CHARACTERISTICS OF INNOVATIONS IN LAST MILE LOGISTICS - USING BEST PRACTICES, CASE STUDIES AND MAKING THE LINK WITH GREEN AND SUSTAINABLE LOGISTICS -

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1. INTRODUCTION

Since the last decade, the e-commerce market is characterized by enormous growth and changes, for the durable consumer product market, as well as for the e-grocery market. This growth has caused an important increase in direct-to-consumer deliveries. These deliveries are not a new phenomenon, thinking about mail order companies in especially the eighties and nineties, but the e-commerce growth has enlarged the market and the number of direct-to-consumer deliveries significantly. This growth has caused and still causes some major issues/problem within especially the last part of the supply chain of such direct-to-consumer delivery chain. This last part is called 'the last-mile'.

The last mile of the supply chain is considered as one of the most, or even "the" most, expensive, inefficient and polluting part of the supply chain. The most important problems are the following ones. First of all, for home deliveries, the high degree of failed deliveries due to the "not-at-home" syndrome is an important problem, which implies extra costs and extra kilometres and emissions. A second problem that can be mentioned is that door-to-door deliveries can create a high degree of "empty running[1]". A third important problem is the one related to security when delivering a parcel if a signature is needed. This security problem can result in discussions between supplier and consignee. A fourth problem is that for some regions, the critical mass of goods is too small to generate a profitable and efficient routing plan. The fact that most of the door-to-door deliveries are done by small vans implies that the carbon footprint per kg is higher than that of transport by a bigger truck, which is a fifth problem

In the following paragraphs, these problems will be analyzed and a list of characteristics/determinants, which can have important effects on efficiency and costs when implementing innovations, will be made. These characteristics/determinants will be listed using cost structures of last mile logistics providers and academic literature. Product types/groups will be used to classify the different characteristics.

During the last decade, special attention has been paid to the aforementioned problems in the last-mile and as a result, some remarkable innovations to optimize the last mile were launched. Some of these innovative concepts will be described too.

The structure of this article will be as follows. First of all, the last mile will be defined. Secondly, some academic literature typologies for the last mile will be analyzed. Third, attention will be paid to the so called "last mile problem" and hereafter, the different characteristics and sub-characteristics of the last mile will be analyzed and applied to several last-mile topics. To end with, two innovative last-mile concepts will be highlighted and the characteristics will be applied to these concepts.

The research question for this paper is as follows: **which are the important/significant characteristics which define the efficiency, effectiveness and cost structures in the last-mile?** With other words, **what are the characteristics that companies need to take into account when implementing innovative concepts in the last mile for obtaining optimization and cost reductions in that last mile?**

2. THE LAST MILE

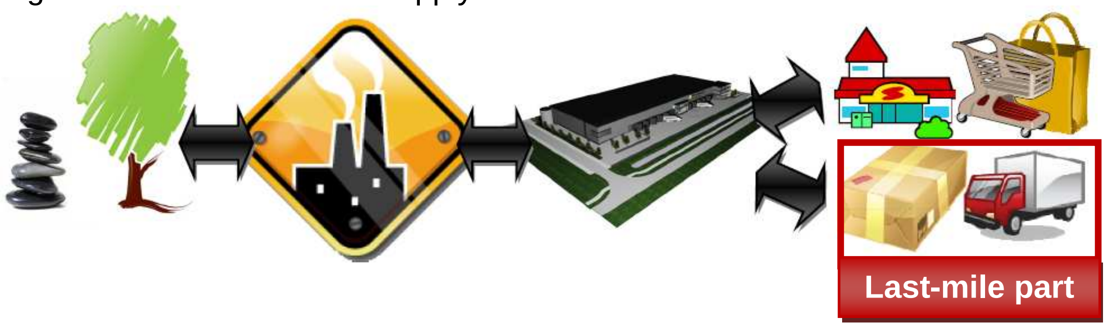
2.1 Definition of "the last mile"

The following terminology is used to define the last-mile: *"The last mile is the last stretch of a business-to-consumer (B2C) parcel delivery to the final consignee who has to take reception of the goods at home or at a cluster/collection point.".* This definition is not exhaustive.

The focus in this paper will be on that part of the last mile starting from the point where the parcels have left the storage place[2] of the supplier. As a result, order-picking will NOT be taken into account, although some literature consider this also to be part of the last-mile.

Following diagram (fig.1) illustrates which part of the chain will be discussed in this article.

Fig. 1: Basic structure of a supply chain



Source: Own reproduction based on De Smedt, Gevaers (2009)

Most supply chains have the following standard structure: the raw materials go to the processing industry. Later on they are stored in most cases in a warehouse (distribution center). From that point on, two main ways of distributing the goods are possible: the traditional system with supermarkets and retail shops, and a system with direct-to-consumer deliveries. The **last-mile part** in the supply chain is considered as the last part of the supply chain for the direct to consumer market.

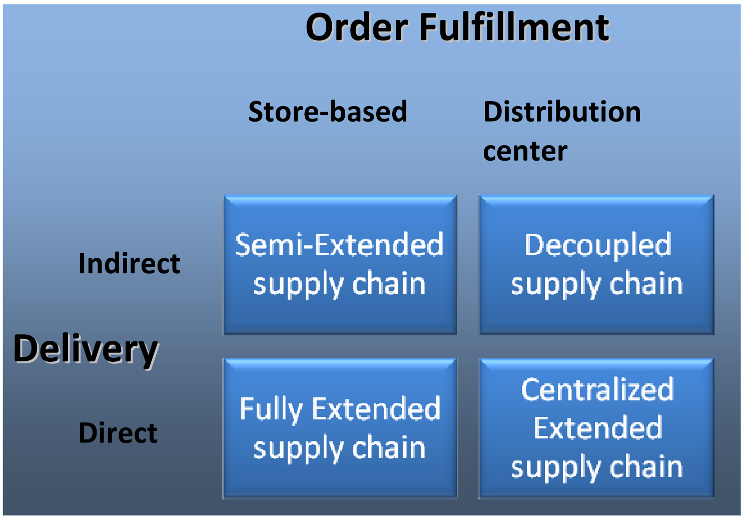
Due to the constantly growing e-commerce market, the direct-to-consumer market is characterized by important growth figures. This implies important effects/impacts on last mile suppliers and systems regarding capacity needs to deal with these innovative concepts. This will be analyzed in the following paragraphs, starting with the description of the types/typologies of the last-mile.

2.2 Typologies/types of last-mile deliveries
To analyze and describe characteristics of the last-mile, a typology to describe and classify sub-flows within the last-mile is necessary. In literature, different ways of last mile typologies have been mentioned in the past.

The typology of Boyer, Frohlich & Hult (2005) is a typology that is used in some academic papers and articles. This typology divides the last-mile into four sub-types: semi-extended supply chains, decoupled supply chains, full extended supply chains and centralized supply chains.

This typology is compiled using a matrix format with two variables: order fulfillment and delivery type, like in figure 2.

Fig 2: Typology for the last-mile



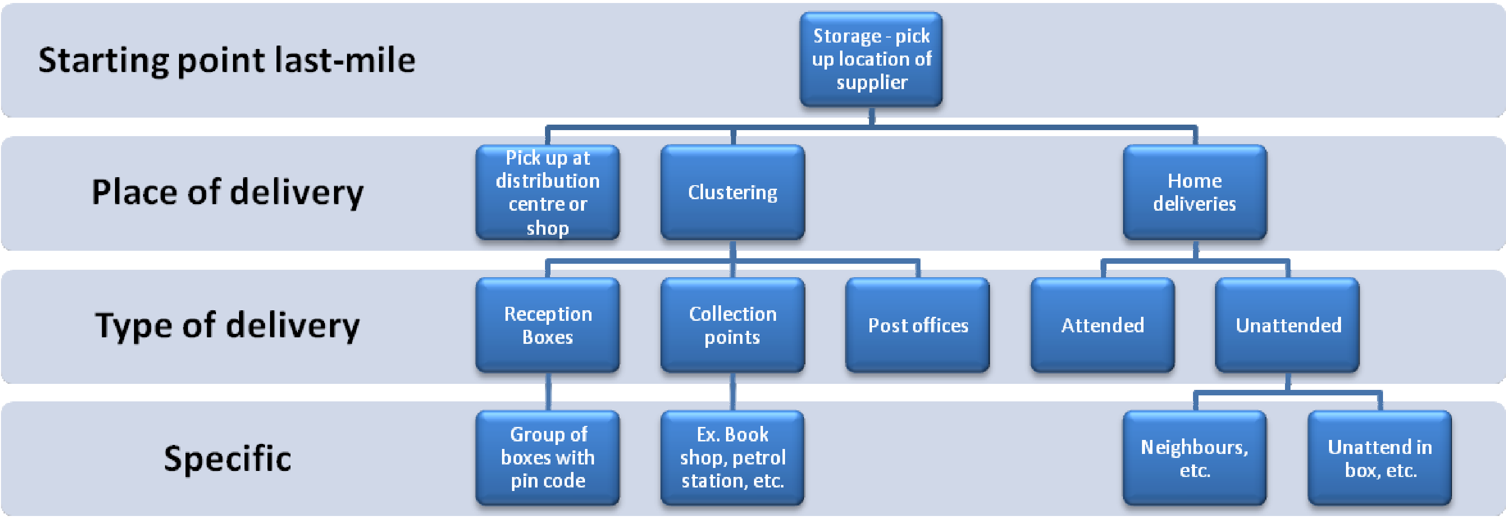
Source: Boyer, Frohlich & Hult (2005)

The **semi-extended** supply chains use goods where the order picking took place in a store and the type of reception was indirect, so not "at home" (for example using collection points). The **fully extended** supply chains use also stores for order picking, but use direct home deliveries as reception type. The **decoupled** supply chains use distribution centers and do not make use of home deliveries. The last type, the **centralizes extended** supply chains, make use of distribution centers and deliver the goods at home.

Although the framework/typology of Boyer, Frohlich & Hult is an analysis of the last-mile part of the supply chain, the most important disadvantage is the fact that by using this scheme, the underlying characteristics will not become clear enough.

When looking to the different types of reception of the goods by the consignee, the following diagram gives a good overview of the many different types of reception. Also for this diagram, the reception methods listed are not exhaustive, as shown in figure 3.

Fig.3: Types of reception method in the last-mile



Source: Own diagram

The major last-mile problems will be discussed using the different types of reception illustrated in fig.3. The characteristics of the last-mile will be discussed after about the section dealing with the last mile problem. The term “characteristics” need to be interpreted in the last-mile context as a **distinguishing feature** that can have important effects on the efficiency and cost structure of the last-mile part of the supply chain.

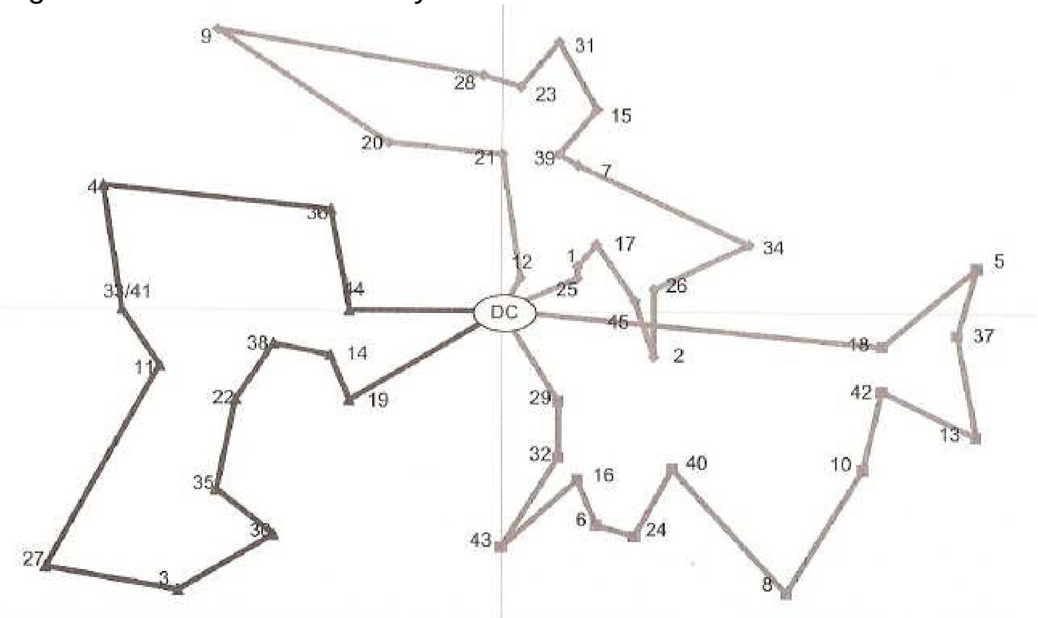
2.3 The related Last-mile problem(s)

As already stated in the introduction, the main issues related to the so called ‘last-mile problem’ are the following ones. This list was compiled using academic literature and contacts with last mile service providers.

The last mile, is, due to its very specific delivery needs, considered as the most expensive part of the supply chain. The last-mile part accounts, depending on several factors/characteristics, for 13% up to 75% of the total supply chain costs. Related to these high costs are the many inefficiencies in the last mile and the poor environmental performance.

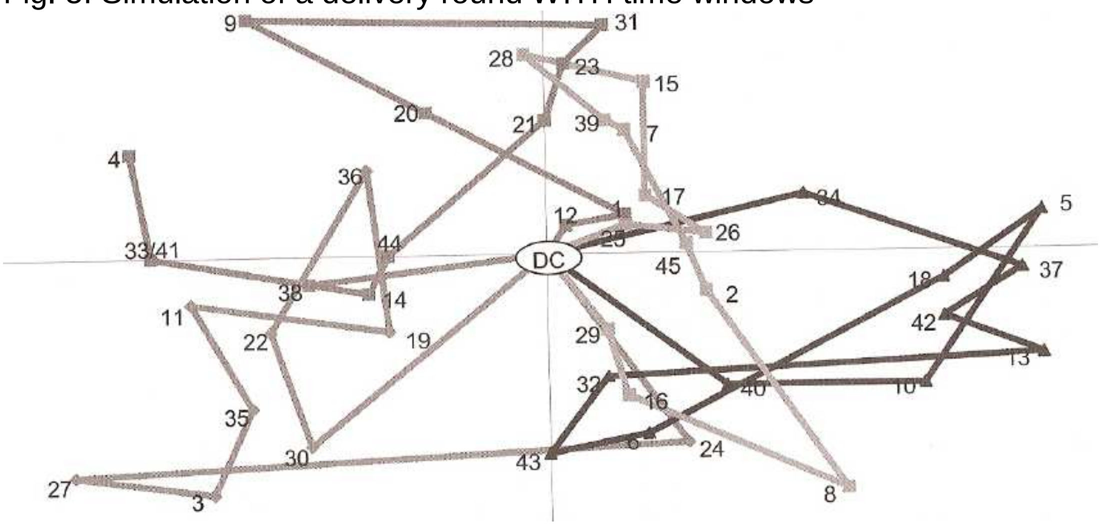
The major problems in the last mile are related to the ‘attended home deliveries’ for the following reasons. In the case that no specific delivery window[3] was communicated, a high level of ‘not-at-home deliveries’ will take place and the courier will have to return again (or even two or three times). In the case that a specific delivery window was agreed, this makes the routing process very inefficient. It should be intuitively clear that, the narrower the time windows are, the more inefficient a delivery route becomes. The following simulation illustrates the differences between a delivery round with (figure 4) and without (figure 5) delivery/time windows.

Fig. 4: Simulation of a delivery round WITHOUT time windows



Source: Boyer, Frohlich & Hult (2005)

Fig. 5: Simulation of a delivery round WITH time windows



Source: Boyer, Frohlich & Hult (2005)

Figure 5 illustrates time-definite deliveries (time windows, maximum delivery lead times, etc.). In most cases, these will cause a so called 'ping-pong effect[4]', which implies a significant raise in driven kilometers and costs.

Although home deliveries (direct to consumer deliveries) do exist already for a very long time. Referring to post order companies such as Neckermann and

3Suisses in Europe, it is the growing level of time-definite deliveries that can make the last-mile very inefficient.

A second major problem, especially for home deliveries but also possible for clustering types of reception, is the fact that for the last mile typically, the level of consumer density is not high enough to operate at an acceptable level of costs. It should be clear that once a courier has to drive for example 30 km for delivering one parcel, this increases the costs of the last mile significantly.

Furthermore, since the last decades, consumers are getting more and more aware of the environmental issues of logistics and transportation. As a result, they expect a constantly decreasing carbon footprint. But in most cases, they do not wish to make a trade-off between for example a longer delivery window and a more environmentally friendly delivery route. Also with this fact, the last mile has to deal.

Aforementioned problems are the major ones, but this list is not exhaustive. Another problem within the last mile, from an economical point of view, is for example the high degree of "critical mass" needed for setting up a last-mile network for smaller retail chains etc. But these more "general" problems are not discussed/analyzed.

In the following paragraphs, the significant characteristics/determinants, in relation with innovative concepts, of the last mile, will be described.

2.4 Characteristics/determinants of innovations in the last-mile

Here, the main characteristics of the last mile part of the supply chain will be listed and analyzed. As a result, when companies want to optimize their last mile by implementing innovative concepts, the most effective concepts will be those that focus/anticipate on these listed characteristics. The list of characteristics was drafted using the aforementioned problems, based on inefficiencies and cost structures.

For the last-mile, there are five generalized characteristics[5]: **consumer service levels**, **security & type of delivery/reception**, **geographical area & market penetration**, **fleet & technology** and **the environment**. In the following paragraphs, these generalized characteristics are described more in detail and hereafter, they will be classified in last mile sub flows.

Customer service levels

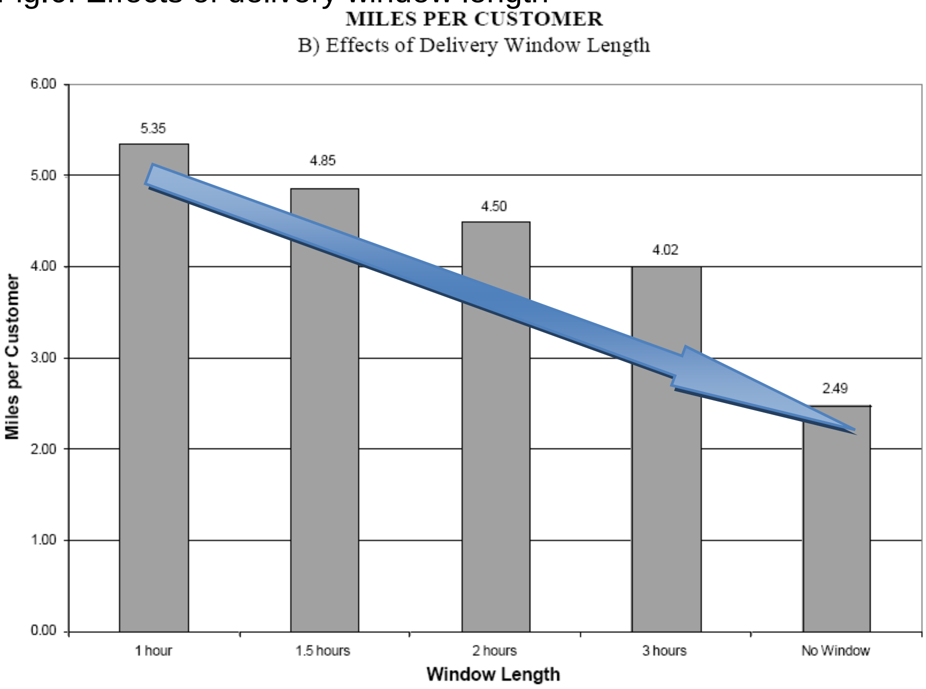
As described already in the last-mile problem, too narrow **time windows** can have important effects on the efficiency of the last-mile. These time windows are a sub-characteristic of consumer service levels.

Not only those time windows are sub-characteristics. Also the agreed **maximum lead times**, the **frequency of delivery** and the **possibility of returning goods** are sub characteristics of consumer service levels.

To stress the importance of these aforementioned sub-characteristics, some figures in the following paragraphs will show the significant impacts on the efficiency and costs of the last-mile.

Boyer, Prud'Homme & Chung (2009) simulated some effects of differences in time windows. Following figure [6] illustrates the average number of miles per customer/parcel. This simulation was drawn in their attempt to evaluate the effects of customer density and delivery window patterns on vehicle routing. For this simulation, they used Descartes' Fleetwise routing system, a common used system by logistics companies.

Fig.6: Effects of delivery window length



Source: Boyer, Prud'Homme & Chung (2009)

There is a clearly descending relationship between window length and miles per customer. As a result, looking at the related costs, these decrease with an increasing number of time-indefinite (no windows) deliveries.

A similar study from Kämäräinen (2001) calculated a cost difference of 42% when comparing reception boxes without time windows and delivery methods with time windows, making use of data from a Finnish grocery shop delivering a parcel with time windows was calculated to represent a cost of €2,1 per parcel, while this was only €1,2 when using reception boxes. This was due to the aforementioned reasons, such as the higher number of kilometers driven per parcel.

<u>security & type of delivery/reception</u>

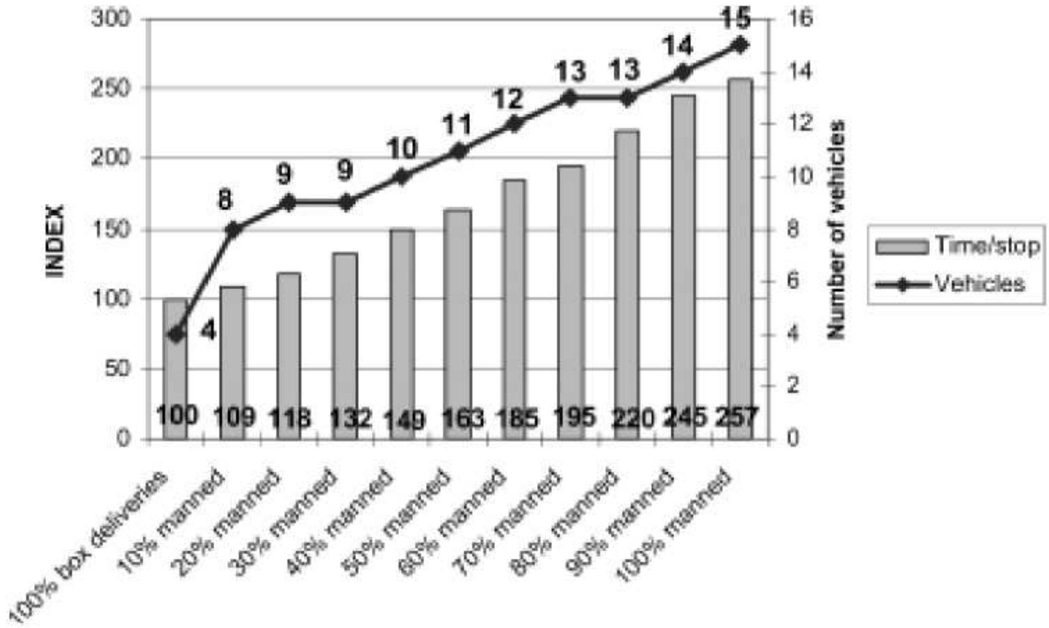
The security & type of delivery characteristic is important because depending on the level of security needed for the reception. Some deliveries will have to take place by handing the goods over to another natural person, while other deliveries can take place by just leaving these goods in a box at the front door of the consignee/consumer.

Also the type of product plays an important role, especially when products need special treatment, for example refrigerating, etc.

The sub-characteristics within this generalized characteristics are the types already described above: **attended/unattended deliveries**, **collection points**, **delivery boxes**, etc.

Punakivi & Saranen (2001) made a simulation, with the number of vans needed and the average waiting time as a dependent variable, using an index comparison, as shown in figure 7.

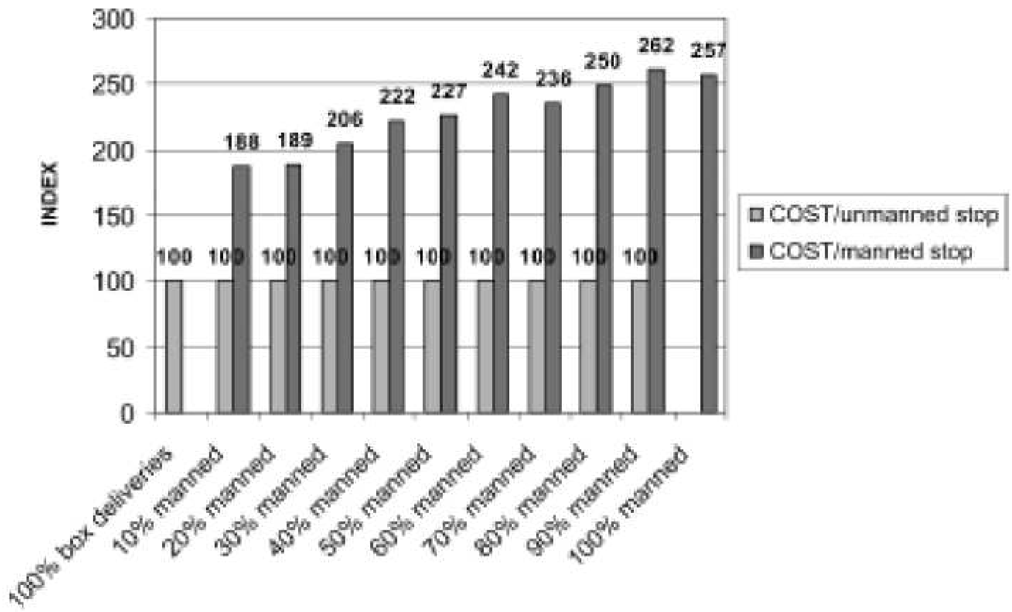
Fig..7: Relation type of reception with time/stop & number of vans



Source: Punakivi & Saranen (2001)

When looking to the costs, the authors calculated the cost increase shown in figure 8. A significant rise in costs can be concluded.

Fig. 8: Comparing costs of manned and unmanned reception



Source: Punakivi & Saranen (2001)

Another important problem to mention is the high level of failed deliveries when using attended reception. Due to this phenomenom, couriers sometimes have to go back two or three times to the same home address with the same parcel. This implies skyrocketing costs for last-mile service providers. This is another reason why fig. 8 reports an increase in costs between unattended and attended reception of +157%. Fernie &, McKinnon (2004) state that the average number of first failed delivery is approximately 30%, depending on the type of products delivered.

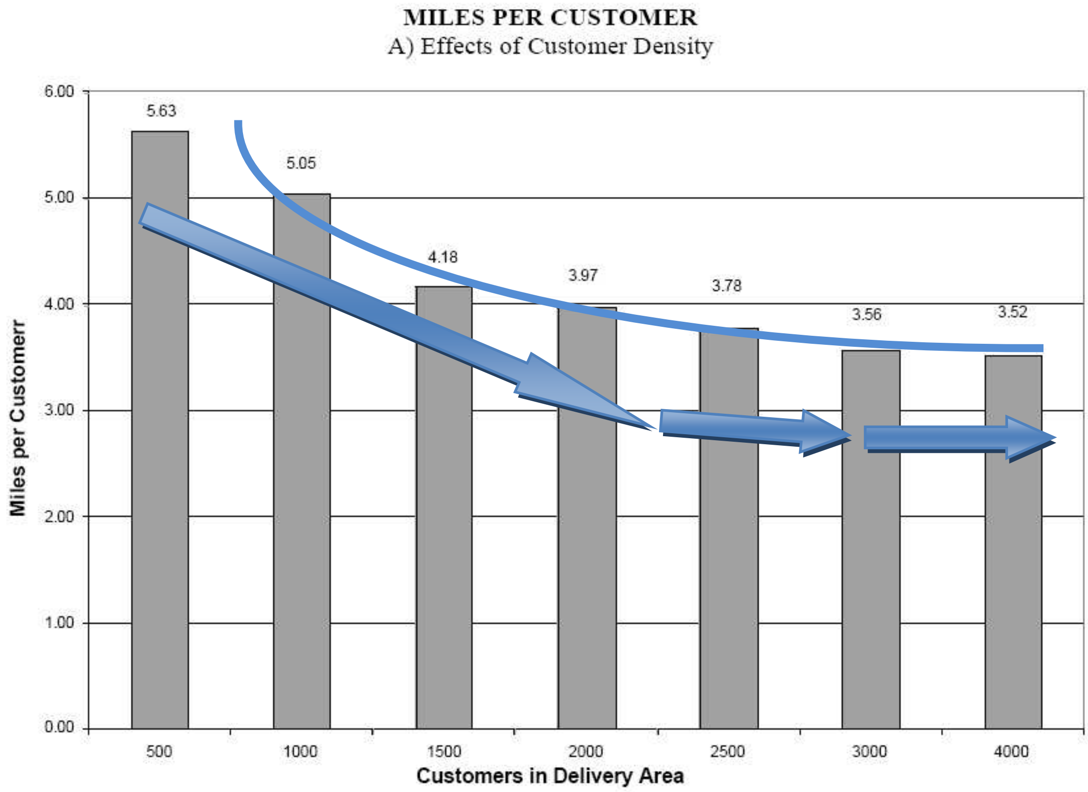
<u>Geographical area & market penetration</u>

It was already stated that the market penetration within specific areas and the related market densities in these regions are of significant importance. The most important sub-characteristics for this generalized characteristic are **density of the region/market & average distance between the different points of reception** and the **percentage of the number of goods that can be pooled/clustered during delivery routes**.

Just as for traditional retail shops, market density and market penetration are very important market issues for last-mile efficiency and economics. It should be clear that when in a specific area only one parcel has to be delivered, the delivery route for this parcel will be very uneconomic and inefficient due to the high number of kilometers dedicated to that specific parcel.

Boyer, Prud'Homme & Chung simulated some effects of differences in customer density in figure 9. This graph provides the average number of miles per customer/parcel.

Fig. 9: Effects of customer density



Source: On the base of Boyer, Prud'Homme & Chung (2009)

In this simulation, the delivery area was one square mile. These are a clearly decreasing relation between miles per customer and the number of customers in the delivery area. As a result, looking to the related costs, these decrease with an increasing number of customers in the delivery area. However, as can be seen on graph 9, this relation has a decreasing marginal reduction in miles. For example[7], between 1,000 and 1,500 customers, the average number of miles decreased from 5.05 to 4.18 while it decreased only from 3.56 to 3.52 miles in the interval 3,000 to 4,000 customers in the delivery area. As a result, it can be concluded that the optimum will be somewhere between 3,000 and 5,000 consumers in the delivery area.

<u>Fleet & technology</u>

The main sub-characteristics for this topic are: **type of vans/rolling material** and the type of **information & communication technologies**.

The type of fleet can play an important role on many different cost influencing parameters/factors, such as: fuel consumption, (optimal) load capacity, methods for loading and unloading procedures, safety, etc.

Less obvious, but also of significant importance are the used information & communication technologies used. For optimal routing, it is important that the couriers can be informed that they have to pick up parcels on the route they are driving on that specific moment or that a consumer has changed the delivery address/reception point at a late moment. By using communication technologies, in most cases, a significant amount of time and fuel can be saved.

Information technologies, for example RFID and routing systems, also play an important role in the efficiency and cost structure of the last-mile. In former decades, when the level of information technologies was significantly lower, much more paper work had to be done, more manual checks and sub-optimal routes were common events. By using the situation-specific information technologies, in most cases, a significant amount of time, fuel and paperwork can be saved. Another result of increased use of IT is the increased level of reliability of deliveries.

<u>The environment as a characteristic/determinant of innovations in the last-mile</u>

Consumers and companies are getting increasingly aware of environmental issues in the economy and in transportation/logistics. However, in many cases, consumers want companies to be more environmentally friendly, but they do not wish to pay more, or do not accept a longer service time for “green products or services”.

Specifically for the last-mile, companies need to make a trade-off between the fast and narrow time windows they offer to the consumers and the level of environmental friendliness they wish to obtain. As already mentioned, the narrower the time windows and the shorter the delivery/lead times, the more polluting the delivery of the parcel becomes.

For the future, companies probably will have to keep up several delivery options (fast <-> slow, narrow time windows <-> window indefinite, etc.), but they will have to make the consumers aware which environmental implications and also a different price the several delivery options can have.

It is a misunderstanding that home deliveries are always more polluting than traditional shopping. The Green Logistics research Initiative[8] has compared the environmental performance of traditional shopping with home deliveries in Edwards, McKinnon & Cullinane (2009). Depending on which assumptions and parameters interfere, in some cases delivery of a parcel was more environmentally friendly than traditional shopping. The results depend in most cases on the aforementioned characteristics like market density, time windows, etc.

The results of this study are the following ones (Edwards, McKinnon & Cullinane (2009), pp.35)

The factors influencing emissions from home deliveries: drop densities (the number of drops per delivery round); the distance and nature of the delivery round; the type of vehicle used; and the treatment of failed deliveries and returns.

On average, when a customer buys fewer than 24 items per shopping trip (or fewer than 7 items for bus users) it is likely that the home delivery will emit less CO2 per item purchased.

These findings require several qualifications, they assume that: the car-based trip was solely for the purpose of shopping (no other activity was undertaken during the course of the trip); the online purchase was delivered successfully the first time; the shoppers was satisfied with the purchase and did not return the item; home deliveries and shopping trips were made over average distances; no allowance was made for different types of road network or traffic conditions; only the last mile and not the upstream supply chain has been considered in the analysis (although reference was made to previous studies).

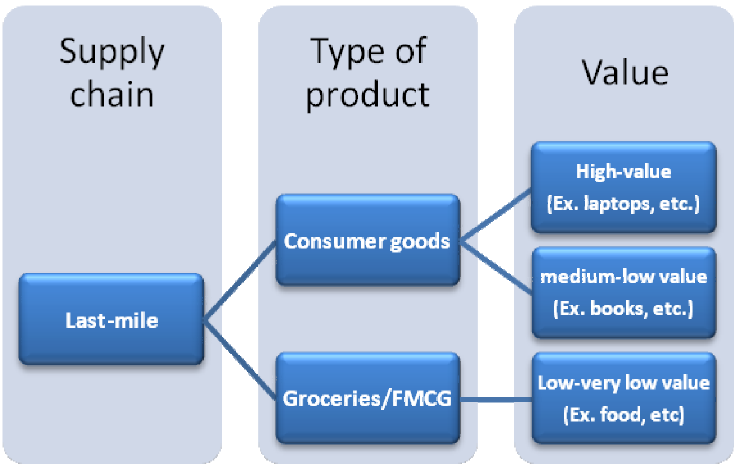
As an important observation, it can be stated that some of the characteristics discussed earlier do not only have impacts/effects on the efficiency and cost structures, but are also highly correlated with the environmental performance of the last-mile.

2.5 Typology for the characteristics/determinants of innovations in the last mile

We will now try to classify the aforementioned sub characteristics in a typology, so that generalized conclusions can be drawn.

During the research process of this article, it became clear that the aforementioned typologies (Boyer, Frohlich & Hult (2005) and types of reception are not the most appropriate ones because they do not offer a good "classification" base for the characteristics. With other words, these typologies do not distinguish the last mile in appropriate sub-flows For this reason it was decided to classify the sub-characteristics to specific types of goods (variable), as illustrated in the following figure. This method distinguishes appropriate last-mile sub-flows for qualification of characteristics.

Fig. 10: Typology for sub flows within the last-mile



Source: Own figure

The main differences in the last mile can be found by looking deeper into the types of goods that are delivered. In other words, the last-mile can be split up in three main sub-last mile flows, with each of them roughly specific sub-characteristics. Very low to low value products are for instance food and fast moving consumer goods, low to medium goods are for example DVD's, books, etc. and high value products are for example laptops, other electronics, so the more durable goods.

In the following table, the sub-characteristics are assigned to the three last mile sub-flows.

Table 1: assigning characteristics to product types/values

	Groceries/FMCG	Medium value	High-value
Service level			
Time windows	x		
Lead times	x	x	x
Frequency	x		
not-at-home		x	x
Security & type of delivery			
Manned		x	x
Unmanned	x		
Collection point		x	x
Box	x		
Geographical area & market penetration			
Density	x	x	x
Pooling of goods	x	x	x
Fleet & technology			
Type of vans	x	x	x
Infomation & communication technology	x	x	x
Environment			
Packaging	x	x	x
Trade of between time and environment	x	x	x

Source: Own table

Table 1 must be interpreted as follows: for each sub characteristic that applies to a last mile sub-flows, an "x" is placed into that cell. So for instance, to groceries, time windows do apply much more significantly than to medium or high-value products. When a specific cell is marked in red, this sub-characteristics can have significant impacts on the efficiency and costs in that specific last mile sub-flow.

<u>Interpretation of table 1</u>

When looking to the characteristic **service level**, time windows and very short lead times are in most cases problematic (red cell) for the sub-flow of the groceries and FMCG, for example food. When people are, for example, ordering food on-line, the food should arrive in most cases the **same day** with very specific **time windows** (for example before lunch or dinner) **several times per week** (for fresh products). When comparing this with for example a book or a personal computer, same day deliveries and time windows are of less importance because these are more "**durable products**" . But in the case that a consumer whishes that his medium or high value goods are delivered at home, the percentage of failed deliveries is much higher when compared to groceries/FMCG. This is because **high and medium valued goods** are in most cases not delivered using unattended deliveries. In contrast, for low valued food for example, this is done frequently by leaving a special (sometimes refrigerated) boxes next to the front door of the consignees' house.

Collection points are much more applied on medium and high valued products, if compared to groceries. This is a result of the fact that consumers that make use of e-grocery shops do opt for home deliveries due to their speed, so they wish not to pick it up at a **collection point**. It is the time factor that implies this consequence. When speaking about durable goods, consumers are more willing to pick up goods at a collection point.

When looking to the **density of the market** and the possibilities to pool goods, the major problem is the low-value product markets. This is a consequence of the fact that delivery/lead times are much shorter and delivery windows are narrower. Due to this, last-mile service providers are remarkably less able to pool the goods at an economically efficient transportation level. For instance, delivery routes in cities are economically much more efficient, if market penetration is sufficient, compared to delivery routes in rural areas.

Another sub-characteristic that can imply significant efficiency increases and decreases is the **ICT system**. This is especially the case for those delivery routes with very narrow time windows, with a lot of fluctuations and changes during driving.

In the aforementioned trade-off between environmental performance and the level of customer service (time windows, delivery times, etc.), it was already mentioned that this is a major issue for **low valued product deliveries** and a minor issue for other products, due to the specificity of more time definite grocery deliveries.

It is clear that all of the sub characteristics depend on specific last-mile sub flows. In other words, each sub flows has some specific characteristics. However, when they are aggregated to more generalized characteristics (one level up), than it can be stated that the overall characteristics for the "whole" or "total" last-mile are: **service levels**, **security & type of delivery**, **geographical area & market penetration**, **fleet & technology** and **environmental issues**.

When even generalizing these characteristics to a higher level, to the more overall supply chain characteristics stated in logistics academic literature, than it can be stated that these are: **time**, **flexibility**, **security**, **market lay-out**, **technology** and **environment**.

The following paragraphs will highlight some innovative concepts, using case studies, for the last mile with description and analysis of the aforementioned sub-characteristics.

3. CASE STUDIES

The first innovative concept that will be analyzed by applying the (sub-) characteristics is the SmartTruck concept of DHL.

3.1 SmartTruck (pilot in Berlin - Germany)

The SmartTruck project is an innovative last-mile concept that has been launched in March 2009 in the inner city of Berlin. The project focused on some remarcable innovations.

First of all, due to a tour planning system, it is possible to make use of dynamic planning of pick-up and delivery routes, using GPS, etc. Secondly, higher punctuality of deliveries is achieved by using RFID (in depots as well as in the vans) for outgoing shipments. Thirdly, for reducing the number of (tonne-) kilometers, each van is equipped with an automatic navigation system with an adaptive sequencing stop list. This navigation system takes into account up-to-date traffic data/information, which is collected from a network of 500 taxis in Berlin which are connected with a central traffic controlling system. A last feature of SmartTruck is that each customer receives an SMS as notification of delivery time.

Fig.7: Simplification of SmartTruck

Source: DHL Press Room

The summary of the SmartTruck is as follows. In this new concept, attention is paid to the characteristic **consumer service levels** (time windows, maximum lead times, frequency of delivery, possibility of returning of goods) by using dynamic planning of pick-up and delivery. This is possible due to the use of many ICT techniques, such as RFID, GPS, SMS, etc. This ICT component can be considered as an adaptation of a second characteristic: **fleet & technology**. The use of traffic conditions information, provided by more than 500 taxis equipped with GPS and smart phones and linked with a traffic center in Berlin, is also an example of an adaptation of the characteristic: fleet & technology.

SmartTruck is designed especially for delivery rounds with high density delivery zones (for example cities), can be classified as the characteristic **geographical area & market penetration**.

The use of dynamic planning, RFID for optimal loading and unloading operations, the reduction in tonne-kilometers, etc. can be interpreted as the characteristic **environment.** The characteristic **security & type of delivery** was also dealt with, because the system is designed to deliver to unmanned as well as to manned reception.

As such, SmartTruck is an example of an innovation, that during development focused on the main characteristics of the last-mile.

3.2 Collection points in shops with long opening hours and collection boxes, stations or kiosks

The second innovative concept that will be discussed is the concept of collection points in shops with long opening hours, such as petrol stations, newspaper shops, small supermarkets and collection boxes, etc. This concept is not as new as the former one, but is also a good example of an innovative concept for optimizing the last-mile, taking into account the several characteristics of the last-mile.

Starting from the year 2000, companies which had to deal with last-mile deliveries, realized that clustering goods in collection points could save money for several reasons. These reasons are clearly linked to the last-mile (sub-) characteristics. First of all, a lot of expensive ‘not at home’ deliveries are prevented due to the use of manned shops with long opening hours, which is a result of applying the characteristics **security & type of delivery** and **customer service levels**. On the other hand, clustering of goods implies a higher load factor for the truck and van fleets and a lot of fuel is saved (with a reduction of emissions as a direct environmental effect) for the supplier, which is an adaptation to both the **geographical area & market penetration** and the **environmental** characteristic.

The fact that collection points in shops are always manned[9], can be classified as **security & type of delivery** characteristic whereas the real time information data flows between supplier, provider and shop/box can be classified as **fleet & technology** characteristic.

These collection points are mostly located in shops with long opening hours, such as bookshops, petrol stations, etc. The Kiala Company is an example of a company that tries to cluster goods for several companies by using a network of about 4,660 collection points in Europe. Around mid 2008, Kiala distributed around 78,000 parcels per day using collection points. In 2008, TNT Express has signed a contract with Kiala for using this system for some of their B2C parcels. DHL uses several Shell petrol stations as collection points and GLS uses also a network of parcel collection points in several shops, but under their own GLS label (See figure 9).

Fig. 8: Kiala collection point

Fig. 9: GLS collection point

Source: Kiala (2009) Source: GLS Group (2009)

Just as for the SmartTruck concept, the concept of collection points is an example of an innovation in the last mile, that during development focused on the main characteristics of the last mile.

4. FURTHER RESEARCH

When looking in particular at the characteristic service levels, the so called no-time windows delivery is in most cases interpreted as “deliveries are possible from 9 a.m. till 5 p.m.”, because these are in most cases the traditional working hours of couriers and express delivery service companies.

A possible, and to our opinion not existing, last-mile concept that should be analyzed for introduction in the future is the “extension” of time windows to off-peak moments (so called day border included), for example from 5 a.m. till 11 p.m. using silent delivery methods. These silent technologies do already exist since the introduction of the Piek project in The Netherlands. This project was launched in 1998 to start develop quiet technologies[10] for transport and logistics companies. This creates the opportunity to increase the level of deliveries during evening and early morning, because the noise levels will almost certainly not be exceeded, while this can be the case when using older and loud delivery material

If it would be possible to introduce broader time windows than nowadays, this would be an adaptation of the **service level characteristic** and also an adaptation of the **environmental characteristic.** This due to the fact that driving during off-peak moments produces on average less carbon emissions as the result of the lower level of congestion at these moments. The **fleet & technology characteristic** is also taken into account using silent technologies.

5. CONCLUSION

The research question of this paper was: “what are the characteristics that companies need to take into account when implementing innovative concepts in the last-mile for obtaining optimization and cost reductions in the last mile?”. It can be stated that when optimizing the last part of a supply chain, one has to focus on the following characteristics: **service levels, security & type of delivery, geographical area & market penetration, fleet & technology** and **environment**.

This list of characteristics does not guarantee success when implementing innovative last-mile concepts, but it appeared **out of the existing academic literature that the aforementioned characteristics do increase the possible success of implementing a new concept**, when they have been taken into account. In other words, the chance to obtain increased performance and competitiveness in the last mile chain, is higher by adapting these characteristics in new concepts.

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NOTES

[1]Driving with almost or completely empty trucks or vans.
[2]Distribution center, retail shop, etc.
[3]And the related lead time.
[4]This increase in driven kilometers (and the "ping-pong pattern" is the result of the not optimal (and **not shortest**) rout/loop which connects the delivery addresses in comparison with a route without time definite deliveries.
[5]This selection is made on the basis of academic literature and contacts with logistics companies.
[6]This as well as the following graphs were calculated using statistical models. For each of these models, some minor assumptions were made in the related academic articles. In the article of Boyer, Prud'Homme & Chung (2009) for example, an assumption was that *"The delivery windows were spread evenly across a nine hour day. This is done to provide a relatively even spread for demand. In actual practice, this simplifying assumption would likely not be true as customers are likely to have highly variable demand patterns (i.e., certain windows will be more popular than others)".* Due to the fact that these are minor assumptions, these are not listed in this article. We refer to the related literature in the bibliography for the simulation specific assumptions.
[7]Figures based on a simulation model.
[8]Several Universities in the UK have formed Green Logistics.org.
[9]Unmanned collection boxes are also an innovative concept and are more applicable on the grocery/FMCG market. A network of collection boxes can be compared with a locker room where goods can be stored, but with this difference that these lockers are used to store the parcels delivered by couriers. From the moment that a courier has put a parcel in a dedicated box/locker, the customers can collect this parcel. The collection box can be opened with a dedicated code, which the customer will receive by e-mail/SMS once the parcel is put in the box/locker, for each parcel. These boxes can be refrigerated etc.
[10]Noise level below 60 d(B)A or 65 d(B)A.