as a 2016 base year approximation. Looking at the recent growth therein, current CEP demand is highly likely to grow further. Recent market data for Belgium confirmed a boom in e-commerce, leading to additional transport demand. This growth is considered specifically in step (iii).

5.2. User- and societal benefit estimation (ii)

Freight transport activities, while performing their services, do not fully compensate their (considerable) amount of external costs (costs that are not directly paid for by the transport operators or his clients). Transport prices represent currently only a portion of the total costs. Transport operations influence society positively as goods reach consumers, growth in e-commerce sales prove their benefit. Customers benefit from the speediness and frequency of having access to a dense network of numerous CEP transport services.

But also negative effects are present, as operators and consumers do not pay the full or fair price for their shipments. Unquestionably, urbanised areas are suffering from the effects of excessive transport activities in the form of increased road congestion, pollution, noise etc. Transport prices would be higher if all costs would be charged to the final consumers.

Hitherto, the simulation only generate private transport costs. The preliminary conclusions on the business case (Chapter 4) showed a limited competitiveness for cargo bicycle transport, when operating in a routed structure for the 'Post & CEP' market segment. this compared to transport prices current attained by LCV transport.

In contrast to cargo bicycles, LCVs emit more pollutants locally and do contribute to road congestion. If these type of costs were to be internalised, the competitiveness balance would be altered. To get insight in the real welfare-economic effects thereof, here the social total transport cost should be calculated. These will be simulated by means of an elaborated transport cost equation, based on the initial transport cost equation [1] on page 171.

5.2.1. Investment and operator costs

The first of four elements in the societal evaluation of the two transport solutions, are the investment- and operator costs (estimates were retrieved via the business case, in Chapter 5). The outcomes of the business case are summarised as a starting point.

These were:

i) The Average Transport Costs (ATC) for cargo bikes are in the majority of the range of the simulation elevated. Only in low-volume markets, e.g. own account transport in urban areas, bicycle transport has a niche product which is very competitive with LCV transport.

ii) In these intervals of the total market, the bike solution is less costly. These intervals are mainly found in the lower volumes, below somewhat 22 stops per vehicle per day. The ATC_{LCV} cost curve is there higher than the one of bike transport. When a minimum scale is achieved, above 200 stops per day per company for example, LCV transport is considerably cheaper.

Q per day	LR ATC LCV	LR ATC Bike
1	124.59	105.52
2	63.99	55.06
3	43.79	38.24
4	33.69	29.84
50	5.82	6.63
100	4.61	5.62
150	4.20	5.28
200	4.00	5.11
250	3.88	5.01

300	3.80	4.94
350	3.74	4.90
400	3.70	4.86
450	3.67	4.83
500	3.64	4.81
600	3.60	4.78

iii) The yearly Total Transport Cost (TTC) of the LCV-based routings (TTC_{LCV}) is lower than TTC_{Bike}. The TTC curve moves sawtooth-wise up, originating from the underlying need for supplementary vehicles in the company's total fleet, when a certain average demand per day is reached (the tipping point of maximum capacity in number of stops per bike per day was set at 40, per LCV it was set at 65). In this simplification, the demand goes up by one stop whereas the costs to fulfil this demand go up by approximately one extra driver and one extra vehicle.

Average Q per day	Linear LR TTC LCV	Linear LR TTC Bike
1	27,435	32,392
2	28,633	33,275
3	29,831	34,158
4	31,029	35,041
50	86,135	75,658
100	146,033	119,806
150	205,930	163,955
200	265,828	208,103
250	325,726	252,252
300	385,624	296,400
350	445,522	340,548
400	505,420	384,697
450	565,318	428,845
500	625,215	472,994
600	745,011	561,291

iv) The Marginal Transport Costs (MTC), the long run ATC curve also repeats the ATC differences. These are lower for LCV than for bike transport.

MTC LCV	MTC Bike
3.4	4.61

5.2.2. Social (operational) costs

The key difference between the SCBA and the business case is seen in the inclusion of parameters related to external costs and benefits. These external costs and benefits are not directly borne by the entrepreneur organising the urban logistics services, nor by the consumer, but are important from a societal point of view. A theoretical overview was already specified in Chapter 2 depicting the problem analysis.

At this point, the additional appraisal parameters are defined. These values will be used to fuel the SCBA calculations. Now the model, after business costs and profits, likewise regards the external costs and benefits.

I. Taking account of external costs

The main negative external effects of freight transport services are, according to research by Blauwens et al (2012) and Ricardo-AEA (2014), related to five elements. The first two ones are external congestion costs and external emission costs. These are both significant effects of transport on society and will both be taken into account. External noise costs are an important third factor, especially for urban areas, and therefore will be considered too. Though these are much lower than former two. The fourth category of external costs is related to road accidents. These are of importance, certainly in urban areas with a dense traffic. These do not include the internalised costs, already borne and/or insured by the consumers.

A fifth and last external cost is infrastructure wear and tear. These costs are mainly related to heavy freight vehicle transport, less to LCV transport and certainly not to bicycle transport. Therefore, these external costs are not regarded further on. Recently, new external cost data were published by Ricardo-AEA (2014). This extensive work compares data on different European countries, regions and areas. The data of Ricardo-AEA (2014), shown in the next table, are Belgian external cost estimates (in 2016 price level).

Table 45: Consolidated external cost urban freight transport (EURct/vkm) (2016) (BE)

		EURct per vkm	
		Cycling	**LCV**
c	**External congestion cost per vkm**	0.00	1.35
m	**External climate change cost per vkm**	0.00	0.03
e	**External emission cost per vkm**	0.00	0.04
u	**External up- and downstream cost per vkm**	0.00	0.013
n	**External noise emission cost per vkm**	0.00	0.00001
a	**External accident cost per vkm**	0.09	0.003
t	**External wear and tear cost per vkm**	0.00	0.01

Source: Based on Ricardo-AEA, 2014

A significant difference is seen between urban and non-urban external cost estimations (Ricardo-AEA, 2014). For some external cost parameters, e.g. climate change and congestion, values for different densities of traffic and/or time of the day are given.

Mira (2010) and CE Delft et al (2011) and Delhaye et al (2017) were also considered, but Ricardo-AEA's (2014)[129,130] publication has also recent and more specific external cost data. This dataset was chosen because of its European comparability. More details on these differences with other sources can be found in the Annexes on page 295.

II. Taking account of external benefits

In addition to the external costs, one can also identify external benefits. These are smaller in comparison to the external costs and can be divided in two groups: external health benefits and the external labour benefits (which are expressed in saved unemployment benefits). Due to uncertainties about the data and the applicability on commercial bicycle transport, this effect will not be taken account of in the appraisal. Nonetheless, it is advised to the research community to further research this likely impact.

Health benefits

Research by Thompson (2008) for example, provides awareness on positive external benefits of cycling. Cyclists live, when being compared to LCV and truck drivers, a more healthy life. It could be that cargo cyclists choose this job because they are healthier. Cycling in congested urban areas can be less healthy than in rural areas though. Healthier people cause less medical costs for society (the healthcare system has to pay less to these individuals). But the effect will only be considerable if many bicycle drivers would be used to transport freight. chapter 2, section 2.2, showed a market analysis on Belgian cargo cyclists and indicated there is a small market, with a potential growth, however at a slow pace.

For Flanders, an indication of this parameter value was found. Mira (2010) estimated this external benefit of cycling at 11.63 EUR per 100 vkm (2010 estimates). The direct and external effect on health of cycling comprises following sub-elements:

(i) The increase of value of human lives is the first one. Cycling 160 times 3.9 km is enough to lower health problems, according to Cycling England (2007). In this study, the benefits total then from 27 EUR up to 285 EUR, depending on the age and the health of the actual population. A conservative average for the UK would account for a benefit of 71 EUR. Andersen et al (2000) proposed a higher value of

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[129] Mira (2010) and CE Delft et al (2011), were considered as well, but Ricardo-EAE's (2014) publication has recent and specific external cost data. Despite the more recent data, not all parameter values needed to fuel the simulations in this chapter could be found in this source. Therefore, it was opted to use the research results of urban external costs of CE Delft et al (2011), data from 2008 but inflated to 2010. Moreover, these values are representative for quite some other European historic cities, making the conclusions after the simulation more valuable, than when a local focus would be kept.

[130] Air pollution are LCV and HDV averages based on Euro 3 and Euro 4 vehicles.
Wear and tear HDV average of all trucks 7.5-40t.
Noise and congestion LCV and HDV based on average of thin and dense day traffic.
Accident costs LCV are defined on the basis of car values.

605 EUR per Danish cyclist. The Nordic Council (Saelensminde, 2002) estimates the benefit even higher for 'new' cyclists up to 900 euro per year or 15 cent per km (calculating with an estimate of 16 km per day).

WHO (2007) estimates the km value at 0.81 € per km per individual. The DfT/Sustrans model approached the question from the non-active population and estimated the external benefit of cycling at 149 EUR per year. TNO came up with 48 eurocent/km for regular cyclists and KiM (2007) states that regular cyclists are physically on average 10 years younger than their actual age. Moreover, they are less vulnerable for diseases and have 50% less heart attack chance. KiM however sees as well a negative effect of cycling. Breathing in pollution while being active is more dangerous for infiltration of fine particles to the core of the lungs. Also TNO (2010) researched the fitness of people, and concluded that active regular cycling can increase the fitness of people by 3%. Belgian research on cycling by de Geus (2008) concluded that the effect of commuting by bicycle is advantageous for the average health level.

(ii) The second effect of cycling is related to the social security systems. Cycling England (2007) estimated a saving of 34 EUR per year per inactive person getting active. Others estimated lower values: 22.91 – 46.14 EUR/year (Game Plan) and higher values: 212.61 EUR/year (Macdonald, 2007).

(iii) A third effect is an increase in productivity by a lower rate of absenteeism. The company's competitiveness increases when staff productivity levels increase (Macdonald, 2007). TNO concluded that regular cyclists are on average one day less sick per year. Regular was defined as minimum 3km one way or minimum 4 times 2 km one-way per week. Non-regular are cyclists not cycling every week(day) to work. Saved costs, or increased productivity, for The Netherlands were estimated at 280 EUR/day. Cycling England estimated these at 57.93 EUR per day. VITO (2010) estimated these savings at 123 EUR per day per employee being more productive.

(iv) Obesity is the fourth factor. Cycling increases the average calories consumption of the population and as such decreases the rate of obesity. No monetary estimate was retrieved.

The total could sum up to 71 EUR for the health benefits, 46 EUR for the social security benefit and 123 EUR for the increase in productivity. This totals to an average of 240 EUR per cyclist per year. A Belgian cyclist on average commutes 9.19 km per day, or 2,067.56 km per year, which is resulting savings amounting to 11.63 EUR per 100 km.

Recent updates on Dutch cycling benefits (Schepers en Wijnen, 2015) showed research impacts on mortality, morbidity and values of additional healthy human lives. These are included in the update of MIRA (2010) i.e. Delhaye, De Ceuster et al (2017). For mortality, with an estimate of statistic live (a WHO method[131]) a cyclist is representing benefits of 1.29 EUR/bikekm.

A second method, estimated values between 0.38 and 0.63 EUR/bikekm. Here, only decreased death risk is regarded, and not the positive health impacts. Therefore, the last approach with values of additional healthy human lives is more accurate. There values between 0.28 and 0.47 EUR/bikekm are obtained.

But, there are three major elements of critique to this external health benefits research.

- First, the value results mainly from leisure activities on bicycles. It cannot be said with absolute certainty that these values are equal in a business situation where time pressure and urban traffic causes higher stress levels for the cyclists.
- Second, the market of urban freight transport by bicycle is not big enough to really define a significant benefit for the whole healthcare system.
- Third, Schepers en Wijnen (2015), KIM (2017) and also Rable et al (2011) notice the negative impact of local air pollution on cyclists. A cyclist is breathing more intensely when in action, which could lead to health costs.

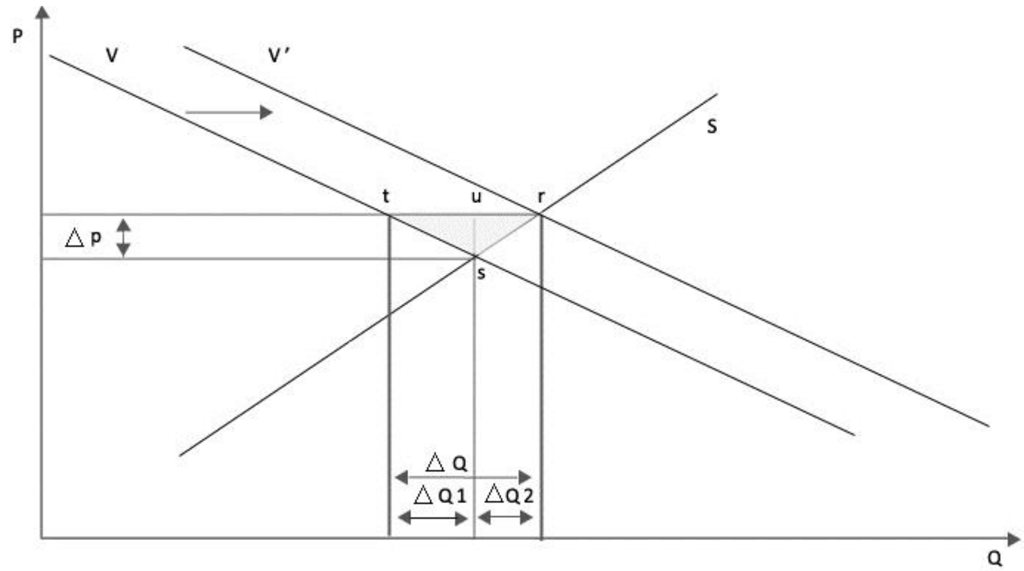
Employment benefits

Besides external health benefits, positive employment benefits can be identified. When employing drivers, an entrepreneurs, one needs for the same volume of cargo (x parcels for example) more cyclists than one would need LCV drivers. This indicates a growth in employment, without an increase in the number of shipments in total. Only by changing modes, the same volume of urban pickups and deliveries generates more employment. The idea is illustrated in Figure 63.

The gross employment change from the modal split does however not always reflect new employment. A part of the staff employed in the new concept is attracted from other jobs, and only a certain share of the new employees results from unemployment. This net part resulting from unemployment should be taken into account and depends on the slope of the demand and supply curves on the labour market. The figure on the next page sketches the principles. The additional demand for labour is projected as a shift of the demand curve from V to V’. The horizontal move of the equilibrium for ΔQ is equalling the gross change. The equilibrium however shifts from point s to point r. The net change is equal to ΔQ2, smaller than the gross increase (Debisschop, 2001).

[131] WHO (2007) Economic assessment of transport infrastructure and policies; methodological guidance of health effects related to walking and cycling.

Figure 63: Indirect effect of a project on employment



Source: Based on Debisschop, 2001

The services of cargo bicycle transport can be performed by lower educated people, of whom many are available on the labour market. In total, when a shift to bicycles is made, there is a considerable increase of employment in the sector, and that regardless of the total CEP market growth.

Therefore, this positive effect is included in the calculations by the new parameter ‘b’ which is representing the saved unemployment benefits per day per employed bicycle courier employee. This parameter value is defined as the avoided average daily unemployment benefits in Belgium. It would not be sound to consider every new employee of the bicycle courier company as an employee originating from unemployment. Therefore, a second parameter is added to the equation.

b	Benefit of saved unemployment support
%b	The percentage of the total bicycle courier staff originating from unemployment

And %b is the percentage of the total bicycle courier workforce originating from full unemployment. If the parameter value is set at 20, it means that the model assumes one out of five employees originate from full unemployment.

Parameter b was estimated at 51 EUR. When this employee goes from being unemployed towards full employment, the Belgian state-funded unemployment benefit cost drops by this sum equally. This is a cautious estimation as a person in employment will as well pay income tax on the earned salary (in contrast to the majority of the unemployed, not paying income taxes). This consequence is not included in the parameter value, only the saved unemployment support is taken account of. This impact is only true when the labour market does not reach full employment and should therefore be included in SCBAs with preservations.

III. Social total transport costs

The business cost equation used in Chapter 4 will need to be adapted to the internalisation of external effects (costs and benefits). Several parameters need to be added to the former TTC equation **[1]**.

Including the external effects into the TTC equation then results in the Social Total Transport Cost (STTC) equation [13] shown on the next page. Start-up costs are added between brackets; as these are depreciated over five years and from there on do not count fully. This leads to the Social Total Transport Cost (STTC) equation **[8]**:

[8]

$$= ((f \times D) \times H) + (t \times D \times H) + (m \times D \times H) + (c \times D \times H) + (e \times D \times H)$$

$$+ (n \times D \times H) + (a \times D \times H) + (u \times D \times H)$$

$$+ [(((l + i) \times U) \times L) - (b \times (L \times \%b/100)] + ((h + t) \times H) / W) + z / W + [z_S / 5) / W]$$

$((f \times D) \times H)$	**Energy cost**
$+ (t \times D \times H)$	**External wear and tear**
$+ (m \times D \times H)$	**External climate change**
$+ (c \times D \times H)$	**External congestion**
$+ (e \times D \times H)$	**External emission**
$+ (n \times D \times H)$	**Energy noise**
$+ (a \times D \times H)$	**External accident**
$+ (u \times D \times H)$	**External up-downstream**
$+ [(((l + i) \times U) \times L)$	**Labour cost**
$- (b \times (L \times \%b/100)]$	**- External labour benefits**
$+ ((h + t) \times H) / W)$	**Vehicle costs**
$+ z / W$	**Fixed costs**
$+ [z_S / 5) / W]$	**[Start-up costs]**

IV. Social average transport costs

Dividing the Social Total Transport Cost (STTC) equation by the daily volume q x Q (expressing the average number of stops and parcels per stop) results in the Social Average Transport Cost (SATC) equation [14]. This is the social average transport cost equation including $1/5^{th}$ of the start-up costs. Social Average Transport Cost (SATC) **[9]**:

[9]

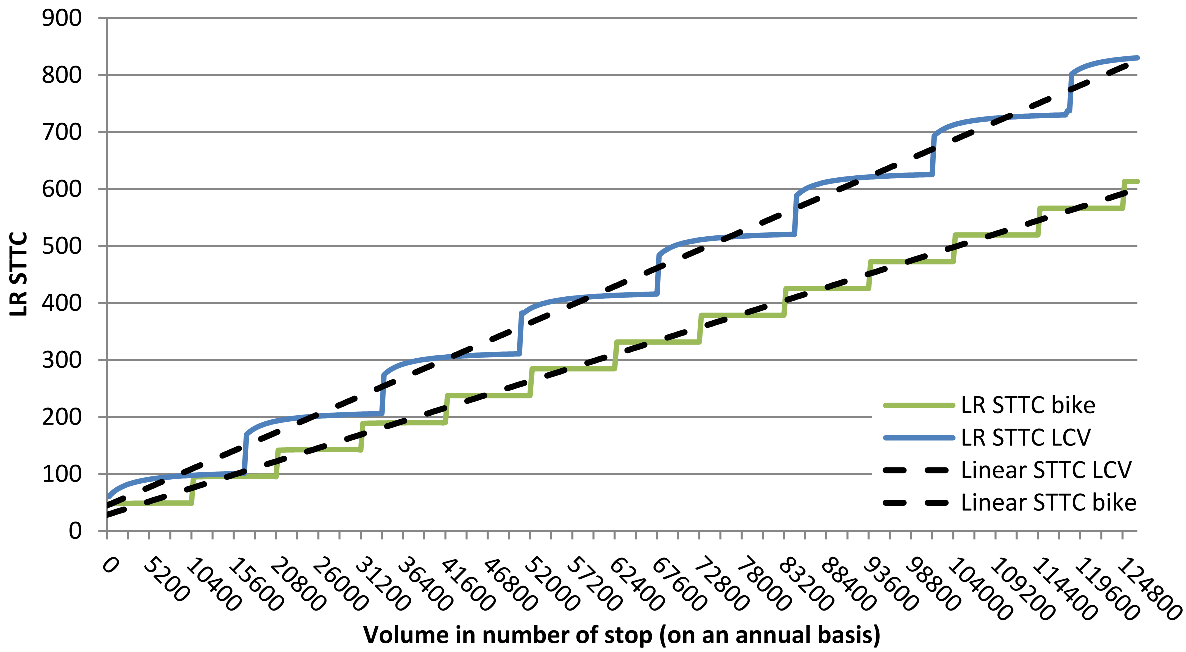
$$= \frac{((f \times D) \times H) + (t \times D \times H) + (m \times D \times H) + (c \times D \times H) + (e \times D \times H) + (n \times D \times H) + (a \times D \times H) + (u \times D \times H) + [(((l + i) \times U) \times L) - (b \times (L \times \%b/100)] + ((h + t) \times H) / W) + z / W + [(z_S / 5) / W]}{q \times Q}$$

5.2.3. Welfare-economic evaluation for routed deliveries by cargo bicycle couriers when internalising external costs and benefits

In correspondence to the business case simulation (Chapter 4), a distinction is made between the short-run and long-run transport costs. The difference between the two is clearly explained in the Chapter 5, therefore this welfare-economic approach will only focus on the long-run transport costs.

The Social total Transport Costs (STTC) graphs are shown below and include the external cost and benefit parameters.

Figure 64: Long Run Social Total Transport Cost (LR STTC)

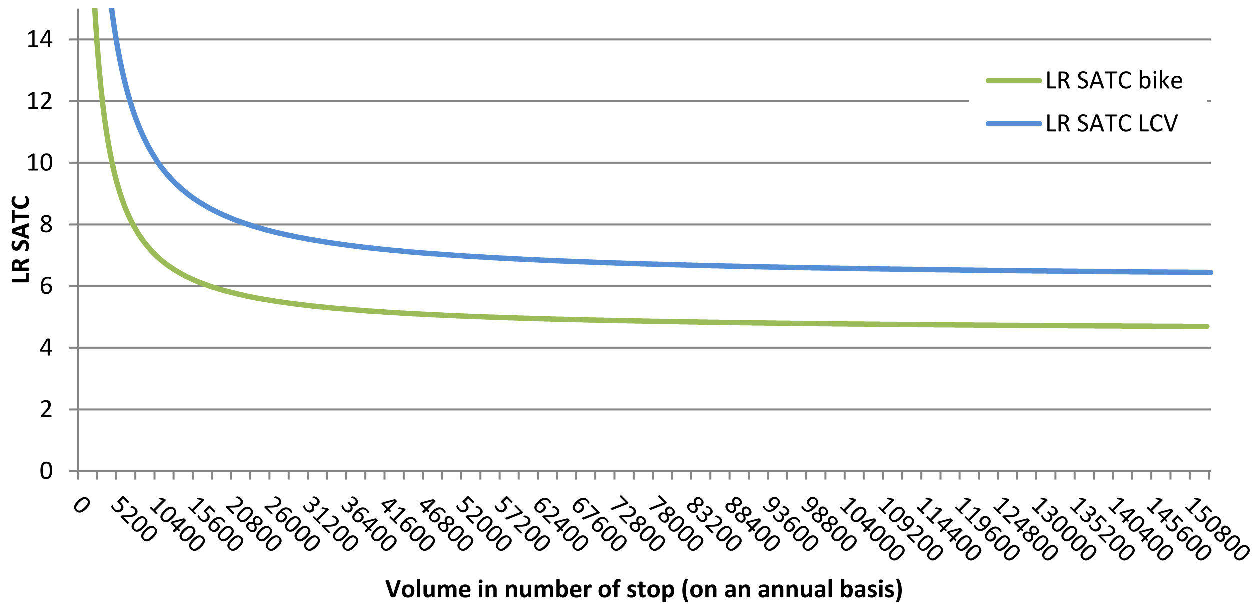


This results in a downward shift of the ATCBike to the new $SATC_{Bike}$. The $SATC_{Bike}$ is almost continuously competitive with the SATC of LCV transport. The internalisation of external costs and external benefits does result in a lower cost per stop, shown below.

Internalising the external benefits and external costs results in new average cost values, ranging from about 4.5 EUR per stop for Bike transport till 6.5 EUR for LCV transport; depending on the size of the company.

Hence, when internalising the external effects (costs and benefits), bike transport prices reflect the clear socio-economic benefit they have over LCV transport. The bicycle transport solution is in contrast to the result of the initial business case, simulating only the private transport costs, more competitive.

Figure 65: Social Average Transport Cost simulation (long run SATC)



5.2.4. Matching supply of cargo bicycle capacity with market demand

In this section, the aggregated supply and demand curves for the two last mile parcel delivery concepts will be estimated. This step is undertaken to subsequently estimate the business/ societal costs and benefits, and changes in consumer surplus, when *traditional* LCV companies would converse their fleet towards cargo bicycles.

To start a CBA analysis, an estimation of the supply and demand curve for the market is needed. The supply curve, being the upward sloping part of the marginal transport cost (MTC) curve, can be calculated on the basis of equation [5] on the Total Transport Cost (TTC), equation [7] on the Social Total Transport Cost (STTC) and equation [8] on the Social Average Transport Cost (SATC). That way, the supply curve for this specific market is obtained.

Prices of these urban freight transport services are not openly shared nor published in literature. Data are dispersedly available with for example the big express operators (e.g. TNT, DHL and UPS), small and medium size delivery companies, postal services and others. These know their own part of the market well and will have a good view on their market share and competitors' behaviour. Due to the lack of data, estimates on the costs, not real cost data, will be used to perform a cost-benefit analysis. These estimates were verified in the interviews with cargo bicycle couriers which were undertaken for Chapter 2.

I. Estimating the market supply curve of urban freight transport via MTC

On the basis of the preceding research at a business economic level, the (social) marginal cost curve or supply curves of both last mile solutions will be estimated. From preceding (S)TTC equations [9] and [10], respectively the Marginal Transport cost (MTC) and the Social Marginal Transport Cost (SMTC) equations can be obtained. The derivative of the equation which internalises relevant external costs and benefits - to Q - will result in equations [11] for the Social Marginal Transport Cost of bicycle transport ($SMTC_{bike}$) and [12] for $SMTC_{LCV}$.

It was supposed, as shown in Table 39 on page 174, that every cargo bike can handle a maximum number of stops per day, and that one extra vehicle will be engaged from the moment an entrepreneur encounters the tipping point at 'q x Q => 40'. The LCV however has a bigger carrying capacity and can handle a service of 65 'q x Q' or stops on average. This means that the number of vehicles (H) and the number of drivers (L) are both a function of Q.

- H_{bike} = f(q x Q/max. volume per vehicle) = f(q x Q/40);
- L_{bike} = f(q x Q/ max. volume per vehicle) = f(q x Q/40);
- H_{LCV} = f(q x Q/ max. volume per vehicle) = f(q x Q/65);
- L_{LCV} = f(q x Q/ max. volume per vehicle) = f(q x Q/65).

This results in the several steps of rewriting equation [9], before taking the derivative to q x Q. First, the SMTC for bike transport is calculated, which implies replacing H_{bike} and L_{bike} by (q x Q)/40.

To clarify the result, all intermediate steps are given, even though these are straightforward. However, the experienced reader is free to jump towards equation **[10]** immediately.

Social Total Transport Cost (STTC):

[10]

$$= ((f \times D) \times H) + (t \times D \times H) + (m \times D \times H) + (c \times D \times H) + (e \times D \times H) + (n \times D \times H) + (a \times D \times H) + (u \times D \times H) + [\, (((l + i) \times U) \times L) - (b \times (L \times \%b/100)\,] + ((h + t) \times H) / W) + z / W$$

Taking de derivative to Q of the above finally results in the Social Marginal Transport Cost of bicycle transport ($SMTC_{Bike}$) [11]:

[11]

$$SMTC_{bike} = \frac{[\, W \times (((f \times D)) + W \times (t \times D) + W \times (m \times D) + W \times (c \times D) + W \times (e \times D) + W \times (n \times D) + W \times (a \times D) + W \times (u \times D) + [\, (W \times (l+i) \times U) - (W \times (b \times \%b /100) + (h + t)\,]}{40 \times W}$$

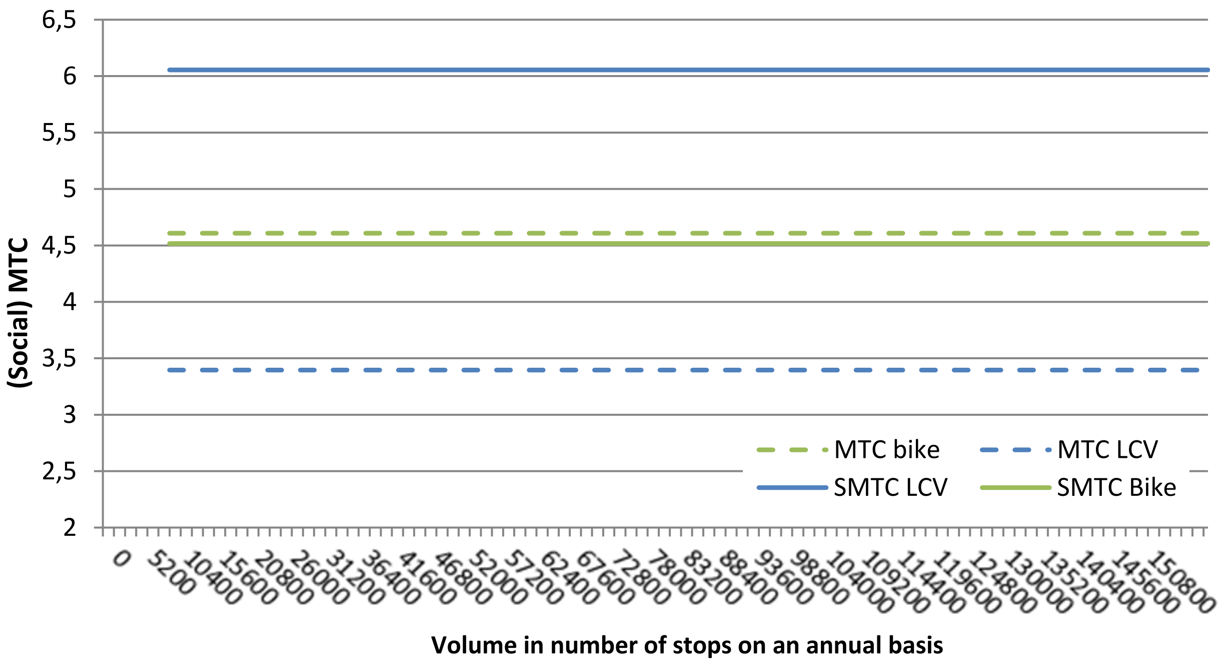
Performing the same steps on [10] with variables H_{LCV} = f(Q/65) and L_{LCV} = f (Q/65), results in the Social Marginal Transport Cost of LCV transport ($SMTC_{LCV}$) equation [12]:

[12]

$$SMTC_{LCV} = \frac{[\ W \times (((f \times D)) + W \times (t \times D) + W \times (m \times D) + W \times (c \times D) + W \times (e \times D) + W \times (n \times D) + W \times (a \times D) + W \times (u \times D) + [\ (W \times (l+i) \times U) - (W\ (b \times \%b\ /100) + (h + t)\ ]}{65 \times W}$$

The result of equations [11] and [11] are graphically shown below. These results are compared to equations [6] and [7] of the business case analysis in Chapter 4. Figure 66 depicts the simplified SMTC and MTC graphs. These marginal costs are a constant value, because of the disappearance of the factor Q in equations [11] and [12]. The hypothesis of non-existing or limited diseconomies of scale, mentioned in the introduction of this chapter, results in a constant or a flat MTC curve. This indicates that on average, every extra stop adds between 3 and 4 EUR.

Figure 66: Long Run (Social) Marginal transport costs - bike and LCV



For the MTC_{bike}, the value of 4.61 EUR was obtained. The MTC_{LCV} was estimated at 3.40 EUR. These values, which can be considered a price per parcel drop, do not include the external costs and benefits. These were only incorporating business costs.

When the external costs are included, as in Figure 66 above, it has mainly the effect of an upward rise in the MTC_{LCV}.

- MTC_{Bike} decreases a little till a $SMTC_{Bike}$ of 4.52 EUR, as a result of the employment benefits for cargo bicycle companies. Cargo bicycle couriers demand for the same number of parcels more employment. Remember that health benefits were not included.

- MTC_{LCV} shifts up significantly, to a value of 6.05 EUR, the $SMTC_{LCV}$. Table 46 summarises the results depicted in Figure 66 above.

Table 46: (Social) marginal transport costs bike and LCV transport (in EUR)

	LCV	Bike
MTC	3.40	4.61
SMTC	6.05	4.52

The former section elaborated on the estimation of the supply curve for LCV and bicycle freight delivery services in urban areas. The supply curves were obtained by comparing the long-run marginal costs of both options. These long-run marginal cost curves indicate the supply curve. This supply curve is estimated at a fixed value as an additional shipment should cover the long-run marginal cost curves. Below these values, it is not possible to organise services in an economically viable way.

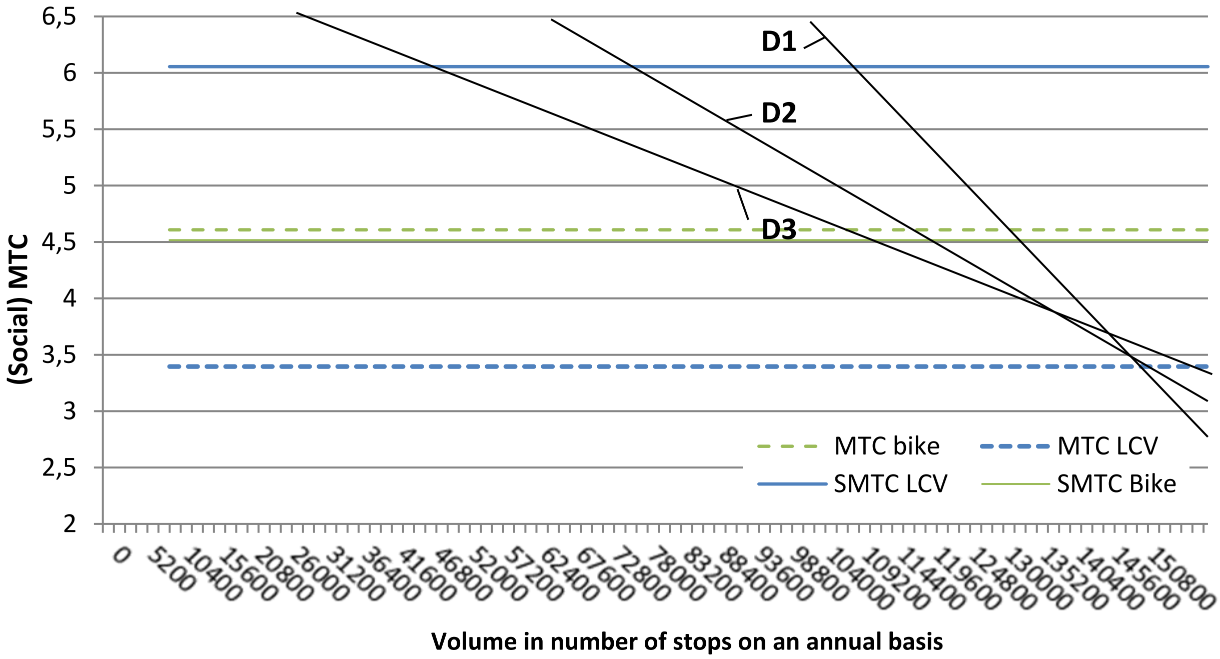
The marginal costs do not continue to decline in the long run, unlike in for example industrial production environments; as a maximum capacity restriction (a fixed cap of drops per vehicle per day) was applied. Both the bike and the LCV can handle at maximum a certain amount of stops a day, making it necessary for the entrepreneur to invest in additional vehicles when volumes surpass these critical points. Once a fleet has a certain size, this results in a nearly fixed cost environment, with variable revenues.

II. Estimating the market demand curve based on data in literature

This step leads to the market approximation for urban CEP transport. First, the supply curves were estimated. Now , the demand curve is included in the appraisal (illustrated in Figure 67 below).

The Figure shows also three suggestive demand curves, indicating possible effects of different price elasticities of demand. It is credible that the market demand will be influenced by the market price: the higher the Total Transport Cost, the smaller the demand will be. This is reflected by a downward sloping curve. Still, the value of the elasticity of demand is unknown; though it is making a major difference when estimating CBA's.

Figure 67: Illustration of supply and demand curve framework



For D1, D2 and D3 correspond to theoretical demand curves, to illustrated the theory. The price/demand elasticity of D2 and D3 is higher than for D1, reflected by a bigger change in total volumes Q by a small price change. To estimate the demand curve, a detailed market analysis should be executed. This way, for example, exact volumes and price sensitivities can be obtained. This type of research is very demanding in terms of time consumption and research budget. However, the sketched framework above allows a market analysis framework when estimating the demand curve to be linear. Values from earlier published research in literature can assist in constructing the demand curve.

Urban freight transport demand: price sensitivities in literature

Prices for urban transport services are not published publicly. However, recent parallel European literature on postal services came up with comparable results on the elasticity of demand for postal services in an urban area. The results of these researchers are briefly discussed below.

Robinson (2006) estimated the price elasticity for postal products to be low. In this large but less recent study, 45 studies were analysed for six countries. These were the UK, France, Portugal, Finland, Canada and the US. For regular mail products, the elasticity was estimated to be less than -1.0. The range is between **-0.2** and -0.8. The lowest value is attributed to the first class mail products with a limited price sensitivity.

Estupiñan and Rene (2011) estimated the price elasticities for Belgian post shipments. Data from 2008 and 2009 were used. According to their research, the price elasticity for regular, and partially regulated, postal services is -1.1. The elasticities for unregulated segments fluctuates between -2.1 and -2.8. The market with value added services (-2.1) and registered mail are highly sensitive (-3.3). The lowest price elasticity is found again in the direct mail services (-1.0).

Niederprüm et al (2011) obtained similar results for the Dutch market. From literature, these obtained the lowest price elasticities for social and office mail (-0.2 resp. **-0.25**), while transaction mail (invoices etc.) was assumed to have a slightly higher level in absolute terms (-0.3) because – resulting from interviews – bulk mailers reduced and will continue to reduce mail volumes by other measures than digital substitution, e.g. by reducing the mailing frequency of regular statements. The price elasticity in their research is the highest for advertising mail and periodicals (-0.5).

Triangle Management Services (2006) and Dietl, Lang, Lutzenberger and Wagner (2009) expected a lower price sensitivity in the B2C segment. They assumed in their research an elasticity of -**0.5**.

BIPT, the Belgian postal market regulator, published recently a study with elasticities for the Belgian market. There, postal parcels (2 - 10 kg) were estimated to have a price elasticity of - 1.45. Post parcels for professional users were estimated to have an elasticity of -1.12 (BIPT, 2016).

- ✓ Given that this elasticity is specific for Belgian parcel transport, and the fact that the results align with Estupiñan and Rene (2011), Triangle Management Services (2006) and Diet et al (2009), the elasticity value of **-1.12** will be used in the next steps.

However, because of the uncertainty about this elasticity, a sensitivity analysis will be undertaken later, where also sensitivities to this assumed elasticity are simulated (Chapter 7).

Conclusion: the demand curve for CEP transport in Belgium

In this section, Harberger's approach is used for calculating the effect of bicycle transport compared to LCV transport. A *theoretical* demand curve is drafted in the figure below for explaining the market dynamics when internalising external costs and benefits.

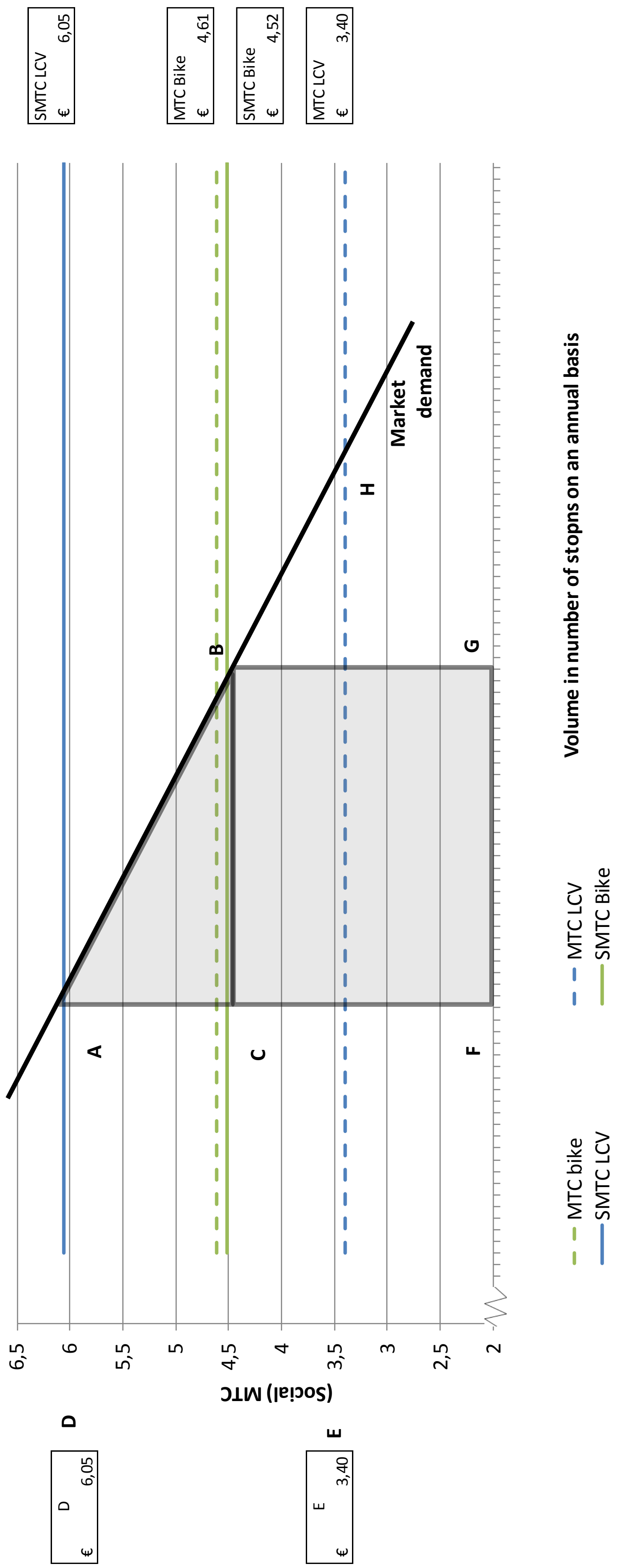
The dotted lines are the current supply curves for cargo bicycle and LCV transport. The LCVs have an advantage in routed urban deliveries, as they allow for a higher payload, as such covering more easily their fixed costs.

In this chapter, also the external costs and benefits are taken account of. This results in the new supply curves shown in green and blue. Then, the LCV cost per Q is higher than before.

If no alternative would be available, the market equilibrium would move towards price E and volume F. Prices would go up, market volumes would go down.

Then, the more efficient cargo bicycles will be a plausible alternative. The new supply curve of the market is then the green line. The market equilibrium will move towards B (with volumes G and prices C). The volumes would be lower than currently seen, and prices would be higher.

Figure 68: CBA setting before and after internalisation of external costs & benefits



This theoretical setting (depicted in Figure 68) serves as the basis for the next steps. In the hypothesis of full internalisation of external effects, a new transport solution is added to the current urban freight delivery possibilities. This means that the market can grow by "G minus F" after internalisation of costs pushed the market equilibrium to A. The welfare increase is equal to the shaded area ABC plus the shaded area BCFG.

The basis for the calculation is the earlier obtained (S)MTC_{LCV}, or H, the market equilibrium before the new delivery concept is introduced. The bike solution is represented by the (S)MTC_{bike}, lying with its transport costs higher than the former supply curve.

Based on Table 44 on page 197, illustrating the approximates for current shipment volumes for the largest 13 Flemish cities, some scenarios can be developed for estimating the welfare-economic impact of bikes versus LCVs. When evaluating a supply chain change, here a change from LCV to bicycle based transport, the formula of Harberger is highly valuable. The rule is applied in this setting, as it is simulates the market situation in which individual transport operators offer their services at Marginal Cost, while the CEP market regulator implies a hypothetic 'tax' (i.e. internalisation of external costs in this case), which will be leading to a different market equilibrium.

This approach is used for calculating whether the group welfare is increasing, and by how much, when a new supply chain concept like cargo bikes is implemented, given external costs being internalised. The implementation of this cargo bike mode into the CEP market is organised in an imperfect market and the researcher is calculating the welfare in- or decrease, by means of estimated demand and supply curves.

5.2.5. Estimating the welfare change

Table 44 on page 197 showed Belgian PUD estimates via proxies in the 'Post & CEP' transport market for the city of Antwerp, and the Brussels region. The table showed how current market approximations can be used to develop estimates for future volumes. These two scenarios were developed with low- and high-growth percentages to illustrate the magnitude.

The $SMTC_{Bike}$ is 4.52 EUR, the $SMTC_{LCV}$ is 6.05 EUR, the MTC_{Bike} is 4.61 EUR and the MTC_{LCV} is 3.4 EUR. When the latter is used in the setting of Figure 68, point H (current market demand and market prices) is than 25,852 daily CEP PUDs for Antwerp; and 59,395 for Brussels daily CEP PUDs. This is the approximation of the current CEP market equilibrium: around 25,000 PUDs per day in Antwerp at around 3.4 EUR per stop, assuming 1 stop equals 1 parcel. The current equilibrium does not internalise the external costs in the transport prices and therefore reaches an equilibrium at point H, and not at the higher SMTC.

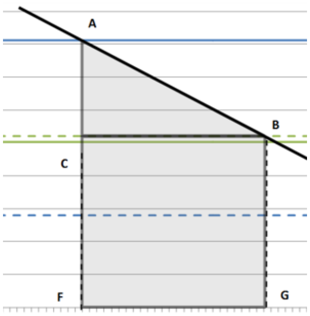
Annually, this parcels share in the 'Post & CEP' market segment represents a LSP turnover of 88 million EUR in Antwerp and 201 million EUR in Brussels. This is the market value of routed deliveries from the depot to the final receiver in the urban area, not accounting the long distance (air/truck) transport leg nor the express couriers working in an un-routed manner.

Knowing the approximated market equilibrium, i.e. daily demand and current price levels, the demand curve is estimated. This Demand curve 'D' is first estimated with a price elasticity of - 1.12 (BIPT, 2017). This hypothesis is tested in Chapter 6. The difference between the MTC_{LCV} and $SMTC_{LCV}$ is 2.64 (6.05 - 3.40). This means a price change of 2.64 EUR / 3.40 EUR, or a price increase of 78% when internalising all transport externalities in the transport prices. Agreeing to the hypothesis on the elasticity, a decrease of the average daily number of PUDs with some 87% can be expected. Only when not considering the cargo bike as an alternative.

Point A (in Figure 68 on page 213) then becomes the new market equilibrium (shift from H to A), with a lower market demand and considerably higher prices per stop. The current market equilibrium will shift left owing to the internalisation of costs, and a higher cost per stop.

At that moment, the cargo bike is becoming a viable alternative for the 'Post & CEP' market segment. Part of the market demand will shift to cargo bicycle delivery services, at that point the more competitive transport solution. The internalisation of external costs will push, in theory, the LCVs out of the market. The new equilibrium will move from first from H > A, and then from A > B.

This new market equilibrium is found at a volume of 16,293 PUDs per day in Antwerp, and 37,432 PUDs in the Brussels region. The shaded areas, indicating the welfare economic change, compared to the SMTCs, are calculated by summing the triangular area between the $SMTC_{Bike}$ and the demand curve, i.e. ABC, in addition to the rectangular area E x (G-F).



The triangle marks a value of 2.6 million EUR annually for Antwerp, 6.0 mil. EUR for Brussels. And the rectangle results in a value of 15.4 million EUR for Antwerp, and 35.4 mil. EUR for Brussels.

Together, the annual welfare change, after internalising external costs and shifting the market equilibrium from LCVs to cargo bicycles, is 18.0 mil. EUR for Antwerp and 41.4 mil. EUR for the Brussels region.

Table 47 below depicts the results of the welfare-economic change if all external costs and benefits would be fully accredited to both modes; meaning transport pieces would increase. The cargo bicycle solution would be a better option then as it is not accountable for a considerable amount of local emissions and congestion costs. Frist, volumes drop from H to A. Then, an increase of volumes till point G (from F) will be seen, combined with a drop in transport costs (from 6.05 till 4.52 EUR per shipment, as a switch will be triggered from LCVs to bikes).

Table 47: Estimated turnover change (in EUR) for Antwerp and Brussels region when internalising external costs (and benefits) of urban road freight transport in prices

	Daily basis	Yearly basis
Antwerp	69,334 EUR	18.0 mil. EUR
Brussels region	159,293 EUR	41.4 mil. EUR

III. Estimating the consumer surplus change

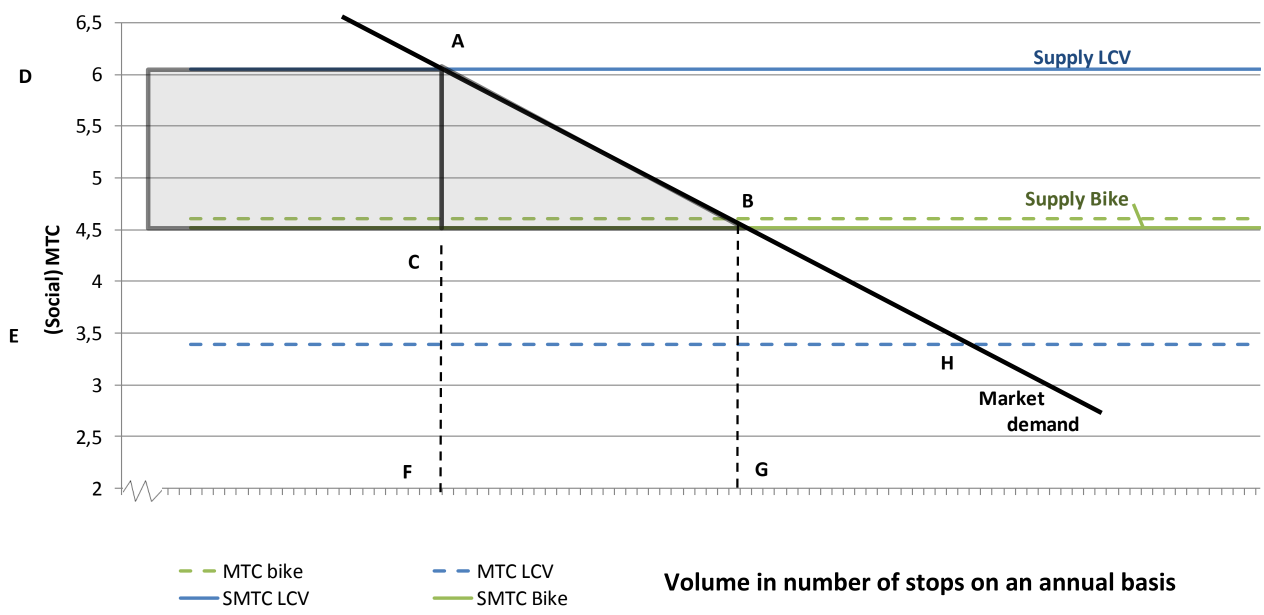
In this section, the change in Consumer Surplus (CS) will be estimated. The consumer benefit is calculated via the difference between what consumers are willing to pay for a good or service in comparison to the market price. A CS arises when the consumer is willing to pay more for than the actual market price.

Before internalisation of all external costs, the market (current) equilibrium is found at point H in Figure 69 below. The market equilibrium moves to A, when external costs would be internalised. Negative impacts related to congestion, emissions, accidents and wear and tear are fully taken account of. Prices will rise, CEP volumes will drop.

The CS is the value defined by the total area under the Demand curve, between the supply curves $SMTC_{LCV}$ and $SMTC_{Bike}$. The change of vehicle type after internalisation is presented by the shaded area.

First external costs are introduced, the equilibrium moves to. After introducing the cargo bike solution, the equilibrium moves along the Demand curve to B. To calculate this net change in CS: i) the triangular area ABC and the shaded rectangular area, and ii) (A-C) x F are to be calculated.

Figure 69: Calculating the consumer surplus change



ABC is equal to a 10,090 EUR / day for Antwerp; while the rectangular area is equal to [(A-C) x F] or a 4,885 EUR per day. For Antwerp this results in an estimated total net CS change 3.9 mil. EUR annually. The value of the shaded area for Brussels is 23,179 EUR per day for the triangle ABC and 11,224 EUR for the rectangle. In total, this brings the change in CS to a yearly amount of 8.9 mil. EUR. Consumers would still be delivered at home, the impact is the change in CS.

The preceding calculation of the net change in consumer surplus, after the external costs are fully internalised, shows a positive impact of bicycle transport. The net change in consumer surplus is summarised in Table 48 below.

Table 48: Estimated CS change (in EUR) for Antwerp and the Brussels region

	Antwerp	Brussels region
Daily basis	14,974 EUR	34,403 EUR
Yearly basis	3.9 Mil. EUR	8.9 Mil. EUR

IV. Intermediate conclusion on the SCBA appraisal

When evaluating a new logistics option, like bicycle freight transport, via a structured appraisal it is essential to obtain a good understanding on the cost structures of the current and transportation option.

The first step in the appraisal was identifying qualitative information on the markets and market segment ‘Post & CEP’. This bottom-up research, with a Belgian focus, increased the knowledge on the business concept of bicycle freight transport for the specific market segment. Following the results, in different steps, the obtained qualitative knowledge was quantified. Equations described the Total and Average Costs (TTC & ATC), from which Marginal Transport Costs (MTC) were defined.

The estimation of the business-economic costs resulted in Chapter 4 in the preliminary conclusion that LCV transport is, in the majority of the volume range per company, more competitive than bicycle transport. However, the asset of bicycle transport is the low local impact and social strengths: low impacts on urban road congestion, more employment and low local air pollution. When these positive side effects are also taken into account, by internalising external costs in the TTC & ATC equations, the competitiveness of bicycle freight transport alters in its favour.

In the CBA appraisal, different steps were undertaken to identify the supply and demand for the given market setting. The supply was defined by the obtained curve of SMTCs, equal to the long run SATCs. This implies a full internalisation of external costs. The entrepreneur is supposed to supply services from the moment his SMTC is covered. The equilibrium shifts towards higher prices per shipment, and an expected lower demand.

Constructing the demand curve for CEP shipments is more challenging. Large scale data collection would help to fully estimate the price/volume of demand path of this curve. But data collection is a challenge for business, small and large, governments and as well researchers. Very little transparency is found on current urban freight transport volumes and prices. Therefore an estimation attempt of the demand was undertaken. By taking into account literature proxies on urban freight transport by BESTUFS (2006), Ogden, (1992), LET (2000) and Figliozzi (2007), volumes for Antwerp and Brussels were estimated. These approximations were cross-checked with current data by BIPT on the Belgian CEP market. By combining these volumes with price elasticities retrieved from BIPT too, a linear demand curve was attained.

5.3. Inter- and extrapolation (iii) and Discounting and Net Present Value (iv)

All the results are based on 2016 approximations for prices and demand. Given the strong growth in CEP demand, it is it necessary to broaden the scope to the future demand. The research results for Antwerp and Brussels, are extrapolated at a Belgian scale. This is the second step, as depicted in Figure 62 outlining the Chapter's structure. The extrapolation is discussed together with the Net Present value (step iv).

The 'Post & CEP' market segment, is highly likely to grow. According to the annual CEP market study conducted by AT Kearney (2015)[133], the global CEP market grew between 2009 and 2011 at a pace of 6% in number of shipments and 4% in revenues. The years after, the Compound Annual Growth Rate (CAGR) decreased slightly to 5%. Even though CEP Markets presented continuous growth in the last years, sector studies do not identify yet indications of maturity.

Apex Insight (2015) forecasts for the European CEP market expect a steady CAGR of 4.5%. the forecast was based on desk research, published information and interviews with senior contacts in the market. The report focusses on Germany, the UK, France, Spain, Italy, the Netherlands, Belgium and Poland. An expected decrease in the return rates is a potential risk to the growth rates (AT Kearney, 2015).

E-commerce Europe (2017) see a steady further increase in e-commerce demand. Even though there has been a rise between 2016 and 2010 of EU businesses selling goods online from 13 to 18% of the total, there is still room for growth. Belgium's' B2C share of e-commerce in total sales is still only 3.31% (9.1 bn. EUR in turnover), up from 1.87% in 2012. Nevertheless, this market's turnover grew in 2016 by 10.42%. E-commerce resulted in 8% of sales in demand for goods transport when turnover is considered, and 5% when number of purchases is considered. According to E-commerce Europe (2017) the Belgian e-commerce has been rising steadily these past few years. In 2014, 6.0 million e-shoppers in Belgium spent on average each about 722 EUR per year (E-commerce Europe 2017; Apex Insight, 2015).

According to BeCommerce (2016), in 2016, a total online turnover in Belgium of 9 bn. EUR was realised. The selection of the 100 biggest e-commerce shops in Belgium were realising together 3.7 bn EUR (nov 2015- oktober 2016). A major increase compared to their 2.6 bn EUR in the previous year. The top-10 of Belgian e-commerce companies represent 2.3 bn. EUR. The

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[133] Based on yearly interviews with 500 industry executives and research on company performance in 10 EU Member States.

market grew year on year, and newest data confirm this trend. Online sales grew by 4.5% in the first quarter of 2017 (BeCommerce, 2017). In this period, also the average turnover per sales increased to 114 EUR per transaction. If this trend continues, then Belgians will consume by the end 2017 online a 1,364 EUR per year on average. The current trend of 4% increase in sales is in line with expert expectations. For example, Apex Insight (2015) forecasts a compound average annual growth rate of 3.5% for the Belgian Parcels market until 2019 (EC, 2016).

In a recent CEP market outlook, Salehin, Ryssel and Matuska (2015) expect the global CEP market to continue to grow strongly. Some sub-markets however show a split picture: the international CEP market is growing faster, and is expected to continue to grow faster by a 7% growth rate. The domestic CEP market is expected to grow at a 4% growth rate. Lower growth trends are expected for B2B, where a modest annual growth of 2%.

This growth in online sales reflects on the demand for goods transport. Between 2010 and 2015 there has been a continuous linear volume growth in Belgium, with an annual 11% CAGR. As a result, the number of packages and express services, both domestic, international and international, increased from 88 million in 2010 to 139 million by 2015. Per capita, the number of delivered parcels rose from an average of 8.1 in 2010, to 12.4 in 2015. Thus, per capita, a package is sent monthly, or an express service is used (BIPT, 2015).

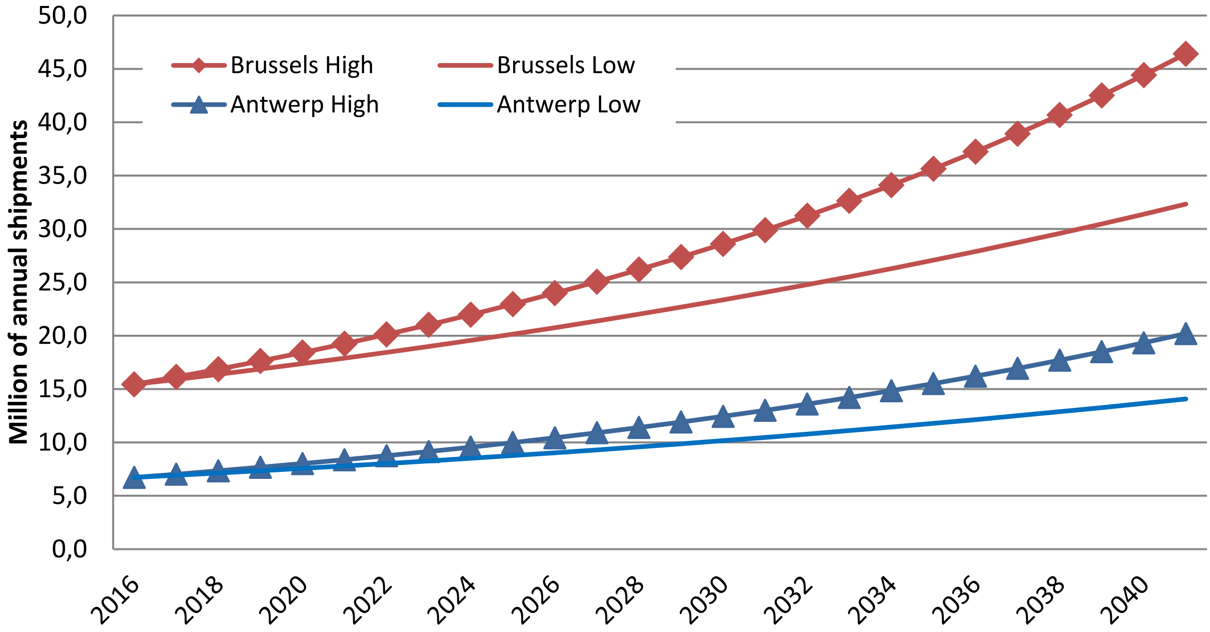
According to a study by KPMG (BIPT, 2017) for the Belgian postal market regulator, the total turnover of logistics companies delivering parcels amounted up to 1,089 bn. EUR in 2015. Of this turnover, 54% is related to standard CEP deliveries, and 46% is related to express services. The market is concentrated, with bpost, UPS, DHL and DPD taking the majority stake. This was also seen in Belfirst data presented in Table 32 on page 124. Standard deliveries are related mainly B2C deliveries, where express is more linked to B2B. The first market grew 9.8% in turnover in 2014-2015, an acceleration from the growth trend of 4.72% in the period 2014-2013. Express deliveries also grew in turnover, but only by 3.57% (KPMG, 2017).

Based on the various growth expectations depicted above, two growth forecasts for the Belgian CEP market are assumed. Based on AT Kearny (2015), Apex Insight (2015) and BeCommerce (2016), an annual growth trend for e-commerce sales in the upcoming years is situated between 3.5 and 5%. Given the long time span of the forecast, for the next 25 years:

- ✓ A low growth scenario is assumed of 3% CAGR.
- ✓ And a high growth scenario of 4.5% CAGR.

The implications of these two scenarios are shown in the next Figure 70, using these upper and lower forecasts. Only Antwerp and Brussels our shown. For all Belgian centrum cities concerned in the analysis, the scenarios could result in the number of PUDs shown in Table 49 on the next page.

Figure 70: Forecast annual PUDs per city - Antwerp and Brussels (low and high scenario)



Note: Base year 2016

The whole Belgian market in the 13 largest Flemish cities and the Brussels region together is currently estimated at 34.12 million CEP shipments per year, illustrated in . In the low growth scenario, these volumes could grow to 44.52 mil. shipments by 2025. If current growth would be continued, indicated by the high growth scenario, the market could grow to 93.21 mil. shipments by 2025.

Table 49: Forecast million PUDs in Belgian cities (low and high scenario)

	Average mil. PUD estimate per year in 2016	Low scenario forecast in 2025	Low scenario forecast in 2050	High scenario forecast in 2025	High scenario forecast in 2050
Aalst	1.10	1.43	2.99	1.63	4.90
Antwerp	6.72	8.77	18.36	9.99	30.02
Bruges	1.53	2.00	4.19	2.28	6.85
Genk	0.85	1.11	2.33	1.27	3.81
Ghent	0.85	1.11	2.33	1.27	3.81
Hasselt	1.00	1.30	2.72	1.48	4.45
Kortrijk	0.98	1.28	2.68	1.46	4.38
Leuven	1.29	1.68	3.53	1.92	5.76
Mechelen	1.10	1.43	3.00	1.63	4.91
Oostende	0.92	1.20	2.51	1.36	4.10
Roeselare	0.79	1.03	2.17	1.18	3.54
Sint-Niklaas	0.98	1.28	2.67	1.45	4.37
Turnhout	0.56	0.73	1.53	0.83	2.49
Brussels	15.44	20.15	42.19	22.95	68.97
Belgium	**34.12**	**44.52**	**93.21**	**50.70**	**152.38**

These two growth scenarios were used to develop a high and low growth forecast for Belgian CEP transport demand (data for 2025 and 2050 are shown in Table 46). By 2025, Belgian CEP PUDs are expected to amount up to 44.53 million in the low-growth scenario or 50.70 million in the high growth variant.

This indicates that the current welfare-economic effects of shifting CEP cargo transport in urban areas (in Flanders) to cargo bicycles for 2016 only, are expected to further increase. The low and high CEP growth estimates will lead to a potentially higher CS change. This is the fourth step in Chapter 5.

The future effects are also discounted, this is step (v). It is needed to discount the impacts to one Net Present Value (NPV). The NPV calculates the current monetary value of future cash flows. This NPV is calculated with a discount rate of 4%. The table below summarises the outcomes of the NPV for the period 2017-2042.

The estimates of the modal shift from LCV to cargo bikes per year account for a net Consumer Surplus gain for Antwerp and Brussels of respectively 372 and 854 million EUR in the low-growth scenario; and 444 and 1,022 million EUR for the high-growth scenario.

Table 50: Estimated welfare change (in mil. EUR) for Antwerp, Brussel region and Belgium when internalising external costs and benefits of urban road freight transport

	Low growth scenario 3% CAGR	High growth scenario 4.5% CAGR
Antwerpen	371.84	444.62
Brussels region	854.30	1,021.51
Belgium	1,887.46	2,256.87

For the whole Belgian market (defined as the 13 biggest cities in Flanders and the Brussels region) the net benefit for consumers could result in a gain between 1,888 and 2,257 million EUR NPV 2017-2042.

5.4. Presentation of results (v)

A STEEP framework can be used to structure the conclusion. In the complex urban freight transport setting, a STEEP analysis provides a tool for organising the problems into six problem domains. These domains are: Social, Technological, Economic, Environmental and Political.

I. Social aspects

First, social aspects are discussed. (S of STEEP). The impact of urban freight transport on society is significant. Research on the safety, vehicle emissions, noise hindrance and congestion of urban mobility clearly showed a negative influence of urban freight transport.

The main social aspect of the increased use of cargo bicycles transport for CEP deliveries in urban areas, after internalisation of external costs in the transport prices, is seen in the increased need for drivers. The current use of LCVs has the advantages of payload and a larger cargo space. When delivering these volumes to the market via cargo bicycles (having a maximum payload of around 250 kg and only one m³ of loading space), a bigger than before number of vehicles and cyclists/drivers would be needed.

The estimates for Belgian cities Antwerp and Brussels are exemplary for the **increased need for bicycle riders**. The estimated yearly PUDs of 6.7 million in Antwerp and 15.44 million in the Brussels region. The capacity per vehicle was in this appraisal set at respectively 40 stops per bike and 65 stops per LCV on an average day. Then, this demand in PUDs will result respectively in a total of 168,000 and 386,000 vehicle routes per year. This is the total sum of the routes of every single bike is performing. The market demand will result in an average need for 646 FTE bikers in Antwerp and 1,485 FTE bikers in Brussels. This is however the total demand for bike couriers, assuming all LCVs are replaced by cargo bicycles after internalisation of costs in the delivery price. Then, the current **LCV drivers will lose their job** (or should become bike drivers). The lost number of jobs is estimated at 398 for Antwerp and 912 for Brussels.

This leads to a maximum **net gain for the labour market** of 249 jobs in Antwerp and 571 jobs in the Brussels region (see Table 51). The total Belgian impact would be maximum 1.262 FTEs. This is when all CEP deliveries would shift to cargo bikes after full internalisation of the external costs.

Table 51: Estimated labour market impact for Antwerp and Brussels region

	Antwerp	Brussels region	BE
Increase in bikers demand	646	1,485	3.281
Decrease in LCV drivers	398	914	2.019
Net gain for the labour market*	**294**	**571**	**1.262**

* The total for 13 centrum cities in Flanders and the Brussels region

II. Technological aspects

Also technological innovations were encountered (T, of STEEP). The use of cargo bicycles requires a different supply chain organisation. In the assumptions, it was assumed that the cargo bicycles can find their parcels in the same logistics hub as the LCVs currently do. This assumption requires that the logistics hub is located in the outskirts of the city. Otherwise, additional investments will be needed. E.g. in an urban transshipment hub, transshipment staff or IT tools.

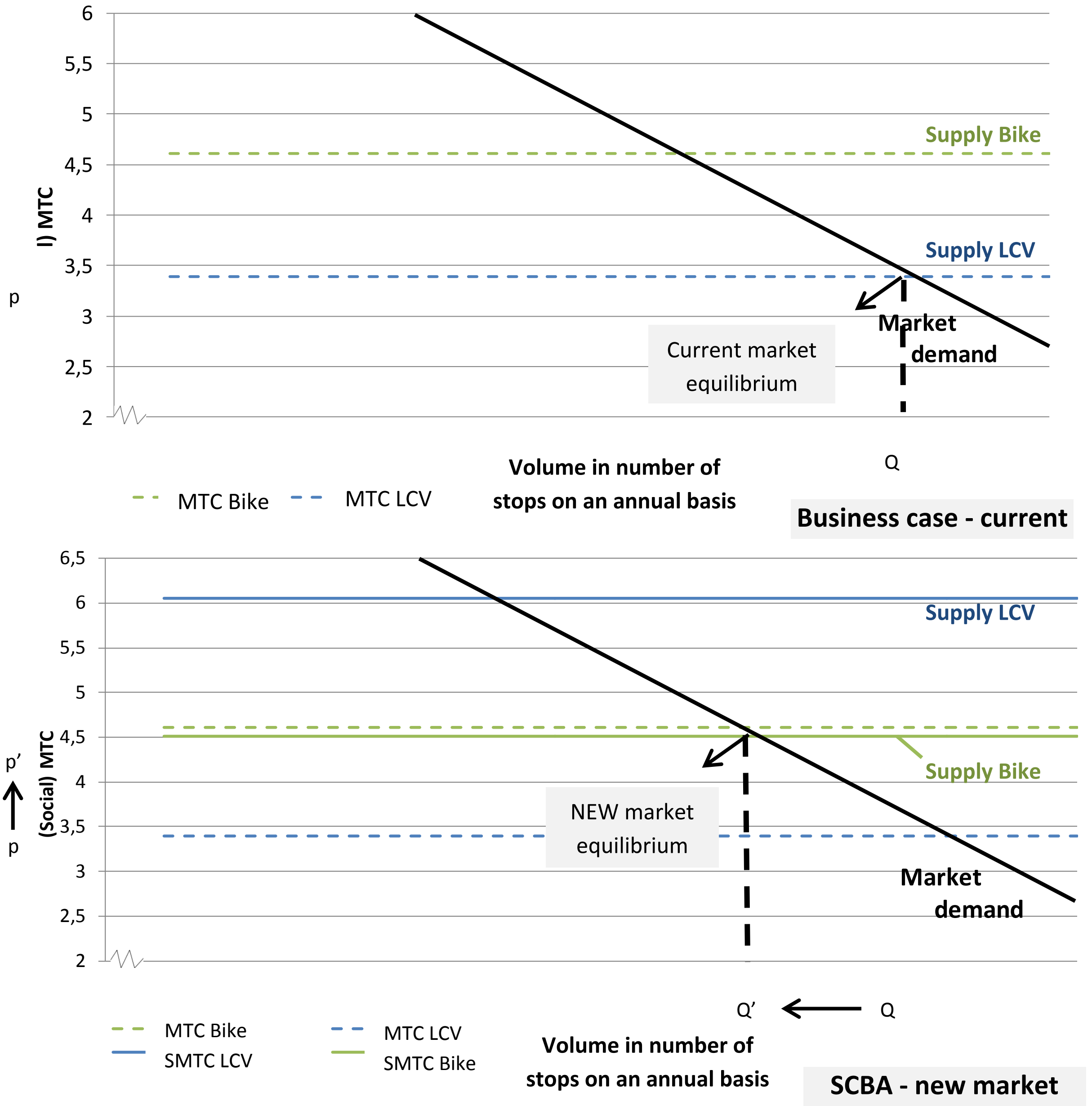
The vehicle itself is the technological aspect of the appraisal. The bicycle courier uses a cargo bicycle, which is light and compact. The power is originating from the driver, which has a little electric assistance battery. This electric motor is to push the vehicle if it is heavy loaded, but the bicycle cannot be regarded as an electric vehicle.

III. Economic aspects

The economic impacts were structured first in the business case (Chapter4), and second in the SCBA (Chapter 5).

The first assessment pointed out that the current market is not beneficial for cargo bicycle transport in a routed structure. The long run average costs are significantly higher than those of LCVs (1.21 EUR per stop more expensive). The social costs benefit analysis proved however that the market shifts to cargo bicycles when all external costs would be internalised. Valuing the negative environmental performance and large impact on congestion makes the social operational costs of LCVs shift to 6.05 EUR per stop, and the cargo bicycle's cost per stop drops till 4.16 EUR. This dynamic play is drafted in Figure 71 below.

Figure 71: Market dynamics when internalising external costs



When the external costs would be internalised, the current market equilibrium shifts left. The total market shrinks from Q to Q'. The price also jumps up from p to p'.

The direct consumer surplus then shrinks as the area below the demand curve shrinks (p shifts to p', while Q shifts to Q'). Though, this is only one element of the welfare-economic effect. The external costs charges currently levied on society would lead to a net consumer surplus below the demand curve, limited by the blue supply curve LCV transport.

Related to the environmental aspects, one can also expect an impact on taxes. Current fuel taxes are an important source of income for governments. When cargo bicycles would take the place of LCVs, a decrease of fuel consumption can be expected.

In the assumptions, it was considered that these vehicles do an average trajectory of 110 km per work day, consuming 13 liters per 100 km at 1,22 EUR per litre. So, the fuel consumption is 17.46 EUR per day per vehicle. The decrease for Antwerp and Brussels would each amount up to respectively 398 and 914 LCVs, performing transport services all year round. The total cost for fuel is currently amounting to 1.8 million EUR for Antwerp and 4.2 million EUR for Brussels. Knowing that the taxes on fuel are 51% of the fuel price (illustrated in Table 52), the loss in taxes by a shift of CEP services to cargo bicycles would amount up to 0.9 million EUR and 2.1 million EUR per city. For the Belgian scale, the impact would be in the magnitude of 4.6 million EUR per year.

Table 52: Share of taxes in Belgian fuel prices

Element	Current share in fuel price (%)	Current share in fuel price (EUR)
CIF product price	35%	0,43
Margin for distribution	13%	0,16
Additions (eg. Strategic supply)	1%	0,01
Taxes	51%	0,62
Total fuel price end user	**100%**	**1,22**

Source: Based on carbu.be

Some of the decreased turnover in fuel consumption will also have an indirect impact on the fuel distribution sector, and the supporting activities related therewith. The decrease in fuel use would on the other hand also lead to considerable environmental benefits.

IV. Environmental aspects

The Environmental challenge for urban freight transport was discussed in Chapter 2 (E, of STEEP). There, it became clear that freight transport, and urban freight transport in particular, is confronted with a pollution challenge especially. Emissions of LCVs in urban areas are high, even though the share of LCVs expressed in urban vkms is rather limited.

EC regulation No 715/2007 set the emission standards for passenger and commercial vehicles. The emission standards should be met by al new vehicles sold on the European market.

Significant emission decreases have been achieved via technological innovation. Real life tests showed however less significant decreases[134]. The table with emission standards is shown in Annex IV on page 298. Still, the almost zero CO_2 emissions of cargo bicycles will lead to a significant environmental impact. The decrease in vkms polluting the urban area, after the shift from LCV to cargo bicycles, is translated via the table of emission per LCV km (based on type approval values for EURO 5 vehicles (Type N1 II in Annex IV).

Table 53: Effect of a simulated higher pick-up and delivery density per stop

	LCV km per year of all LCVs in the 'Post & CEP' market segment	Total fuel use of LCV in liter diesel	Maximum savings in ton CO_2 *
Antwerp	11.374.924	147.874.012	38.447.243
Brussels Region	26.133.580	339.736.540	88.331.500
Belgium	57.738.340	750.598.420	195.155.589

* Assuming 260 gr CO_2 emissions per litre diesel

As shown in Table 53, emissions savings in Antwerp could amount up to 38 million tonnes of CO_2 per year, for Brussels savings could amount up to 88 mil. tonnes of CO2. This is true when all current LCVs in the 'Post & CEP' market segment would shift their operations fully to cargo bikes. In addition Antwerp could save a total of 20 million kg of CO, and 0.3 million kg of PM. The savings in Brussels could amount up to 47.3 million kg of CO, and 0.65 million kg of PM.

V. Political aspects

In this respect, the steering factor is again the European policy level. The ambitious policy objectives for the EU's urban freight activities will likely give a competitive advantage to modes and supply chain solutions, now not being extremely profitable nor competitive.

From the policy analysis in Chapter 2, it became clear that the urban freight industry was not targeted specifically by EU policies until recently when the European Action Plan on urban mobility got adopted (2009).

Action 19 of this Action Plan indicated the intention of the Commission to provide help on how to optimise urban logistics efficiency, including on improving the links between long-distance, inter-urban and urban freight transport, aiming to ensure efficient 'last mile' delivery. However, clear and ambitious targets were only developed in the 2011 White Paper on transport. From there on, the policy focuses on achieving essentially CO_2-free city logistics in major urban centres by 2030.

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[134] TNO (2015) recently tested a sample of light commercial vehicles on emission levels. This resulted in average emission measurements of 224 gr CO2 per km for loaded (28% of capacity) LCVs, in urban traffic. Loaded vehicles (100% of capacity) were measured to emit 239 g CO2 per km. NOx emissions were measured as well. The NOx emissions of LCVs in urban congested areas were measured as 2.45 g/km.

Still, the urban freight transport policies themselves are not the core competence of the European policy level. The guidance is organised at the EU level, setting clear and ambitious targets (for example on emissions). Local policy makers adopt a more practical approach in developing urban freight transport policies.

The recommendations, based on the simulation of the use of cargo bicycles for CEP deliveries, will be elaborated more in detail in the concluding chapter 7.

6. Sensitivity analyses and policy options

Chapters 4 and 5 analysed the business and welfare economic impact of cargo bicycle transport. A simulation model was constructed to compare LCV and cargo bike transport costs. This analysis led to conclusions on the competition between the two vehicle options.

The simulation was based on a number of hypothesis regarding model parameters. Of which the number of maximum PUDs per vehicle per day, the fuel price, the labour costs and price elasticities are the most pertinent. Table 39 on page 174 introduced the parameter values, and the hypotheses on which these were based. In this sixth Chapter, these parameter values are tested in a sensitivity analysis, as such reflecting the impact of uncertainty on the exact value of these cost parameters. This sensitivity analysis is depicted in section 6.1.

The model and its underlying equations can also be used for simulating policy approaches for increasing uptake of cargo bicycle transport for the 'Post & CEP' market. Section 6.2. simulates two policy options: internalization of external costs via km pricing, and labour subsidies.

6.1. Sensitivity analyses

In order to see the impact of changes to key parameters in the cost model, some key parameters are further analysed via a sensitivity analysis. The key parameters in the cost function are:

i) The pick-up and delivery density, including a capacity cap per vehicle type.
ii) The average number of drops per vehicle stop.
iii) The fuel price of diesel (only applicable to the LCV).
iv) The fuel consumption of LCVs.
v) Labour cost of cyclists and LCV drivers.

These five assumptions are tested in a sensitivity analysis of -30/+30% around the initial assumption. The impact on MTC_{bike}, MTC_{LCV}, $SMTC_{bike}$ and SMT_{LCV} is shown.

vi) elasticity of demand to price changes for transport services

A last sensitivity analysis is executed on the assumption of the elasticity of demand to price changes for transport services. In the initial appraisal, an elasticity of -1.12 was applied (BIPT, 2017). There is an uncertainty regarding the elasticities in literature (refer to page 211 for more details). The sensitivity analysis will give more insight into the impact of price changes on volumes and market dynamics, when different elasticities are regarded.

6.1.1. Effect of a higher pick-up and delivery density per stop

The next table summarises the effect of a different density of pick-up and deliveries. The simulation conducted in chapters 4 and 5 assumed an average number of PUDs of 40 per day per bike and 65 per day per LCV. The drop density, which can be considered as the effect of more drops on one route, was assumed to be one. This was indicating that every stop equals one parcel.

Table 54 below shows the impact of the density increase/decrease, with a 30% margin around the assumption. A density increase indicates that the vehicle can perform more PUDs in one delivery round, for example more consumers per km² or more deliveries per route because individual receivers receive more than one parcel.

A decrease could also indicate the effect of rising road congestion, in the case of the LCV. Less PUDs per day as a result of lost efficiency, will influence competitiveness. More delivery vehicles are needed per company, to be able to serve the same number of customers.

Table 54: Effect of a simulated higher pick-up and delivery density per stop

% difference	PUD per day per bike	MTC bike	SMTC bike	PUD per day per LCV	MTC LCV	SMTC LCV
-30%	29	6.58	6.45	48	4.86	8.71
-25%	31	6.14	6.02	50	4.53	8.12
-20%	33	5.76	5.65	53	4.25	7.61
-15%	34	5.42	5.31	56	4.00	7.15
-10%	36	5.12	5.02	59	3.77	6.74
-5%	38	4.85	4.75	62	3.58	6.39
0%	**40**	**4.61**	**4.52**	**65**	**3.40**	**6.05**
5%	42	4.39	4.30	68	3.22	5.65
10%	44	4.19	4.11	72	3.08	5.40
15%	46	4.01	3.93	75	2.94	5.14
20%	49	3.84	3.76	79	2.82	4.92
25%	51	3.69	3.61	83	2.70	4.72
30%	54	3.54	3.47	87	2.60	4.51

The analysis shows that efficiency of cargo bicycle transport should increase by 30% in order to reach the MTC currently obtained by LCVs (see Table 54 above and Figures 71/72 below).

When the delivery density would allow the bikers to reach over 55 PUDs per day per vehicle, then the MTCbike will result below 3.54 EUR (q x Q = 54; p = 3.54 EUR). If the efficiency of LCVs is at the same time equal to the initial assumption of 65 PUDs per day per vehicle (MTCLCV was 3.40 EUR), then both vehicle types are in line with each other regarding MTCs (a bike performing 55 stops a day, LCV 65 stops per day).

A 30% increase of the number of PUDs for cargo cyclists leads to a 23% change in MTC_{Bike}, while the same increase leads to a 22% decrease of LCV competitiveness (MTC_{LCV}). The cost of cargo bicycle and LCV transport have moderate elasticity to density fluctuations.

Figure 72: Effect of a higher pick-up and delivery density per stop on MTC LCV

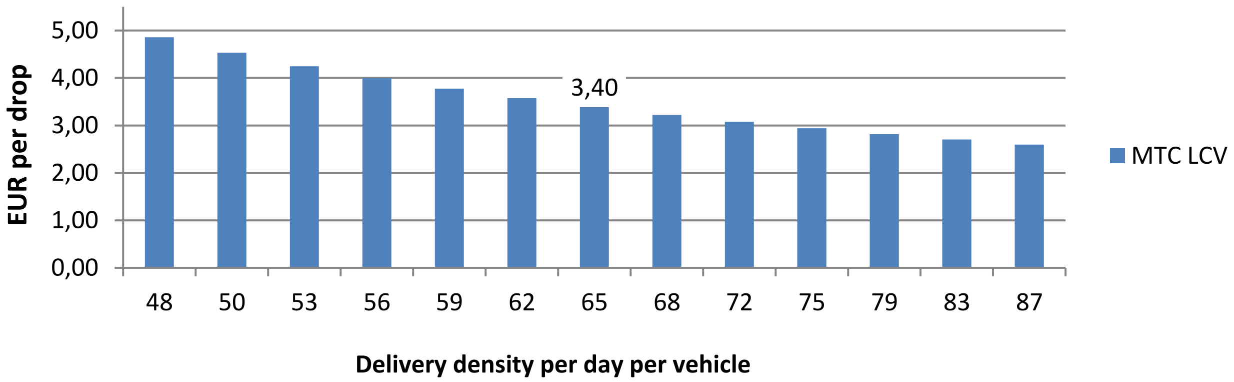
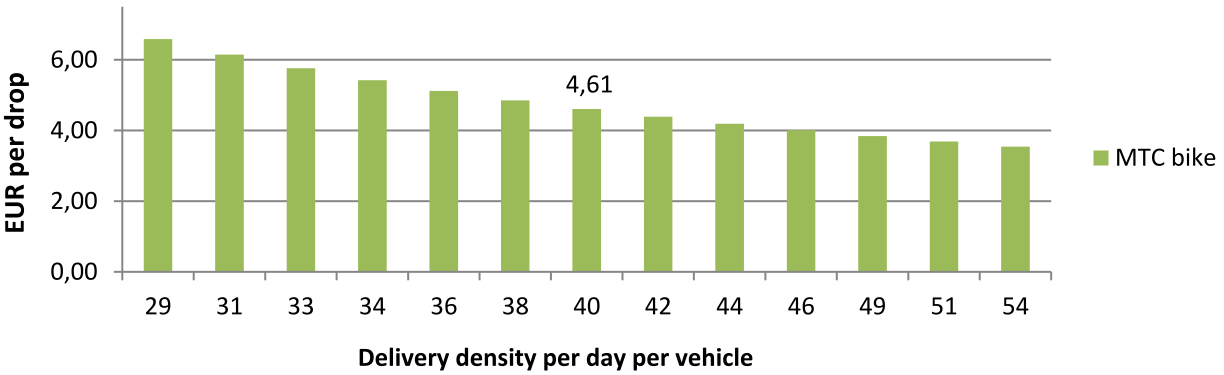


Figure 73: Effect of a higher pick-up and delivery density per stop on MTC Bike



6.1.2. Effect of an increased number of parcels per stop

The simulation conducted in chapters 4 and 5 assumed an average number of PUDs of 40 per day per bike and 65 per day per LCV. The drop density was assumed to be one, indicating that every stop equals one parcel. This assumption is tested in a second sensitivity analysis of -30/+30% around the initial value.

Table 58 summarises the effect of a number of drops per stop keeping the initial density of pick-up and deliveries. The impact on the MTC_{bike}, MTC_{LCV}, $SMTC_{bike}$ and SMT_{LCV} are shown.

As an decrease in drops per stop will not occur, it is not relevant to test with a -30/+30% interval around the initial value for q (being 1). Here, an increase in drops per vehicle stop (a higher q in the equation q x Q x W) is assumed, with steps of 5% above the initial value. Also extreme values of +125%, +150% and +200% are tested.

Table 55: Effect of increased number of parcels per stop

% difference	Parcel per PUD (q) Q = 40	MTC bike	SMTCbike	Parcel per PUD (q) Q = 65	MTC LCV	SMTC LCV
0%	**1.00**	**4.61**	**4.52**	**1.00**	**3.40**	**6.05**
5%	1.05	4.39	4.30	1.05	3.22	5.65
10%	1.10	4.19	4.11	1.10	3.08	5.40
15%	1.15	4.01	3.93	1.15	2.94	5.14
20%	1.20	3.84	3.76	1.20	2.82	4.92
25%	1.25	3.69	3.61	1.25	2.70	4.72
30%	1.30	3.54	3.47	1.30	2.60	4.51
35%	1.35	3.41	3.35	1.35	2.50	4.34
40%	1.40	3.29	3.23	1.40	2.41	4.19
45%	1.45	3.84	2.82	1.45	2.33	4.04
50%	1.50	3.07	3.01	1.50	2.25	3.87
60%	1.60	2.88	2.82	1.60	2.11	3.63
75%	1.75	2.63	2.58	1.75	1.93	3.32
100%	2.00	2.30	2.26	2.00	1.68	2.86
125%	2.25	2.05	2.01	2.25	1.49	2.50
150%	2.50	1.84	1.81	2.50	1.34	2.24
200%	3.00	1.54	1.51	3.00	1.11	1.81

The table shows that the efficiency per cargo bicycle should increase by 35% in order to reach the level of MTC currently obtained by LCVs (q x Q = 65, p = MTC_{LCV} = 3.4 EUR). When the delivery density would allow the bikers to reach over 1.6 drops per pick-up and delivery, then the MTC_{bike} will result below 3 EUR (q x Q = 1,6 x 40, p = 2.88 EUR).

A 30% increase of the density, by more PUDs per stop, leads to a 22% change (decrease) in MTC_{Bike}, while the same increase leads to an increase of LCV competitiveness by 23% (23% lower MTC_{LCV}). Given the simulated increase of density by 30%, it indicates that the density has a rather decent elasticity of 0.77 to density fluctuations. It is however only one of the cost elements of the TTC function. Other parameters have more importance.

6.1.3. Effect of a higher fuel price per litre diesel

The fuel price of diesel (only applicable to the LCV) is fluctuating. In the initial cost function, a value of 1.22 EUR per litre was assumed (2016 average fuel price in Belgium).

This assumption is tested in a third sensitivity analysis of -30/+30% around the initial value. The impact on the MTC_{bike}, MTC_{LCV}, $SMTC_{bike}$ and SMT_{LCV} are shown in . The costs for bicycles is not impacted on.

Table 56 shows that fuel price should increase by more than 30% in order to reach the level of MTC currently obtained by bikes. A fuel price increase will not result in a rebalanced competitiveness between LCV and cargo bicycles.

Table 56: Effect of a higher fuel price per litre diesel (in EUR)

% difference	Fuel price per liter	MTC bike	SMTC bike	Fuel price per liter	MTC LCV	LR SMTC LCV
-30%	0.90	4.61	4.52	0.90	3.31	5.97
-25%	0.94	4.61	4.52	0.94	3.32	5.98
-20%	0.99	4.61	4.52	0.99	3.34	6.00
-15%	1.05	4.61	4.52	1.05	3.35	6.01
-10%	1.10	4.61	4.52	1.10	3.37	6.03
-5%	1.16	4.61	4.52	1.16	3.38	6.04
0%	**1.22**	**4.61**	**4.52**	**1.22**	**3.40**	**6.05**
5%	1.28	4.61	4.52	1.28	3.41	6.07
10%	1.35	4.61	4.52	1.35	3.42	6.08
15%	1.41	4.61	4.52	1.41	3.44	6.10
20%	1.48	4.61	4.52	1.48	3.45	6.11
25%	1.56	4.61	4.52	1.56	3.47	6.13
30%	1.63	4.61	4.52	1.63	3.48	6.14

A 30% increase of the diesel fuel price leads no change in MTC_{Bike}, while the same increase leads to a decrease of LCV competitiveness of 10% in MTC_{LCV}. Given the simulated fuel price rice of 30%, it indicates that the cost of LCV transport has a rather low elasticity to fuel price fluctuations. Fuel is only one of the cost elements of the TTC function. Other parameters have more importance.

6.1.4. Effect of a more fuel efficient LCVs

Fuel consumption might influence the competitiveness. In the initial cost function, an average consumption was assumed of 13 litres of diesel per 100 km (in urban traffic).

This assumption is tested in a fourth sensitivity analysis. As an increase in fuel consumption will not occur, it is not relevant to test with a -30/+30% interval around the initial value. Here, a decrease in fuel consumption is assumed, with steps of 5% below the initial value. Also a zero fuel vehicle is tested (if a 'zero emission' vehicle would cost the same as the current LCV). The impact on the MTC_{bike}, MTC_{LCV}, $SMTC_{bike}$ and SMT_{LCV} are shown. The costs for bicycles is not impacted.

The table shows that a possible fuel consumption decrease always impacts the competitiveness of cargo bikes. A fuel price decrease will not result in a different conclusion on the competitiveness between LCV and cargo bicycles.

Table 57: Effect of more fuel efficient LCVs (in litre per 100 km)

MTC bike	SMTC bike	% difference	LCV fuel consumption per 100 km	MTC LCV	SMTC LCV
4.61	**4.52**	**0%**	**13**	**3.40**	**6.05**
4.61	4.52	-5%	12.35	3.38	6.04
4.61	4.52	-10%	11.70	3.37	6.03
4.61	4.52	-15%	11.05	3.41	6.01
4.61	4.52	-20%	10.40	3.34	6.00
4.61	4.52	-25%	9.75	3.32	5.98
4.61	4.52	-30%	9.10	3.31	5.97
4.61	4.52	-35%	8.45	3.29	5.95
4.61	4.52	-40%	7.80	3.28	5.94
4.61	4.52	-45%	7.15	3.27	5.92
4.61	4.52	-50%	6.50	3.25	5.91
4.61	4.52	-60%	5.20	3.25	5.91
4.61	4.52	-75%	3.25	3.25	5.84
4.61	4.52	-100%	0.00	3.11	5.76

Based on the simulated increase of LCV fuel efficiency of 30%, resulting in a decrease of MTC of 3%, it indicates that the fuel consumption has rather low elasticity of almost zero.

6.1.5. Effect of a differing labour costs

In the fifth sensitivity analysis, a lower labour cost for cargo cyclists and LCV drivers is simulated. In this analysis, it is tested whether a decrease in labour costs could lead to a considerable increase of competitiveness for cargo bicycles. The labour cost was tested with a -30/+30% interval around the initial value. The impact on the MTC_{bike}, MTC_{LCV}, $SMTC_{bike}$ and SMT_{LCV} are shown in Table 58 below.

The table shows that a possible decrease of labour costs by 30% impacts on the market competitiveness of cargo bikes. Then, an average cost per stop of 3.35 EUR could be reached, not even taking account of the lower external costs the mode can rely on. An equal increase in labour costs for both modes shows that the MTC of cargo bicycles decreases at a faster pace than MTCLCV. A 30% decrease of labour costs leads to 27% lower MTCBike, while the same decrease leads to a decrease of 23% in MTCLCV. It is an important parameter in the TTC.

Table 58: Effect of different labour costs

% difference	Labour cost per hour	MTC bike	MTC LCV	Labour cost per hour	SMTC bike	LR SMTC LCV
-30%	15	3.35	2.62	15	3.26	5.28
-25%	17	3.56	2.75	17	3.47	5.41
-20%	18	3.77	2.88	18	3.68	5.54
-15%	19	3.98	3.01	19	3.89	5.67
-10%	20	4.19	3.14	20	4.10	5.80
-5%	21	4.40	3.27	21	4.31	5.93
0%	**22**	**4.61**	**3.40**	**22**	**4.52**	**6.05**
5%	23	4.82	3.52	23	4.73	6.18
10%	24	5.03	3.65	24	4.94	6.31
15%	25	5.24	3.78	25	5.15	6.44
20%	26	5.45	3.91	26	5.35	6.57
25%	28	5.66	4.04	28	5.56	6.70
30%	29	5.87	4.17	29	5.77	6.83

The significant decrease in labour cost is a theoretical approach, given that minimum wages and other regulations limit the decrease in labour costs. Nevertheless, new business models in the gig- economy seem to have found a way to engage people as (false) self-employed riders with vast decrease in labour costs as a result. As such, a decrease in labour cost till 15 EUR per hour might be feasible. Based on the frequent discussion on the legality of this false self-employed model, it cannot be guaranteed that this option will still be available in the long term.

6.1.6. Effect of a price elasticities

In the sixth and last sensitivity analysis, the assumption of the elasticity of demand to price changes for transport services.

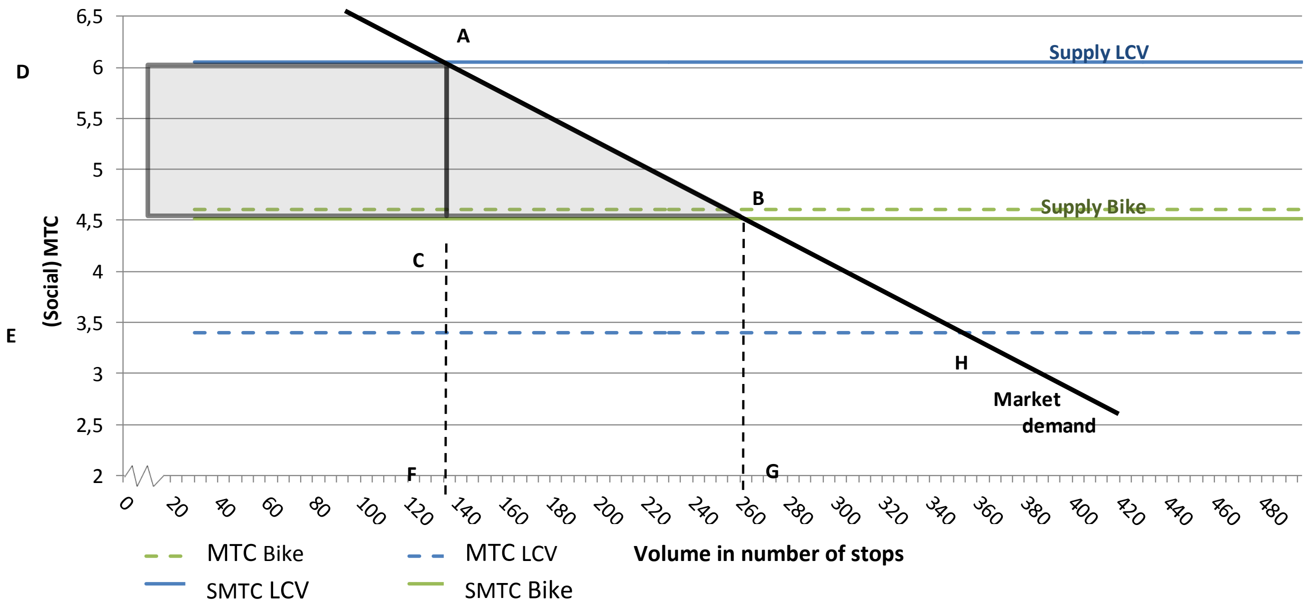
In the initial appraisal, an elasticity of 1 was applied. There is a great uncertainty on elasticities in literature. Within the logistics market, several sub-markets can be identified. The postal market, the CEP market, the logistics services and ow-account transport are only examples of a larger market fragmentation.

Based on BIPT (2016), Estupiñan and Rene (2011), Triangle Management Services (2006) and Diet et al, (2009), the elasticity value of -1.12 was used. This is illustrated in the next Figure.

However, because of the uncertainty about this elasticity, a sensitivity analysis is needed . The sensitivity analysis is undertaken with an elasticity of -1.5 and -1.25. This sensitivity analysis will give more insight into the impact of price changes on volumes and market dynamics.

As shown in Figure 75, the elasticity which is the slope of the demand curve, influences the change in market demand after price increases as well as the consumer surplus. In the analysis, it was assumed that the LCV transport supply curve would move upwards after internalisation. The market equilibrium would move from MTC_{LCV} to $SMTC_{Bike}$. The difference between the two is indicated by A – C, and was 1.54 EUR.

Figure 74: Market setting



It was calculated that, by increasing the delivery price by internalising external costs, that the demand would drop from currently 25,852 stops per day for Antwerp, to 16,293 stops per day after internalisation of external costs in transport prices. The impact is shown Table 59. Instead of a drop in demand by an amount of 9,559 / day (see column Antwerp for Elasticity = - 1.22) demand would drop with 12,803 PUDs / day when elasticity would be -1.5, or with only with 8,535 when elasticity = -1. Consumer surplus is only increasing by 1.7 if elasticity is 1.5, while it increases by 4.6 mil. EUR on an annual basis when elasticity would be - 1.

Table 59: Effect of different elasticities on consumer surplus and market volumes

	Elasticity	= -1	Elasticity	= -1.22	Elasticity	- 1.5
Cities / Impact	ANR	BRU	ANR	BRU	ANR	BRU
Difference between MTC_{LCV} and $SMTC_{Bike}$ (A-C)	1.54 EUR					
Current demand/day (Q)	25,852	59,395	25,852	59,395	25,852	59,395
New demand/day (Q)	17,317	39,785	16,293	37,432	13,049	29,981
Lost demand/day (Q)	8,535	19,609	9,559	21,962	12,803	29,414
Lost demand/year (mil. Q)	2.3	5.1	2.5	5.7	3.3	7.7
CS change (Mil. EUR)	4.6	10.5	3.9	8.9	1.7	3.9

The first section of Chapter 6 discussed the impact of changes to parameter values in the model on the simulated transport costs. The model can also be used to simulate policy approaches. Two measures were identified and simulated: internalization of external costs via km charging, and labour subsidies for cargo bicycle transport.

6.2. Policy options for enabling cargo bicycle use

The business-economic and welfare-economic analysis of the use of cargo bikes and LCVs for urban freight transport resulted in the conclusion that the cargo bikes are more competitive, only when external costs are internalised.

Currently, a significant share of the TTCs are not internalised (e.g. emissions, noise and congestion). Then cargo bicycle users will find it difficult to compete on CEP transport markets. Analysis arguments that the competitiveness could be improved by two policy measures. The first is internalising the external costs so that the business-economic and welfare-economic outcome are more in line with each other (section 6.2.1). The second is influencing the most important parameter, the labour costs (section 6.2.2).

6.2.1. Internalisation of external costs via kilometer pricing for LCVs

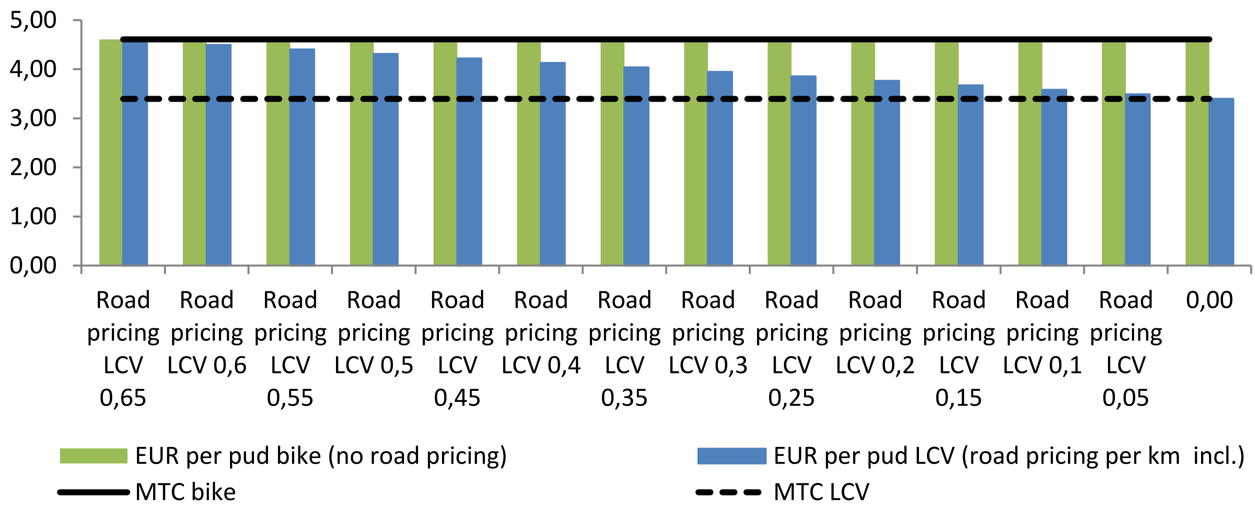
The internalisation of external costs could result in more expensive transport by LCV, in favour of the competiveness of cargo bikes. The next table summarises a sensitivity analysis around the business-economic costs, with a policy of internalisation of external costs via road pricing. The road pricing measure could lead to higher LCV transport cost. An analysis was performed with a tariff between 0.05 and 0.65 EUR per vkm.

Table 60: Impact of road pricing on Bike – LCV MTC

MTC bike	MTC LCV	Road pricing per km (in EUR)	EUR per PUD by Bike (no road pricing)	EUR / PUD by LCV (road pricing / km)
4.61	3.40	Road pricing LCV 0.65	4.61	4.59
4.61	3.40	Road pricing LCV 0.6	4.61	4.49
4.61	3.40	Road pricing LCV 0.55	4.61	4.40
4.61	3.40	Road pricing LCV 0.5	4.61	4.31
4.61	3.40	Road pricing LCV 0.45	4.61	4.22
4.61	3.40	Road pricing LCV 0.4	4.61	4.13
4.61	3.40	Road pricing LCV 0.35	4.61	4.04
4.61	3.40	Road pricing LCV 0.3	4.61	3.94
4.61	3.40	Road pricing LCV 0.25	4.61	3.85
4.61	3.40	Road pricing LCV 0.2	4.61	3.76
4.61	3.40	Road pricing LCV 0.15	4.61	3.67
4.61	3.40	Road pricing LCV 0.1	4.61	3.58
4.61	3.40	Road pricing LCV 0.05	4.61	3.49

Figure 75 and Table 60 show that ceteris paribus road pricing should be increased to 0,65 EUR per vkm in order to make cargo bikes and LCVs equally competitive. Then, both modes would result in 4.59 EUR per stop.

Figure 75: Impact of road pricing on Bike – LCV MTC



Road pricing will not affect the competitiveness too much. Only when the km charge would be very high (0.65 EUR per km). Current road pricing on Belgian highways is around 0.15 EUR per truck km, while there is no road pricing on LCVs.

6.2.2. Labour subsidies for cargo bike riders

In a sensitivity analysis, simulating a policy approach, a lower labour cost for cargo cyclists and LCV drivers was simulated. Based on this analysis, it can be concluded that a decrease in labour costs will lead to a considerable increase of competitiveness for cargo bicycles. A labour cost decrease by 30% below the initial value, 15 EUR per hour, would make that the MTCbike would be competitive to the MTCLCV. The impact is shown in the next table.

Table 61: Effect of different labour costs

% diff	Labour cost per hour	MTC bike	MTC LCV	Labour cost per hour	SMTC bike	LR SMTC LCV
-30%	15	3.35	2.62	15	3.26	5.28
-25%	17	3.56	2.75	17	3.47	5.41
-20%	18	3.77	2.88	18	3.68	5.54
-15%	19	3.98	3.01	19	3.89	5.67
-10%	20	4.19	3.14	20	4.10	5.80
-5%	21	4.40	3.27	21	4.31	5.93
0%	22	4.61	3.40	22	4.52	6.05

With a labour cost of 15 EUR per hour, for cargo cyclists, an average cost per stop of 3.35 EUR could be reached. This cost is not even taking account of the lower external costs the mode can rely on. Then, cargo bikes could be competitive in the ‘Post & CEP’ market segment.

7. Conclusions and recommendations

The impact of urban mobility, and urban freight transport in particular, on the liveability of an urban area is elevated. Growing urban road congestion in most European cities, to which urban freight transport is an active contributor, vehicle emissions and road safety are pertinent challenges for society. Europe's cities continue to grow: almost 4 out of 10 of Europe’s inhabitants live in cities. Also Belgian cities realised a steep growth of population in urban areas. These challenges lead to stakeholders identifying urban liveability challenges and protesting there against.

Ambitious (European) transport and environmental policies increased pressure on stakeholders to ameliorate vehicle efficiency, innovate and become more sustainable in their day to day business. One of the solutions is urban freight transport by cargo bicycles.

Centrally placed in the research was the main research question:

“Can cargo bicycles contribute to an enhanced economic/environmental/societal liveability of urban areas, and to what extent?”

New cargo bikes with electric assistance and IT developments allow new business models to flourish (examples are Deliveroo and Bubble Post). Long-lasting bike couriers stay strong in niche markets (e.g. Pedal BXL). And long-existing global transport organisations (like TNT Express, UPS and DHL) develop own cargo bicycle transport solutions.

This chapter concludes the dissertation via answering the research questions, defined in Chapter 2, after applying the evaluation framework defined in Chapter 3 in the analysis performed in Chapters 5 and 6; including a sensitivity analysis and policy simulation (in Chapter 6).

The main research question is supported by four sub-research questions. As such, the research regards the economic and societal benefits separately. As such, a well-founded conclusion can be made on the societal impact of increasing cargo bicycle use for urban freight transport. Also the magnitude of the societal and business economics was quantified.

The main conclusions are summarised in the following table.

Table 62: Summary of answers to sub-research questions

	Sub-research questions	Summarised answers
1	**In which constellation and political context do these cargo bicycle companies operate?**	The European mid-term policy objective of halving the use of conventionally fuelled cars in urban transport by 2030, and the aim for CO_2 free city logistics in major urban centres, both depicted in the 2011 White Paper, are greatly ambitious. This policy goal influences policies in Member States, regions and local levels too. Urbanised areas are suffering the effects of excessive transport activities. These are mainly congestions, local emissions and safety. In addition noise, climate change and wear and tear are problems. These challenges lead to stakeholders identifying urban liveability challenges and protesting there against. City policy makers, the general public and the EC is favourable to cargo bicycle transport. It was moreover politically confirmed as a chanceful alternative mode via the 'Luxembourg Declaration' or Declaration on Cycling as a climate friendly Transport Mode. The solution is proposed and deployed in various EU-funded research and dissemination projects. Cargo bicycle entrepreneurs themselves are committed to society and often started a small business with an idealistic enthusiasm. Often, the couriers originate from a specific urban culture. Seldom have they had their roots in the logistics or transport industry. Cargo bicycle entrepreneurs currently offer mainly three type of services: courier services, 'Post & CEP' transport or they contribute to the gig-economy. - The first market is where cargo cyclists started. The A-B transport, recognisable by the bike-backpack combination is a niche market with a stable client base (e.g. 'Pedal BXL' and 'De Fietskoerier'). This market expanded to accidental transport of larger volumes, following innovations in cargo bikes, trailers and heavy lift bicycles (e.g. 'Cargo velo'). These services can be labelled the short mile, from A to B in the same urban area. - The second market of 'Post & CEP' transport was identified by companies looking for a niche market in the transport sector (e.g. 'Ecopostale' and 'Bubble post'). These invested larger sums in a fleet of tri-cycles, often electrically assisted. This market grew considerably in recent years. Financial data on their business shows limited profitability. - The third market was only recently created as a result of an opportunity in the app-based economy and access to cheaper labour (self-employed riders and students). The boom in ODD is recent, and does not show signs of profitability. It is to be seen if this boom in cargo cyclists working for tech players will find a legal place in the new economy. If not, they could as easily disappear as they emerged. With Take Eat Easy as an effective example.

		The initial transport demand in the 'Post & CEP' market segment is favourable for urban transport by light-weighing and compact vehicles. E-commerce sales boom, and a significant share thereof has an impact on demand for goods transport. Parcel demand in urban areas grows. The volumes in Belgian grew by 24.3% between 2013 and 2015. 79% of Belgian e-shoppers usually choose to be delivered at home. In 2015, an average Belgian ordered 12.4 parcels per year, a strong increase from 8.1 in 2010.Often, the delivery is shoe-box seized and light. Which is a perfect fit for cargo bikes. It is concluded that the that the most promising market for cargo bicycles is: contributing to the last mile delivery of the online sales, resulting in the 'Post & CEP' delivery market. Out of urban areas, LCVs will have a stronger position. Cargo bikes are only fit for urban areas, as there density of delivery demand is found. This density allows efficient and compact delivery rounds. In addition, cargo bikes can be used as service vehicles, for own-account transport and as niche sector for courier activities. Probably the own-account transport services, are the most under-developed cargo bicycle market. Local SME's can be stimulated to think about this option via awareness raising campaigns. This is a policy option for local policy makers. The policy makers willing to increase cargo bicycle use can in addition show the good example and shift city vehicles to cargo bikes (internal mail, greenery, etc.).
2	**What is the magnitude of their economic benefits?**	Based on this business case analysis, it is concluded that the long-term economic sustainability of cargo bicycles for replacing LCVs in the 'Post &CEP' market segment is a challenge. Even though the market booms, as a result of e-commerce, the eminent characteristics of cargo bicycles result in a higher average cost per delivery. The transport costs when using cargo bikes for urban deliveries are elevated. Only in low volume (niche) markets, bicycle transport has a unique product that is then very attractive and competitive with LCV transport (e.g. not a lot of stops per vehicle per day: for example own account transport or couriers). The rest of the market shows that LCV can obtain still a considerable lower cost per delivery. The Marginal Transport Costs (MTC), repeats just as the long run ATC curve the competitive differences. The MTC of cargo bicycle transport in this Ph.D.'s setting is 4.61 EUR, higher than the 3.40 EUR MTC for LCV transport. The ATC graph moves saw tooth-wise up, originating from the need for supplementary vehicles in the total company fleet when a certain average number of stops per day is reached (the tipping point per bike was set at 40 stops per day per vehicle, whereas for LCV the cap of capacity per day was set at 65). There, the volume goes up by one stop, whereas the costs go immediately up by one extra driver and one extra vehicle. The main cost parameter is the labour cost. Scenarios showed that the vehicle cost is relatively less important. The fuel consumption is less relevant than expected, so is the diesel price.

		These research outcomes are also supported by the overview of the financial data published by current bicycle couriers. Their yearly accounts show accumulating losses. The market is organised by only some small SMEs, which compete with the larger CEP sector. This sector, with bpost, DLH and UPS as example has a immense scale. The top-15 has realised a turnover of 1.6 bn. EUR last year. While the cargo bicycle sector in Belgium does not reach 5 million EUR in total. Strong-grower and best practice Ecopostale continued services after a recent bankruptcy. Bpost took over bubble post.
3	**What is the magnitude of the societal benefit of an increased cargo bicycles use?**	The impact of urban mobility, and urban freight transport in particular, on the liveability of an urban area is elevated. Growing urban road congestion in most European cities, to which urban freight transport is an active contributor, vehicle emissions and road safety are pertinent challenges for society. While performing their delivery services, operators and customers currently do not fully compensate for their considerable quantity of societal costs (e.g. emissions and congestion). Transport operations influence society positively as goods reach consumers, but also negatively as operators and consumers do not pay the full or fair price for their shipments. When the external costs were to be included in transport prices, then this will mainly result in an upward rise in the MTC_{LCV}. The $SMTC_{Bike}$ decreases after internalisation just a little till 4.52 EUR, this as a result of the employment benefits for cargo bicycle companies. The inefficiency of cargo bikes, more drivers are needed for delivering the same amount of parcels as a labour market advantage. Health benefits of cycling were not included, provided the range of indicator values and concerns on the applicability to commercial bicycle transport in polluted urban areas. The MTC_{LCV} shifts up significantly after internalisation, to a value of 6.05 EUR, the $SMTC_{LCV}$ .This would be the fair price if consumers would pay their fair share in urban external costs of transport. Demand for urban deliveries is difficult to approximate. Current CEP volumes were determined via proxy methodologies. This CEP transport demand is mainly fuelled by e-commerce growth. So, two growth scenarios were based on expert expectations sales in this sector. This lead to a high and low CAGR growth forecast for Belgian CEP transport demand (somewhere between 3 and 4.5% CAGR). By 2025, Belgian CEP PUDs in Flemish urban areas (13 biggest cities and Brussels) is expected to amount up to 44.53 million pick up and deliveries (PUDs) per year in the low-growth scenario or 50.70 million PUDs (per year) in the high growth variant. The estimates for CEP demand are exemplary for the increased need for bicycle riders. The future market demand will result in an average need for 646 FTE bikers in Antwerp and 1,485 FTE bikers in Brussels.

		This is however the total demand for bike couriers, assuming all LCVs are replaced by cargo bicycles after internalisation of costs in the delivery price. Then, the current LCV drivers will lose their job (or should become bike drivers). This leads nevertheless to a maximum net gain for the labour market of 249 jobs in Antwerp and 571 jobs in the Brussels region. The total Belgian impact would be maximum 1.262 FTEs.
4	**How can policy contribute to the sustainability and liveability of urban areas by enabling cargo bicycle use?**	A density increase indicates that the vehicle can perform more PUDs in one delivery round, for example, there are more consumers per km². The analysis shows that the efficiency per cargo bicycle should increase by over 30% to reach an equally competitive MTC currently obtained by LCVs. The sensitivity analysis also pointed out that a fuel price increase of diesel (only applicable to the LCV) will not alter the competitiveness. A 30% increase of the diesel fuel price leads to a decrease of LCV competitiveness of 10% in MTCLCV. It indicates that LCV transport has a low elasticity to fuel price fluctuations. Fuel is only one of the cost elements of the TTC function. Other parameters have more importance. Lower labour cost for cargo cyclists could lead to a considerable increase of competitiveness for cargo bicycles. A decrease of labour costs by 30% would significantly impact the competitiveness in the 'Post & CEP' market segment. Then, an average cost per stop of 3.35 EUR could be reached, not even taking account of the lower external costs the mode can rely on. Analysing wide range of policy local policies, these can either individually or collectively, contribute to further deployment of cargo bicycle transport. - **Planning measures** (e.g., infrastructure) can assists the bicycles. Bicycles paths and car-free zones are the direct measures, helping the bicycles to better move true traffic. If there is an UCC, they can be a delivery partner. - **Regulatory measures** influence the behaviour of stakeholder. Access restrictions for LCVs can help the use of cargo bicycles, (e.g. LEZ and time windows), provided they receive a preferential policy. - **Fiscal measures** will change the cost basis of cargo bicycles, or LCVs. Internalisation of external costs will lead to higher LCV transport costs, benefiting cargo bicycles. - **Stakeholder Engagement and nudging**. Communication and awareness raising can change e-commerce delivery behaviour and resolve local liveability issues. E.g. installing lockers, offering local green delivery options to consumers. This is mainly an action for the private sector. - **Technical innovations**. This relates to innovations in the vehicle technology, traffic steering and planning. The vehicle technology of cargo bicycles allows rapid roll out. The vehicles are cheaper than LCVs and do not require engines, fuel or charging. Policy can influence market uptake locally, or can define a national strategy. The stacked policy framework for urban freight transport complicates the policy

		approaches. Most applicable local options are: access regulations (time windows and car free zones), infrastructure investments (bicycle paths and if present UCCs), awareness raising (dissemination projects) and economic policies (road pricing, subsidies for cargo bike transport). Leading unemployed to the labour market via cargo bicycle transport jobs could also be a policy option. The social economy can benefit from pilots with cargo bicycle use. Then labour costs are lowered, and the labour market benefits from less unemployment.

The summarising table is substantiated in the following four sections. The four sub-research questions are used to structure the conclusions.

7.1. In which constellation and political context do these cargo bicycle companies operate?

EU policy targets make them a must-consider option for reaching CO2 free urban logistics by 2030. Especially local politicians are attracted to this innovation. Cargo bicycle companies are small SMEs and start-ups. The general public and policy is favourable to their business model and often provide (pilot-test) funding. The current boom in the gig-economy , the legal doubts about the self-employed model they rely on, and the financial position of cargo bicycle companies are two major threats for a long term sustainable sector development.

Research on bicycle transport as a solution for freight transport in urban areas can be considered a rather new research stream. The entrepreneurs which establish start-ups of courier/messenger activities often originate from a particular group with a distinct 'urban culture' and therefore have specific motivations and often different viewpoints on freight transport.

The concept of couriers, messengers, or bike freight transport, is however not new. Old European examples exist. Throughout the early years of the 20th century, 'les triporteurs', µ were to be seen throughout France. And in 1907, C. Ryan and J. Casey, founded a delivery services company "American Messenger Company" which developed into the United Postal Service (UPS).

Nowadays, the cargo bicycles are light-weighted and they are often equipped with a battery-based electric assistance. Biking and the cargo bike transport are definitely making a comeback. This *renaissance* of bicycle messengers began in the 70's in New York City and from the mid-80's onward also in major German cities. Now, opportunities for using bikes for freight are emerging. In particular, in busy congested urban centres where parking is difficult, expensive and journey times are slow and unpredictable. The most powerful argument for using cargo bicycles for the majority of businesses is often the public support for it.

Since only recently, bike couriers are perhaps first perceived as students riding for ODD apps like Deliveroo and UberEATS, i.e. the 'gig-economy'. This app-based urban economy provided easy access to cheap labour and allowed new business models to flourish. A new demand for urban transport was generated. Financial success is not anywhere near though.

Research on bicycle freight transport

A separate urban freight transport discipline and academic research stream was shaped within the freight transport research community; mainly in the last two decades. There within, research in urban freight and logistics moved towards green and efficient vehicles. Attention shifted from the benefits of different fuels to electric vehicles and cargo bicycles. And micro-consolidation of freight in urban areas was beneficial for EV and cargo bicycle pilot tests.

Literature shows that the business economic viability of cargo bicycle transport is researched to a far lesser extent. Research was often focused solely on the technicalities, dissemination or on the environmental and social aspects. The publications on the market demand, i.e. the characteristics of supply and demand of bicycle courier delivery services, delivery costs, external effects (costs and benefits for society) and market behaviour are rather limited. Operational and economic insight are limited to a handful of papers.

In Belgium, the economic aspects of freight transport by bike have not been researched thoroughly before. A historical overview of the market was therefore not possible. Belgian Post (bpost) services employ bicycle drivers since a very long time. There is hardly any knowledge regarding the potential and conditions of (electric) cargo bikes use in city-centre commercial transport today.

Best practices and dissemination projects

Best practices are published in various EU research publications, e.g. BESTUFS and BESTUFS II. Also demonstration projects were encountered. Straightsol µ mapped effects of seven innovative edge urban freight demonstrations, of which cargo bicycles deployed in Brussels by TNT Express was a case study. The project resulted, in a three-month test period, in achieving -24% CO_2 and SO_2, -78% in NO_X, - 98% in PM_{25} and -22% in PM_{10}. The delivery cost in the project was however twice the cost of the state of affairs. After the case study, TNT Express returned to LCVs.

The ‘Cyclelogistics’ project was awarded European funding and researched specifically the opportunities for freight transport by bicycle in Europe. Within the motorised trips in urban areas, 21% was estimated to be commercial traffic (delivery, service and business) and 28% private logistics (shopping, leisure and commuting). The research pointed out that one out of four of the total motorised freight trips in urban areas is interesting for cargo bicycles.

The project resulted in the CycleLogistics Federation, creating a communal feeling between and professionalisation of European cargo cyclists. More than analysing the economic potential, the project mapped the knowledge on cycling couriers. The CycleLogistics project ended in 2014 and was followed by the CycleLogistics AHEAD project which had a stronger focus on business applications and initiated several new courier businesses.

SWOT and market segments

A round table discussion with Belgian bicycle courier services, contacts with bicycle couriers in Belgium and a survey in the Belgian market and internet search on their websites led to a SWOT analysis. Entrepreneurs in various EU cities, also Belgium, started enthusiastically their businesses. Given the congestion and emission challenges for urban freight transport, many have seen chances.

All cargo cyclists perform transport activities in urban areas, only some work with larger delivery volumes. Most stick to the traditional A-B transport, characterised by the bicycle-backpack combination. This is the courier/messenger niche market. In general, six markets are distinguished: the Post & CEP market, Courier services, Delivery services, Service vehicles, UCC partnerships and the gig-economy. Bike couriers are hardly connected to the global CEP networks. The SWOT, as depicted in Chapter 2, is summarised:

S) Bicycle transport is more environment-friendly (little emissions, noise etc.), couriers are fast in urban areas even in congested streets. And they are good for employment. The same CEP demand (volume of packages) generates more employment in the transport sector.

W) There are also some considerable weaknesses. The market is not professionally developed and lacks proper logistics chain organisations. Many companies are small and cannot handle bigger volumes (yet). They are often active in one city only. The scale difference compared to CEP companies organised globally is huge. As the awareness among possible customers, and the general public, about the product 'bike delivery' is limited, their own created market is small. Many start-up companies are undercapitalised and created year-on-year losses. And their volumes are not stable enough to develop a growth strategy. There is no Flemish or Belgian association, making it difficult to address the market issues by among others policy makers. Many start-ups went bankrupt.

O) The rising road congestion and urban logistics challenges results in market opportunities. The awareness for sustainable transport among shippers grew. Especially cities and the EU have an increased interest in cycling policies. And as the bicycle couriers have a good image regarding fast and sustainable transport, they could benefit government support. Operationally, smaller vehicles have advantages. Bicycles do not need to pay for parking, and they can easily find parking in an urban area. The new gig-economy can provide access to flexible and cheaper labour.

T) The market prices for bike transport nowadays are not always competitive. Low prices make that many of the start-ups cease operations within 1 or 2 years. The majority of companies in the bike transport market is not professionally developed. This limits trustworthiness. The image of the market regarding their level of professionalisation is not good, especially by the non-users. The cost per delivered item needs to be competitive with traditional transport by LCV or truck. The market is weak if the financials are regarded. This led to the bankruptcy (and restart) of Ecopostale and the takeover of bubble post by bpost.

Conclusion on sub-research question 1

After a market scan, interviews with logistics and cargo bicycle entrepreneurs, and reading literature, it was concluded that the that the most promising market for cargo bicycles is: contributing to the last mile delivery of CEP market. E-commerce sales are rising, parcel demand in urban areas grows. The parcel volumes in Belgian grew by 24.3% between 2013 and 2015. 79% of Belgian e-shoppers usually choose to be delivered at home. In 2015, an average Belgian ordered 12.4 parcels per year, which was only 8.1 in 2010.

The current constellation in politics is favourable for cargo bicycles. The EC White Paper ambition to have CO_2 free city logistics by 2030 is a big push.

It is concluded that the **most promising market for growth of cargo bicycles transport: contributing to the last mile (at-home) delivery in urban areas of online sales: the 'Post & CEP' delivery market segment**. Out of urban areas, LCVs will have a stronger position anyhow. Cargo bikes are only fit for urban areas, as there density of delivery demand is found. This density allows efficient and compact delivery rounds.

There are also some threats. The freight transport by bicycle is rather unknown to the public, and the market is therefore small. Several bicycle entrepreneurs have set up a company on a micro scale. All perform transport activities in urban areas, only some work with larger volumes. Most stick to the traditional A-B transport, characterised by the bicycle-backpack combination.

Key features are the flexibility, the limited impact of road congestion on their reliability, the 'can-do mentality' and the low environmental impact is seen as a key motive for customers choosing cargo bikes over LCVs.

In addition to the services in the 'Post & CEP' market, cargo bikes can be used as **service vehicles,** for **own-account transport** and as niche sector for **local courier activities**. Probably the own-account transport services, are the most under-developed cargo bicycle market. Local SME's can be stimulated to think about this option via awareness raising campaigns. This is a policy option for local policy makers. The policy makers willing to increase cargo bicycle use can in addition show the good example and shift some of their own LVC vehicles to cargo bikes (for internal mail, repairs, greenery, etc.).

7.2. What is the magnitude of their economic benefits?

Based on of a business case simulation, using the own developed cost estimation tool conclusions can be made on the cargo bicycle's competitiveness. Three aspects were regarded for LCV and Cargo bikes: Average Transport Costs, the Total Transport Costs and Marginal Transport Costs (MTC) in the spreadsheet model. The main outcomes of the business case analysis are summarised below on four aspects. These are:

i) The Average Transport Costs (ATC) for the bike are in the majority of the range of the market simulation elevated. Only for low volume companies, bicycle transport has a niche product which is very competitive with LCV oriented transport. In general, LCV transport can be organised at a considerable lower cost per stop.

Average vehicle stops per day	LR ATC LCV (in EUR per stop)	LR ATC Bike (in EUR per stop)
1	124.59	105.52
2	63.99	55.06
3	43.79	38.24
50	5.82	6.63
100	4.61	5.62
400	3.70	4.86
600	3.60	4.78

ii) The yearly Total Transport Cost (TTC) of the LCV-based solution (TTC_{LCV}) is lower than the bike's TTC_{Bike}. The TTC curve moves sawtooth-wise up, originating from the underlying need for supplementary vehicles in the company's total fleet, when a certain average demand per day is reached (the tipping point of maximum capacity per bike was set at 40, per LCV it was set at 65). There, the volume goes up by one Q whereas the costs go immediately up by one extra driver and one extra vehicle.

Average vehicle stops per day	Linear LR TTC LCV (in EUR)	Linear LR TTC Bike (in EUR)
1	27.435	32.392
2	28.633	33.275
3	29.831	34.158
50	86.135	75.658
100	146.033	119.806
400	505.420	384.697
600	745.011	561.291

iii) The Marginal Transport Costs (MTC), the long run ATC curve also repeats the ATC differences. These are lower for LCV (3.50 EUR per stop) than for Bike transport.

MTC LCV (in EUR)	MTC Bike (in EUR)
3.40	4.61

iv) The main cost factor is labour costs. The imminent characteristic of the cargo bikes make it difficult to compete with LCV transport. The lower volume of cargo space and the low load factor lead to a supplementary need of vehicles and riders, in comparison to current fleets and staff numbers. As labour is expensive, this inefficiency leads to higher costs per stop; despite savings on fuel, flexibility and low-cost vehicles.

Conclusion on sub-research question 2

The business-economic simulation gave a good insight in the competitiveness of two companies, choosing different vehicles to operate an urban freight transport service in the 'Post & CEP' market segment. One choosing for cargo bikes, the other for LCVs. Both operating as urban delivery vehicles for global CEP players. There are some particular elements to highlight, concerning the conclusions on business economic opportunities.

Based on this business case analysis, it is concluded that **the long-term economic sustainability of cargo bicycles for replacing LCVs in the CEP market is a challenge**. Labour is the most important cost factor, increasing cargo bicycle's delivery costs considerably. Scenarios showed that the vehicle cost is relatively less important. The fuel consumption is less relevant than expected, so is the diesel price.

The 'Post & CEP' market has the biggest volume, and the boom in e-commerce shows a lot of potential growth. The ATC graphs move sawtooth-wise up, originating from the need for supplementary vehicles in the total company fleet when a certain average number of stops per day is reached (the tipping point per bike was set at 40 stops per day whereas for LCVs it was considered that 65 stops per day are feasible). At these specific points, demand goes up by one stop, whereas the costs go theoretically up by one extra driver and one extra vehicle. But when companies reach a scale of above 250 stops a day, transport per delivery costs flatten. It can be noticed that the costs go to an almost fixed cost per stop from around 250 stops per company per day, and beyond. A minimum scale is needed to be active in the 'Post & CEP' market.

Niche markets exist too, e.g. own account transport, heavy load cargo bike transport and A-B trajectories in the courier market. They are however smaller than the CEP market, and were therefore not analysed into detail in this research. In the specific markets of less stops a day per company, delivery costs are high for both modes. E.g. own-account transport will benefit of deploying cargo bikes as an alternative to their own LCV.

This conclusion does not suggest that cargo bicycles cannot be deployed in a successful manner. However, then the **local setting is one of the more influential factors**. E.g. when an historic urban area is difficult to access by LCVs, but not by cargo bikes, then the latter has a competitive advantage. Second, when the cargo bicycle is offered separate bicycle lanes, and therefore are able to avoid structural congestion (unlike the LCV), the latter has again a competitive advantage. Or when congestion is leading to gridlocks, then cargo bikes are a more reliable solution.

7.3. What is the magnitude of the societal benefit of an increased cargo bicycles use?

While performing their delivery services, operators and customers currently do not fully compensate for their considerable quantity of externalized costs (e.g. emissions and congestion). Transport operations influence society positively as goods reach consumers, but also negatively as operators and consumers do not pay the full or fair price for their shipments. Unquestionably, the urbanised areas are suffering the effects of excessive transport activities in the form of increased road congestion, pollution, noise etc.

Conclusion on sub-research question 3

The intermediate conclusions on the business case (sub-research question 2) showed a limited competitiveness for cargo bicycle transport when operating CEP urban deliveries in a routed structure. Nonetheless in contrast to the use of cargo bicycles, currently deployed ICE vehicles emit far more pollutants (e.g. PM, NO_X, CO_2 but also noise) locally and they contribute to road congestion too. If these external costs were to be internalised in the cost structures and so in the commercial tariffs offered to customers, the competitive balance bike-LCV would be altered.

To get insight in the real welfare-economic effects, the social total transport cost were calculated. The spreadsheet model was used to calculate the Social Total Transport Costs (STTC), Social Average Transport Costs (SATC) and Social Marginal Transport Costs (SMTC). SATC and SMTC are shown in the next two tables.

i) Average transport costs for LCV transport go up after internalization of external costs. The competitive balance with Bike transport shifts.

Average vehicle stops per day	LR SATC LCV (in EUR)	LR SATC Bike (in EUR)
1	108.23	170.96
2	56.37	88.56
3	39.09	61.10
50	6.59	9.46
100	5.55	7.81
200	5.03	6.99
600	4.69	6.44

ii) When the external costs were to be included, then this will result in an upward rise in the earlier estimated MTC_{LCV}. The $SMTC_{bike}$ decreases after internalisation just a little till 4.52 EUR, this as a result of the employment benefits for cargo bicycle companies. Health benefits of cycling were not included owing to the uncertainty about values and the applicability thereof in commercial bicycle transport in polluted urban areas. The MTC_{LCV} shifts up significantly after internalisation, to a value of 6.05 EUR, the $SMTC_{LCV}$.

SMTC LCV (in EUR)	SMTC Bike (in EUR)
6.05	4.52

Current CEP demand in Flemish cities and the Brussels region, was determined via proxy methodologies. CEP transport demand is mainly fueled by e-commerce growth. Data on the Belgian Post & CEP market were used to crosscheck hypotheses. In 2015, an average Belgian ordered 12.4 parcels per year. Based on this data, and the number of Belgian inhabitants in 2016, the yearly number of CEP PUDs for a city as Antwerp comes near to 6.72 million stops on an annuals basis. And for Brussels the approximation is 15.44 million PUDs per year.

E-commerce sales is still rapidly developing. And over half of these sales has an impact on demand for CEP freight transport. Based on recent reports, growth scenarios were used to develop a high and low growth forecast for Belgian CEP transport demand in Flemish urban areas (growth is expedite to increase by between 3% and 4.5% CAGR). By 2025, Belgian CEP PUDs in Flemish urban areas are expected to amount up to 44.53 million in the low-growth scenario or 50.70 million in the high growth variant.

The growing CEP market will potentially lead to higher benefits of an increased uptake of bicycle cargo services, replacing LCVs. The estimates of the modal shift from LCV to cargo bikes per year account for a net Consumer Surplus gain for Antwerp and Brussels of respectively 372 and 854 million EUR in the low-growth scenario; and 444 and 1,022 million EUR for the high-growth scenario. For the whole Belgian market (defined as the 13 biggest cities in Flanders and the Brussels region) the net benefit for consumers could result in a gain between 1,888 and 2,257 million EUR NPV 2017-2042.

The estimates for Belgian cities Antwerp and Brussels are exemplary for the increased need for bicycle riders. This demand in PUDs will result respectively in a total of 168,000 and 386,000 vehicle routes per year. This is the total sum of the routes of every single bike is performing. The market demand will result in an average need for 646 FTE bikers in Antwerp and 1,485 FTE bikers in Brussels. This is however the total demand for bike couriers, assuming all LCVs are replaced by cargo bicycles after internalisation of costs in the delivery price. Then, the current LCV drivers will lose their job (or should become bike drivers). The lost number of jobs is estimated at 398 for Antwerp and 912 for Brussels. This leads to a **net gain for the labour market of 249 jobs** in **Antwerp** and **571 jobs** in the **Brussels region**. This is the absolute maximum, assuming all CEP deliveries would shift to cargo bicycle transport. The total Belgian net-impact would be maximum **1.262 FTEs.**

To conclude this section, the lessons learnt from a variety of performance indices are used to translate the indicators to this research. The aspects regarded are summarised in the next table. These consist of economic, social and ecological aspects. The indicators, qualitative of nature, were regarded as part of the literature overview (Chapter 2).

Table 63: Urban freight transport indicators

	Quantitative aspects	Quantitative
Economic Urban freight transport has an economic impact on entrepreneurs and citizens. Impacts are measurable and/or qualitative.	• Turnover/profits of urban businesses (EUR) • Turnover/profits of LSP (EUR) • Turnover/profits delivery at home (EUR) • Margins (EUR) • Transport tariffs (EUR) • Number of deliveries in the urban area (Stops) • Number of delivery vehicles in the urban area • Accessibility of receivers (number of urban kms needed)	• MTC_{bike} 4.61 EUR, while MTC_{LCV} is 3.40 EUR. • Cargo bicycle companies in Belgium come and go. A lot of start-ups did not survive very long. • The financial weakness of the incorporated bicycles companies is pertinent. • Ecopostale, a best-practice company went bankrupt recently and restarted soon thereafter. • Bubble post increased losses to over 2 million EUR, and was taken over by bpost.
Social Urban freight transport has a large impact on social criteria. Company and societal values are only minor quantitative in nature.	• Jobs (Number of) • Accidents (Number of fatalities) • Road congestion (Time lost) • Accidents (fatalities)	• Consumer Surplus gain for Antwerp and Brussels of respectively 372 and 854 million EUR in the low-growth scenario; and 444 and 1,022 million EUR for the high-growth scenario. For the whole Belgian market 1,888 and 2,257 million EUR NPV 2017-2042. • $SMTC_{bike}$ 4.52 EUR, while $SMTC_{LCV}$ is 6.05 EUR. • Net gain for the labour market of 249 jobs in Antwerp and 571 jobs in the Brussels region. The total Belgian impact would be maximum 1.262 FTEs. • Bike couriers are more vulnerable. The increase could lead to more casualties.
Ecological Urban freight transport has a large impact on the ecological values of an urban area.	• Emissions (CO_2, PM, NO_X)	• Emission savings in Antwerp could amount up to 38 million tonnes of CO_2 per year, for Brussels savings could amount up to 88 mil. tonnes of CO_2. • In addition, Antwerp could save a total of 20 million kg of CO, and 0.3 million kg of PM. The savings in Brussels could amount up to 47.3 million kg of CO, and 0.65 million kg of PM. • This is true when all current LCVs in the 'Post & CEP' market segment would shift their operations fully to cargo bikes.

7.4. How can policy contribute to the sustainability and liveability of urban areas by enabling cargo bicycle use

The last research question was related to policy options to contribute to the sustainability and liveability of urban areas by enabling cargo bicycle use. Cargo bicycle transport is (actively) supported by policy, and policy objectives in the transport and environmental field. Local policies see the innovation as a means to meet the policy objectives. The local options are varied, from infrastructure, pricing, curbing to awareness raising. Some examples are listed.

Cargo bicycle transport was politically confirmed as a chanceful alternative mode via the Luxemburg Declaration of 2015. This 'Declaration on Cycling as a climate friendly Transport Mode' is a publication following an informal meeting of EU ministers for Transport in Luxemburg on the 7th of October 2015.

The developed transport cost simulation model was used to assess the business- and welfare-economic impacts. The model, its underlying equations and parameters can also be used to test sensitivities of certain parameter values and to simulate policy options.

i) In the sensitivity analysis, it was concluded that a **density** increase and an increase of the number of parcel deliveries per stop could make cargo bicycles more competitive.

A density increase indicates that the vehicle can perform more PUDs in one delivery round, for example, there are more consumers per km². The analysis shows that the efficiency per cargo bicycle should increase by over 30% to reach an equally competitive MTC currently obtained by LCVs (3.40 EUR). When the delivery density would allow the bikers to reach over 55 PUDs per day per vehicle, then the MTC_{Bike} will result below 3.54 EUR (q x Q = 54, p = 3.54 EUR).

Density is related to the urban morphology and terrain, but not only. The infrastructure characteristic of urban areas define for a big deal the accessibility of consumers by LCV and/or cargo bikes. Historic city centres with narrow roads and limited parking opportunities are a natural habitat for cargo bicycle transport. But local governments can also assist the uptake when they put in place time-windows, car-free zones, bicycle paths etc. The access regulations to cities define more and more the easy accessibility by bicycles, in the contrary the accessibility of (mostly) large trucks and also LCVs.

ii) The sensitivity analysis also pointed out that a **fuel price** increase of diesel (only applicable to the LCV) will not alter the competitiveness. A 30% increase of the diesel fuel price leads to a decrease of LCV competitiveness of 10% in MTC_{LCV}. It indicates that LCV transport has a low elasticity to fuel price fluctuations. Fuel is only one of the cost elements of the TTC function.

The price of fuel influences the competitiveness of cargo bikes positively. Other parameters have more importance. Contrary, more fuel-efficient LCVs could even make them extra competitive.

iii) In the fifth sensitivity analysis, a lower **labour cost** for cargo cyclists and LCV drivers was simulated. It tested whether a decrease in labour costs could lead to a considerable increase of competitiveness for cargo bicycles. A decrease of labour costs by 30% would significantly impact the competitiveness of cargo bikes. Then, an average cost per stop of 3.35 EUR could be reached, not even taking account of the lower external costs the mode can rely on. Cities could lead unemployed to cargo bicycle transport. This is the social economy option, which was explicitly not considered in the research.

This leads to the conclusion that policy should target the main cost parameters of cargo bike transport, for increasing the uptake thereof in the 'Post & CEP' transport market. Analysing wide **range of policy local policies, these can either individually or collectively, contribute to increased uptake of cargo bicycle transport**.

- **Planning measures** (e.g., infrastructure) can assists the bicycles. Bicycles paths and car-free zones are the direct measures, helping the bicycles to better move true traffic. If there is an UCC, they can be a delivery partner.
- **Regulatory measures** influence the behaviour of stakeholder. Access restrictions for LCVs can help the use of cargo bicycles, (e.g. LEZ and time windows), provided they receive a preferential access policy.
- **Fiscal measures** will change the cost basis of cargo bicycles, or LCVs. Internalisation of external costs will lead to higher LCV transport costs, benefiting cargo bicycles.
- **Stakeholder Engagement and nudging**. Communication and awareness raising can change e-commerce delivery behaviour and resolve local liveability issues. E.g. installing lockers, offering local green delivery options to consumers. This is mainly an action for the private sector.
- **Technical innovations**. This relates to innovations in the vehicle technology, traffic steering and planning. The vehicle technology of cargo bicycles allows rapid roll out. The vehicles are cheaper than LCVs and do not require engines, fuel or charging.

Policy can influence market uptake locally, or can define a national strategy. The stacked policy framework for urban freight transport complicates the policy approaches. Most applicable local options are: access regulations (time windows and car free zones), infrastructure investments (bicycle paths and if present UCCs), awareness raising (dissemination projects) and economic policies (road pricing, subsidies for cargo bike transport). Leading unemployed to the labour market via cargo bicycle transport jobs could also be a policy option. The social economy can benefit from pilots with cargo bicycle use. Then labour costs are lowered, and the labour market benefits from less unemployment.

In addition, cargo bikes can be used as service vehicles, for own-account transport and as niche sector for courier activities. Probably the own-account transport services, are the must under developed cargo bicycle market. Local SME’s can be stimulated to think about this option via awareness raising campaigns. This is a policy option for local policy makers. The policy makers willing to increase cargo bicycle use can in addition show the good example and shift city vehicles to cargo bikes (internal mail, repairs, greenery, etc.).

7.5. Synopsis

The answers on the four sub-research questions identified a number of research gaps, points of attention and recommendations for further research.

The conclusions and recommendations provided a research-based insight in the benefits and weaknesses of cargo bicycle transport. The modelled transport costs were based on own research on the Belgian cargo bicycle transport market. As such, hypotheses retrieved in literature were cross-checked with entrepreneurs. The limited transparency and data on urban freight transport in general, and on cargo bicycle transport specifically is one of the main points of attention though.

The model developed and applied this dissertation is relevant for other urban areas, cities areas and specific urban freight transport markets. The parameters are generally applicable, and the (parameter) values can be adapted to other case studies. The conclusions depicted in this chapter are applicable to urban freight transport in a Belgian context. A context without mega-cities, a region with a mix of historic city centres, countryside, wide-spread suburbs and with a fair density.

The local setting influences the efficiency of LCV transport greatly. Further research on case studies where cargo bikes have a better chance of being profitable, without internalisation on external costs or subsidies is recommended.

The four points of attention and advise are:

1. More data collection is needed. Current data on urban freight practices, the CEP market, delivery prices, cost structures, price elasticities etc. can only be approximated. The market trend is nonetheless clear : strong growth in the e-commerce market fuels the demand for CEP transport in the coming years.

2. Specificities of the urban area influence efficiency of LCV and cargo bike transport. Historic city centres with limited road capacity are a perfect setting for cargo bicycle use. The sensitivity analysis provides already insight in the effect of cost parameter values (number of stops per vehicle, labour costs, fuel price, km charging). This general modal can be used in case studies to simulate different local situations. In addition, (urban) vehicle routing issues should be better substantiated.

3. Cargo bike transport can become a niche market in other market segments. Bike couriers are currently hardly connected to the global CEP networks. And based on current transport costs, substantial uptake by CEP transport services without financial support by governments is not expected.

Other market segments exist. Courier services, Delivery services, Service vehicles and the gig-economy are other chanceful opportunities, which need further research. Mainly own-account transport services could benefit from shifting to cargo bikes.

Pilot tests should be organised to research local chances for cargo bike transport. The six market segments identified in this Ph.D. can be a basis for discovering opportunities. Unlike former case studies in dissemination projects, and in literature, it is advised to better explore and publish social, environmental, and also economic impacts.

4. Policy can influence market uptake locally. Policy options are: access regulations (time windows and car-free zones), infrastructure investments (bicycle paths and UCCs), awareness raising (dissemination projects, setting the example as city administration and stimulating own-account transport operators to shift vehicles) and economic policies (road pricing, subsidies for cargo bike transport).

But in urban logistics, there is no ‘one-size-fits-all’ approach. It is therefore strongly recommended to first analyse the local urban freight transport challenge thoroughly, map the problem, collect data (see also 1.), talk to stakeholders and then simulate the policy approach and its impacts on the economy, society and specifically on logistics. Cargo bicycle transport can be one of the solutions to further study. Maybe other innovations are more appropriate.

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Annex I

Table 64: External congestion costs for metropolitan, urban and rural areas BE (2010)

	Region	Road type	Free flow *(EURct/vkm)*	Near capacity *(EURct/vkm)*	Over capacity[135] *(EURct/vkm)*
Car	Metropolitan	Motorway	0.0	31.9	73.4
		Main roads	1.1	168.5	216.2
		Other roads	3.0	190.2	289.3
	Urban	**Main roads**	**0.7**	**58.0**	**90.5**
		Other roads	**3.0**	**166.3**	**274.9**
	Rural	Motorway	0.0	16.0	36.7
		Main roads	0.5	21.8	72.4
		Other roads	0.2	50.1	166.1
HDV	Metropolitan	Motorway	0.0	60.7	139.4
		Main roads	2.1	320.2	410.7
		Other roads	5.6	361.4	549.7
	Urban	**Main roads**	**1.4**	**110.3**	**171.9**
		Other roads	**5.6**	**316.0**	**522.4**
	Rural	Motorway	0.0	30.3	69.7
		Main roads	0.9	41.5	137.5
		Other roads	0.5	95.2	315.5
Truck-trailers	Metropolitan	Motorway	0.0	92.6	212.8
		Main roads	3.2	488.7	626.9
		Other roads	8.6	551.5	839.0
	Urban	**Main roads**	**2.2**	**168.3**	**262.3**
		Other roads	**8.6**	**482.3**	**797.3**
	Rural	Motorway	0.0	46.3	106.4
		Main roads	1.4	63.3	209.9
		Other roads	0.7	145.3	481.6

Source: Ricardo-AEA, 2014

[135] Capacity is, in the FORGE output model, defined as a ratio of demand vs. the supplied capacity of the infrastructure. Indicator value 1 is at capacity, over 1 is over capacity. (Ricardo-AEA, 2014)

Table 65: Marginal external air pollution costs HDV EU28 (2010) in EURct/tkm

	Category	EURO-Class	Urban[136] *(EURct/tkm*	Suburban[137] *(EURct/tkm*	Interurban [138]	Motorway *(EURct/tkm*
HDV	<=7,5 t	Euro I	2.3	1.3	1.0	1.1
		Euro II	1.8	1.2	1.0	1.1
		Euro II	**1.6**	**1.0**	**0.8**	**0.8**
		Euro IV	1.0	0.7	0.6	0.6
		Euro V	1.0	0.6	0.3	0.2
		Euro VI	0.5	0.2	0.1	0.1
	7,5 - 12 t	Euro I	1.3	0.8	0.6	0.6
		Euro II	1.1	0.7	0.6	0.6
		Euro II	**0.9**	**0.6**	**0.5**	**0.4**
		Euro IV	0.6	0.4	0.3	0.3
		Euro V	0.5	0.4	0.2	0.1
		Euro VI	0.2	0.1	0.0	0.0
	>32 t	Euro I	0.9	0.6	0.4	0.3
		Euro II	0.7	0.5	0.4	0.3
		Euro II	**0.6**	**0.4**	**0.3**	**0.3**
		Euro IV	0.3	0.3	0.2	0.2
		Euro V	0.3	0.2	0.1	0.1
		Euro VI	0.1	0.0	0.0	0.0

Source: Based on Ricardo-AEA, 2014

The next table summarizes then the emission costs in tkm for LCVs in urban-, suburban- and interurban areas and motorways.

Table 66: Marginal external air pollution costs LCV EU28 (2010) in EURct/tkm

	EURO-Class	Urban *(EURct/tkm)*	Suburban *(EURct/tkm)*	Interurban *(EURct/tkm)*	Motorway *(EURct/tkm)*
LCV diesel	Euro 1	1.9	0.9	0.5	0.5
	Euro 2	2.1	0.9	0.5	0.5
	Euro 3	**1.6**	**0.7**	**0.4**	**0.4**
	Euro 4	1.1	0.5	0.3	0.3
	Euro 5	0.5	0.3	0.2	0.2
	Euro 6	0.4	0.2	0.1	0.1

Source: Based on Ricardo-AEA, 2014

[136] Urban population density of 1,500 inhabitants per km^2

[137] Suburban population density of 300 inhabitants per km^2

[138] Interurban population density below 150 inhabitants per km^2

Table 67: Number of European road fatalities (1990-2011)

	1990	1995	2000	2005	2010	2011
EU27	**75,977**	**63,155**	**56,427**	**45,346**	**31,030**	**30,268**
BE	1,976	1,449	1,470	1,089	812	858
DE	11,046	9,454	7,503	5,361	3,648	4,009
FR	11,215	8,892	8,079	5,318	3,992	3,963
NL	1,376	1,334	1,082	750	537	546
UK	5,402	3,765	3,580	3,336	1,905	1,960

Source: European Union, 2013

Annex II

Table 68: Industry initiatives for optimizing urban freight logistics

		Observations and remarks
Monoprix short rail	Urban logistics project in combination with rail transport Privately funded project	In the Monoprix concept, short rail transport services are used for developing a sustainable urban distribution concept of freight for the inner city of Paris. The rail cars are loaded at Monoprix's premises 35 km South of Paris. Every evening, the 20 rail car long train leaves the warehouse to arrive half an hour later in the core of Paris at Bercy's RER station. There, the freight is transhipped to Natural Gas (NGV) powered trucks. These leave the inner city warehouse in the early morning to distribute the commodities to Monoprix's own retail location. Over 90 locations are receiving goods via this supply chain concept.
	Privately funded project	• Rail transport is a viable alternative in specific cases like the Monoprix example. • Monoprix proved in Paris that alternative transport modes generate positive welfare economic effects. • The use of NGV for the last mile distribution also contributed to improve negative impacts generated by road freight traffic. Emissions of the supply chain decreased significantly. In one year 70,000 litres of fuel, i.e. a reduction in CO_2 and NO_X emissions by respectively 340,000 tonnes and 25 tonnes. (Maes, Vanelslander, 2010) • Congestion is less affecting the logistics chain of the retailer. • However, the new supply chain cost structure is not (yet) competitive with traditional road transport supply chains. The cost per pallet using the new scheme is 17.61 EUR, while the cost per pallet using the conventional scheme was 13.25 EUR (Maes, Vanelslander, 2010)
	References	Maes, Vanelslander (2010) *The use of rail transport as part of the supply chain in an urban logistics context*, 12th World Conference on Transport Research, Lisbon, 11-15/7/2010 - Lisbon, 2010 Delaître., L., Barbeyrac (2012) *Improving an Urban Distribution Centre, the French Case of Samada Monoprix, Seventh International Conference on City Logistics, June 7- 9, 2011, Mallorca, Spain* Alessandrini, A., Delle Site, P., Filippi. P. And M. Valerio Salucci (2012) *Using rail to make urban freight distribution more sustainable*, European Transport \ Trasporti Europei (2012) Issue 50, Paper n° 5, ISSN 1825-3997 http://www.openstarts.units.it/dspace/bitstream/10077/6113/1/D_Alessandrini%20-%20ET2012.50.05.pdf

			Dablanc, L., (2010) *TURBLOG- Urban logistics practices - synthesis of selected case studies, Deliverable 3... – Case Study Paris*", Turblog, Transferability of urban logistics concepts and practices from a worldwide perspective, FP7 project				
	Score	12	Innovativeness	Feasibility	Capital intensiveness	Implementation phase	Publicly available knowledge
			2	3	1	5	1

Bierboot		
	Water transport for hotel, restaurant and bar needs in urban areas	In Utrecht, the Netherlands, a freight distribution concept was adopted involving the use of a larger inland vessel for urban freight transport. The electric vessel is mooring at the outside of the city, where truckloads are transshipped to the vessel. Then, the vessel sails to the core where the vessels tranship rolling cages at the historic quays of the city core, via a crane. The vessel distributes HoReCa (Hotel Restaurants and Cafes)materials like drinks, foods and also collects empty bottles etc. The vessel was evaluated positively, and as a result a second vessel was custom-built.
	Public private project supported by the city of Utrecht	• The flexibility increases as otherwise strict time windows should be followed. • The concept is much more sustainable as the vessel does not emit anything, and uses electric power. • Water transport is a good alternative for road transport in historic these cities. • No cost data are published and the start-up was subsidized. • Time windows on road transport are creating a market for this concept.
	References	Maes, J., Sys, C., Vanelslander, T. (2010) *Vervoer te water: linken met stedelijke distributie?* -University of Antwerp, Steunpunt Goederen- en personenvervoer, 2012, 59p. Negenborn, R., and C. Ocampo-Martinze (2015) *Transport of water versus Transport over water – Exploring the dynamic interplay between transport and water*, Springer Janjevic, M. and Ndiyae, A.B. (2014) *Inland waterways transport for city logistics: a review of experiences and the role of local public authorities*, In Urban transport XX, eds. C. A. Brebbia, Wit press, ISBN 978-1-84564-778-0, 2014 BESTUFS 2 (2008) *Best practice update*, Available at: http://www.bestufs.net/download/BESTUFS_II/key_issuesII/BESTUFS_II_%20D2_4%20II_PPP_2008.pdf

Score	14	Innovativeness	Feasibility	Capital intensiveness	Implementation phase	Publicly available knowledge
		3	2	2	5	2

DHL Floating service centre	Water transport for parcels in Amsterdam		In Amsterdam, CEP global player DHL, developed a distribution concept involving the use of an old tourist boat and bicycle couriers. The boat moors in the morning at a quay just outside of Amsterdam. There, parcels are transshipped from trucks to the vessel. The vessel sails to the city , and embarks for transshipping the parcels to cycle couriers which distribute the freight throughout the historic city.				
	Privately funded project		• Flexibility increases as all day long, freight can access the city • The company renovated a former tourist boat as a mobile warehouse • Time windows on road transport were creating a market for this concept • No economic data are shared by the company				
	References		Maes, J., Sys, .C, Vanelslande, T., (2012). *Vervoer te water : linken met stedelijke distributie?, Antwerpen, Steunpunt Goederen- en personenvervoer*, 2012.- 59p. Negenborn, R., and C. Ocampo-Martinze (2015) *Transport of water versus Transport over water – Exploring the dynamic interplay between transport and water*, Springer Janjevic, M. and Ndiyae, A.B. (2014) *Inland waterways transport for city logistics: a review of experiences and the role of local public authorities*, In Urban transport XX, eds. C. A. Brebbia, Wit press, ISBN 978-1-84564-778-0, 2014				
	Score	13	Innovativeness	Feasibility	Capital intensiveness	Implementation phase	Publicly available knowledge
			2	2	3	5	1

Electric urban freight transport	European research projects	• The ELCIDIS European Research project was an unique project which has tested a better solution for urban logistics Electric distribution of goods • Recently FREVUE stepped into the footsteps of this first research project and started testing 120 electric freight vehicles (LCVs and smaller HDVs) in 8 EU locations with and investment of over 15 million EUR. • Ehrler and Hebes (2012) study the implementation of electromobility in city logistics from a multi-actor perspective. A good selection of other studies of electric delivery trucks is available in Davis and Figliozzi (2013).
	FP7 research projects in close cooperation with European cities and LSP's	• ELCIDIS Tested in La Rochelle, Rotterdam, Stockholm and other cities a platform proving good acceptance by the receivers. Nonetheless, the company exploiting the platform went bankrupt. Then, a private party took over the business and is still operating the platform • FREVUE EFVs demonstrate both positive and negative operational performance characteristics compared to conventional vehicles. Often permitted in all city cores, still hindered by limited ranges. Lower fuel costs were reported by all operators. Correos (ES) declared their spend as 1.50 EUR electricity consumption on 100 kilometres. Capital investment is still high, limiting market uptake. There is a lack of field-proven information on residual value of electric vehicles, batteries as well as on battery replacement costs. These aspects will be addressed in more detail in the FREVUE project soon. Currently, as operators are usually more focused on short term benefits, the wider uptake of electric vehicles (EVs) is difficult. Leasing and financing companies are also reluctant to invest due to these uncertainties. The vehicles have resulted in increasing environmental performance, ie. via reduced CO_2 and reduced local emissions.

	References		Davis, B. A., Figliozzi, M. A. (2013) "A methodology to evaluate the competitiveness of electric delivery trucks", Transportation Research Part E: Logistics and Transportation Review, 49,pp. 8-23. Ehrler, V. & Hebes, P. (2012) "Electromobility for City Logistics–The Solution to Urban Transport Collapse? An Analysis Beyond Theory". Procedia - Social and Behavioral Sciences, 48, pp. 786-795. van Duin, J.H.R; Tavasszy, L.A.; Quak, H.J.(2013) *Towards E(lectric)- urban freight: first promising steps in the electric vehicle revolution*, European Transport / Trasporti Europei (2013) 54 Vermie, T. (2002) *ELCIDIS Electric Vehicle City Distribution FINAL REPORT*, for DG TREN Energy and Transport Nestrova, N., Quak, H., Balm, S., Roche-Cerasi, I., and T. Tretvik (2013) *State of the art of the electric freight vehicles implementation in city logistics*, 1.1 final draft				
	Score	15	Innovativeness	Feasibility	Capital intensiveness	Implementation phase	Publicly available knowledge
			2	3	3	4	3
Chronocity	Last mile distribution of goods by electric push cars in Paris		• A daily shuttle between a suburban hub and the underground facility (Operating from an underground parking lot) • Local deliveries made by 12 small electric vans and two "Chronocity" (small containers on chassis hauled by hand with electric power assistance) • Limited transparency in published economic results. The total investment costs have been more than 500,000 EUR (fittings, vehicles, rental, etc). The subsidies have been from Paris authorities and EDF (electricity supplier). The part of the Mayor of Paris was 36% of renting platform cost; subsidies of EDF concern fittings. The subsidies are decreasing and will stop.				
	Public –private project, still operational and growing		• 10 to 50% of reductions in emissions. The CO_2 emissions calculated over a six month trial period represent 11.4 tonnes. Without the ULS, these emissions would have reached nearly 28 tonnes. (Dablanc 2010) • Low noise levels • The implementation of the ULS has located 19 new jobs within Paris (mainly low qualified jobs). • No extra costs, nor saving. The additional costs, due to the renting of the site and the energy needed to run the electric fleet, are compensated by the savings made on fuel. Each year, 41,000 km of fuel powered. vehicles are saved by using electric vehicles.				

	References		Dablanc, L., (2010) *TURBLOG- Urban logistics practices - synthesis of selected case studies, Deliverable 3… – Case Study Paris*”, Turblog, Transferability of urban logistics concepts and practices from a worldwide perspective, FP7 project Grant Thornton (2007). *Bilan ecodurable de l’espace logistique Urbain Concorde*. Rapport pour la mairie de Paris. Patier, D., Browne, M., (2010) *A methodology for the evaluation of urban logistics innovations*, The Sixth International Conference on City Logistic, Procedia Social and Behavioral Sciences 2 (2010) 6229–6241				
	Score	19	Innovativeness	Feasibility	Capital intensiveness	Implementation phase	Publicly available knowledge
			2	4	5	5	3

Bicycle freight transport	Research projects and start-ups	Browne, M., Leonardi, J. And J. Allen (2011) researched the use of electric tricycles in combination with urban consolidation centres in London La Petite Reine is a cycle logistics company which developed a new delivery service in Paris. (Dablanc, 2010) Gruber et al (2013) worked on a research project in Germany where the focus was exclusively laid on electric cargo bicycles. Cycle logistics was a European Research project researching, involving 15 cities, where cargo bicycles were researched and a platform was set up bringing together cycle logistics entrepreneurs. The project reports strong growth in cargo cycling activities in Europe. The project ended with launching the European Cycle Logistics Federation at the 12th of April 2014 in Nijmegen.
	Public –private projects, companies developing urban freight distribution by bicycle	• London Total distance travelled fell by 14% The total CO_2 emissions decreased by 55% Successful for the transport company, in environmental and financial terms. Not a lot of publically available information. • Paris Each day, 3000 business or home locations are being served by the 40 drivers of La Petite Reine. At the end of the research, 96% of the deliveries were related to express deliveries. Gaining market share is difficult. Strong competition between the CEP companies and the permanent need for cost cuts means that low cost subcontractors are preferred to the high quality subcontracting service of La Petite Reine. Over one year 600,000 tonnes-km hauled by vans in Paris, 89 TOE (tonnes of oil equivalent) in engine consumption, 203 tonnes of CO_2, 84 kilos of particles and vehicle noise pollution was reduced. La Petite Reine created 50 jobs in Paris over a period of seven years, with a constant growth rate of job creation. Limited economic data published. The Turblog project stated a high transferability potential.

<table>
<tr><td rowspan="4"></td><td colspan="2"></td><td colspan="5">• Berlin
Gruber et al (2013) evaluated cargo bikes characteristics and competitiveness. Demand for courier shipments concentrated in specific inner-city areas. For Berlin, 83% of the pickup locations, 77% of the drop-off locations are positioned within the inner city perimeter. Potential has been identified in the urban freight markets, and close cooperation with the cargo bicycle companies is setup for future research. No economic data published.
• Cycle logistics
Cycle logistics brought together the European cargo bicycle entrepreneurs, and created a platform for exchanging ideas and experience. The project also researched the past of cycling and cargo cycling in particular. Still, a lack of data and economic focus exists. This gap will be filled in the follow up project Cycling logistics ahead, planning to set up numerous new start-ups in many European urban areas.</td></tr>
<tr><td colspan="2">References</td><td colspan="5">Browne, M., Leonardi, J. And J. Allen (2011) Evaluating the use of an urban consolidation centre and electric vehicles in central London, IATSS Research, Volume 35, Issue 1, July 2011, Pages 1–6
Browne, M., Leonardi, J., Allen, J., Toshinori, N., and J. Visser (2010) Light goods vehicles in urban areas, Procedia - Social and Behavioral Sciences, The Sixth International Conference on City Logistics, 2(3): 5911-5919
Cyclelogistics (2013) Cyclelogistic moving Europe forward, Final report, Austrian Mobility Research on behalf of the Cyclelogistics ,consortium www.cyclelogistics.eu
Cycling logistics (2014) Closing conference of the cycling logistics project, Nijmegen
Dablanc, L., (2010) TURBLOG- Urban logistics practices - synthesis of selected case studies, Deliverable 3… – Case Study Paris", Turblog, Transferability of urban logistics concepts and practices from a worldwide perspective, FP7 project
Gruber, J., Kihm, A. and Lenz, L. (2014) A new vehicle for urban freight? An ex-ante evaluation of electric cargo bikes in courier services, German Aerospace Center (DLR), Berlin, Germany, Presented at Metrans I-NUF 2013
Gruber, J., Ehrler, V. And L. Barbara (2013) Technical potential and user requirements for the implementation of electric cargo bikes in courier logistics services, 13th WCTR, July 15-18, 2013 – Rio de Janeiro, Brasil
Janjevic , M., Kaminsky, P., Ballé Ndiaye, A., (2013) Downscaling the consolidation of goods – state of the art and transferability of micro-consolidation initiatives, European Transport \ Trasporti Europei (2013) Issue 54, Paper n° 4, ISSN 1825-3997
Rhiele, E-B., (2012) Cargo bikes as transportation vehicles for urban freight traffic</td></tr>
<tr><td rowspan="2">Score</td><td rowspan="2">21</td><td>Innovativeness</td><td>Feasibility</td><td>Capital intensiveness</td><td>Implementation phase</td><td>Publicly available knowledge</td></tr>
<tr><td>4</td><td>4</td><td>5</td><td>5</td><td>3</td></tr>
</table>

<table>
<tr><td rowspan="4">Cargo tram transport</td><td colspan="2">Using urban rail, tram tracks, for setting up freight distribution concepts
Business idea, research project</td><td colspan="5">• CarGo Tram in Dresden is supplying car parts to the Volkswagen factory, located in the urban area. The tram been successful since the start in 2000 but it is a purpose-built project with very specific conditions, the project facilitates one customer on one route only at this point.
• City Cargo Amsterdam aim to take out half the number of trucks that enter the city. In Amsterdam it would mean cutting the number from 5,000 to 2,500 a day. The company however did not find enough resources after a successful trial. It went bankrupt in 2008, after the company faced a problem with financial stability.
• 'GüterBim' in Vienna considered using the existing rail network, for urban freight transport. Only tests have been conducted.
• In 2003, a cargo tram was tested in Zurich. Disposing waste by Cargo tram has achieved a reduction of 37,500 liters of diesel annually. A new waste container had to be designed. The cargo tram still collects bulky waste at 10 different collection points around Zürich, calling at each on different days of the month.</td></tr>
<tr><td colspan="2"></td><td colspan="5">Civitas (2005) Cleaner and Better transport in cities, Available at: http://www.civitas-initiative.org/docs1/CIVITAS_Award_2005_nondemonstration_city_Dresden.pdf
Browne, M. and N. Arvidsson (2013) A review of the success and failure of tram systems to carry urban freight: the implications for a low emission intermodal solution using electric vehicles on trams, European Transport \ Trasporti Europei (2013) Issue 54, Paper n° 5, ISSN 1825-3997
Neuhold, G. (2005) Cargo Tram Zurich. The environmental savings of using other modes, First Bestufs II Conference, Amsterdam, June 23-24. Available at: http://www.bestufs.net/download/conferences/Amsterdam_Jun05/BESTUFS_Amsterdam_June05_Neuhold_ERZ.pdf
Marinov, M., Mortimer, P., Zunder, T., Islam, D.M.Z. (2011) Short haul rail freight services, Journal of Transport Literature 5 (4), pp. 136-153.
Delanghe K., Meersman, H., Sys, C., Van de Voorde, E. and T. Vanelslander (2017). Trams for urban freight distribution : a private and/or social success?, 10th International Conference on City Logistics : 14-16 June, 2017, Phuket, Thailand , in Taniguchi, Eiichi [edit.]; et al.-p. 563-57</td></tr>
<tr><td rowspan="2">Score</td><td rowspan="2">9</td><td>Innovativeness</td><td>Feasibility</td><td>Capital intensiveness</td><td>Implementation phase</td><td>Publicly available knowledge</td></tr>
<tr><td>2</td><td>1</td><td>1</td><td>2</td><td>3</td></tr>
</table>

Source : Own composition

The innovation implementation phase[156] is a method for positioning on a scale based on the distance of the particular innovative activities to the market (the closer to the market, the closer the implementation of new ideas, products, processes or concepts are commercialised).

Table 69: Scheme of innovation implementation path

Upstream research	**Downstream research & development Technological barriers**			**Market introduction**	**Market uptake**
Scientific research	Applied / industrial research	Development of innovations	Demonstration	Market replication Tackling non-technological market barriers	Production/ Operations
Discovery	Resulting in: • Knowledge development • Test models	Resulting in: • Prototypes	Resulting in: • Demonstration of projects	Resulting in: • Pilots • First user projects of innovations	

Source: PNO, 2014

[156] PNO Consultants, 2014

Annex III

In the dissertation, the recent external costs estimates from Ricardo-AEA (2014) were used. Mira (2010) and CE Delft et al (2011), and Delhaye et al (2017) were also considered, but Ricardo-AEA's (2014) publication has recent and specific external cost data. Data are also mapped on a European scale, which improves comparability. More details on the differences between the different sources can be found in this Annex.

Ricardo-AEA (2014)

The estimates, shown in the next table, are Belgian external cost estimates (in 2010 price level) retrieved from Ricardo-AEA (2014).

Table 70: Consolidated external cost urban freight transport (EURct/vkm) (2010) (BE)

	Urban	
	LCV	Bike
Wear &tear (t)	1.2	n.a.
Climate (m)	2.8	0
Air pollution (e)	3.9	0
Noise (n)	0.127	0
Accidents (a)	0.3	9
Congestion (c)	121.8	0
Up-downstream (u)	1.2	0

Source: Based on Ricardo-AEA, 2014

A significant difference is seen between urban and non-urban external cost estimations (Ricardo-AEA, 2014). For some external cost parameters, e.g. climate change and congestion, values for different densities of traffic and/or time of the day are given. For the principles behind these differences, Chapter 2 can be re-consulted. The total external costs in congested urban areas sums up to 131 EURct per vkm for LCVs.

Mira (2010)

In this publication 'Externe kosten van transport', Transport & Mobility Leuven (TML) provided MIRA (The Flemish environmental agency) updated[157] external cost estimates for various transport modes. The study also provides private costs per mode and estimates current Internalisation percentages.

[157] De Ceuster G. (2004) Internalisering van externe kosten van wegverkeer in Vlaanderen.

The research contains various estimates for urban, regional and national traffic, each split per vehicle category. Based on the urban, or local, road stretches and light (LCV, 3,5 – 12 tonnes per vehicle), following Mira (2010) estimates for external costs were retrieved. The external costs for LCVs range between 17,138 and 23,63 EURct per vkm, 2008 price level.

Table 71: Consolidated external cost average freight transport (EURct/vkm) (2008) (BE)

	Urban	
	LCV	Cycling
Wear &tear (t)	2.832 -3.422	n.a.
Air pollution (e) + Climate (m) + Up-downstream (u)	2.643 - 3.302	0
Noise (n)	5.21 ('07)	0
Accidents (a)	3.792	n.a.
Congestion (c) LCV	7.904 - 2.661	0
Health benefits	n.a.	11.63

Source: Mira (2010)

CE Delft et al (2011)

In 2011, CE Delft et al published 'External Costs of Transport', containing 2008 European estimates for urban, regional and national traffic, each split per vehicle category. Based on the urban roads and the light (LDV) vehicle category, following estimates for external costs were retrieved. The external costs for LCVs range between 119,75 and 135,75 EURct per vkm, 2008 price level.

Table 72: Consolidated external cost urban freight transport (EURct/100 vkm) (2008) (BE)

	Urban	
	LCV	Cycling
Wear &tear (t)	3.422	n.a.
Air pollution (e) + Climate (m) + Up-downstream (u)	14.41	0
Noise (n)	10.91	0
Accidents (a)	8.01	n.a.
Congestion (c) LCV	83 - 98	n.a.
Health benefits	n.a.	n.a.

Source: CE Delft et al (2014)

Delhaye et al (2017)

In this publication an update of data in 'Internalisering van externe kosten van wegverkeer in Vlaanderen' by De Ceuster G. (2004) was provided to MIRA. It contains again external cost estimates for various transport modes. The research contains various estimates for urban, regional and national traffic, each split per vehicle category. Based on the urban, or local, road stretches and light (LCV, 3,5 – 12 tonnes per vehicle), following Delhaye et al (2017) estimates for external costs were retrieved. The external costs for LCVs range between 18,13 and 30,53 EURct per vkm, 2008 price level. Health benefits of cycling were recalculated, resulting in a much higher value of 45,2 EURct per vkm.

Table 73: Consolidated external cost urban freight transport (EURct/100 vkm) (2015) (BE)

	Urban	
	LCV	Cycling
Wear &tear (t)	1.32 - 1.59	n.a
Air pollution (e) + Climate (m) + Up-downstream (u)	6.52 - 12.70	0
Noise (n)	1.25	0
Accidents (a)	2.87	2
Congestion (c) LCV	6.17 - 12.12	0
Health benefits	n.a.	45.2

Source: Delhaye et al (2017)

General overview and comparability

Wear and tear indicators for external costs are comparable these range from 1.2 EURct per 100 vkm to. 3.422. Provided some of the external costs sources split air pollution, climate change and up-and downstream and others do not, comparability is not guaranteed. Moreover, the data is based on external costs from different years. Noise costs differ and range to 10.19. This indicator heavily relies on the trajectory and vehicle. Noise only encompasses the vehicle riding noises, and in urban areas loading and unloading might be more important. Congestion costs range from 2.6 EURct per 100 vkm to 121.8. They also depend a lot from the local situation.

Annex IV

Table 74: Euro 5 emission standards for light commercial vehicles

Category	Class	Reference mass (RM) (kg)	Limit values: Mass of carbon monoxide (CO) L_1 (mg/km)		Mass of total hydrocarbons (THC) L_2 (mg/km)	Mass of non-methane hydrocarbons (NMHC) L_3 (mg/km)	Mass of oxides of nitrogen (NO_x) L_4 (mg/km)	Combined mass of total hydrocarbons and oxides of nitrogen ($THC + NO_x$) $L_2 + L_4$ (mg/km)	Mass of particulate matter (PM) L_5 (mg/km)
M	—	All	1 000	500	100	68	60	230	5
N_1	I	RM ≤ 1 305	1 000	500	100	68	60	230	5
	II	1 305 < RM ≤ 1 760	1 810	630	130	90	75	295	5
	III	1 760 < RM	2 270	740	160	108	82	350	5
N_2			2 270	740	160	108	82	**350**	5

Source: REGULATION (EC) No 715/2007 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information

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