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Distributing the benefits of urban consolidation centers
an application on Westfield Shopping Center, London

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Distributing the benefits of Urban Consolidation Centers:
An application on Westfield Shopping Center, London

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Roel Hoyer

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Distributing the benefits of Urban Consolidation Centers - An application on
Westfield Shopping Center, London

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ABSTRACT

This project is conducted at DHL and provides a quantitative economic evaluation model for urban consolidation centers and suggests a distribution of the centers economic benefit using the Shapley value. The model is applied on a simplified case of the Westfield Shopping Centre in London. It is shown that consolidation is economically beneficial for the supply chain and that a stable allocation is possible. Additionally insights into the sensitivity of the model and allocation rule are obtained.
Management Summary

At DHL the current operating norm is for a retailer to bear the additional handling and transportation costs associated with consolidated last-mile and last-metre deliveries. This cost burden is perceived by DHL as one of the most important reasons explaining why there has not been a greater uptake of consolidated last-mile deliveries in the last 5 to 10 years. Stakeholders that could potentially benefit from consolidation avoid it for financial reasons and local & central governments have limited mandate to regulate the use of these consolidation centers.

The retailer is the only stakeholder that bears the additional costs of consolidated delivery, as it is unclear what the effects are for the different stakeholders in the supply chain. In the literature the success of an Urban Consolidation Centre (UCC) is subject to extensive qualitative analysis, however a thorough economic analysis is lacking. Therefore there is no clear understanding of the economic benefits and costs of using a consolidation centre for the supply chain. The aim of this master thesis is to capture these economic benefits and costs of urban consolidation and distributing these benefits among stakeholders using principles from cooperative game theory.

For this analysis, the model is based on a case study of the consolidation centre operated for the Westfield Stratford City (WSC) shopping centre in London. DHL had the unique position to operate this centre during (and after) the London 2012 Olympic games. The consolidated supply chain was compulsory for all retailers in the shopping centre during the Olympic period for security reasons. This provides a rich database of operational data on which a quantitative economic benefit model is designed.

There are many stakeholders directly involved — they can be grouped into three stakeholder groups: retailers, freight operators and the mall owner (the Westfield Group). The selection of these stakeholders is based on data availability and economic impact. For the benefit analysis, the consolidated supply chain (delivery via consolidation center) is compared to the traditional one (direct delivery).

The economic urban consolidation model is based on the processes that are directly related to the movement of the freight from the supplier’s distribution centre to the retailer’s store floor for a traditional and for a consolidated supply chain. The processes can also be grouped into three high level processes, each with one or more aspects. The haul/last-mile process relates to the physical movement of the freight to the shopping center. Relevant aspects are processes, loading-bay opportunity costs and shrinkage costs. The process aspect relates to the actual movement: due to consolidation there will be less truck movements and added freight handling. Loading-bay opportunity cost is the potential opportunity that could be achieved because of reduced loading bay need (due to reduced truck arrivals). Shrinkage is the cost of lost and damaged freight — this might change with the added handling of a consolidation center. The last-metre high-level process relates to the physical movement of the freight inside the shopping center. The two related aspects are process and shrinkage, defined in a similar way as the last-mile high-level process. The final high-level process is recycling revenue; due to the collaboration during consolidation it is possible to obtain extra recycling revenue. These three high-level processes are used to determine the benefit of the consolidated supply chain. It is assumed that a high-level process is only consolidated when that process is beneficial for the supply chain (hence: cheaper).
A cooperative benefit game is built by examining if consolidation is possible if not all stakeholders (players) take part in the consolidation effort. In certain situations (sub-coalitions) not all high-level processes can be consolidated. The Shapley value is then used to distribute the benefits of the complete consolidation among stakeholders. The computation time of the Shapley value is reduced by grouping the stakeholders: Freight operators are grouped into four truck types, retailers into three zones and a single mall owner. This grouping, however necessary, does not represent the actual situation. The grouping method should be agreed upon in advance by all players.

The total benefit obtained by complete consolidation at the Westfield Shopping centre is: 115,000 pounds for the two month period analyzed by the model. This is a cost reduction (compared to the traditional situation) of 16%. The Shapley value is used to allocate these benefits to the stakeholders.

The Shapley allocation results in an individually rational allocation (a player is better of cooperating than acting alone). This suggests that a business model for urban consolidation centers is possible if all stakeholders cooperate. The Shapley allocation in this form, however, does not represent the allocation to individual stakeholders. The sensitivity of the Shapley allocation to the grouping method means that increasing the number of stakeholders changes the allocation to the player groups — the Westfield Group becomes relatively less important.

The WSC case is used to find some additional insights in relevant factors for the success of Urban Consolidation Centres. Some interesting insights are listed below:

- Strategic placement of the consolidation centre is very important: A well-chosen location is a significant driver for the success of consolidated deliveries.
- Situations with high-volume and low load-factor (many trips) are suitable for unsubsidized consolidation success. Otherwise additional incentives are needed, e.g. centre fixed cost subsidies or a regulatory force (mandatory consolidation).
- Governmental policy measures like CO2-tax and congestion charges only have a minor effect on consolidation success, even when added in extreme forms.

For future research, there are three main topics that can be extended upon: Evaluation improvement, Allocation improvement and implication for social sciences. The most effective way to improve UCC evaluation is including the haul segment. This improves the model because of the sensitivity of UCC placement. Additional research is required for the allocation rule selection. Finding a rule that is less sensitive to grouping (or does not require grouping) can extend the usage of the model. Finally, rationality of stakeholders is assumed while various social sciences imply that this need not be the case. Extending the model to include perception would greatly improve predictability of stakeholders.
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CHAPTER 1

Introduction

The trend of urbanisation creates many challenges for the supply chains of modern cities: increased delivery cost due to congestion, increased pollution and higher delivery volume — all these effects are interlaced. The world’s large cities become more and more aware of this problem and try to counter their challenges by implementing / enforcing smart urban supply chain strategies (summarized under the banner: City Logistics). One of these smart strategies is to consolidate urban freight at the edge of the city and thus (theoretically) reducing cost and congestion. This consolidation effort is done by Urban Consolidation Centres (UCCs).

The London 2012 Olympic Games gave DHL a chance to operate one of world’s first large scale Urban Consolidation Centres at the Westfield Stratford City shopping centre. Using the data and knowledge from this operation this thesis contributes to the knowledge of (quantitative) economic benefit of Urban Consolidation Centres in general and the Westfield Stratford City Consolidation Centre is particular. Furthermore the research extends this by fairly allocating the supply chain benefit to the involved stakeholders.

This thesis consist of three main parts. The first part introduces the situation and context of the research. In the second part, a model is developed to be able to quantify and allocate the benefits of an UCC. Using this model, the third part of this thesis analyses the Westfield Stratford City case.

In order to guide the reader through the abbreviations and defined variables, these are summarized in appendix A and B.
CHAPTER 2

Literature Review

2.1 Introduction

This section is in support of the development of the urban consolidation centre evaluation model. First, several concepts of city logistics and urban consolidation are introduced, this will help understand the logistics behind the evaluation model (chapter 6) and the relevance for this research in practice. Second, cooperative game theory and several allocation rules are discussed. This is especially relevant for chapter 7 and up.

2.2 City Logistics and Urban Consolidation Centres

2.2.1 City Logistics

The movement of freight within urban areas is very important as these areas are the epicenter of economic and social activity in a modern world. This movement of goods often puts a large strain on urban transport infrastructure and the regional environment. Congestion levels in these areas are on the rise. These transportation movements are very complex, mainly due to the involvement of many stakeholders (e.g. freight carrier, retailer, resident and local government) (Taniguchi and Thompson, 2001).

Efficient city logistics is of great interest to companies worldwide because of potential cost savings and new governmental regulations (e.g. vehicle size limits in cities). The main goal of an urban transportation system is to improve economic performance while minimizing the effects on the environment. For this type of activity it generally implies decreasing costs and increasing efficiency while controlling environmental effects and ensuring safety (Hicks, 1977).

Urban freight transportation involves the entire process of the actual delivery of goods to the addressees in a city. These addressees can be anything from large retail chains to hotels and the goods involved can vary in size from a full truck load (FTL) to a few bags of toilet paper. However, the essence of each delivery is the same, namely delivering goods that extra mile into the city centre. Delivering in cities gives new challenges due to regulation (e.g. pollution and noise regulations) and congestion.

There are different ways to making urban logistics / city logistics more efficient or less pollutant. For example: Policies could be used to force the large truck types out of the city. Another option is a consolidation centre on the edge of the city. This will be the focus of this master thesis.
2.2.2 Urban consolidation centres

2.2.2.1 Urban consolidation centres benefits

A way of responding to the problems described in the previous section are Urban consolidation centres. The purpose of consolidation centers in general is sharing vehicle capacity among firms (or even within firms) (McDermott, 1975). It is the natural solution to the problems of declining load factors and traffic circulation. It is a complex solution as it requires careful planning, coordination and facilities (Danielis and Rotaris, 2010). For the purpose of this project we use a broad definition of UCCs: "A UCC is as a logistics facility that is situated in relatively close proximity to the geographic area that it serves, be that a city centre, an entire town or a specific site (e.g. shopping centre), from which consolidated deliveries are carried out within that area. A range of other value-added logistics and retail services can also be provided at the UCC." (Browne et al., 2005)

Using consolidation centers can improve load factor efficiency. A number of case studies show more full trucks, allowing for more consolidation or, at least, lighter (less energy-intensive) shipments. Improved load factor efficiency is the goal of an urban consolidation centre. If done properly the concept can have huge benefits e.g.: less trucks in cities, this reduces pollution, costs, noise and congestion. (Nemoto, 1997; City-Ports-Project, 2005)

2.2.2.2 Evaluating UCCs

In order to evaluate the success of UCCs a framework was designed by Browne et al. (2005) based on an evaluation of 17 UCC case-studies published in literature. Evaluation frameworks that did exist were "fairly ad hoc and generally limited in scope". The frameworks used in the case studies did not consider all effects and thus do no capture the effect to the fullest extent and the evaluation was tailored to a specific situation.

The reason behind the evaluation or the suggested goal of a consolidation centre has an important influence and determines how the success of the UCC is evaluated. These objectives could be:

- Objectives based on economic efficiency and/or environmental factors;
- Objectives based on supply chain-wide / geographical improvements;
- Objectives based on greater consolidation / transshipment into smaller vehicles.

For example: If an UCC is evaluated by a freight carrier and is mostly build and operated to increase transport efficiency the main criteria for evaluation will be money. If this is the case, the performance measures stated below should be translated to the evaluation criteria. Another example could be: If Greenpeace evaluated an UCC their main criteria would be CO2 reduction. Thompson and Hassall (2005) argued to much the same extent. When evaluating city logistic initiatives (like UCCs) the objective and therefore the criterion on which is evaluated is different. The literature on city logistics often stresses the importance of policy measures to support these urban consolidation centres. For more information on various policy measures and effects on success, please refer to Hoyer (2012a).

The thing currently missing in literature is an economic analysis with a distribution between beneficiaries. Once determined the costs and benefits that arise during an UCC collaboration
could be divided among stakeholders. This can be done with ad-hoc methods or with methods developed in the field of cooperative game theory. This project contributes to this field.

### 2.3 Cooperative game theory

This section introduces the basics of game theory and the Shapley value. It is limited to the concepts needed or considered for this project. For more information about game theory, more allocation rules and practical applications please refer to Hoyer (2012a).

#### 2.3.1 The cooperative game

In contrast to non-cooperative game theory the cooperative part of game theory focuses on working together. Cooperative game theory focuses on coalitions with binding agreements and on issues which arise when coalitions are formed, such as: value allocation.

Cooperative game theory primarily deals with obtained joint profits by groups of players if they coordinate their actions or work together. There are two main types of cooperative games: cooperative games with transferable utility (TU games) and cooperative games without transferable utility (NTU games). Transferable utility refers to the fact that the total pay-off of the game can be measured by a single number that can be distributed among the players (e.g. money) (Leyton-Brown and Shoham, 2008) — in this project transferable utility is assumed.

Transferable utility (TU) games are games in which players can form groups among themselves and can transfer the utilities within the group. Utility is a measure of a player’s level of happiness in the given states — it quantifies the preferences among choices. For this project the transferable utility is money — more money is always preferable. (Leyton-Brown and Shoham, 2008)

This paragraph is focused on games with a finite set of players. First, we denote a game by \((N,v)\). Denote \(N = \{1, 2, \ldots, n\}\) as the finite set of players. A subset of players in \(N\) is called a coalition denoted as \(S\). The value of each player and coalition is denoted with a function \(v\) with an empty coalition \(\emptyset\) that has zero value \(v(\emptyset) = 0\). A value \(v(S)\) can be interpreted as a total game value for all players in coalition and is not dependent on the other players in the finite set of players in \(N\) (mathematically: \(N\setminus S\)). The outcome of a game with value \(v\) can be assigned by \(f\) resulting in a game pay-off vector \(f(v) \in \mathbb{R}^N\). There is a pay-off for every player \(i\) where \(i \in N\). The pay-off vector can be interpreted as player \(i\) gets \(f_i(v)\). (Leyton-Brown and Shoham, 2008)

A subclass of games which is relevant is called superadditive games. This is the case whenever \(S \cap T = \emptyset\) then \(v(S \cup T) \geq v(S) + v(T)\) for all coalitions \(S, T \subset N\) holds. This essentially means that the grand coalition is the coalition with the highest value in a superadditive game (in the case that more value is better). A sub class of superadditive games is convex games. A game is convex if for all coalitions \(S, T \subset N\) it holds that \(v(S \cup T) \geq v(S) + v(T) - v(S \cap T)\). (Leyton-Brown and Shoham, 2008)

#### 2.3.2 Allocation rule properties

For players to agree on a solution, players can first agree on solution properties and characteristics and then find an allocation rule for which this holds. There is no right allocation rule, if there is
no agreement on the allocation characteristics. We consider an allocation rule \( f \). An allocation rule \( f \) for game \( v \) prescribes just one suggested payoff vector \( f(v) \) for each game. Some common solution concept properties are listed below.

The first property is **efficiency** of the allocation rule. Efficiency states that the payoff vector that is derived using the allocation rule distributes all created value among the players. This means \( \sum_{i \in N} f_i(v) = v(N) \), in words: the sum of all pay-offs of players \( i \) that are in coalition \( N \) must be equal to the total value of the coalition. (Heijboer, 2004)

**Symmetry** is the second property. Symmetry states that if two players are identical in terms of contribution to each (sub)coalition they should receive the same pay-offs (players are interchangeable without changing the value of the coalition). (Heijboer, 2004)

**Zero-allocation to zero player** is the property which prevents players, who do not contribute value to a (sub)coalition, to get any pay-off. So a zero-player gets zero pay-off. (Heijboer, 2004)

When combining two independent games \( v \) and \( w \) the pay-offs are equal to the sum of the pay-offs of the individual games. This is called **additivity**. This means that in case of two games it should make no difference in the pay-offs whether each game is considered separately or both games are considered together as a single game. (Heijboer, 2004)

**Individual Rationality** states that each player should at least get what the player would get individually. So each player is not paid less than his individual value when joining the coalition \( N \). In mathematical terms: \( f_i(v) \geq v(\{i\}), \forall i \in N \). (Heijboer, 2004)

Another property important property is **stability**. This means that no player has the incentive to leave the grand coalition. The pay-off of cooperation in grand coalition is higher than the pay-off of working alone or in any other coalition: \( \sum_{i \in S} f_i(v) \geq v(S), \forall S \subseteq N \). (von Neumann and Morgenstern, 1944)

### 2.3.3 Shapley value

Maybe the most famous solution concept is the Shapley value. This solution can be interpreted as the "average marginal contribution" of player \( i \), where all the different sequences according to which a players can be added to the coalition from the empty coalition \( \emptyset \) to form the grand coalition are averaged overall. So the coalition is assembled by starting with the empty set and adding one player at a time, with the player to be added chosen at random. Within this assembly of additions, look at player i’s marginal contribution when he is added to coalition \( S \). Adding all possible marginal contributions and dividing that by the number of different combinations gives the Shapley value for player \( i \). (Shapley, 1953)

\[
\phi_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!(n - |S| - 1)!}{n!} (v(S \cup \{i\}) - v(S))
\]

The Shapley value is the unique pay-off vector which has the properties: efficiency, symmetry, additively, and zero allocation to zero player. We also know that in every convex game, the Shapley value is in the core. (Shapley, 1953)

Other allocation rules and the core are discussed in appendix C.
CHAPTER 3

Methodology

3.1 Introduction

In this chapter the research methodology is discussed. In the first section a background is given to the problem at hand after which the problem is defined. Using the background and the problem definition project aims and research questions are formulated. The regulative cycle is used to explain the method of research and the logic behind this report structure.

3.2 Problem background

DHL sees that the growing trend of urbanization causes a number of significant problems for town planners, business and for residents. Cities will not only compete with one another for resources, investments and for talented residents, they are the core of the economy. DHL expects sustainable logistics to become important to these cities. With the number of large cities growing all over the world, the challenges facing inner-city logistics and city welfare are becoming more acute: cities cannot continue to grow and to have a correspondingly large carbon footprint, coupled with the congestion and poor resilience.

City planners are reviewing solutions for decreasing traffic congestion and local pollution; for some years now there has been a drive to get cities more eco-friendly, which seems to become more important for residents and government in the future. To date, much emphasis has been placed on private and public transportation — freight transportation has often been an afterthought in the planning departments of municipalities.

DHL knows that the logistics industry has a significant role to play in ensuring that businesses and consumers have the right products and services available, no matter what local influences affect the global supply chains. It can be expected that both consumers and investors will have a growing interest in the eco-credentials of these supply chains; the rise in carbon counting is one such trend.

Deutsche Post DHL (DPDHL) (an abbreviations list can be found in Appendix A) recognizes this through one of the pillars of the 2015 Corporate Strategy and is researching and piloting solutions for urban logistics through its City Logistics Program.

A major response to the problems caused by urbanization is to increase surface transportation efficiency. Increasing transport efficiency can not only potentially decrease unit delivery costs but also decrease congestion, pollution and increase general urban welfare.

DHL believes that smart, technology enabled Urban Consolidation Centres (UCCs) will play an important role in these improvements. DHL has started and operated a number of these centres in the United Kingdom and other, complimentary urban initiatives in a few cities, together with local municipalities and partners. UCCs collect incoming goods from haulers/carriers and then distribute these downstream in the city in a more efficient and compliant manner — the so called last-mile logistics.
3.3 Problem definition

At DHL the current operating norm is for the end-customer (such as a retailer) to bear the additional handling and transportation costs associated with consolidated last-mile deliveries. This cost burden is perceived by DHL as one of the foremost reasons as to why there has not been a greater uptake of consolidated last-mile deliveries in the last 5 to 10 years. Local & central government has limited mandate to regulate the use of these consolidation centres and they are avoided by much of the potential user group, for financial reasons.

One of the reasons that currently the end-customer bears the additional costs of consolidated delivery is that it is unclear what the effects are for different stakeholders in the supply chain. Although the literature contains various qualitative research of urban consolidation centres (UCCs), quantitative evaluation is rare — let alone an economic evaluation.

At DHL and in literature the success of an UCC is subject to extensive qualitative analysis, however a thorough economic analysis is lacking. Therefore there is no clear understanding of the economic benefits or costs of using an UCC scheme for the supply chain. This analysis is needed to understand stakeholder behaviour in choosing to use an UCC.

3.4 Problem Scope

The scope of the problem is limited to processes that are directly involved with the delivery process. The delivery process is defined as the freight movement from the supplier distribution centre (DC) to the retailer shop floor. All activities before the supplier DC and after arriving at the shop are out of scope. This also renders management activities like (not limited to) planning and management out of scope.

3.5 Research questions

Before the main aims of the project can be addressed the first step is to select the case that should be identified. This is done in the research proposal by Hoyer (2012b) and explained in chapter 4.

The aims of this project are captured in the following four main research questions:

1. What are the economic benefits and costs of consolidated last-mile deliveries for the supply chain and its stakeholders?
   (a) Who are the stakeholders involved?
   (b) What are the characteristics of the case and stakeholders?
   (c) What are the benefits and costs that should be included in the analysis?

2. Is it necessary to and how can additional incentives be included to make urban consolidation the rational choice for the supply chain?

3. How could consolidation benefits be allocated among stakeholders?
(a) What are the requirements for an allocation rule?
(b) How can the costs be allocated in a fair way — is a trade-off between requirements necessary?

4. What is the sensitivity of the solution for changes in costs, benefits and volume on the economic benefits and cost distribution?

3.6 Problem aims

The aim of the project is to create understanding about the economics of consolidated last-mile logistics by analysing a case. The analysis will (in chronological order):

1. **Determine**: the unique attributes and requirements of the last-mile solution for available cases and select a case for analysis;
2. **Identify**: the stakeholders of consolidated last-mile deliveries for the selected case;
3. **Capture**: the economic and additional benefits and costs of consolidated last-mile deliveries for each of the stakeholders and the general supply chain;
4. **Investigate**: which extra (dis)incentives could be included in order for a consolidated last-mile delivery to be a rational choice for the supply chain;
5. **Suggest**: a fair cost distribution for the cost for the consolidated last-mile solution including all stakeholders and the requirements of such a solution.

3.7 Research design

3.7.1 Regulative cycle

For this project I will use the regulative cycle as a guideline for the redesign. The list below displays the steps of the cycle. (van Strien, 1997)

1. Problem definition
2. Analysis and diagnosis
3. Plan of action: design of problem solution and change plan
4. Intervention: applying the change plan
5. Evaluation

This cycle is completed by the evaluation step which restarts the cycle for further improvements. However, in this project only the first three phases are followed and some recommendations of improvement and implementation are given.
In the next sections the research design will be explained further with the help of the regulative cycle. The first step of this cycle is started in this chapter and elaborated on in chapters 4 and 5 — these chapters define the case analysed and stakeholders involved in this case. These two steps are crucial for a rigid analysis and diagnosis.

3.7.2 Analysis and diagnosis

When the problem is clearly defined the second stage of the regulative cycle is entered: analysis and diagnosis. For this a model for the overall benefit for the supply chain is created — as if one decision maker decides how to design the supply chain. A model must be made in order to access what is saved by using a consolidated supply chain. As this part of the evaluation is economical it should be determined which variables drive the costs of a supply chain. This is an essential part of the analysis needed in order to be able to design a problem solution.

The economic model is discussed in chapter 6. The model is later use to develop a plan of action, in order to address the issues that arise from the problem definition.

3.7.3 Plan of action

Once it is established that the consolidation scheme is beneficial for the supply chain, the next step is to determine how to share the benefits of operating a consolidation centre among all stakeholders involved. The situation becomes a benefit sharing game between multiple retailers, Westfield, multiple haulers and multiple suppliers. There are several case examples of cost sharing games in the literature — none of which involves this amount of players. Two examples are: (Frisk et al., 2010) and (Audy et al., 2010).

For this situation a transferable utility game is defined. This means that the costs of the consolidated solution can be shared among stakeholders. The utility being transferred is money (in this case in the form of benefits). When describing a game all possible coalitions of stakeholder groups are established. The game is defined in chapter 7. The final step of this “plan of action” or redesign is the actual allocation of the benefits to the various stakeholders in the supply chain. This can be done by an allocation rule.

The model and the allocation are tested on the case selected in the first step. Results and sensitivity analysis of this study are given in chapter 8.
CHAPTER 4

Situation

4.1 Introduction

In this chapter the case that the model and analysis is based on will be introduced. In appendix D, a summary is given of the case selection method which is based on the research proposal (Hoyer, 2012b). The case considered is a shopping centre in the North-East of London: Westfield Stratford City.

4.2 Westfield Stratford City

Westfield Stratford City (WSC) is a shopping mall located near the London Olympics 2012 (athlete) village and several Olympic sports’ arenas (e.g. aqua dome). The shopping mall is home for about 350 retailers and 80 restaurants. The Stratford City area is considered a severely congested area of London. In this chapter three supply chain scenarios are introduced: the Pre-Olympic situation, Olympic and the Post-Olympic situation. All three of these situations are discussed in the next sections.

When the WSC started early September 2011 initially there was no special supply chain in place. All freight deliveries were delivered to the shopping centre loading bay by freight operators that are hired by either the supplier or the retailer. This situation is called the Pre-Olympic situation in this report and depicted in figure 4.1.

![Fig. 4.1: Pre-Olympic high-level supply chain overview](image)

During the Olympics there is special regulation in place around WSC. Due to the unique location and the security risks involved with the London summer Olympic games of 2012, the Olympic committee (OC) restricts vehicle movement around the mall by only allowing certified and security screened vehicles in the vicinity of the Olympic Games — the main concern is terrorist attacks. Obviously, this creates a challenge for the Westfield Shopping Centre supply chain. This is known as the Olympic situation.

In collaboration with the OC, the municipality of London and Westfield Group (shopping centre owner), DHL developed a solution for this challenge. The Westfield Consolidation Centre (WCC) is set up approximately 12 kilometres from the shopping centre just outside of the restricted perimeter.
on a multiuser logistics facility near several major traffic arteries. The centre is operated by DHL. During the Olympics it is compulsory for all ambient freight to pass through the WCC and be transported to the WSC by certified DHL truck. Ambient freight is all freight that does not require a chilled/frozen delivery. The goal is to control and minimize the truck movement near the Olympic stadiums and the Olympic village and thus increasing security for the Olympic infrastructure and the Olympic’s visitors. Figure 4.2 is a high-level supply chain overview depicting the goods flow of this situation.

After the Olympics (post-Olympic situation) DHL has been granted the opportunity to maintain the consolidation centre as a service to the retailers and freight operators by the shopping centre owner: the Westfield Group. The goal of the centre now changes from a security objective to economical (and environmental) objective. It is also no longer compulsory for deliveries to be directed through the WCC — alternatively freight operators can deliver to one of the loading bays. Supply chain stakeholders can choose their preferred supply chain solution. Figure 4.3 is a high-level supply chain overview showing the goods flow of this situation — illustrating the possibilities of some freight being consolidated and some being directly delivered.

In the next section the high-level supply chain financing structure is discussed for each of the situations. Detailed supply chain process descriptions, however relevant, are not discussed in this chapter but in a later chapter whilst developing an evaluation model (chapter 6.2).

### 4.3 Supply chain financing

#### 4.3.1 Introduction

In this section the financing of the three situations are discussed briefly. The pre-Olympic situation is not discussed separately as all entities pay for their own supply chain and there is no need for a collective consolidation centre as in the other two situations.
4.3.2 Olympic

During the Olympics the consolidation centre is operated by DHL in an open book agreement with the Westfield Group. In this situation open book means that DHL prepared a detailed budget which is agreed upon by the centre owners — the consolidation centre can be viewed as a separate financial entity. The centre costs are paid for by the mall owners and also financed by retailers who are obligated to pay a £15 fee per cage delivered to their store during the Olympic lockdown. The fee per cage is a break even fee calculated by DHL based on forecasted volume and expected centre costs. For running the centre DHL receives a management fee: fixed percentage + a variable percentage of centre profit based on operational performance from the Westfield Shopping Centre. A graphical representation of this is given in 4.4

![Fig. 4.4: Olympic supply chain financing overview](image)

4.3.3 Post Olympic

After the Olympics the consolidation centre is still operated by DHL. The funding structure is subject of this thesis. However DHL still receives a management fee for running the centre. The idea behind the post-Olympic situation is that the WCC is fully funded by the stakeholders that benefit from it. Contrasting the Olympic situation the freight operators are expected to participate in the funding of the project. The way DHL is included in the centre cost structure is open for debate and discussed in a later chapter. A graphical representation of the Post-Olympic situation is given by 4.5

![Fig. 4.5: Post-Olympic supply chain financing overview](image)
CHAPTER 5

Stakeholders

5.1 Introduction

A shopping centre like the WSC has many stakeholder groups and a multiple more individual stakeholders. A stakeholder is an entity that is somehow affected by the shopping centre. Stakeholders have different priorities, goals and involvement. For this reason their interest in a consolidated supply chain, like the one achieved with the WCC, differs among them. The stakeholders chosen and described in this chapter will become the player types of the TU game defined in chapter 7.

This chapter will discuss stakeholders and explain on which stakeholder groups this project is focused and why. These focus stakeholder groups, also known as the stakeholder scope, will be explained more thoroughly.

5.2 Stakeholder selection

It is important to include the stakeholders in the analysis which are the most relevant to the economic analysis in a later stage of this project. During the literature review conducted for this project, Hoyer (2012a), many different stakeholders are identified. On the highest level the stakeholders of the WSC supply chain can be grouped in two groups: direct stakeholders and indirect stakeholders. The first group is directly involved in the supply chain as an actor, physically moving freight and thus supplying the shopping center, and the second only regulates the process or experiences the effects (both positive or negative) of the WSC supply chain. The stakeholder groups are segmented in table 5.1 based on an analysis of the situation discussed in the previous chapter.

Table 5.1: Overview of direct and indirect stakeholders of the Westfield Stratford Shopping Centre

<table>
<thead>
<tr>
<th>Direct</th>
<th>Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suppliers (1,000+)</td>
<td>City/Municipality of London</td>
</tr>
<tr>
<td>Freight operators (1,000+)</td>
<td>Westfield Group</td>
</tr>
<tr>
<td>Retailers (300+)</td>
<td>Residents of London (7,000,000+)</td>
</tr>
<tr>
<td>WCC operator (DHL)</td>
<td>Shoppers (7,000,000 + tourists)</td>
</tr>
<tr>
<td></td>
<td>Other government/regulatory bodies</td>
</tr>
</tbody>
</table>

It must be noted that some of these groups contain a vast amount of stakeholders. An indicative number of individual stakeholders that belongs to each group are found in the parentheses next to the stakeholder group name in table 5.1. The quantity of stakeholders makes it apparent that some form of grouping is necessary, as stated in the introduction of the chapter, in order to keep
the problem manageable. Stakeholder grouping is discussed in more detail in the implementation chapter 8.

To further understand the complexity created by the stakeholders involved, it would be useful to understand the stakeholder interactions. Figure 5.1 is an indicative interaction map between stakeholder groups of the WSC supply chain. This interaction map is based on Taniguchi and Thompson (2001) and will be used in a later stage to connect stakeholders to process steps. It is a complex network of supply chain internal and external interactions. In this figure, the dashed line is the actual delivery process and the arrows represent an one or two way interaction. There are also interactions outside of the supply chain. These are effects caused by the supply chain or regulatory bodies. Obviously the supply chain impacts the city, its residents and the environment (and more). Residents experience negative impacts of the supply chain (pollution, noise) but also can shop at the retailers (and thus supplying themselves). Residents control the municipality actions by elections, this way residents influences the government. The municipality regulates its residents, the supply chain and the WSC owner by laws, subsidies and taxes. Finally WSC owner and the retailers interact. The WSC can influence retailer supply chain decisions by means of contracts/rent rules and on the other hand has to keep the retailers happy — otherwise they could leave and no rent is collected.

![Fig. 5.1: Interactions between WSC supply chain stakeholders](image)

Before a more detailed description of each stakeholder is given, it is necessary to select the stakeholders included in the analysis. The stakeholders are subjectively grouped on two criteria: data availability (unique to this project) and economic impact. One of the goals of the project is to access the economic impact of consolidation on the supply chain and therefore it makes sense to select the stakeholders that are most effected in economic sense. In general, the separation between low and high economic impact is largely similar to the direct and indirect grouping. This is because the players involved in the actual physical movement of goods endure most of the costs of the transportation. The exceptions to this are suppliers and WSC (the owner of the shopping mall). The economic impact for suppliers is low because the consolidation takes place downstream. For WSC the consolidation effort can potentially have large effects on their logistical infrastructure and the investment involved with this.

For this project, executed at DHL, the data available of external parties is limited. External ”direct” stakeholders with low data availability are suppliers, freight operators and the various regulatory organizations. Including these stakeholders would limit accuracy of the model as the evaluation
will be based on estimates. The stakeholders are placed in a matrix found in figure 5.2.

Fig. 5.2: Stakeholder matrix on data and economic impact

The analysis of the supply chain is based on economic value. For this reason the scope of this project is limited to the stakeholders that are financially impacted by changes in the supply chain in a significant way. The final goal of the evaluation is to establish a cost sharing scheme. It is highly unlikely that stakeholders that have little economic benefit from the change in policy are willing to pay for the change in policy. Based on this reasoning, the relevant parties taken into account are: Freight operators, WCC operator, WSC owner and the retailers.

This does not mean the government does not influence the feasibility of the project. Subsidies and taxes can influence the cost of a supply chain strategy (either reduce or increase). However these subsidies and taxes could be included as a cost or revenue. Policies are seen as external forces that are not directly involved as stakeholders.

In the next sections the selected stakeholders will be introduced more thoroughly along with goals and interests, the current position in the supply chain (both operational and financial) and the expected future position if consolidation was to take place.

5.3 Westfield Group

The Westfield Group (denoted by: WG) has interests in and operates one of the world’s largest shopping centre portfolios. The global portfolio has 111 regional shopping centres in Australia, New Zealand, the United States, the United Kingdom and Brazil with a total value around €50 billion, with approximately 23,400 retailers in 10 million square meters of retail space. WG is a vertically integrated shopping centre group. The group manages all aspects of shopping centre development, from design and construction through to leasing, management and marketing. WG is currently listed on the Sydney stock exchange. (DHL, 2012)

One of the most recent developments of the Westfield Group is the Westfield Stratford City shopping centre — the shopping centre analysed in the project. Westfield Stratford City (WSC) opened in September 2011 and represents £2.2 billion investment in London for WG. The development
comprises 0.2 million square meters of retail space. Also there are plans to build 0.15 million square meters of office space, three hotels in future phases. The centre is located adjacent to the Olympic Park in east London. (DHL, 2012)

As a public company the goal of the WG is to generate shareholder value. For this reason they are always looking for ways to cut costs or increase leasing revenue. The company is vertically integrated and therefore has control over new developments. A way of generating more revenue and cutting costs would be to design shopping centers with a reduced amount of loading bays. If this could be done without jeopardizing the retailers supply chain, the WG could not only save loading bay construction costs but also use the space saved to generate additional revenue by converting it into retailer floor. Of course the cost of converting a loading bay can be high (this is not relevant when designing a new shopping centre). According to the WG the benefit will be substantial. This is the interest of the WG in a consolidated supply chain as this would theoretically reduce truck arrivals at the shopping centre and thus reducing the requirement for loading bays. (DHL, 2012)

The current involvement of the shopping centre owner in the supply chain is twofold. As a service to the retailers leasing stores the WG manages the loading bays of the center. This is done by contracting DHL to run the loading bay operation — DHL receives a management fee for doing this. The WG also heavily subsidizes the consolidation centre (and its management) which is needed to comply with the added security requirements of the London 2012 Olympic Games. The actual operation of the consolidation centre is also contracted to DHL which again receives a management fee for this. (DHL, 2012)

In the future, when consolidating is no longer compulsory, the involvement of the WG will change. The subsidy of the consolidation scheme will be significantly lowered. DHL does have permission to facilitate this as a service to the retailers. As part of the retailer lease, the loading bay operations will still be paid for by the WG. (DHL, 2012)

In a generic model the Westfield Group would be included as the shopping centre owner stakeholder.

5.4 Retailers

The WSC is an up-market shopping centre is London. All retailers that can be expected of a luxury shopping centre are present. Major retailers include John Lewis, Marks & Spencer and Waitrose and high-end retailers include Louis Vuitton, Armani and Jaeger. Besides shops this group also includes food outlets. These outlets also range from high-end restaurants like Jamie Oliver’s restaurant ”Jamie’s Italian” to the lower-end fast-food outlets like McDonalds. It can therefore be concluded that the retailer group has very diverse members. (Westfield-Group, 2012)

The main aim of all retailers is to make a profit, similar to the main goal of other stakeholders. For a retailer to generate revenue it is important to keep stores stocked. Most retailers only sell products if they are in stock. In most cases shoppers do not wait for “backorders” to arrive. Besides maximizing revenue the retailer also tries to minimize costs. In light of this project the effect of a consolidated supply chain strategy on supply chain related costs is examined. For a retailer the supply chain related cost include: ordering cost, storage cost and handling costs.

From June 2012 to September 2012, all ambient goods delivered to the mall are transported through the WCC. Prior to the Olympics, retailers realised that in this unique situation of the Olympics an extra investment in supply chain was to be expected due to security reasons — this is based
on a survey by the shopping mall among all retailers. Consequently all retailers complied with the new consolidation policy and the warm-up period of the consolidation. The warm-up period is the consolidated period from June 2012 until the actual Olympics (27 July - 12 August). Retailers are required to pay £15 a cage delivered while the Olympic consolidation scheme is in place. (DHL, 2012)

All chilled goods are not delivered via the WCC due to the lack of facilities at the centre. These goods follow a different supply chain which is not covered by this thesis. However, if the consolidation proves to be successful the WCC could be extended towards a chilled supply chain. This would enable the WCC to handle all retailer goods. Chilled goods include: fresh vegetables, meat and drinks. (DHL, 2012)

Now the Olympic Games are over, the use of the WCC is no longer compulsory. Retailers have a choice about which route their goods are delivered. Without being forced by policy (like during the Olympics) retailers must be convinced rationally that consolidation is a good idea. This most probably requires other paying stakeholder types. The main reason to choose for retailers is economic however other reasons may include: convenience, environment and added-services. (DHL, 2012)

5.5 Freight Operators

Being a shopping centre, many trucks arrive to make deliveries. In this project, all arriving trucks are owned/managed by freight operators. Some brands (e.g. Marks and Spencer) and suppliers may have a vertically integrated supply chain — meaning they manage production, transport and retail. In this case, the freight part of the organisation is still seen as a separate entity. Freight operators come in all shapes and sizes. There are local organisations but also large multinational freight corporations (like: UPS and DHL). (DHL, 2012)

Again the aim of the freight operators is similar to the other stakeholders: profit. Assuming the demand/volume of freight does not change due to a change in policy the only way of convincing freight operators to join is by reducing costs. The WSC is located in the heart of London in the midst of a very congested area. The reduction of truck movements (and thus distance and time related supply chain costs) in these areas account for a significant cost saving and so increased profit for the freight operator. That is the reason freight operators could be supporting the consolidation initiative. Besides reduced last-mile delivery costs they also have other added benefits — which will be discussed later. (DHL, 2012)

During the Olympics the freight operators do not take part in the funding of the consolidation scheme. The only thing that is changed compared to the consolidated deliveries is the delivery address — which changed from WSC to WCC. Even though freight operators do not officially take part in the scheme they do enjoy the benefits (e.g. no need to drive the last-mile in the city centre). After the Olympics the funding is supposed to change. (DHL, 2012)

5.6 WCC Operator / DHL

At the shopping centre DHL operates three supply chain solutions for the Westfield Group. As stated before DHL manages and operates the WSC loading bays, last-metre operation (within
WSC delivery) and the Westfield Consolidation Centre. At DHL the Supply Chain UK division is responsible for both operations. A subsidiary of this division "special projects" runs consolidation schemes throughout the UK (e.g.: Heathrow Consolidation Centre). (DHL, 2012)

The aim of DHL is of course making profit however as a secondary aim DHL would like to market these urban consolidation solutions as a product. Under the name of "GoGreen", DHL researches and pilots various methods of reducing environmental impact of supply chains. This shopping centre consolidation project is the first of its kind and DHL is eager to investigate the possibilities of such a solution in the future. (DHL, 2012)

For this reason DHL acts as a facilitator of the consolidation centre by using their experience and expertise to run the operations. DHL reasons a management fee for its involvement. DHL is still looking at how it will be involved with this scheme in the future however for the sake of this research project DHL is considered a facilitator and is included as a cost of running the centre. The centre is treated as if the other stakeholders choose to establish and run it on their own accord. This implicitly assumes that any large supply chain company can facilitate the centre. (DHL, 2012)
Chapter 6

Urban Consolidation Centre Evaluation Model

6.1 Introduction

This chapter explains the model used to evaluate the consolidation centre financial performance (supply chain cost). This model is later used to determine the benefits of the centre (by comparing costs of a traditional and consolidated supply chain) and fairly distributing these benefits between stakeholders chapter 7. One of the main complexities in the real-life situation is the sheer number of players involved. The model is build for individual retailers and freight operators, this would be the most fair way to allocate benefits. However it should be realized that this ideal allocation is not feasible (the cooperative game will get too large and not computable) and some sort of grouping will be necessary. Costs are discussed using high-level player types to increase clarity.

This chapter first distinguishes the steps needed to deliver an item from the supplier’s distribution centre (DC) to the shop floor and lists the processes the item undergoes. The parties that are involved with these processes are then listed. Combining processes with stakeholders allows the cost functions for the process steps to be defined. These steps are done for both a consolidated delivery and a traditional delivery (non-consolidated) — the two delivery types represent the two supply chains that are compared. The model is a single period evaluation model which will later be used to allocate benefits to the various stakeholders in the supply chain.

6.2 Delivery Process

In light of this project, the WSC supply chain can be split into two different delivery processes that can occur side-to-side: consolidated deliveries — which use consolidation services — and traditional non-consolidated deliveries, which do not use consolidation services. These are the two options each retailer and freight operator has when the London 2012 Olympics are over (post-Olympic situation). The process diagrams explaining the situation are from the perspective of one volume unit being the delivered from supplier to the shop floor. The delivery processes are determined by following a single item from the supplier’s DC to the retailer’s store. An item can be seen as one volume unit, it can be a cage, pallet or other transportable medium. Each distinctly different process is mentioned, albeit grouped together with a similar process in order to ensure clarity and reduce the number of very small processes (e.g. unloading involves parking the truck, unloading, signing the papers, closing the truck door etc.). Besides the processes involving the moving of goods, for each supply chain type three additional processes will be explained.

Both delivery types are discussed separately, starting with consolidated deliveries.
6.2.1 Consolidated Deliveries

Figure 6.1 is an overview diagram of the consolidated Westfield Stratford City (WSC) supply chain. The first leg of the "journey" — the freight transport from supplier’s DC to Westfield Consolidation Centre (WCC) — is typically the longest (in terms of distance). In this report this part is called the haul. The second leg is the final "road" transport from the consolidation centre to the shopping mall loading bays — in this report this is called the "last-mile delivery". The delivery from the loading bay to the shop floor is called the "last-metre delivery". Finally, the transport media (pallets / roll-cages) is returned to the loading bay — the "return". In the consolidated supply chain recyclable material is transported back using the return process. After this the recyclables are picked up by a garbage handler (out of scope).

![Fig. 6.1: High-level process of consolidated supply chain of the WSC (not to scale)](image)

Within the three high-level delivery steps more detail can be distinguished. Each leg has various process steps. All movements before supplier DC are considered decoupled from this aspect of the supply chain by the supplier’s DC, and is therefore left out of scope.

![Fig. 6.2: Haul process of consolidated deliveries](image)

The haul process for a single item consists of loading the item into a truck, driving towards the WCC, waiting for a loading bay and finally unloading. After this the item will be handled by the "last-mile" process which handles final delivery towards the shopping center. The consolidation centre is also included in this last-mile" process.

The administration aspect of the supply chain is considered out of scope as it is probable that this will not change between supply chain — no additional overhead/administration is assumed. This consists of processes such as: booking in, planning and customer support.

![Fig. 6.3: Last-mile process of consolidated deliveries](image)

The first step of the last-mile process is putting items in roll cages (in short: cages) and occasionally on pallets. After this the truck is loaded and driven to the WSC were it waits to be unloaded. In the consolidated supply chain, the items are transported in cages/on pallets. Once unloaded at
the WSC loading bay the last-metre crew will take over. The last-mile process is depicted in figure 6.3. The WCC can store freight briefly (while waiting for a full truck) however the costs of this are not considered

![Location Diagram](image1)

**Fig. 6.4: Last-metre process of consolidated deliveries**

The final step of the delivery is the walk from the loading bay to the store with cages (shown in figure 6.4). After this it is possible to add another process: recyclable waste returns (mainly cardboard). This consists of taking recyclables to the loading bay. This can be done using the normal return process. Each cage has to be returned to the WCC at some point. It is assumed therefore that returns do not require extra work because the transport media has to return anyway. This return process is depicted in figure 6.5.

![Location Diagram](image2)

**Fig. 6.5: Return process of consolidated deliveries**

The return supply chain is the return leg of an operator delivery. In order to be able to compare the traditional and consolidated supply chain: it is assumed that the return processes end at the WSC loading bay — the more upstream return process is assumed the same for both supply chain. The scope of the model limits itself to the delivery process — therefore the in store processes are excluded (e.g. unpacking).

The model will also look at three additional effects: recycling revenue, shrinkage and loading bay opportunity. These are three potentially relevant cost exclusive to consolidated deliveries that are not considered yet. All these costs and revenues are considered potential relevant advantages of consolidation by UCC literature, e.g: Browne et al. (2005).

First is the return recycling revenue which is sold by the freight operators: a positive revenue stream (e.g. cardboard). It is assumed that in the traditional supply chain the recyclable material is picked up by a recycling company (for free). The recycling company is traditionally out of the scope of the model and thus if the revenue is moved inside the scope (because the Westfield group starts selling it), it is a benefit for the stakeholders in scope. For individual retailers it is not possible to sell off recyclable materials themselves because of the low volumes. The recycling effort does not add any costs because it is done by the normal "sunk" return supply chain. Pure pickups are rare and therefore not included in the model — a pure pickup is a pickup of recyclable material without a delivery. It is assumed that empty cages and recycling cages (cages filled with e.g. cardboard) follow the same process.

The second relevant cost is loading bay opportunity cost. This is a potential large cost relating to the number of loading bays that are needed. The space lost for loading bays could be potentially be
retail space (or another value adding activities such as training). This is included into the last-mile process group as these are closely related — loading bay opportunity relies on the consolidation of the last-mile. For a single loading bay approximately 100m$^2$ is needed (including road), rough estimates by the Westfield Group put the opportunity cost of one loading bay in the range of £3000 – £5000 a month.

Finally a relevant cost can be inventory shrinkage of deliveries. Inventory or stock shrinkage is the loss of products between purchase from supplier and point of sale (hence: in delivery/store). In the definition used in this model shrinkage also includes breakage. Shrinkage is an additional aspect which occurs in haul, last-mile and last-metre segments of the supply chain and will thus be included in those segments accordingly.

6.2.2 Traditional Deliveries

Figure 6.6 is an overview of the non-consolidated WSC supply chain. The first leg of the "journey" is the transport from supplier DC to WSC, named Haul: the combined distance that needs to be covered for the haul and the last-mile delivery. The delivery is direct from the supplier DC to the WSC loading bays. The last-mile part of this transport is incorporated in the haul part of the transportation.

![Fig. 6.6: High-level process of traditional supply chain of the WSC (not to scale)](image)

As can be seen above three main parts can be distinguished. Again for the sake of this model all upstream movements are excluded from the analysis as well as the in store processes.

![Fig. 6.7: Haul process of traditional deliveries (including last-mile)](image)

In the traditional haul, an item is loaded on to a truck and then driven to the WSC loading bay. Here the truck waits to be unloaded (figure 6.7). Once unloaded the item is ready for the last-metre (figure 6.8).

![Fig. 6.8: Last-metre process of traditional deliveries](image)
After the item is unloaded and checked, similarly to the consolidated deliveries, the item is picked up by foot and brought to the designated store. In the store, the item is out of the scope of this model. However the transport medium has to be returned to the loading bay — either for disposal or pickup. The more upstream return flow is assumed similar between the two situations and therefore left out of scope. This is the inverse of the last-metre delivery process and illustrated in figure 6.9.

![Fig. 6.9: Return medium process of traditional deliveries](image)

It is vital to include the same supply chain aspects in both supply chains. For this reason the same additional processes are added to the traditional supply chain: recycling revenue, shrinkage and loading bay opportunity — as explained in the previous section. However recycling revenue is not applicable to the traditional supply chain.

### 6.3 Relevant Facilitators and Players

It is important to connect relevant players/facilitators to the various process steps as these connections are later used to determine the costs involved for each of the process steps. For the traditional deliveries the relevant processes for each stakeholder can be determined — this is necessary for traditional sub-coalitions and for consolidated deliveries this chapter will help to determine which high-level processes can be consolidated in certain sub-coalitions.

The relevant stakeholders in question are discussed in chapter 5. The players that are relevant in each process step are based on observations and experts at WSC. The WCC and the WSC loading bay are not defined as players, they are involved in various process steps — for this reason they are included as facilitators in the tables presented. In the actual situation there will be multiple freight operators and retailers, for this reason these players can be seen as player types. A single item is always transported by one freight operator and is destined for one retailer. Freight operators can however carry freight for multiple retailers and retailers can be supplied by multiple freight operators.

The relevant facilitators and players are determined by looking at who is involved in the physical movement of freight (and thus incurs costs). In an earlier stage indirect stakeholders (e.g. government) are already excluded due to lack of economic / measurable effect of consolidation, see chapter 5.2 for more information. The players are active stakeholders and facilitators are included as a cost.

#### 6.3.1 Consolidated deliveries

With consolidated deliveries, a part of the process is handed over to the centre — various parts are done by different centre entities, all of which are run by DHL. These are the participants discussed in the introduction. The consolidation and last-mile effort is handled by the Westfield
Consolidation Centre (WCC), the loading bay is operated by the dedicated loading bay staff and the last-metre delivery to the shop floor is also done by a dedicated crew. The two unloading process steps: after the haul when the freight operator arrives at the WCC and the last-mile unloading (WCC to WSC), involves multiple stakeholders. After the haul (table 6.1), WCC operators will help the driver to unload the truck. After the last-mile (table 6.2), the WCC and WSC loading bay operators and work together to unload the truck. In table 6.3 the involved stakeholders of the last-metre delivery to the stores is illustrated. Finally the return process is discussed in table 6.4.

<table>
<thead>
<tr>
<th>Load</th>
<th>Drive</th>
<th>Wait</th>
<th>Unload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight operator</td>
<td>Freight operator</td>
<td>Freight operator</td>
<td>Freight operator</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accept</th>
<th>Check</th>
<th>Cage</th>
<th>Load</th>
<th>Drive</th>
<th>Wait</th>
<th>Unload</th>
</tr>
</thead>
<tbody>
<tr>
<td>WCC</td>
<td>WCC</td>
<td>WCC</td>
<td>WCC</td>
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<td>WCC</td>
<td>WCC</td>
<td>WCC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accept</th>
<th>Walk</th>
<th>Deliver</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSC Last-metre</td>
<td>WSC Last-metre</td>
<td>WSC Last-metre</td>
</tr>
<tr>
<td>WSC Last-metre</td>
<td>WSC Last-metre</td>
<td>WSC Last-metre</td>
</tr>
<tr>
<td>WSC Last-metre</td>
<td>WSC Last-metre</td>
<td>WSC Last-metre</td>
</tr>
<tr>
<td>WSC Last-metre</td>
<td>WSC Last-metre</td>
<td>WSC Last-metre</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Get</th>
<th>Walk</th>
<th>Checkout</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSC last-metre</td>
<td>WSC last-metre</td>
<td>WSC last-metre</td>
</tr>
<tr>
<td>WSC last-metre</td>
<td>WSC last-metre</td>
<td>WSC last-metre</td>
</tr>
<tr>
<td>WSC last-metre</td>
<td>WSC last-metre</td>
<td>WSC last-metre</td>
</tr>
<tr>
<td>WSC last-metre</td>
<td>WSC last-metre</td>
<td>WSC last-metre</td>
</tr>
</tbody>
</table>

In consolidated deliveries the three additional processes also have several relevant stakeholders. Consolidated recycling revenue involve retailers and the Westfield Group as the origin of recyclable material is the retailers and the Westfield Group coordinates the collection/sale. Loading bay opportunity involves freight operators and the Westfield Group — the Westfield Group is involved
as they have to design their centre to have sufficient loading bays for all simultaneous unloading WCC trucks — how sufficient is defined is discussed in a later stage. Shrinkage depends on freight operators (for haul), WCC (for last-mile) and WSC Last-metre (for last-metre), as they are the stakeholders handling the freight and thus are responsible for loss/damage. These participants per process are summarized in table 6.5.

Table 6.5: Involved stakeholders during additional processes in consolidated supply chain

<table>
<thead>
<tr>
<th>Additional Processes</th>
<th>Recycling Revenue</th>
<th>Loading bay opportunity</th>
<th>Shrinkage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Retailer</td>
<td>Freight Operator</td>
<td>Freight operator</td>
</tr>
<tr>
<td></td>
<td>WCC</td>
<td>Westfield Group</td>
<td>WCC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WSC last-metre</td>
</tr>
</tbody>
</table>

6.3.2 Traditional deliveries

With traditional deliveries the supply chain is fairly straightforward: most process steps only involve a single stakeholder, only during "unload" multiple stakeholders are involved. In the traditional supply chain retailers pick up deliveries at the loading bay on arrival of the freight operator. Again the Westfield group is involved because the maximum amount of simultaneous unloading efforts determines the loading bay need.

Table 6.6: Involved stakeholders during haul in traditional supply chain

<table>
<thead>
<tr>
<th>Haul</th>
<th>Load</th>
<th>Drive</th>
<th>Wait</th>
<th>Unload</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freight operator</td>
<td>Freight operator</td>
<td>Freight operator</td>
<td>Freight operator</td>
</tr>
<tr>
<td></td>
<td>Retailer</td>
<td>Westfield Group</td>
<td>WSC loading bay*</td>
<td>Retailer</td>
</tr>
</tbody>
</table>

In the process step "load" all small and separate processes needed to verify and check in the load are included. It should be noted that the role of Loading bay* is different as in the consolidated situation. Loading bay* is only the overhead for loading bay arrival schedules and security — there is no inference with operation.

Table 6.7: Involved stakeholders during last-metre in traditional supply chain

<table>
<thead>
<tr>
<th>Last-metre</th>
<th>Accept</th>
<th>Walk</th>
<th>Deliver</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Retailer</td>
<td>Retailer</td>
<td>Retailer</td>
</tr>
</tbody>
</table>
Due to union/labor laws, retailers can only transport one item at a time—they are lacking manual handling equipment. By contrast the loading bay and last-metre staff used while consolidating can transport up to three cages at once due to the use of specialist equipment. Use of this specialist equipment is restricted to licensed operators and thus is not an option for retailers.

The inverse of the delivery is the return process—this process is given in table 6.8.

Table 6.8: Involved stakeholders during return in traditional supply chain

<table>
<thead>
<tr>
<th>Return</th>
<th>Get</th>
<th>Walk</th>
<th>Check-out</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Retailer</td>
<td>Retailer</td>
<td>Retailer</td>
</tr>
</tbody>
</table>

In traditional deliveries the three additional processes also have several stakeholders. Traditional recycling revenue is not possible and thus do not depend on any stakeholder. Loading bay opportunity depends on freight operators and Westfield Group—for the same reasons as with consolidated deliveries freight operators arrive at the shopping centre and thus cause the loading bay need. Shrinkage depends on freight operators (for haul) and retailers (for last-metre), as they are the stakeholders handling the freight and thus are responsible for loss/damage. These participants per process are summarized in table 6.9.

Table 6.9: Involved stakeholders during additional processes in traditional supply chain

<table>
<thead>
<tr>
<th>Additional Processes</th>
<th>Recycling Revenue</th>
<th>Loading bay opportunity</th>
<th>Shrinkage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freight Operator</td>
<td>Westfield Group</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Freight operator</td>
<td>Retailer</td>
<td></td>
</tr>
</tbody>
</table>

6.3.3 Distinction between players and facilitators

This section explains the distinction between players and facilitators in the WSC supply chain. Both players and facilitators are stakeholders in the supply chain. Facilitators facilitate parts of the supply chain, but will not join the collaborative cost sharing effort—in this model they are services of the consolidated supply chain. Coalitions have the option to join in the collaborative consolidation scheme and use the services provided by the facilitators. An exception is the WSC loading bay, which also provides planning services for the traditional supply chain—however a lot less than in the consolidated situation. In table 6.10 a list of player (types) and facilitators in this model is given.
Table 6.10: List of players / facilitators in model

<table>
<thead>
<tr>
<th>Player</th>
<th>Facilitators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight operator</td>
<td>WCC</td>
</tr>
<tr>
<td>Retailer</td>
<td>WSC Last-metre</td>
</tr>
<tr>
<td>Westfield Group</td>
<td>WSC Loading bay</td>
</tr>
</tbody>
</table>

6.4 Relevant Costs

The relevant costs are derived by looking at the processes and the stakeholders involved. For each of the process steps a cost function is defined. As the processes, the cost functions are based on a single "cage" movement. Cost functions for similar processes can differ between traditional and consolidated deliveries. This is because the WCC operates using an aggregated cost function for all consolidation process steps. The centre also has fixed costs, these are the minimal costs needed in order to consolidate freight (e.g.: for consolidation at least a truck is needed). Fixed costs for a larger centre are aggregated in the variable cost.

All variables denoted with a \((T)\) relate to the traditional supply chain. In this section the relevant costs that are determined are the total supply chain costs — meaning that the costs in this chapter are in the case that the delivery of a volume unit is either traditional delivery or a consolidated delivery. In a later stage using the drivers presented in the tables the total supply chain costs of each of the solution is discussed.

6.4.1 Consolidated deliveries

6.4.1.1 Haul

When evaluating the haul processes for consolidated deliveries, relevant costs can be determined. The relevant costs for the consolidated haul can be found in table 6.11. All variables will be listed below. In the table the cost function for a single delivery is given. In the model these costs can scale with either the number of trips or volume transported — this is called the "cost driver" in the table. For example, total supply chain haul costs will be: trips \(x\) all trip related costs + volume \(x\) all volume related costs. This is a simplified representation compared to literature where many of these costs depend on multiple factors. For example fuel costs depend on weight, speed and truck type. Even though the model loses accuracy, including these factors increases model complexity disproportionately — when weight and speed are included as unique parameters each trip is different (Levinson et al., 2004; Powell, 2001).

The simplified representation is based on (Blauwens et al., 2001) — basically distinguishing fixed and time/distance related costs. Using this principle and the processes all process cost functions are determined. The technique used in this model is called job costing. All relevant cost are allocated to a trip or volume unit.

Congestion charges that are included into the model are distinct to London. The congestion charge is a charge on motor vehicles operating within the congestion zone in central London between 07:00
and 18:00 (during weekdays). These charges are based on a vehicle movement and type. It is a policy designed to reduce congestion at preset times and areas.

Table 6.11: Grouped costs related to the haul processes of consolidated deliveries

<table>
<thead>
<tr>
<th>Process</th>
<th>Cost Description</th>
<th>Cost function</th>
<th>Cost Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>Loading time costs</td>
<td>(t_{load}(C_{driver} + C_{operative}))</td>
<td>Volume</td>
</tr>
<tr>
<td>Drive</td>
<td>Fuel costs</td>
<td>(\gamma_{tr}2\alpha_{haul}D_{wcc}C_{fuel})</td>
<td>Trips</td>
</tr>
<tr>
<td></td>
<td>Depreciation or Rent</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Driver costs</td>
<td>(2\alpha_{haul}D_{wcc}C_{rent,tr})</td>
<td>Trips</td>
</tr>
<tr>
<td>Wait /Dwell</td>
<td>Waiting time costs</td>
<td>(t_{wait}C_{driver})</td>
<td>Trips</td>
</tr>
<tr>
<td>Unload</td>
<td>Unloading time costs</td>
<td>(t_{unload}C_{driver})</td>
<td>Volume</td>
</tr>
<tr>
<td>Additional</td>
<td>Congestion charges</td>
<td>(2C_{congest})</td>
<td>Trips</td>
</tr>
<tr>
<td>Shrinkage</td>
<td>Shrinkage effect</td>
<td>(SC_{haul%}C_{product})</td>
<td>Volume</td>
</tr>
<tr>
<td>CO2 Tax</td>
<td>Costs relating to haul emissions</td>
<td>(2\alpha_{haul}D_{wcc}E_{tr}C_{co2})</td>
<td>Trips</td>
</tr>
</tbody>
</table>

Table 6.12: Variable definitions for relevant haul costs

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(t_{load})</td>
<td>[hour/cage]</td>
<td>Loading time</td>
</tr>
<tr>
<td>(t_{wait})</td>
<td>[hour]</td>
<td>Waiting time</td>
</tr>
<tr>
<td>(t_{unload})</td>
<td>[hour/cage]</td>
<td>Unloading time</td>
</tr>
<tr>
<td>(\alpha_{haul})</td>
<td>[% return]</td>
<td>Multi drop factor</td>
</tr>
<tr>
<td>(D_{wcc})</td>
<td>[km/trip]</td>
<td>Distance from supplier DC to WCC</td>
</tr>
<tr>
<td>(\overline{v}_{haul})</td>
<td>[km/hour]</td>
<td>Average speed</td>
</tr>
<tr>
<td>(C_{driver})</td>
<td>[£/hour]</td>
<td>Driver costs</td>
</tr>
<tr>
<td>(C_{operative})</td>
<td>[£/hour]</td>
<td>Operative costs</td>
</tr>
<tr>
<td>(C_{rent, tr})</td>
<td>[£/km]</td>
<td>Rent costs (all costs included) for truck type (tr)</td>
</tr>
<tr>
<td>(C_{congest, tr})</td>
<td>[£/trip]</td>
<td>Congestion charge for truck type (tr)</td>
</tr>
<tr>
<td>(C_{fuel})</td>
<td>[£/L]</td>
<td>Driver costs</td>
</tr>
<tr>
<td>(\gamma_{tr})</td>
<td>[L/km]</td>
<td>Fuel consumption for truck type (tr)</td>
</tr>
<tr>
<td>(E_{tr})</td>
<td>[tonne CO2/km]</td>
<td>CO2 emission by truck type (tr)</td>
</tr>
<tr>
<td>(SC_{haul%})</td>
<td>[% volume lost]</td>
<td>Percentage of volume lost in the consolidated haul segment</td>
</tr>
<tr>
<td>(C_{product})</td>
<td>[£/cage-eq]</td>
<td>value of transported freight</td>
</tr>
<tr>
<td>(C_{co2})</td>
<td>[£/tonne CO2]</td>
<td>Cost of CO2 emission (tr)</td>
</tr>
</tbody>
</table>

In table 6.12 the variables are defined. The sum of the separate process costs is the total haul costs for a trip with one item. The volume driven costs is denoted by \(C_{haul,v}\) and the sum of all
processes driven by trips is \( C^C_{haul,T} \) (from table 6.11). The total consolidated haul related cost is:

\[
C^C_{haul}(T, V) = V \cdot C^C_{haul,V} + \sum_{k \in T} C^C_{haul,k} \tag{6.1}
\]

In this formula \( V \) is the total volume in the system in [cage-eq] and \( T \) the set of incoming trips with a distance and a truck type for each trip \( k \). A [cage-eq] is a volume unit. Pallets and other transport media are standardized by this measure.

If \( \alpha_{haul} = 1 \) it is assumed that the costs of the haul are for the route to and from the WCC (back to supplier). This need not be the case if the freight operator, doing the delivery, makes multiple drops or returns back to a different place. In the first case, the full distance and time should not be allocated to the WSC delivery and in the second case, the actual total distance and time could be both more or less then the values used. \( \alpha_{haul} \) is used as a correction factor for this effect. This is a sensitive variable and it might be complicated to get (accurate) data on this for each individual supplier however incorporating this effect would greatly improve the model.

Shrinkage is defined by a lost percentage \( S^C_{haul\%} \) in [%volume lost] times the purchase value of this product \( C_{product} \) in [\( £/cage-eq \)]. Potentially these effects — that can represent significant loses — could differ between traditional deliveries (many involved stakeholders) and consolidated deliveries (more handling but less involved stakeholders). Different shrinkage percentages occur in various segments of the supply chain.

A potential relevant cost that is included in the model is \( CO_2 / \text{environmental taxes} \). Currently companies pay taxes on \( CO_2 \) emissions — denoted by \( C_{co2} \) in [\( £/ton \ CO_2 \) emission] and the emissions \( E \) in [ton \( CO_2 \)]. Emissions of consolidated deliveries should be split in the haul segment operated in the freight operator truck and the last-mile segment operated in consolidated trucks. Both these elements are included in a different way in the process tables of the respective segments. The emissions reduction that is potentially received is also an added "non-economic” benefit for stakeholders participating. Companies increasingly focus their attention on becoming "greener" and more sustainable. The government is also increasingly concerned with reduced emissions. The EU is currently discussing \( CO_2 \) tax as a way to create a disincentive to produce emissions (Kanter, 2010).

In this model emissions are a function of distance and truck type. Literature also identifies other relevant emission drivers like: time, weight and driving style. (Benjaafar and Li, 2009) These are all relevant drivers however adding these would make analysis needlessly complex while having little effect on the overall costs — \( CO_2 \) related costs are low compared to many other costs justifying this simplification.

### 6.4.1.2 Last-mile & WCC

In this section relevant costs relating to the last-mile segment of consolidated deliveries are discussed. All last-mile costs relate to the centre operations, loading bay operations. In this model the high-level function replaces the separate process cost functions in order to keep interactions apparent. In table 6.13, the cost functions of the last-mile delivery are given based on the processes described in the preceding sections.

If the cost driver of drive-time and wait/dwell-time is volume, this implicitly assumes that all last-mile trucks are (almost) full. This is the case with trucks leaving the WCC. Also the segment
Table 6.13: Grouped costs related to the consolidated last-mile processes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cost function</th>
<th>Cost driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accept</td>
<td>$C^V_{wcc}$</td>
<td>Volume</td>
</tr>
<tr>
<td>Check</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wait /Dwell</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unload</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return-Load</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return-Drive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return-Wait</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return-Unload</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shrinkage</td>
<td>$S_{last-mile%}^C_{product}$</td>
<td>Volume</td>
</tr>
<tr>
<td>CO2 Tax</td>
<td>$D_{lm} \cdot E_{tr} \cdot C_{CO2}$</td>
<td>$T_{out}(V)$</td>
</tr>
<tr>
<td>Loading bay opportunity</td>
<td>$lb^C C_{opp}$</td>
<td>WSC incoming trucks</td>
</tr>
</tbody>
</table>

of the return supply change between loading bay and WCC is also included in this last-mile cost. These costs are indicated by "Return-" in front of the process step discussed.

In table 6.13, $C^V_{wcc}$ is the variable cost related to processing/transporting one truck from WCC to the WSC loading bay in [£/cage-eq]. The WCC variable costs is driven by the consolidated volume. Although some last-mile processes depend on trips (e.g. driving) this can be stated as volume if it is assumed that these trips all carry the same volume (which is approximately the case for this consolidation centre — almost FTLs). Besides the variable cost, the centre components also have a fixed cost base independent of volume/trips. In table 6.13, the fixed cost is is denoted by $C^F_{wcc}$ in [£/month]. The fixed cost includes (but is not limited to) minimal rent of the multi-user facility on which the WCC is located, operation overhead (like management and admin personnel), truck lease/investment, insurance premiums, cage investment and software. $C^F_{wcc}$ can be seen as the minimal fixed cost needed in order for the centre to be in operation.

An additional cost that is closely connected to last-mile consolidation is loading bay opportunity cost. This component can be seen as the opportunity for which the loading bay could be used if it was not needed as a loading bay — uses can be: retail space, storage or parking lots. There is an opportunity cost for each loading bay — denoted by $C_{opp}$ in [£/loading bay] and $lb^C$ as an integer number of loading bays in [#loading bay]. $lb^C$ is the minimum loading bay requirement. This number should be calculated using data to determine what the maximum number of arrivals per hour in the analysed time period is, if all volume is consolidated. This number is the number of loading bays needed, and not the number of loading bays that are actually there. This model chooses for loading bay requirement because actual loading bays are also needed for arrivals out of the scope of this model (e.g. chilled freight and service).
In the above table 6.13, there are volume $V$, outgoing trips ($T_{out}(V)$) which depends on volume using the centre), loading bay and fixed elements relating to the last-mile segment. $C_{last-mile, V}^V$ is the centre variable cost and shrinkage combined (both volume related). The total consolidated last-mile process related cost of a system is:

$$C_{last-mile}(V) = V \cdot C_{last-mile, V}^V + C_{wcc}^F + lb^C \cdot C_{opp} + T_{out}(V) \cdot (D_{im} \cdot E_{tr} \cdot C_{CO2}) \quad (6.2)$$

### 6.4.1.3 Last-metre

The next segment of the supply chain is the last-metre delivery. Similarly to the last-mile segment, the cost of consolidated last-metre deliveries are portrayed in table 6.14. Again the return supply chain is included. In table 6.14, $C_{last-metre, i}^V$ is the variable cost related to processing/transporting one cage from WSC loading bay to store $i$ in [£/cage-eq]. The variable cost will vary between store location as a cage that takes 30 minutes to deliver will add more costs dan a cage that takes 15 minutes to deliver. $C_{last-metre}^F$ is the fixed cost related to last-metre delivery in [£/month], the minimal needed to operate the last-metre operation.

The cost of a last-metre delivery consists of volume driven costs and fixed costs — The total consolidated last-metre costs of a system are therefore:

$$C_{last-metre}^C(V) = V \cdot (C_{last-metre}^V + S_{last-metre}^C C_{product}) + C_{last-metre}^F \quad (6.3)$$

In this formula $V$ is the total volume in the system in [cage-eq].

### 6.4.1.4 Recycling revenue

A included consolidation effect is the potential to add recycling revenue. For one item the recycling revenue can be denoted by: a waste percentage $W_\%$ [%recyclable/cage-eq] and a waste value $-C_{recycling}$ in [£/cage-eq] (please observe the minus, indicating revenue). This is driven by volume because each volume unit has some kind of recyclable waste.

The total recycling revenue in a system are:

$$C_{recycling}^C(V) = -V \cdot W_\% C_{recycling} \quad (6.4)$$

---

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cost function</th>
<th>Cost driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accept</td>
<td>$C_{last-metre,i}^V$</td>
<td>Volume</td>
</tr>
<tr>
<td>Walk</td>
<td>$C_{last-metre,i}^V$</td>
<td>Volume</td>
</tr>
<tr>
<td>Deliver</td>
<td>$C_{last-metre,i}^V$</td>
<td>Volume</td>
</tr>
<tr>
<td>Return-Accept</td>
<td>$S_{last-metre}^C C_{product}$</td>
<td>Volume</td>
</tr>
<tr>
<td>Return-Walk</td>
<td>$S_{last-metre}^C C_{product}$</td>
<td>Volume</td>
</tr>
<tr>
<td>Shrinkage</td>
<td>$S_{last-metre}^C C_{product}$</td>
<td>Volume</td>
</tr>
</tbody>
</table>
6.4.2 Traditional deliveries

In the traditional supply chain, costs can be allocated to the separate process-steps of the segment in question. This section will discuss the cost functions for a single volume movement. This will be discussed in the next sections.

This can be assumed because this will be the same independent of the supply chain — organizationally it seems reasonable that it requires an equal amount of work to schedule a delivery to the WCC or the WSC, justifying this assumption.

6.4.2.1 Haul (inclusive last-mile)

As stated before the haul and the last-mile delivery are combined in the non-consolidated supply chain — referred to as haul in this model. It assumed that the delivery of the same item is done by the same truck and drivers at the same time, this means the approximately the same congestion (at time of delivery) and thus same driving speed.

Table 6.15: Grouped costs related to the haul processes of traditional deliveries

<table>
<thead>
<tr>
<th>Process</th>
<th>Cost Description</th>
<th>Cost function</th>
<th>Cost Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>Loading time costs</td>
<td>$t_{load}^T(C_{driver} + C_{operative})$</td>
<td>Volume</td>
</tr>
<tr>
<td>Drive</td>
<td>Fuel costs</td>
<td>$\gamma_{tr}2\alpha_{haul}D_{wsc}C_{fuel}$</td>
<td>Trips</td>
</tr>
<tr>
<td></td>
<td>Depreciation or Rent</td>
<td>$2\alpha_{haul}D_{wsc}C_{rent, tr}$</td>
<td>Trips</td>
</tr>
<tr>
<td></td>
<td>Driver costs</td>
<td>$2\alpha_{haul}D_{wsc}C_{rent, tr}$</td>
<td>Trips</td>
</tr>
<tr>
<td>Wait</td>
<td>Waiting time costs</td>
<td>$t_{wait}^T C_{driver}$</td>
<td>Trips</td>
</tr>
<tr>
<td>Unload</td>
<td>Unloading time costs</td>
<td>$t_{unload}^T \cdot C_{driver}$</td>
<td>Volume</td>
</tr>
<tr>
<td>Additional</td>
<td>Congestion charges</td>
<td>$2C_{congest}$</td>
<td>Trips</td>
</tr>
<tr>
<td>Loading bay</td>
<td>Opportunity costs</td>
<td>$lb^T \cdot C_{opp}$</td>
<td>Total Trips</td>
</tr>
<tr>
<td>Shrinkage</td>
<td>Shrinkage effect</td>
<td>$S_{haul}^T C_{product}$</td>
<td>Volume</td>
</tr>
<tr>
<td>CO2 Tax</td>
<td>Costs relating to haul emissions</td>
<td>$2\alpha_{haul}D_{wsc}E_{tr}C_{co2}$</td>
<td>Trips</td>
</tr>
</tbody>
</table>

For the variable definitions and units please refer to table 6.12. $D_{wsc}$ is the distance between WSC and the origin of the freight in [km], this will differ between trips as they may originate from a different location. For the same reason as in the consolidated last-mile processes, the loading bay opportunity cost is included in the haul process of the traditional deliveries. The number of trips in this haul process determines the number of trucks arriving at the WSC loading bay and thus the need for the loading bays.

The volume driven processes is denoted by $C_{haul, V}^T$, the sum of processes which costs are driven by trips by $C_{haul, T}^T$ and (all from table 6.15). The total traditional haul related costs are:

$$C_{haul}^T(T, V) = V \cdot C_{haul, V}^T + \sum_{k \in T} C_{haul, k}^T + lb^T \cdot C_{opp} \tag{6.5}$$
In this formula $V$ is the total volume in the system in [cage-eq] and $T$ the set of trips with distance and truck-type for each trip $k$.

### 6.4.2.2 Last-metre

Table 6.16: Grouped costs related to the last-metre process of traditional deliveries

<table>
<thead>
<tr>
<th>Process</th>
<th>Cost Description</th>
<th>Cost function</th>
<th>Cost Driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unload</td>
<td>Unloading time costs</td>
<td>$T_{unload} \cdot C_{clerk}$</td>
<td>Volume</td>
</tr>
<tr>
<td>Walk</td>
<td>Retailer costs</td>
<td>$2T_{walk}C_{clerk}$</td>
<td>Volume</td>
</tr>
<tr>
<td>Deliver</td>
<td>Delivery costs</td>
<td>$T_{deliver}C_{clerk}$</td>
<td>Volume</td>
</tr>
<tr>
<td>Shrinkage</td>
<td>Shrinkage effect</td>
<td>$S_{last-metre%}C_{product}$</td>
<td>Volume</td>
</tr>
</tbody>
</table>

The delivery costs consist of the time it takes to handle formalities at the loading bay. $T_{deliver}$ is in [hours] and $C_{clerk}$ is the full cost of a retailer employee per hour [/hour]. In the traditional supply chain the costs endured are a function of volume — union laws require them to transport one cage at the time. The sum of the volume driven costs listed in 6.16 is denoted by $C^{T}_{last-metre,V}$.

The last-metre cost for one volume unit is the summation of all costs described in this section. However the total system is denoted by:

$$C^{T}_{last-metre}(V) = V \cdot C^{T}_{last-metre,V} \quad (6.6)$$

In this formula $V$ is the total volume in the system in [cage-eq].

### 6.4.2.3 Recycling revenue

As stated before, in the traditional supply chain return revenue is not possible due to disinterest of recycling firms to buy small amounts from many different players. Currently the recyclables are picked up for free — the revenue by this third party is assumed to be generated out of the scope of this model and therefore not included = 0. Other additional costs like loading bay opportunity and shrinkage are included in the high-level processes that most closely relate to them.

The total traditional costs relating recycling revenue is:

$$C^{T}_{recycling}(V) = 0 \quad (6.7)$$
Chapter 7

Collaborative benefit sharing

7.1 Introduction

In this chapter the cost functions are used to determine a benefit sharing game for this situation. To create a collaborative game, the value of the grand coalition and all sub-coalitions are determined, using the cost functions discussed earlier and discussing the possibilities of interaction for certain sub-coalitions. In the first section the players are listed after which the value of the grand coalition (all players joining) is given based on the functions of the previous chapter. Finally the values for all possible sub-coalitions are discussed, both for the traditional and the consolidated supply chain. Special attention is given to conditions when certain aspects of the supply chain can be consolidated.

7.2 Players in the model

In the situation on-hand many stakeholders play a role — in chapter 5 these are discussed extensively. The relevant stakeholders selected should also be the players for the model, these are: freight operators (FOs), retailers (R) and the Westfield Group (WG). Obviously the first two mentioned are player types. These groups can contain many individual players. For this model multiple retailers and freight operators are assumed. This means that mixed supply chains are possible. Mixed supply chains are supply chains in which the traditional and the consolidated supply chain occur simultaneously — some freight arrives consolidated and some freight arrives in traditional manner.

Each of the participants has certain characteristics in this model, summarized in the table below:

<table>
<thead>
<tr>
<th>Player</th>
<th>Player ID</th>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight Operator</td>
<td>FO_j</td>
<td>( T_j = ((V_{j_1}^{FO}, D_1, Tr_{j_1}), (V_{j_2}^{FO}, D_2, Tr_{j_2}), \ldots, (V_{j_K}^{FO}, D_k, Tr_{j_K})) )</td>
</tr>
<tr>
<td>Retailer</td>
<td>R_i</td>
<td>( D_{wcc,j}, D_{wsc,j} )</td>
</tr>
<tr>
<td>Westfield Group</td>
<td>WG</td>
<td>( V_i^R, T_{walk,i} )</td>
</tr>
</tbody>
</table>

For each freight operator FO\(_j\) there is a collection of trips \( T_j \) in which each trip \( k \) consists of a volume \( V_{j,k}^{FO} \) in [cage-eq], a distance \( D_{wcc,j} \) or \( D_{wsc,j} \) in [km] and an associated truck type \( Tr_{j,k} \).
Each $T_{r,j,k}$ has a related fuel consumption $\gamma_{Tr}$, maintenance $C_{main, tr}$ and rent $C_{rent, tr}$. Also the freight operator drives a distance to the WSC, $D_{wsc, j}$ in [km] and to the WCC, $D_{wcc, j}$ in [km].

The set of all origin-destination volume units transported by freight operator $FO_j$ is $V_{j,FO}$. $V_{j,k}$ is a set of individual origin-destination volume units $V_{j,k,i}$ transported by trip $k$, with $V_{j,k} \subseteq V_{j,FO} \subseteq V^{FO}$. The total volume (in cage-eq) transported by freight operator $FO_j$ is:

$$vol(V_{j,FO}) = \sum_{i=1}^{\lvert R \rvert} \sum_{k=1}^{\lvert T_j \rvert} V_{j,k,i}$$

Similar to the freight operator, the set of all origin-destination volume units of retailer $i$ is $V_{i,R}$ with $V_{i,R} \subseteq V^R$. Each retailer $R_i$ there is a volume that needs to be delivered to the store, noted by $vol(V_{i,R})$ in [cage-eq] and defined by:

$$vol(V_{i,R}) = \sum_{j=1}^{\lvert FO \rvert} \sum_{k=1}^{\lvert T_j \rvert} V_{j,k,i}$$

In these formulas $\lvert FO \rvert$ is the number of freight operators in the model and $\lvert T_j \rvert$ the total number of trips relating to $FO_j$. The total volume for retailers:

$$vol(V^R) = \sum_{i=1}^{\lvert R \rvert} vol(V_{i,R})$$

The collection of all trips in a coalition $S$ is $T_S$ and is defined as:

$$T_S = \bigcup_{j:F O_j \in S} T_j$$

Also each retailer’s store is located a certain distance from the loading bay denoted by one-way walking time $T_{walk, i}$ in [hours].

The Westfield Group does not have any associated variables.

In order to help the understanding of the volume set/collection structure and hierarchy, an example is made with two retailers and two freight operators (having 2 trips). This is portrayed in figure 7.1. The variables in the figure will be described with formulas below.

In addition to these variables, the variable $T_S^{out}$ is defined as the number of outgoing WCC trips required to last-mile consolidate all volume of sub-coalition $S$ in [#trips].

For this model it is assumed that all other variables defined in the previous sections are constant for all players within the model. For example: the unloading time for each cage-equivalent $T_{load}$ is the same for each FO and retailer. The distances in haul (either to the WCC or to the WSC) will be the most different as the supplier DCs will be located all over the United Kingdom.
7.2.1 High-level process cost functions

It is assumed in this model that all stakeholders are rational and thus always choose for the supply chain strategy with the lowest cost for each high-level process. In this section the cost function for each high-level process is given — based on this assumption. Before this can be done it must be clearly described which high-level processes there are and how they can be compared — the latter is important because the same steps should be compared. The table below shows the processes that are compared for the traditional and the consolidated supply chain. The only comparison that deserves noting is the Haul and Haul + Last-mile. This is necessary because the effect of the processes are the same, namely delivering goods to the WSC loading bays. The set of high-level IDs is denoted by $SEG$ and will be used in the next chapter for the creation of the benefits game.

The cost functions for the three high-level processes: haul (incl. last-mile), last-metre and recycling can be written as:

$$C_{\text{last-mile}}(S) = \min(C^C_{\text{haul}}(V_S, T_S) + C^C_{\text{last-mile}}(V_S), C^T_{\text{haul}}(V_S, T_S))$$  \hfill (7.1)\\
$$C_{\text{last-metre}}(S) = \min(C^C_{\text{last-metre}}(V_S), C^T_{\text{last-metre}}(V_S))$$ \hfill (7.2)
\[ C_{\text{recycling}}(S) = \min(C_{\text{recycling}}(V_S), 0) \]  

(7.3)

In these formulas \( V_S \) is the total volume in the system \( S \) in [cage-eq] and \( T_S \) the set of trips with distance and truck-type for each trip in \( S \). The sum of these three segments is \( C(S) \) and is defined by:

\[ C(S) = \sum_{\text{seg} \in \text{SEG}} C_{\text{seg}}(S) \]  

(7.4)

In this equation, \( \text{seg} \in \text{SEG} \) means which high-level processes are relevant for coalition \( S \). In sub-coalitions not all high-level processes are relevant.

### 7.3 Characteristic function of the benefit sharing game

The goal of this model is to establish a collaborative benefit sharing model. This is based on the costs occurred by players in various coalitions. It is assumed that coalitions make rational choices. The choice to either use traditional deliveries or consolidated deliveries is made by the coalition based on minimal costs. This also means that each coalition has to choose either one and cannot combine choices (e.g. \( FO_1 \) cannot use traditional deliveries for some deliveries and consolidation for others). The coalition requires full commitment. However a coalition may choose different strategies for different high-level processes (e.g. consolidated haul and traditional last-metre deliveries). They will do so if a consolidated high-level process does not have a marginal benefit compared to the traditional delivery strategy.

The value of the game \( v \) for coalition \( S \) is defined by:

\[ v(S) = \sum_{\text{seg} \in \text{SEG}} [C_{\text{seg}}^T(S)] - C(S) \]

\( N \) is the coalition with all players participating, known as the grand coalition. The value of the game \( v \) is a benefit when comparing the consolidated supply chain with the traditional supply chain. As explained in the previous chapter the set \( \text{SEG} \) is filled with the three high-level processes. \( \emptyset \) is known as the empty set — if the coalition is empty nobody participates and the costs are 0 by definition and thus \( v(\emptyset) = 0 \). This also extents to \( R \) and \( FO \) — if \( R = \emptyset \), no retailers join the coalition. Furthermore total costs are, by definition, always more than zero, hence: \( C(S) \geq 0 \).

An example of this benefit game can be found in appendix I. This example is based on a simplified situation with a reduced player set.

### 7.4 Total costs of grand coalition

The grand coalition is the coalition in which everybody participates and is denoted by \( N \). The total benefit of this coalition is \( v(N) \). In the grand coalition all benefits and costs that require interaction are included in the value function - everybody joins and thus every aspect is possible.

Therefore, for the supply chain the total supply chain benefit is:

\[ v(N) = \sum_{\text{seg} \in \text{SEG}} C_{\text{seg}}^T(N) - C(N) \]
All three processes can be consolidated in the grand coalition (all interactions required are present).
In $C(N)$ used above, the variables $T_N$ is the set of all trips in the grand coalition and $V_N$ is the sum of all volume in the grand coalition.

### 7.5 Relevant costs of sub-coalitions

In this section the values of all sub-coalitions $S$ are determined with $S \subseteq N$. This is necessary to populate the game. For each sub-coalition both the costs of the traditional supply chain as well as the costs of the consolidated supply chain are discussed. Eventually these two will be compared and the minimum will be chosen (for more information: section 7.3). Using the processes and the involved stakeholders described in sections 6.2 and 6.3, this section determines which aspects which are relevant for each sub-coalition. First the relevant cost aspects are determined after which they are described with cost functions.

An simplified example of the value of sub-coalitions is given in Appendix I. This example might be useful for comprehension of the various supply chain combinations in sub-coalitions.

#### 7.5.1 Traditional supply chain costs for sub-coalitions

Within the traditional supply chain there are no costs that depend on interactions between players. This means that the cost functions are decoupled of the coalition. In other words: the costs of the traditional supply chain are a linear combination of the cost functions related to the individual players in the coalition. This follows from the lack of collaboration between players.

The traditional supply chain costs for a sub-coalitions are a combination of costs relating to the individual players in the coalition. To determine which processes belong to which player in the traditional supply chain the player / process combinations from chapter 6.3 is used. If multiple players are involved the cost function is split into the relevant part for each player. It is not necessary to distinguish different instances of a player type as the cost functions are the same - due to decoupling.

The costs that relate to a retailer $R_i$ are the combined costs of the separate processes of the last-metre. These costs can be found in table 6.4.2.2. The cost that belong to a retailer are relating to the last-metre high-level process because in the traditional supply chain this segment would be performed by the retailer.

Similarly the costs that relate to a freight operator $FO_j$ are the combined costs of the separate processes that belong to the traditional haul high-level process. These costs can be found in table 6.15. There is one exception however: loading bay opportunity costs belong to the Westfield Group $WG$. This is because the space that could be potentially saved by reduced loading bay requirement can only be utilized by the shopping centre owner. This is also the total costs of traditional deliveries for the Westfield Group.

In the traditional supply chain the opportunity cost of the loading bay is the current number of loading bays needed $lb^T$ because there is no cooperation and thus no reduction possible. The assumption is made so that in the traditional scenario the amount of loading bays is fixed: without consolidation the reduction is zero by definition. Also recycling revenue cannot be obtained.
As the various players are not connected and thus the cost of a sub-coalition $S$ using the traditional supply chain is defined by:

$$C^T(S) = C^T_{haul}(S) + C^T_{last-metre}(S)$$

$$C^T(S) = \sum_{j: FO_j \in S} C^T_{haul}(T_j, V_{FO_j}) - lb^T \cdot C^T_{opp}$$

$$+ \sum_{i: R_i \in S} C^T_{last-metre}(V_{R_i})$$

$$+ \sum_{WG \in S} lb^T \cdot C^T_{opp}$$

All these variables refer back to chapter 6.4.2 with $T_j$ being the incoming trips by freight operator $FO_j$ in $S$, $V_{FO_j}$ being the volume transported by freight operator $FO_j$ in $S$ and $V_{R_i}$ being the volume destined for the retailer $R_i$ in $S$. In this formula, the loading bay opportunity cost should be deducted from the ‘haul’ high level process (this cost function includes loading bay opportunity) for freight operators as this is only a relevant cost when the Westfield Group joins.

### 7.5.2 Consolidated supply chain costs for sub-coalitions

#### 7.5.2.1 Introduction

The consolidated supply chain cost functions are not as straightforward as the traditional cost functions. This is mainly because of the collaborative aspect of the consolidated supply chain. Costs and cost drivers (like volume and trips) are not decoupled from each other. In this section the cost functions of all different coalitions are discussed. For each of these coalitions different consolidation “processes” are possible and therefore it is not possible to discuss them in a generic manner. This section can be considered a thought-experiment in order to be able to allocate benefits using allocation rules from cooperative game theory. In practice it is expected that all players commit to consolidation, either because of policy measures or due to the realisation of economic benefit.

First to illustrate the complexity of sub-coalitions an example:

Consider the costs of a coalition with 2 freight operator and 1 retailer without the Westfield Group. The freight operators might also carry goods for other retailers. Do they then need to deliver to the WCC and the WSC and thus creating a multi drop. This changes the cost driver trips as for a part of the trips the last-mile is driven by two trucks: a WSC truck and a FO truck — both driving from WCC to WSC. Is there anything possible in terms of loading bay reduction or cardboard revenue?

These are obviously choices that need to be made and they differ between coalition combinations. In the following sections the complexity is explained. Starting with the individual coalitions of players (a player acting alone) four "larger" coalition scenarios will be introduced. For these scenarios the possible consolidation “methods” and the value of cost-drivers will be discussed. For use in this section $FO$ is defined as the set of freight operators $FO_j$ and $R$ as the set of retailers $FO_j$.  

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7.5.2.2 Singleton and single player type coalitions

For individual players (also known as a singleton coalition), we assume consolidation is not possible. This means that if a player does not collaborate with other players they do not have the option to either transport via WCC or use DHL last-metre deliveries. Reason for this is that some form of collaboration is necessary in order to make the changes needed to make this happen. A freight operator would need a retailer accepting the new delivery schedule — a similar collaboration is needed for DHL last-metre deliveries to work. Finally: the Westfield Group will not have any loading bay requirement reductions without freight operators using the WCC.

Using a similar logic the one player type coalitions (coalitions of only \( R_i \) or \( FO_j \)) also cannot use consolidation. In other words: pure horizontal cooperation is not possible. Horizontal cooperation is the same type of players collaborating. Not using consolidation means that the supply chain costs are equal to the traditional supply chain costs and thus:

\[
C^C(S) = C^T(S)\text{ if } S \subseteq FO, S \subseteq R \text{ or } S = WG
\]

7.5.2.3 Consolidated processes for sub-coalitions

Apart from the single player type coalitions, sub-coalitions can be grouped into four scenarios. Together with the single player type coalitions they are all possible types of coalitions. The four different coalition scenarios are:

1. Only Freight operator(s) and retailer(s): \( FO \cap S \neq \emptyset, R \cap S \neq \emptyset \) and \( WG \not\in S \)
2. Only Freight operator(s) and Westfield Group: \( FO \cap S \neq \emptyset, R \cap S = \emptyset \) and \( WG \in S \)
3. Only Retailer(s) and Westfield Group: \( FO \cap S = \emptyset, R \cap S \neq \emptyset \) and \( WG \in S \)
4. All player types: \( FO \cap S \neq \emptyset, R \cap S \neq \emptyset \) and \( WG \in S \)

This section will discuss the three high-level processes for each of the scenarios. Within these processes some parts may of may not be possible.

The first scenario is a sub-set of freight operator(s) (or all) and a sub-set of retailer(s) in the coalition. In this situation the haul process can follow three processes depending on the coalition. If freight operators only carry freight for participating retailers (\( V^{FO} \subseteq V^R \)), the haul/last-mile will follow the consolidated haul/last-mile processes. If freight operators do not carry any freight for participating retailers (\( V^{FO} \setminus V^R = V^{FO} \)), the haul/last-mile will follow the traditional haul process. This is because consolidated the haul requires cooperation of the retailers as the delivery time will change. Otherwise the haul will be partially consolidated and require an extra traditional last-mile trip for the trucks that carry volume for participating and non-participating retailers. In this case \( V^{FO} \setminus V^R \) will be delivered to the loading bay by the freight operator and \( V^{FO} \cap V^R \) will use the consolidated supply chain. The fraction of trucks carrying freight for non-participating and participating retailers — and thus requiring an extra last-mile trip) is denoted by \( \kappa_S \) (will be explained later in this section). Loading bay opportunity cost is the same as in the traditional supply chain — the Westfield group is needed for these processes to be consolidated. Even though loading bay requirement might change, the Westfield Group must join the coalition in order to capitalize on the change.
Similarly to the haul/last-mile process, the last-metre process has three different processes it can follow in the first sub-coalition scenario. If retailers only receive freight from participating freight operators \((V_R \subseteq V^{FO})\), the last-metre will follow the consolidated last-metre process. If retailers do not receive any freight from participating freight operators \((V_R \setminus V^{FO} = V^R)\), the last-metre will follow the traditional last-metre process. This is because the freight operator is needed in order to coordinate the delivery with the last-metre process. Otherwise the last-metre will be partially consolidated. \(V^R \setminus V^{FO}\) is the volume that needs to be picked up by retailers (traditional process) and \(V^{FO} \cap V^R\) is the volume that is consolidated on the last-metre.

In the first scenario the recycling revenue are the same as in the traditional supply chain — recycling revenue can only be obtained if the Westfield Group provides the coordinating/collection effort.

The second scenario is a sub-set of freight operator(s) (or all) and the Westfield Group in the coalition. In the haul/last-mile segment all volume can be consolidated in this scenario \(V^{FO}_S\). The Westfield Group provides space in the loading bay area to store goods until the retailers pick them up. This means no collaboration of the retailers is required. It is assumed that storage costs for this service is negligible. The fact that goods now arrive in a different medium (cages) is not enough reason for the retailer to block/veto the last-mile consolidation. The loading bay requirement will change and can be capitalized on as the number of incoming trips is reduced due to consolidated last-mile and the Westfield Group can do something with the space saving. The loading bay requirement is denoted by \(lb_S\) and is dependent on the total arriving trips at the loading bay (explained later in this section).

The last-metre segment cannot be consolidated as this requires the retailers involvement — retailers must allow others to handle there goods. Also, no recycling revenue can be obtained because the retailers are not in the coalition and they supply the recyclable material.

The third scenario is a sub-set of retailers(s) (or all) and the Westfield Group in the coalition. In this situation no haul/last-mile consolidation is possible as this would require freight operators to deliver to the WCC instead of the WSC. No last-mile trips are consolidated and therefore the loading bay requirement will not change.

In the last-metre segment, all volume can be consolidated in this scenario \(V^{R}_S\). The Westfield Group provides space in the loading bay area to store goods until the last-metre process is ready to take the freight to the retailer. It is assumed that the fact that freight is not in cages (because it did not pass through the WCC) does not change last-metre efficiency.

Due to the collaboration of the retailer and the Westfield Group, recycling revenue can be created. The retailers supply the recyclable material and the Westfield Group sells and coordinates this.

The fourth scenario is a coalition of all player types. In the haul/last-mile process all volume can be consolidated \((V^{FO}_S)\) for the same reason as in scenario two: the Westfield Group provides storage and thus the collaboration of the retailers is not required. All last-mile trips in the coalition are consolidated and therefore the number of trips arriving at the loading bays will decrease. For this reason the loading bay need will change to \(lb_S\) (explained later).

In the same way, all volume for participating retailers can be consolidated on the last-metre \((V^{R}_S)\). The Westfield Group provides the temporary storage before the last-metre crew bring freight to the store.

Because both the Westfield Group and retailers participate and therefore recycling revenue can be obtained for the participating retailers.
In order to develop the cost functions for the consolidated sub-coalitions two new aspects need to be defined: the additional trip requirement $\kappa$ and the loading bay need for sub-coalitions when (partially) consolidated.

The $\kappa$ is the fraction of incoming trips by participating freight operator that contain volume for non-participating retailers — as explained in scenario one this means that they do not only have to the WCC but also to the WSC, causing an extra last-mile trip. This value is depended on the coalition. Some freight operators might only deliver for a single retailer and others might deliver to many retailers. No general expression for this value is possible and it should be empirically determined. It can safely be said that this value will drop the more retailers. This value will be complicated to implement in real situations with high retailer and freight operator numbers as the number of possible coalitions is very high.

For the additional trips between WCC and WSC that arise for participating the same cost functions are used as for the traditional haul. The difference is that the distance used is the distance between the consolidation centre and the WSC: $D_{lm}$ and loading in not necessary. The number of trips is $\kappa T^F_O$ and the volume that gets re-routed is $V^F_O \setminus V^R$ — these values drive the costs of this additional last-mile freight. All separate functions are not repeated due to similarity (functions can be found in 6.15).

For consolidated deliveries the loading bay need is based on a combination of traditional trips and consolidated trips. For this model it is assumed that the traditional and consolidated loading bay need — $lb$ and $lb^c$ respectively — scale with the percentage of trips delivered via that route. This is captured in a loading bay need formula:

$$lb_S = \frac{|T^S_{out}| + |T^N\setminus S| - |T^N_{out}|}{|T^N| - |T^N_{out}|} \cdot (lb - lb^c) + lb^c$$

In this formula $|T^N\setminus S|$ is the trips arriving traditionally and $|T^N_{out}|$ the number of trips arriving consolidated from the WCC and $|T^S_{out}|$ is the number of trips arriving when everything is consolidated. As before $T^N$ is the total trips of all freight operators (traditionally). The quantity $|T^S_{out}| + |T^N\setminus S|$ is the total number of trips arriving at the WSC loading bays.

A overview table of when consolidation of processes is possible for all (sub)coalitions is given in appendix E. In appendix I, a simplified example of the game is discussed. This example helps understand the various types of (sub)coalitions even further. The abstract scenarios, in this section, are all discussed using simplified cost functions and a minimal player count. A minimum of two freight operators, two retailers and the Westfield Group is needed for these four scenarios.

Using these conditions the consolidated cost function for each player of $S$ can be made using the cost functions for each consolidation aspect discussed in chapter 6.4.1. This function is denoted by $C^C(S)$. 
7.6 Allocation rule selection

The allocation rule will determine how the benefits will be distributed among the players in the game. In this section the allocation rule will be selected by looking at three dimensions:

1. Fairness
2. Feasibility
3. Understandability

In the literature review (chapter 2.3) three rules are discussed, in this section one of these rules is selected using the criteria listed above.

The properties of a rule are the characteristics which might make the rule fair. The allocation fairness is a perception that depends on the situation of the collaborative game (for more information: chapter ??). All three considered rules have the properties: efficiency, symmetry and zero allocation to zero player. Shapley value also has the property additivity: this property is important to this project as it should not matter in terms of allocation if the consolidation game is considered for two months separately or together. The Shapley value is the only rule that does this. One of the most important properties is individual rationality. Individual rationality is the most desirable property of a rule — many argue a necessary property. The Shapley value is individually rational when the game is super additive, the $\tau$-value is individually rational if the game is quasi balanced and the Nucleolus is individually rational.

Feasibility of the solution is also an issue — with feasibility two sub-criteria are considered: computability and literature support. Many players make the Shapley value can be labour intensive to compute for large coalitions using the traditional manner. This problem can be handled in two ways, either limit the number of players — by for instance grouping — or use a Shapley value approximation method. The Shapley value is also widely used in literature. The $\tau$-value is is not extensively applied in academic literature. The Nucleolus is labour intensive to compute (due to the ordering of each step) and has limited literature backing when it comes to applications. (Leyton-Brown and Shoham, 2008)

It is also important besides these properties the rule is also understandable: it looks at the average marginal contribution of each player to the value of the game and assigns the value based on this. The $\tau$-value is also understandable: balances the minimal right to a maximal expectancy. The Nucleolus is a conceptually difficult rule is unsuitable for practical use on an operations level.

For use in this project the Shapley value is chosen. The main reason for this is the additivity property and understandability. It should be noted that the benefit game of this model is always super-additive and thus the Shapley allocation is individually rational. In the simplified example of appendix I, the Shapley value is used to allocate the benefits to the players. Also, the sensitivity of the allocation to changes in grouping is tested.
CHAPTER 8

Application, Results and Analysis

8.1 Introduction

This chapter first explains how the developed UCC cooperative benefit sharing model is applied to the case of the Westfield Shopping Center. This is done by matching the data available with the theoretical requirement of the model. Discrepancies will be solved by feasible assumptions or by slightly adapting the model for this situation. Another application issue discussed in the previous chapter — the vast amount of players — will be resolved for this situation. Using these adaptations and assumptions the parameters for the model are set or approximated.

Once the model application is thoroughly explained, the model is tested in Excel. This will show economic benefit for the supply chain and eventually allocate these benefits to the stakeholders in a fair way. The validity of the results is then assessed by checking sensitivity.

8.2 Application on Westfield Group

8.2.1 Data availability

In this section the availability of data is reviewed. Two types of data are distinguished: internal data and external data. Internal data is the data automatically collected by DHL — this is the data created by the three DHL operations in the last-mile and last-metre section of the WCC supply chain. This is mainly operational data. External data is everything that is not directly controlled by DHL — which would require other parties to get accurately.

The gathering of internal data relies on the database behind the ICT system Styleflow (DHL custom consolidation centre back-office) and, time and motion studies, done by DHL, in the shopping centre supply chain. All data is focussed on last-mile and last-metre operations. In appendix F an overview of internal data can be found linked to the model requirement as well as a graphical overview of the database structure. Most of this information is captured automatically by the ICT system or by DHL accountants, making it accurate. It is accurate because the data gathering is computer automated and financial data (from management accounting reports) are checked via compulsory internal accounting procedures. The time motion studies done are based on a limited sample and thus more likely to be more variable in real life.

External data is more difficult to obtain. It is less accurate because it depends on expert estimates and interviews and might vary between stakeholders. This variation is not always captured in the model (e.g. retailer clerk salary is fixed for all retailers). In appendix G an overview of internal data can be found linked to the model requirement.

There are a few variables included in the model which are not covered by both types. This is because there is no information about them. The most important and influential are: $D_{wcc,j}$ and
$D_{WSC,j}$ — the distance from supplier to either the WSC or WCC. These distances are influential because these drive the driving costs (personnel and vehicle costs) towards to the WSC.

Two other variables that are difficult to obtain accurately are $\alpha$ and the extra trip fraction $\kappa_S$. The first is a variable the compensates possible multi-drops done by a freight operator. Due to the lack of contact with freight operators the next destination of trucks is unknown. This can also vary heavily between operators — it depends on many factors. The latter variable, $\kappa_S$, can be estimated with the data available. It is known which truck carries freight for multiple retailers. This makes it possible to determine the $\kappa_S$ for all combinations of joining freight operators and retailers (basically all coalitions).

All information discussed above is about the consolidated supply chain, with all freight consolidated — there is no data about traditional supply chain. It is obvious that assumptions need to be made about the behavior of freight operators while using the traditional supply chain.

### 8.2.2 Assumptions

#### 8.2.2.1 Model’s assumptions

This section summarizes assumptions made in the development of the model. A clear list can help to determine the sensitivity of assumptions to the accuracy of the model. First the list of assumptions is given after which the implications and validity will be discussed:

1. All trucks are (almost) full. (consolidated last-mile segment)
2. The delivery of the same item is done by the same truck and drivers at the same time. (traditional / consolidated haul segment)
3. Recycling returns do not require extra work (consolidated last-metre segment)
4. The loading bays can be put to other uses easily and without significant investment (consolidated last-mile)
5. The fact that freight is not in cages does not change last-metre efficiency. (consolidated last-metre)

The first assumption is reasonable because trucks can wait until they are approximately full at the WCC. The frequency of outgoing trucks is about 20 a day, evenly spread. Waiting for a full truck load (FTL) does not cause a long delay. The other possibility is to create the FTL with freight that arrived early. Trucks are only assumed full between WSC and WCC in the consolidated situation.

The second assumption is an assumption in order to compare the two supply chains (traditional and consolidated). This assumption is in favor of the traditional supply chain. With the consolidated deliveries night deliveries are also possible — at night there is less congestion and thus the average driving speed will significantly increase. Adding ”change in delivery time” as a benefit is something for further research.

The third assumption simplifies reality somewhat. There will be some extra work involved in obtaining recycling revenue and bringing it back to the loading bay. It will be a small difference though, as the retailers have to get rid of their cardboard and other recyclables anyway.
The fourth assumption is unrealistic for this case study. The Westfield Stratford City Shopping centre is already build. This means it will require an investment to change loading bays to something else. The model however could be used for new shopping malls in this way.

The fifth assumption does not cause inaccuracies in the model. The loading bay and last-metre crew have specialist equipment to handle all types of freight. The fact that goods are not in cages should not effect efficiency and lead to extra costs.

8.2.2.2 Application assumptions

To address the complexities of the data requirement for the model, a few simplifying assumptions have to be made. In order to be able to compare the consolidated and traditional supply chain it is assumed that the difference between the traditional and consolidated supply chain for the freight operator is the delivery location (WSC v. WCC) — time, volume and truck type are the same. Although there is no data on the traditional supply chain, this assumption makes it possible to compare the two supply chains. The same delivery time indicates that the driving speed (due to congestion) is approximately the same, the same truck type ensures the same fuel usage and rental costs and the same volume suggests that delivery strategy has not changed. Implicitly, no change in delivery strategy does not incorporate upstream consolidation effects (FOs consolidate towards the WCC). DHL’s experience is that FOs indeed do not do this. Inventory costs can also be excluded if the delivery schedule stays the same — there is no reason to assume these costs will change.

Another assumption that needs to be made concerns how the haul and last-mile distance changes is the supply chain strategy is changed. In other words: how does \( D_{wcc,j} + D_{lm} \) differ from \( D_{wsc,j} \). This is the total driving distance for both delivery schemes — consolidated and traditional. It is assumed for this model that the total driving distance is equal. This is justified by the location of the WCC, next to a major traffic artery. This assumption suggests that freight travels the same distance to the WSC independent of the supply strategy chosen. On average this is probably the case. It is important to check the sensitivity of this assumption.

DHL does not know how many trucks have multi-drops as there is no direct contact with the freight operators. It is not possible to make a sensible assumption about this and therefore the multi-drop factor is excluded. This means \( \alpha = 1 \).

Loading bay need, which drives opportunity, can be empirically determine for the grand coalition by looking at the number of incoming trips. For sub-coalitions the need scales proportionally with the number of incoming trips. It is also assumed that the loading bays can be put to other uses easily and without significant additional investment. The validity of this assumption depends on the new use for the loading bay (in this present situation). This would be the case if consolidation is included at shopping centre design.

The time spend by the retailer can be directly allocated to the last-metre pickup in the traditional supply chain. The hours spend with last-metre freight would not be needed if last-metre is consolidated and thus the total cost of the employee is saved.

The assumptions described above are summarized in the list below:

1. Trips to the WCC can be used as indication of the traditional supply chain. Only the delivery address changes — ceteris paribus.
2. The total driving distance is the same. And so, $D_{wsc,j} + D_{lm} = D_{wsc,j}$.

3. DHL does not know how many trucks have multi-drops and thus it is excluded with $\alpha = 1$.

4. Loading bay need scales linearly with the number of total incoming trips.

5. Retailer personnel costs are not sunk costs i.e.: retailers could do something else with their time (other than picking up freight) and thus full retailer clerk costs is opportunity.

### 8.2.3 Players

In order to be able to compute the Shapley value, the number of players must be reduced. This can be done by grouping players that are similar — and thus have similar costs. Grouping does have an effect on the accuracy of the allocation, this will be analysed in a later stage. The total player group will be segmented in few types of similar players. The two stakeholder groups that need grouping are retailers and freight operators. In this section they will be discussed separately.

Freight operators come in all shapes and sizes. This makes it complex to find common ground between them. With the assumption made about haul distance, the difference in cost of a single trip is driven by the truck type — as all last-mile trips with a truck type have the same cost function. The problem is that freight operators all use a different vehicle mix to transport the goods. For this reason the freight operators could not be grouped but the trips could be. Grouping trips by truck type allows groups with near equal cost functions. In this model the trips are grouped by incoming truck type and value is also allocated to these groups. This way of grouping allows the model to lose complexity (as the number of players is reduced) and however the allocation accuracy will be reduced. The ICT system, Styleflow, logs four different truck types: Articulated vehicle, 17.5ton truck, 7.5ton truck and 3.5ton van. It makes sense to use these four types as trip groups as the four types have significant different size and costs. In appendix H.1 characteristics of the truck groups can be found. Also, in the example posed in appendix I this grouping is already done — as each freight operator uses a distinct truck type.

In a similar way, the common cost differentiator for retailers is determined. Just like with freight operators the retailers differ greatly — especially in quantity of volume received. When looking at a single volume unit the key differentiator between volume units is distance from the loading bay (walking time). This distance is thus a sensible way to separate volume units. Like with freight operators the total costs for the retailer then depends on the number of volume received in a certain store-zone.

To determine the number of retailer groups/zones the average travel time is plotted on the map of the WSC. A time and motion sample exists for a part of the stores. These are plot on the map and grouped. In appendix H.2 the retailer grouping details can be found.

The new player grouping somewhat changes the way to look at coalitions. For retailers little changes as they are used grouped without changing the composition. However the fundamental understanding of freight operators changes. The freight operators are now represented by a collection of trips in a certain truck type. So, for defining the game the truck group takes the place of the freight operator. The various segments discussed in the previous chapter will stay the same.

Using the segmentation, the game is defined for an 8-player situation. This is tractable when wanting to compute the Shapley value once but is less convenient to do extensive sensitivity analysis.
The sensitivity of grouping in this way is investigated in a later stage by analysing the change in Shapley allocation to player types when the number of players change or are differently grouped. It is suggested by the simplified example of appendix I that changes groups might have a profound effect on the Shapley allocation.

The trips or volumes are not later re-allocated to the freight operators or retailers that actually own the trip because this would create another allocation game.

8.2.4 Shapley value and individual rationality

In chapter 2.3.1 and 2.3.3 it is explained that the Shapley value of superadditive games is always individually rational. The allocation must be individually rational in order to assure stability. So, Shapley allocation is appealing when the game is superadditive. For this report a solution in the core is not required because it is assumed that all players will choose the grand coalition if consolidation proves beneficial — joining a sub-coalition to improve benefits is not possible.

First let us remind ourselves what superadditivity is. Superadditivity can be seen as a snowballing effect; the larger the coalition grows the benefit obtained does not drop. Mathematically: \( \forall S, T \subseteq N \) it holds that \( v(S \cup T) \geq v(S) + v(T) \). In essence, it must be proven that merging coalition \( T \) and coalition \( S \) will have a higher or equal than the coalitions separately. A coalition has benefit if the total consolidation costs are lower than the traditional supply chain costs, the difference being the coalition benefit.

In order the prove that the allocations of the benefit game of the model are individually rational, it must be proven that the benefit game is superadditive. The benefit game of the model is superadditive because the costs of a high level-process only changes if it is better then the original cost — the game is designed with a superadditivity cover. A superadditivity cover only consolidates segments if consolidating the segment adds benefit to the total game. This will only be the case if enough volume or trips are consolidated (depending on the respective high-level process) to outweigh the high fixed consolidation cost. If two coalitions are added they will increase volume/trips that could be consolidated so by merging the coalitions there will be more marginal benefit (each volume/trip adds a bit of benefit) to outweigh the fixed cost. It the coalitions are already consolidated separately, the benefit is also rise as the fixed cost has to be paid once. There is no possibility of decreasing benefit by adding subcoalitions hence the game is superadditive and the Shapley value will yield an individually rational allocation vector.

In the analysis section of this chapter, costs will be changed. If the marginal benefit of adding volume is negative (meaning: variable consolidation costs are higher than variable traditional costs) may cause the game to loose superadditivity. The overall benefit of consolidation will remain positive but lower than the separate coalitions (hence: not superadditive). A benefit game that is not superadditive cannot guarantee individual rationality. If this is the case it will be clearly noted.

8.2.5 Parameter selection

This section explains the parameter selection in the Westfield situation. It is discussed earlier that there are two types of parameters. Internal variables are based on internal DHL information. The parameter selection for these variables can be found in appendix F. Some variables are database
intersections, these are listed separately. Also the weighted average walking time to a retailer in zone $z$ is listed.

External variables are more difficult to determine accurately. The parameter settings can be found in appendix G. It can be seen that several variables are set to zero in the base situation. The $CO_2$-tax and congestion charges are set to zero because they are not yet active in the area. In the analysis the effect of these additional charges will be examined. Little is known about the effect and size of shrinkage, for this reason this effect is currently excluded by setting parameters to zero. The costs of a certain truck type per km are estimated by using internal DHL truck cost allocations. This rent includes MOT (road tax), insurance and depreciation.

In the paragraphs below some costs are treated to give a feel for the scale — in appendix F and G exact parameters can be found. Figure 8.1 is a graph for the consolidation costs for a two month period.

![Figure 8.1: The consolidated costs depended on volume](image)

It is not possible to put traditional costs in a graph as these depends on number of trips, truck type and on volume. It can be stated though, that because of the relatively high fixed cost to start up consolidation, the traditional supply chain is cheaper with low volumes. The fixed cost of centre are the minimal costs needed to operate it (in the case of the WCC among other things: a truck, a building, management and security. Using the parameters and assumptions set in this chapter so far, a game can be made.

### 8.3 Results

#### 8.3.1 Benefits of grand coalition

The model yields results in a total supply chain benefit for the grand coalition. This benefit is analysed in more detail looking at the changes in the three underlying processes. The total benefit obtained by complete consolidation at the Westfield Shopping centre is: £115k for the two month period analysed with the model. This is a cost reduction (compared to the traditional situation) of 16%.

In figure 8.2, it can be seen that all three high level processes have a positive consolidation benefit. The absolute benefit of the segments last-mile and last-metre are the same but the percent-wise
improvement is much higher for the last-metre segment. Also it can be seen that the recycling revenue is a relatively small benefit of consolidation.

Fig. 8.2: The benefit of the grand coalition for each high level segment in thousands of pounds

8.3.2 Allocation of benefits

Using the Shapley value, the total benefit is allocated to the players. This will give insight into the importance/power of players to the success of a consolidated supply chain. More allocated benefit means the player has more important role in the consolidation effort. As explained before the Shapley value is determined by looking at the marginal benefit of the individual players for all subcoalitions. It is worth noting that three truck types get almost equal benefits assigned: Van, 7.5ton and 17.5ton. The reason for this is that last-mile consolidation is not beneficial when either of these players does not participate — therefore, for consolidation to be a success these three players are equally important. The small differences have to do with effects that they might have individually on last-metre consolidation.

Fig. 8.3: The Shapley allocation to players in thousands of pounds

Fig. 8.4: The Shapley allocation to players in thousands of pounds
It is interesting to look at the distribution of benefit between the more high level player groups: Retailers, Freight Operators and Westfield Group. This is done by adding up all truck types (to obtain freight operators) and all zones (to obtain retailers). The result is shown in 8.4. This implies that in this situation the retailer group contributes the most to the benefit of the supply chain. Sensitivity of the allocation to the grouping of trips and volume will be assessed in the chapter 8.5.5.

### 8.4 Transfer Payments

Using the allocation in the previous section it is now possible to determine the cashflow between the stakeholder groups. This illustrates which stakeholders pay each other — the payments between stakeholders are called transfer payments. In order to do this the traditional situation is taken as a base and subtracting the allocated benefits shows what the players should pay for consolidation. After this it is determined what the players actually pay, the difference is of course what players should receive from other players. This is summarized in table 8.1. The amount zones and truck types have to pay for consolidation is determined by weighing the total consolidation cost. For zones, the last-metre consolidation costs are weighed by volume and for truck types, last-mile consolidation costs are weighed by WCC incoming trips.

<table>
<thead>
<tr>
<th></th>
<th>Van</th>
<th>7.5tn</th>
<th>17.5tn</th>
<th>Artc</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>WG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Costs</td>
<td>67.659</td>
<td>52.738</td>
<td>121.965</td>
<td>11.956</td>
<td>44.834</td>
<td>70.729</td>
<td>93.150</td>
<td>264.000</td>
</tr>
<tr>
<td>Consolidation Costs</td>
<td>143.143</td>
<td>90.226</td>
<td>181.621</td>
<td>10.934</td>
<td>51.224</td>
<td>52.314</td>
<td>51.852</td>
<td>27.489</td>
</tr>
<tr>
<td>To Receive</td>
<td>88.450</td>
<td>48.373</td>
<td>73.864</td>
<td>-896</td>
<td>21.366</td>
<td>-1.481</td>
<td>-22.985</td>
<td>-206.691</td>
</tr>
</tbody>
</table>

### 8.5 Analysis

#### 8.5.1 Effects of assumptions on benefit

This section checks the sensitivity of the assumptions to the benefits obtained in the grand coalition. One of the main assumptions is the $D_{wcc} = D_{wcc} + D_{lm}$ assumption — in words: the total driving distance to the WSC is the same for both strategies. In the situation above the sensitivity is checked by varying the extra distance to the WCC $\Delta_{wcc}$ — of course while keeping everything else constant. This delta is added to the formula: $D_{wsc} = D_{wcc} + \Delta_{wcc} + D_{lm}$. This results in figure 8.5. The implication of this figure is that the benefit is very sensitive to the assumption. Each kilometer that needs to be driven extra (on average on all trips) reduces the last-mile benefit with approximately £13k. This means that the last-mile segment is no longer beneficial if an extra distance of 3.2 kilometer to drive passed the WCC. As to be expected the absolute Shapley distribution to retailers stays approximately unaffected. This is intuitive because adding extra driving distance decreases the cost gap between traditional and consolidated last-mile deliveries.
A smaller cost gap means a smaller last-mile benefit and this causes consolidation to be less attractive in (sub) coalitions — sometimes it will even shift the decision (between consolidated and traditional) back to the traditional supply chain. The more coalitions make this switch, the marginal benefit becomes zero. So, the increase in distance to the WCC decreases the Shapley value of the Westfield Group (because of the requirement for parts of the last-mile high-level process) and the truck types.

It is interesting to look at the changes of the Shapley value within the truck type group. The effects of extra distance to the WCC on the Shapley allocation for the different truck types is shown in figure 8.7.

The Shapley allocation for the four truck types under changing last-mile distance follows an interesting pattern. When the distance to the WCC decreases compared to the distance to the WSC, the marginal benefit of a truck trip increases — in other words: the difference in costs for the consolidated trip compared to the same trip in the traditional supply chain increases (consolidated trip becomes cheaper). This increase in marginal benefit of consolidated trips means that less trips are needed to overcome the fixed WCC costs and thus for consolidation to become the logical last-mile option. Once the marginal benefit of adding consolidated trips to the coalition (more
truck types in the coalition) is large enough, less truck-types are needed to make the consolidated last-mile the logical choice. This is also shown in the Shapley distribution - adding approximately 0.7km to the distance requires three truck types, decreasing the distance with 6km (not shown in graph) allows consolidation with only the 17.5tn truck type group.

8.5.2 Effect of volume shifts

This section looks at changes in volume to the consolidation benefit. The analysis is done with by scaling the number of trips and volume (in the same ratios as the original situation). This analysis is shown in figure 8.8 and now it is obvious that last-mile is no longer beneficial at 80% of the original trips and volume, last-metre consolidation is no-longer beneficial at 45% of the original volume. The Shapley allocations for the different player types changes according to the

![Fig. 8.8: Sensitivity of changes in volume/trips to benefits of the different high-level processes](image1)
![Fig. 8.9: Sensitivity of changes in volume and trips to Shapley allocation of the different player types](image2)

benefit of the three sections. The last-mile benefit increases faster with more trips/volume than the last-metre benefit line. This means that the Shapley allocation grows faster for truck types and Westfield group than for zones. Truck types become relatively more important. This relationship is shown in figure 8.9. This analysis assumes that the minimal loading bay requirement ($lb^T$ and $lb^C$) remain the same. This means there is no change in loading bay opportunity costs both in traditional and consolidated strategy.

8.5.3 Effect of incoming load-factor

It would be interesting if the effect of changes in incoming load-factor could be examined. This could happen, if for example freight operators start to consolidate upstream. This is done by varying the number of trips in the model while keeping volume constant. The average load-factor is around 50% in the base situation — load-factor is volume divided by capacity. Figure 8.10 shows a relationship between load-factor and last-mile benefit. Changes in the last-mile benefit also effect the Shapley allocation. As expected, the allocation to truck types and Westfield group increase with decreasing load factor. The retailer allocation also increases, this is because the retailer is required for last-mile consolidation in some coalitions (when the Westfield Group is not participating).
8.5.4 Sensitivity of costs and charges

This section will examine the height of costs and its effects on consolidation success. Fixed centre costs and CO$_2$-tax and congestion charges are discussed in this section. Using similar reasoning, the sensitivity of variable centre costs, loading bay opportunity costs and shrinkage are discussed in appendix J.

8.5.4.1 Changes in fixed consolidation costs

Changes in the fixed cost of either the WCC (for last-mile) or the last-metre centre effect the benefit of the relevant high-level processes. Once the fixed cost is too high to overcome the benefit becomes zero. This can be seen in figure 8.11. Changes in the fixed costs only change the benefit of the high-level process to which the cost belongs. The Shapley allocation changes when the benefit changes. This is shown in figure 8.12. Changes in fixed last-mile cost affect the Shapley value of trucks and the Westfield Group and changes in fixed last-metre cost effect zone and Westfield Group allocation — zones are affected a lot more than the Westfield Group. Within player types the allocation also changes. Similar to the explanation belonging to figure 8.6, when fixed last-mile
costs decrease less trucks are needed to make last-mile consolidation beneficial. For example, in the base situation Vans and 17.5tn trucks joining to coalition can make last-mile consolidation beneficial. If the fixed costs rise to £182k, three truck types are needed for consolidation to be the rational choice (7.5tn is also required). Truck types that are the minimal requirement for consolidation receive approximately equal allocations.

8.5.4.2 CO$_2$ tax / Congestion charge effect

This section will look how CO$_2$ tax and congestion charges make a consolidated supply chain a more rational choice. These are measures that could be implemented by the government to promote consolidation. Therefore it is assumed that the congestion charges only need to be paid by the traditional supply chain. The two measures essentially both do the same — make the traditional supply chain more expensive — but do this in a different way. The CO$_2$ taxes the different truck types in a different way, based on the emissions per truck type listed in appendix G. The congestion charge can be implemented in two ways: disincentive a truck type by charging trucks differently or by charging the same for all four trucks.

All these measures increase the costs of the traditional last-mile supply strategy and thus the benefit that can be obtained by consolidating. However these will not be shown in this report. The changes in Shapley allocations between truck types will be shown. When the CO$_2$ tax is increased the traditional supply chain costs go up for all trucks. It can be seen in figure 8.13 that all allocations go up with the tax. Once the tax becomes very large there are less trips necessary (thus less truck types) for consolidation to be the rational option in (sub)coalitions. This seems like a powerful effect but note that £5 CO$_2$ tax per kg is fifty times more than currently proposed by the EU. This means that realistically CO$_2$ tax does not play a large role in the allocation.

Congestion charge is another measure that increases the last-mile costs of the traditional supply chain. The changes in Shapley allocation are shown in figure 8.14. Even at £10 per trip congestion charge 17.5tn and vans are still needed for last-mile consolidation to work. Allocations to retailers zones are unchanged. A similar picture is obtained if the congestion charge is only charged to one truck type (e.g. van) — for this reason the graph is not shown in this report.
8.5.4.3 Extra sensitivity analysis

In this section, the main conclusions of the sensitivity analysis of variable centre costs, loading bay opportunity costs and shrinkage are discussed — Details are given in appendix J.

- If the WCC variable cost increases to approximately £6.50 (+10%), the articulated vehicles have lower variable cost in the traditional supply chain. Similarly if the last-metre variable cost increases to approximately £17.5 (+60%), Zone 3 has a lower variable cost in the traditional supply chain. In both cases the game in no longer super additive and thus individual rational allocations cannot be guaranteed.

- Loading bay opportunity cost is an important part of last-mile benefit. Minimal loading bay opportunity that maintains a beneficial last-mile is £4800 (per two months).

- Increasing the shrinkage for the entire supply chain linearly changes Shapley allocation for all players.

8.5.5 Effect of player grouping

In this section, an important analysis is made on the effects of grouping (explained in section 8.2.3) on the Shapley allocation. The simplified example of appendix I already suggests that the Shapley allocation is sensitive to changes in grouping. In this section this hypothesis will be tested on the WSC case of this chapter.

First the zone distribution is tested. The "base" zone grouping consists of three approximately equal groups. To check sensitivity of the Shapley allocation vector to the amount of groups, the number of groups is varied. This can be seen in figure 8.15. This proves the hypothesis, based on the simplified example, that the Shapley value is indeed sensitive to the allocation. The zone grouping effects the truck allocation slightly but has a large effect on the zone and Westfield Group allocation. The reason that zones grouping is so sensitive is that a certain amount of volume is needed to change the last-metre process to the consolidated strategy. With more groups, there are more (sub)coalitions in which consolidation is beneficial. This finding suggests that grouping retailers together in this way decreases the allocation compared to the situation in which all 350 retailers are treated as separate "zones". The size of the zone also matters: if one group is large and
the other small, in essence that same happens as when the number of groups is reduced (because the small group alone is not enough). Similarly the sensitivity of the truck type grouping is analysed.

Fig. 8.15: Sensitivity of zones changes to Shapley allocation, note: Arctic allocation is almost 0

Figure 8.16 depicts this analysis. The same conclusion can be drawn from the analysis as was the case with the zones for the same reasons.

Fig. 8.16: Sensitivity of truck grouping changes to Shapley allocation, note: Arctic allocation is almost 0

The conclusion of this paragraph is that the Shapley value is sensitive to grouping, as suggested in section 8.2.3. This begs the question if the Shapley value (in this form) is the most suitable allocation rule to distribute benefit among stakeholders. It all depends on how the collaboration scheme is initiated — if it is not really a collaboration scheme but a contractible requirement of the mall-owner to its suppliers and retailers, this could be an allocation method which can be perceived fair. However if it was a spontaneous collaboration between all freight operators, retailers and the mall owner, this allocation method (with the current grouping) results in an unfair allocation (Westfield Group will get to much and the others to little).
Chapter 9

Conclusions and recommendations

9.1 Conclusions

In this section the main research questions are answered. The answers to these questions form the main conclusions of this thesis.

The economic benefit of consolidated last-mile deliveries for the supply chain and its stakeholders is approximately a 16% cost reduction compared to traditional deliveries in the case of the Westfield Stratford City shopping centre. This is a total supply chain benefit of approximately £110k over the analysed period of two months — that is £55k a month.

This means that the consolidation centre is economically sustainable in this particular case and no additional incentives are necessary. However in other cases, with less volume for example, additional (dis)incentives might be necessary to make urban consolidation the rational choice for the supply chain. In this project several methods of doing this are tested with a sensitivity analysis. Reducing centre fixed costs (possibly by subsidy) is the most effective way. CO2-tax and congestion charges only have a minor effect on total supply chain costs, even when added in extreme forms.

The Shapley allocation rule is used to allocate the benefits to supply chain stakeholders. Due to the nature of the Shapley value, grouping was necessary. In the case of the WSC, it is chosen to group freight operators by incoming trips based on truck type (4 groups) and retailers by zone based on distance from loading-bays (3 zones). This results in the benefit allocation depicted in figure 9.1. Using this allocation the transfer payments can be calculated, this is shown in figure 9.2.

Unfortunately the way of allocating benefit (the Shapley value) is sensitive to the grouping method - this makes it less suitable for allocation to individual retailers and freight operators in practice. This is discussed further in section 9.3.
9.2 Recommendations for DHL

For DHL this research should be primarily used as a quantitative economic analysis of urban consolidation centres (UCCs). This research has proven that urban consolidation centres, like the WCC, are cheaper for the supply chain as a whole. DHL can use the developed model to quantify the benefits of other UCCs. Using this report, DHL can convince various stakeholders that urban consolidation centres can be economically sustainable if they can be implemented on a large enough scale. The sensitivity analysis of the WSC case can help to select the real-life situations (cases) for which consolidation is most beneficial and feasible.

Furthermore, this research begins the search to find a sustainable business model for urban consolidation centres. However, the Shapley allocation method might not be the right choice for the actual allocation of benefits due to the necessity of grouping (and the sensitivity of this grouping) but it does give insight in the relative importance of stakeholders compared to each other. This relative importance is useful in order to target the correct stakeholders (the stakeholders with the most benefit as they will be convinced the easiest) when trying to establish a new UCC. The model shows that strategic placement of the consolidation centre is very important. A well chosen location, which ideally is closer to the supplier DC, is a significant driver for the success of consolidated deliveries. In the next section recommendations for further research are given to improve the allocation.

9.3 Recommendations for future research

This section will describe possibilities and angles of future research on benefit distribution of urban consolidation centers. These recommendations can be grouped into four groups: evaluation improvement, allocation improvement, social science implications and technological) soft benefits.

9.3.1 Evaluation improvement

The first category is quantitative evaluation improvement of the model and thus (indirectly) the benefit allocation. This can be done in different ways which is discussed in this section.

A way of improving the model is to add extra aspects that effect the financial performance of the supply chain. The main aspects are already in the model: “process costs”, “shrinkage”, “loading bay opportunity” and “recycling revenue”. To fine-tune and improve the model the advantage of
night deliveries (which are only possible in the consolidated supply chain) could be possible. These benefits, which are complex to quantify, include less congestion and thus travel-time.

Another aspect that could be included in future research is upstream consolidation. This means that, because of the WCC, suppliers can use bigger trucks for deliveries. This is currently also difficult to quantify because the centre is new and temporary. The upstream supply chain is not yet stabilized. The second way of fine tuning the evaluation model is to include more stakeholders. Interesting candidates would be the city of London (economic effect of reduced congestion caused by reduced truck movement) and government (who might subsidize these solutions because of environmental and welfare benefits).

Finally, the model could be improved or verified by including the haul processes in the evaluation. As seen in a previous section, the assumption that the total delivery distance is the same for both strategies is sensitive. This could be prevented when leaving the haul (supplier DC towards WCC) in the equation. This could either prove that the assumption is valid or provide a more accurate benefit evaluation. The analysis however shows that strategic placement, along major traffic arteries, is very beneficial for consolidation success.

9.3.2 Allocation improvement

Besides improving the evaluation model to improve the fairness of the allocation quality, the allocation itself could also be improved. There are two ways that could be used to influence the allocation directly.

1. Change the grouping of stakeholders

2. Change the allocation rule

As discussed in section 8.5.5, the grouping of stakeholders is a delicate matter as the Shapley allocation is sensitive to this. This is not an issue if all freight operators and retailers are separate groups — this method does not use simplification assumptions. The problem with this grouping method is that the number of stakeholders involved would not only create a gigantic game but also require too many permutations to compute the Shapley value. Currently four groups are used to represent the freight operators and three for the retailers, if these numbers would increase the allocation would become closer to the non-grouped version with each added group. This would be a method of improving the allocation.

Another way of improving allocation is selecting an allocation rule (or Shapley value variant) which is less sensitive to grouping. Ad-hoc (not requiring a game) allocation rules seem to fit this bill. Both these issues are left for further research.

9.3.3 Social sciences

In this model, rationality of stakeholders is assumed. Various social sciences imply that this need not be the case. Rationality implies that the perception of the benefit of the strategy is the same as the actual value calculated. An interesting future research topic could be just this: the perception of benefit for stakeholders.
Another topic in the realm of social sciences is "readiness to pay". A stakeholder / company can have many reasons why they do not want to pay for a consolidation scheme. One reason could be that it is not in their strategic best interest and another could be because of the risk of consolidation. Risks can include dependence on the center: "What happens when it burns down?". Also, the fact that a competitor runs the centre could turn-off potential participants.

Future research on the topics discussed above should be done before implementing any on these collaborative urban consolidation solutions: perception, readiness to pay and risk.

9.3.4 (Technological) Soft benefits

DHL tries to improve willingness of supply chain stakeholders to join a consolidation scheme by investigating additional soft benefits that they could offer. This section discussed some of these benefits and value added technologies.

Quality assurance could be offered. DHL, being a global logistics provider, will offer higher quality of service e.g. timeliness, standard processes, experienced logistics personnel. Temperature data & monitoring could be part of this. Another part of this can be a track & trace service which could increase retailers’ transparency on their supply chains.

Dynamic route planning which instantly incorporates traffic information — this could be an important soft benefit for participating freight operators.

Calculating the carbon footprint reduction of goods delivered. This could be a benefit for companies that market with "green" and "environmental" issues.

All in all, these benefits will never alone be enough to convince stakeholders to join the consolidation scheme. These soft benefits however could tip the scale if hard economic benefits are already proven. Research in the effects of these soft benefits on the perception and readiness to pay would be interesting topics for future research.
Bibliography


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# Appendix A

## List of Abbreviations

Table A.1: Abbreviations in the report

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSI</td>
<td>Customer Solutions &amp; Innovations</td>
</tr>
<tr>
<td>DC</td>
<td>Distribution centre</td>
</tr>
<tr>
<td>DP</td>
<td>Deutsche Post</td>
</tr>
<tr>
<td>DPDHL</td>
<td>Deutsche Post DHL</td>
</tr>
<tr>
<td>FO</td>
<td>Freight operator</td>
</tr>
<tr>
<td>FTL</td>
<td>Full Truck Load</td>
</tr>
<tr>
<td>LB</td>
<td>Loading bay</td>
</tr>
<tr>
<td>R</td>
<td>Retailer</td>
</tr>
<tr>
<td>UCC</td>
<td>Urban consolidation centre</td>
</tr>
<tr>
<td>WCC</td>
<td>Westfield Consolidation Centre</td>
</tr>
<tr>
<td>WG</td>
<td>Westfield Group</td>
</tr>
<tr>
<td>WSC</td>
<td>Westfield Stratford City or Westfield Shopping Centre</td>
</tr>
</tbody>
</table>
## Appendix B

### List of Variables

Table B.1: Variables in the evaluation model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_{haul}$</td>
<td>[%return]</td>
<td>Factor to incorporate multiple drops</td>
</tr>
<tr>
<td>$\gamma_{tr}$</td>
<td>[L/km]</td>
<td>Fuel consumption for truck type $tr$</td>
</tr>
<tr>
<td>$C(S)$</td>
<td>[£/month]</td>
<td>Costs of the supply chain</td>
</tr>
<tr>
<td>$C_{clerk}$</td>
<td>[£/hour]</td>
<td>Retailer employee cost</td>
</tr>
<tr>
<td>$C_{co2}$</td>
<td>[£/ton CO2 emission]</td>
<td>CO2 emission tax</td>
</tr>
<tr>
<td>$C_{conges}$</td>
<td>[£/trip]</td>
<td>Congestion charge</td>
</tr>
<tr>
<td>$C_{driver}$</td>
<td>[£/hour]</td>
<td>Driver costs</td>
</tr>
<tr>
<td>$C_{fuel}$</td>
<td>[£/L]</td>
<td>Fuel (diesel) price</td>
</tr>
<tr>
<td>$C^{F}_{last-metre}$</td>
<td>[£/month]</td>
<td>Fixed last-metre delivery costs</td>
</tr>
<tr>
<td>$C^{V}_{last-metre}$</td>
<td>[£/cage-eq]</td>
<td>Variable cost related to processing/transporting one cage from WSC loading bay to the store floor</td>
</tr>
<tr>
<td>$C_{operative}$</td>
<td>[£/hour]</td>
<td>Operative costs</td>
</tr>
<tr>
<td>$C_{opp}$</td>
<td>[£/loading bay]</td>
<td>Opportunity cost of a loading bay</td>
</tr>
<tr>
<td>$C_{product}$</td>
<td>[£]</td>
<td>Purchase value of product</td>
</tr>
<tr>
<td>$C_{recycling}$</td>
<td>[£/volume]</td>
<td>Price of recyclables per volume</td>
</tr>
<tr>
<td>$C_{rent, tr}$</td>
<td>[£/km]</td>
<td>Rent costs for truck type $tr$</td>
</tr>
<tr>
<td>$C^{T}_{seg}(S)$</td>
<td>[£/month]</td>
<td>Costs of the traditional supply chain for segment $seg$</td>
</tr>
</tbody>
</table>
Table B.2: Variables in the evaluation model (continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C^F_{wcc}$</td>
<td>£/month</td>
<td>Fixed consolidation centre costs</td>
</tr>
<tr>
<td>$C^V_{wcc}$</td>
<td>£/cage-eq</td>
<td>Variable cost related to processing/transporting one cage from WCC to the WSC loading bay</td>
</tr>
<tr>
<td>$D_{lm}$</td>
<td>[km]</td>
<td>Distance from WSC to WCC</td>
</tr>
<tr>
<td>$D_{wcc,j}$</td>
<td>[km]</td>
<td>Distance between WCC and the origin of the freight for $FO_j$</td>
</tr>
<tr>
<td>$D_{wsc,j}$</td>
<td>[km]</td>
<td>Distance between WSC and the origin of the freight for $FO_j$</td>
</tr>
<tr>
<td>$E_{tr}$</td>
<td>[kg CO2/km]</td>
<td>Emissions of haul with truck type $tr$</td>
</tr>
<tr>
<td>$FO$</td>
<td>[freight operators]</td>
<td>Collection of freight operators in $S$</td>
</tr>
<tr>
<td>$i$</td>
<td>Id</td>
<td>Retailer id</td>
</tr>
<tr>
<td>$j$</td>
<td>Id</td>
<td>Freight operator id</td>
</tr>
<tr>
<td>$k$</td>
<td>Id</td>
<td>Trip id</td>
</tr>
<tr>
<td>$lb^C$</td>
<td>[#loading bay]</td>
<td>Minimum loading bay requirement</td>
</tr>
<tr>
<td>$lb^T$</td>
<td>[#loading bay]</td>
<td>Traditional loading bay need</td>
</tr>
<tr>
<td>$R$</td>
<td>[retailers]</td>
<td>Collection of retailers in $S$</td>
</tr>
<tr>
<td>$R_i$</td>
<td></td>
<td>Retailer $i$</td>
</tr>
<tr>
<td>$S_{%_seg}$</td>
<td>[%volume lost]</td>
<td>Shrinkage % of volume for segment $seg$</td>
</tr>
<tr>
<td>$SEG$</td>
<td>[segments]</td>
<td>Collection of segments</td>
</tr>
<tr>
<td>$seg$</td>
<td>[segment]</td>
<td>Segment / high-level process id</td>
</tr>
<tr>
<td>$T$</td>
<td>[trips]</td>
<td>Collection of all trips</td>
</tr>
<tr>
<td>$T_{out}$</td>
<td>[trips]</td>
<td>Total trips on the last-mile (arriving at the WSC)</td>
</tr>
<tr>
<td>$t_{delivery}$</td>
<td>[hours]</td>
<td>Time it takes to handle formalities at the loading bay</td>
</tr>
<tr>
<td>$t_{haul}$</td>
<td>[hours]</td>
<td>Driving time</td>
</tr>
<tr>
<td>$T_{j,k}$</td>
<td>[trip]</td>
<td>Trip by $FO_j$ caring $V^F_{j,k}O$ in truck type $Tr_{j,k}$</td>
</tr>
<tr>
<td>$t_{load}$</td>
<td>[hours/cage-eq]</td>
<td>Loading time</td>
</tr>
<tr>
<td>$t_{unload}$</td>
<td>[hours/cage-eq]</td>
<td>Unloading time</td>
</tr>
</tbody>
</table>
Table B.3: Variables in the evaluation model (continued)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{\text{wait}}$</td>
<td>[hours/cage-eq]</td>
<td>Waiting time</td>
</tr>
<tr>
<td>$t_{\text{walk},i}$</td>
<td>[hours]</td>
<td>Time it takes to walk to store $i$ from loading bay</td>
</tr>
<tr>
<td>$T_j$</td>
<td>[trips]</td>
<td>Collection of trips by $FO_j$</td>
</tr>
<tr>
<td>$tr$</td>
<td>[trucktype]</td>
<td>Trucktype</td>
</tr>
<tr>
<td>$tr_{j,k}$</td>
<td>[truck type]</td>
<td>Truck type of trip $k$ by $FO_j$</td>
</tr>
<tr>
<td>$v_{\text{haul}}$</td>
<td>[km/hour]</td>
<td>Average speed</td>
</tr>
<tr>
<td>$V^{FO}_{j,k}$</td>
<td>[cage-eq]</td>
<td>Volume transported in trip $k$ by $FO_j$</td>
</tr>
<tr>
<td>$V_i$</td>
<td>[cage-eq]</td>
<td>Volume destined for store $i$</td>
</tr>
<tr>
<td>$V_N$</td>
<td>[cage-eq/month]</td>
<td>Monthly total volume in system</td>
</tr>
<tr>
<td>$V^{FO}_S$</td>
<td>[cage-eq]</td>
<td>Volume from freight operators $S$</td>
</tr>
<tr>
<td>$V^R_S$</td>
<td>[cage-eq]</td>
<td>Volume destined for retailers in $S$</td>
</tr>
<tr>
<td>$W^%_e$</td>
<td>[%cardboard/volume]</td>
<td>%Recycling return per volume</td>
</tr>
<tr>
<td>$WG$</td>
<td></td>
<td>Westfield Group</td>
</tr>
</tbody>
</table>
Appendix C

Extra allocation rules

C.1 Concept of the Core

The core is intuitive — it can be seen as the set of all feasible pay-offs such that no player or coalition of players can improve pay-off by acting for themselves or in another coalition. This implies that: once an agreement has been reached that is in the core, no individual player or player coalition could gain by regrouping. This concept was first discussed by (Gillies, 1959).

The core \( \text{Core}(N,v) \) of a game is therefore defined as:

\[
\text{Core}(N,v) = \{ x \in \mathbb{R}^N: \sum_{i \in N} x_i = v(N); \sum_{i \in S} x_i \leq v(S), \forall S \subseteq N \}
\]

For a convex game the core is always non-empty (Scarf, 1967). It can be shown that allocation vectors that are in the core have the properties efficiency (all gain is distributed) and individual rationality.

C.2 Nucleolus

A conceptually different solution concept for TU games is the Nucleolus. The Nucleolus is a pay-off vector which indexes a coalition’s attitude towards any proposed pay-off allocation by the difference between the coalition’s guaranteed pay-off and the pay-off it receives under the newly suggested proposal. The Nucleolus minimizes this difference (called the excess). (Schmeidler, 1969)

Given two pay-off vectors, (Schmeidler, 1969) describes a way to choose the more acceptable of the two. Therefore we define the excess of \( S \) in respect to a payoff vector. The excess is defined as: \( e(x,S) = v(S) - x(S), S \subset N \). This is a measure of the coalition \( S \)'s attitude towards the pay-off vector \( x \). The coalition which is most against a suggested pay-off vector \( x \) is the one with the greatest excess. The suggested vector \( x \) is worst then \( y \) if: \[
\max\{v(S) - x(S) | S \subset N\} > \max\{v(S) - y(S) | S \subset N\}.
\]

Let \( \theta(x) \) be the vector whose components are the excess values, arranged in decreasing order. If all vectors \( \theta(x) \) are ordered (so that \( \theta(x) \leq \theta(y) \) ) means that either \( x = y \) or for the first component \( k \) in which they differ, \( \theta_k(x) \leq \theta_k(y) \), this means all different pay-off vectors in the game are ordered starting with the pay-off vector with the least excess. The Nucleolus is the first imputation set of this ordered set (because this vector has the minimal excess and thus minimal dissatisfaction). The nucleolus of game \( (N,v) \) can be formally written as:

\[
\text{nucleolus}(N,v) = \{ x \in X | \theta(x) \leq_{\text{lex}} \theta(y), \forall y \in X \}
\]

The nucleolus has the properties: efficiency, symmetry, zero allocation to zero players and individual rationality.

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C.3 \( \tau \)-value

A solution concept suggested by Tijs (1981) and Tijs and Driessen (1986) is the \( \tau \)-value (often known as the compromise value). This concept compares a player’s minimum rights pay-off with their utopia payoff (ideal case). The value \( \tau \) is an unique solution which is a compromise between these two values.

The compromise value is based on the maximum \( M_i(v) \) and minimum \( m_i(v) \) amount which each player \( i \) can reasonably claim. The maximum amount (utopia amount) for player \( i \) is the total value minus the value other players can achieve without player \( i \): \( M_i(v) = v(N) - v(N\setminus\{i\}) \) and the minimal amount can be seen as the amount which player \( i \) gets when all other players get their utopia value. This is defined as:

\[
m_i(v) = \max_{i \in S}(v(S) - \sum_{j \in S, i \neq j} M_j(v))
\]

For this solution concept the \( \tau \)-value lies between the minimal and the maximum value and is defined as:

\[
\tau(v) = \alpha M(v) + (1 - \alpha)m(v)
\]

With \( \alpha \in [0, 1] \) and such that the sum of all allocations is the total value of the grand coalition (hence: efficient). The \( \tau \)-value is only defined for a sub-class of games: quasi-balanced games. A game is called quasi-balanced if two conditions hold: \( m(v) \leq M(v) \) and \( \sum_{i \in N} m_i(v) \leq v(N) \leq \sum_{i \in N} M_i(v) \).

If the compromise value is defined it has the properties: efficiency, symmetry, zero pay-offs to zero players, individual rationality.
APPENDIX D

Case Selection

Before writing this thesis a case was needed to be selected in order to complete the problem definition. DHL is running several consolidation efforts in the UK — the focus area of this research. In this section the three centres that were considered are briefly discussed after which the method of selection is explained. The selected case, the Westfield Stratford City consolidation centre, is extensively discussed in the next section.

The three cases considered are:

- Westfield Stratford City consolidation centre
- Bath / Bristol consolidation centre
- Heathrow consolidation centre

The Westfield Stratford City consolidation centre (WCC in short) is a consolidation centre that serves a single shopping mall. The consolidation centre is currently financed by the retailers and supported (by open book agreement) by the Westfield Group, the shopping centre owner. The reason for starting this centre is the security risk posed by the nearby Olympic Games. More information can be found in chapter 4.2.

The Bath Bristol Consolidation Centre (BBCC) is located approximately 12km from Bristol and approximately 35km from Bath. BBCC currently services 80 retailers in Bristol and 25 retailers in Bath. Various retailer types use the consolidation services ranging from electronic stores to soap and fashion shops.

Bath is an UNESCO world heritage site and Bristol has a large historic centre. For this reason the councils of both cities want to reduce truck movement in inner-city and reduce the environmental impact of freight transportation. Bath currently receives an EU grant from CIVITAS for the funding of this project covering the fixed cost of the centre — Bristol received a similar subsidy in previous years (not any more). The aim of the grant is to reduce the environmental impact of freight deliveries to retailers. Fifty percent of the fixed centre costs are funded by each of the municipalities. For each cage / pallet delivered the retailers and municipalities also pay a fee. The centre experiences a low utilization due to a low percentage of retailers participating. Also suppliers/freight haulers are not involved in the scheme financing.

Heathrow airport is one of the largest airports in Europe and is owned and operated by the British Aircraft Authority (BAA). The five terminals all have their own retail and food outlets. For the purpose of this section each terminal can be separated into two parts: before (landside) and after (airside) security/customs.

For obvious security reasons everything that enters the airside part of the terminal need to be subjected to thorough security checks. These security checks are done at the Heathrow Consolidation Centre (HCC) — it is compulsory for airside retailers to use this facility, for landside retailers this
is not the case. This centre is set up by BAA for two reasons: to security screen all incoming goods (both ambient and chilled) and to minimize truck movements on the notoriously congested roads in the vicinity of Heathrow. The HCC is located approximate 10 kilometres from a terminal (on average).

DHL operates the consolidation centre for BAA by means of an open book agreement in which the budgets are agreed upon beforehand and any additional (unforeseen) costs must be cleared with BAA before spending. Some expenses are subject to a range due to volatility (e.g. fuel prices). Open book also means that BAA receives all profit of centre operations. For running the operation DHL receives a fixed 8.5% of this centre profit as a management fee. Retailers also contribute to the scheme by a percentage of the rent for the deliveries via the HCC.

For the selection of the case for analysis, four criteria are used: the availability of reliable data, the willingness of the centre management, the size of the operation and generalizability.

Table D.1: Selection Criteria by case (++ = highly suitable; – = unsuitable)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>WCC</th>
<th>BBCC</th>
<th>HCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of data</td>
<td>+</td>
<td>+/-</td>
<td>++</td>
</tr>
<tr>
<td>Willingness of centre management</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Operation size</td>
<td>++</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>Generalizability</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

When assessing the cases in table D.1 it becomes apparent that the choice should be either WCC or HCC. All possibilities are briefly discussed in the sections below.

The Heathrow case could be chosen on the basis of data availability — available data goes back several years. However the difference with Westfield is the high security level of the operation which makes it less applicable to general situations. The high security level increases the added handling costs of the consolidation operation significantly — this need not be so in a more general, simple, setting.

The Bath and Bristol case is less applicable because of the low uptake — and therefore small size of the operation. It is believed by DHL that this situation cannot be economically viable without high subsidy and therefore it is not suitable for a collaborative cost sharing solution as the solution stability is highly sensitive to changes is subsidy. There is a lot of data available due to the monthly reports required by the EU and the municipalities. However the data available is inaccurate due to the estimation of certain parameters and the centre’s involvement with non-consolidated freight (which are included in the data).

This leaves the Westfield operation, the WCC does not have as much data readily available (because the centre is relatively new) but the setting could be of interest to shopping malls and even town centres making the analysis useable in other settings. On top of that the management and the shopping centre owner are interested in the outcomes of this study and are committed to help.
Appendix E

Consolidated sub-coalitions

Four different coalition types are found when considering the high-level processes and their application conditions — combined with the single type coalitions the grand coalition, these coalition scenarios will define the game. The findings will be stated in a table E.1 at the end of this section. The seven scenarios are:

1. Only Freight operators(or all) in the coalition: $FO \cap S \neq \emptyset$, $R \cap S = \emptyset$, $WG \notin S$.
2. Only Retailers(or all) in the coalition: $R \cap S \neq \emptyset$, $FO \cap S = \emptyset$, $WG \notin S$.
3. Only Westfield Group in the coalition: $FO \cap S = \emptyset, R \cap S = \emptyset$, $WG \in S$.
4. Freight operator (or all) and the Westfield Group in the coalition: $FO \cap S \neq \emptyset$, $R \cap S = q\emptyset$, $WG \in S$.
5. Retailer (or all) and the Westfield Group in the coalition: $FO \cap S = \emptyset, R \cap S \neq \emptyset$, $WG \in S$.
6. Retailer (or all) and a freight operator (or all) in the coalition: $FO \cap S \neq \emptyset$, $R \cap S \neq \emptyset$, $WG \notin S$.
7. All player types in the coalition: $FO \cap S \neq \emptyset$, $R \cap S \neq \emptyset$, $WG \in S$.

For all these scenarios the high-level processes are mapped with the help of the explanations in chapter 7.5.2.3. Table E.1 can help in the understanding of when consolidation is possible. That consolidation is possible does not mean freight is always consolidated in that (sub) coalition. The requirement of consolidating a process is twofold: (1) it is possible to consolidate the process and (2) the process is cheaper consolidated than in the traditional manner. In the table, $T$ means that only traditional deliveries are possible, $C$ means that consolidation is possible and $-$ means that the process is not relevant for the coalition.
Table E.1: Overview of processes that are relevant and can be consolidated

<table>
<thead>
<tr>
<th>Coalition</th>
<th>Last-mile Process</th>
<th>Loading Bay</th>
<th>Last-metre Process</th>
<th>Recycling Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>$FO \cap S \neq \emptyset, R \cap S = \emptyset, WG \notin S$</td>
<td>T</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$R \cap S \neq \emptyset, FO \cap S = \emptyset, WG \notin S$</td>
<td>-</td>
<td>-</td>
<td>T</td>
<td>-</td>
</tr>
<tr>
<td>$FO \cap S = \emptyset, R \cap S = \emptyset, WG \in S$</td>
<td>-</td>
<td>T</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$FO \cap S \neq \emptyset, R \cap S = \emptyset, WG \in S$</td>
<td>C</td>
<td>C</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$FO \cap S = \emptyset, R \cap S \neq \emptyset, WG \in S$</td>
<td>-</td>
<td>T</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>$FO \cap S \neq \emptyset, R \cap S \neq \emptyset, WG \notin S$</td>
<td>C</td>
<td>-</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>$FO \cap S \neq \emptyset, R \cap S \neq \emptyset, WG \notin S$</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>
APPENDIX F

Internal data and parameter selection

In this appendix a list of all required internal variables is given. Besides linking each variable to a data source, the value is given for the variable in the base case situation.

Table F.1: Internal data in the evaluation model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source</th>
<th>Base-value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C^F_{last-metre}$</td>
<td>DHL Financials</td>
<td>40,326</td>
<td>£/two month</td>
</tr>
<tr>
<td>$C^V_{last-metre}$</td>
<td>DHL Financials</td>
<td>10.70</td>
<td>£/cage-eq-hour</td>
</tr>
<tr>
<td>$C_{opp}$</td>
<td>WG Financials</td>
<td>6,000</td>
<td>£/two month</td>
</tr>
<tr>
<td>$C^F_{wcc}$</td>
<td>DHL Financials</td>
<td>176,709</td>
<td>£/two month</td>
</tr>
<tr>
<td>$C^V_{wcc}$</td>
<td>DHL Financials</td>
<td>6</td>
<td>£/cage-eq</td>
</tr>
<tr>
<td>$D_{lm}$</td>
<td>Styleflow</td>
<td>12.8</td>
<td>km</td>
</tr>
<tr>
<td>$V_{haul}$</td>
<td>Styleflow</td>
<td>30</td>
<td>km/hour</td>
</tr>
<tr>
<td>$T_{delivery}$</td>
<td>Time/Motion</td>
<td>4</td>
<td>mininute/cage-eq</td>
</tr>
<tr>
<td>$T_{unload}$</td>
<td>Time/Motion</td>
<td>1.33</td>
<td>mininute/cage-eq</td>
</tr>
<tr>
<td>$T_{wait}$</td>
<td>Styleflow</td>
<td>15</td>
<td>mininute</td>
</tr>
</tbody>
</table>

The centre fixed costs (both for last-mile and last-metre) are the bare minimal costs needed to operate the centre. As explained before, this includes (among others) a truck, small centre space, equipment, cages, security and management. Costs for running a larger centre are aggregated into the variable costs.

The grouping of retailers (chapter 8.2.3) requires to redefine $T_{walk,i}$ to $T_{walk,z}$. The weighted average (by volume) for each of the three zones is shown in the table below.

Table F.2: Weighted average two-way walk time to stores in zone $z$

<table>
<thead>
<tr>
<th>Zone</th>
<th>$T_{walk,z}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.12hours</td>
</tr>
<tr>
<td>2</td>
<td>0.26hours</td>
</tr>
<tr>
<td>3</td>
<td>0.39hours</td>
</tr>
</tbody>
</table>
The input parameters a list of database variables is given in table F.3 — these differ for each stakeholder and coalition.

Table F.3: Internal database in the evaluation model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{j,k}$</td>
<td>Styleflow</td>
</tr>
<tr>
<td>$Tr_{j,k}$</td>
<td>Styleflow</td>
</tr>
<tr>
<td>$V^R_i$</td>
<td>Styleflow</td>
</tr>
<tr>
<td>$V^{FO}_{j,k}$</td>
<td>Styleflow</td>
</tr>
<tr>
<td>$T_j$</td>
<td>Styleflow</td>
</tr>
<tr>
<td>$V^R_S$</td>
<td>Styleflow</td>
</tr>
<tr>
<td>$V^{FO}_S$</td>
<td>Styleflow</td>
</tr>
<tr>
<td>$V$</td>
<td>Styleflow</td>
</tr>
</tbody>
</table>
APPENDIX G

External data and parameter selection

In this appendix a list of all required External variables is given. Besides linking each variable to a data source, the value is given for the variable in the base case situation.

Table G.1: External data in the evaluation model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source</th>
<th>Base-case</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{fuel}$</td>
<td>DHL supply chain</td>
<td>1.5</td>
<td>£/L</td>
</tr>
<tr>
<td>$C_{rent.tr}$</td>
<td>DHL supply chain</td>
<td>see table G.2</td>
<td></td>
</tr>
<tr>
<td>$C_{recycle}$</td>
<td>Westfield Group</td>
<td>0.5</td>
<td>£/cage-eq</td>
</tr>
<tr>
<td>$C_{co2}$</td>
<td>estimate</td>
<td>0.1</td>
<td>£/ton CO$_2$</td>
</tr>
<tr>
<td>$C_{conges}$</td>
<td>DHL supply chain</td>
<td>0</td>
<td>£/trip</td>
</tr>
<tr>
<td>$C_{driver}$</td>
<td>DHL supply chain</td>
<td>14.06</td>
<td>£/hour</td>
</tr>
<tr>
<td>$C_{operative}$</td>
<td>DHL supply chain</td>
<td>12</td>
<td>£/hour</td>
</tr>
<tr>
<td>$C_{clerk}$</td>
<td>estimate</td>
<td>12</td>
<td>£/hour</td>
</tr>
<tr>
<td>$E_{tr}$</td>
<td>DHL supply chain</td>
<td>see table G.2</td>
<td></td>
</tr>
<tr>
<td>$T_{load}$</td>
<td>Time/Motion</td>
<td>1.33</td>
<td>minute/cage-eq</td>
</tr>
<tr>
<td>$\alpha_{haul}$</td>
<td>DHL supply chain</td>
<td>1</td>
<td>factor</td>
</tr>
<tr>
<td>$\gamma_{tr}$</td>
<td>DHL supply chain</td>
<td>see table G.2</td>
<td></td>
</tr>
<tr>
<td>$S_{%<em>{seg}} \cdot C</em>{product}$</td>
<td>estimate</td>
<td>0.20</td>
<td>% product lost</td>
</tr>
<tr>
<td>$S_{%<em>{seg}} \cdot C</em>{product}$</td>
<td>estimate</td>
<td>0.15</td>
<td>% product lost</td>
</tr>
</tbody>
</table>
For the truck variables which depend on truck type, table G.2 shows the variables used for the four truck type groups defined in chapter 8.2.3.

### Table G.2: Truck running cost estimates

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Van</th>
<th>7.5T</th>
<th>17.5T</th>
<th>Articulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{rent.tr}$</td>
<td>£/km</td>
<td>0.243</td>
<td>0.29</td>
<td>0.475</td>
<td>0.65</td>
</tr>
<tr>
<td>$\gamma_{tr}$</td>
<td>L/km</td>
<td>0.21</td>
<td>0.26</td>
<td>0.34</td>
<td>0.59</td>
</tr>
<tr>
<td>$E_{tr}$</td>
<td>g CO$_2$/km</td>
<td>185</td>
<td>268</td>
<td>311</td>
<td>675</td>
</tr>
</tbody>
</table>
APPENDIX H

Player grouping details

H.1 Freight operator grouping

In this appendix there is more detail about the groups created to reduce the number of stakeholders. As explained in the main document the freight operators, or more precise "trips", are grouped by truck type. This results in four groups: Van, 7.5T truck, 17.5T truck and Articulated vehicle. Some metrics are given in table H.1.

Table H.1: Metrics per truck type

<table>
<thead>
<tr>
<th>Truck type</th>
<th>Trips</th>
<th>Volume (cage-eq)</th>
<th>Volume / Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Van</td>
<td>1,836</td>
<td>15,895</td>
<td>5</td>
</tr>
<tr>
<td>7.5tn</td>
<td>1,144</td>
<td>21,733</td>
<td>9</td>
</tr>
<tr>
<td>17.5tn</td>
<td>2,313</td>
<td>44,494</td>
<td>9</td>
</tr>
<tr>
<td>Articulated Vehicle</td>
<td>131</td>
<td>6,911</td>
<td>23</td>
</tr>
</tbody>
</table>

With these trucks it is important to know how many contain freight for non-participating retailers. In the model this is called $\kappa \cdot T_S$. This obviously depends on the truck type and the zones participating. That gives a matrix that is shown in table H.2.

Table H.2: Extra trips per truck type per zone

<table>
<thead>
<tr>
<th>Truck</th>
<th>Zone 1</th>
<th>Zone 2</th>
<th>Zone 3</th>
<th>Zone 1 &amp; 2</th>
<th>Zone 1 &amp; 3</th>
<th>Zone 2 &amp; 3</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Van</td>
<td>1,449</td>
<td>1,259</td>
<td>1,124</td>
<td>944</td>
<td>825</td>
<td>586</td>
<td>0</td>
</tr>
<tr>
<td>7.5tn</td>
<td>867</td>
<td>881</td>
<td>750</td>
<td>640</td>
<td>489</td>
<td>481</td>
<td>0</td>
</tr>
<tr>
<td>17.5tn</td>
<td>1,689</td>
<td>1,587</td>
<td>1,506</td>
<td>1,033</td>
<td>976</td>
<td>744</td>
<td>0</td>
</tr>
<tr>
<td>Arctic</td>
<td>82</td>
<td>108</td>
<td>122</td>
<td>58</td>
<td>71</td>
<td>92</td>
<td>0</td>
</tr>
</tbody>
</table>

H.2 Retailer grouping

The retailer grouping is done with a limited time motion study. The walk times for various retailers are plotted on a map to determine shopping centre zones. On the next page. In table H.3 the volume per zone is given.
Table H.3: Metrics per retailer Zone

<table>
<thead>
<tr>
<th>Truck type</th>
<th>Volume (cage-eq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>13,523</td>
</tr>
<tr>
<td>Zone 2</td>
<td>13,811</td>
</tr>
<tr>
<td>Zone 3</td>
<td>13,689</td>
</tr>
</tbody>
</table>

Fig. H.1: Retailer zones for lower ground and ground floor
Fig. H.2: Retailer zones for first and second floor
APPENDIX I

Example Game

I.1 Example: Situation

A simplified situation with two freight operators, two retailers and the Westfield group is used for this example. Each freight operator uses one truck type and freight travels the same distance to the WSC (even if it is consolidated) — this means the cost functions are the same and that the haul aspect of the journey can be ignored. The retailers are a bit different as they are located 1 and 2 time units away from the loading bay (relevant for the last-metre). Also, for this situation it is assumed that the Westfield Group requires one loading bay for each arrival. All volume units delivered by one truck are single cage-equivalents. The characteristics of the players in this game are:

<table>
<thead>
<tr>
<th>Player</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>FO₁</td>
<td>$T_{1,1} = {V_{1,1,1}, V_{1,1,2}}, T_{1,2} = {V_{1,2,1}}, C_{\text{last-mile},1} = 2$</td>
</tr>
<tr>
<td>FO₂</td>
<td>$T_{2,1} = {V_{2,1,1}}, T_{2,2} = {V_{2,2,2}}, C_{\text{last-mile},2} = 1.5$</td>
</tr>
<tr>
<td>R₁</td>
<td>$t_{\text{walk},1} = 1$</td>
</tr>
<tr>
<td>R₂</td>
<td>$t_{\text{walk},2} = 2$</td>
</tr>
<tr>
<td>WG</td>
<td>$lb^C = 2, lb = 4$</td>
</tr>
</tbody>
</table>

I.2 Example: Parameters

This simplified situation uses simplified cost functions only using a variable and fixed aspect of the 5 high-level processes. As said before the haul process is not considered as: $D_{\text{wsc}} = D_{\text{wcc}} + D_{\text{lm}}$. In the following table the costs for the traditional and for the consolidated supply chain are given in a generic manner — not taking into account when something is possible and what volume/trips use the process. In this table some functions require some explanation. For the last-mile for instance the consolidation centre has a low variable cost per cage-eq (0.5) but has 5 fixed costs. The loading bay opportunity cost is 2 per loading bay and the number of loading bays needed is calculated by total arriving trips. Shrinkage for last-mile depends on the volume consolidated (0.5%) or using the traditional method (1%). The last-metre consolidation speeds up the process by half (0.5) but has 1 fixed costs. Shrinkage for last-metre is 1% for the traditional volume and 0.5% for consolidated volume. Recycling revenue is 5% of the relevant volume.
For the grand coalition all high-level consolidation processes can be used to the full extent. In table I.3 the cost of the various high-level processes are given for the consolidated and the traditional supply chain strategy. It can be seen in the table that for this example consolidation is positive for the grand consolidation throughout the processes. The supply chain would be approximately 25% cheaper if all players would collaborate.

### I.3 Example: Grand Coalition

In the next sections some characteristic sub-coalitions are discussed. It is not chosen to display all sub-coalitions as this would not provide additional insight into the workings of the model.

### I.4 Example: Sub-coalitions

This section is about the costs in sub-coalitions. For this analysis a sample number of sub-coalitions is used — the sample is based on the different scenarios explained in section 7.5. Table I.4 is a list of traditional supply chain costs for various sub-coalitions. It can be seen that traditional costs are the linear combination of costs that each player endures — as no collaboration is possible.

Table I.5 is a list of consolidated supply chain costs for various sub-coalitions. These coalition costs are not as straightforward as in the traditional supply chain. Single player type coalitions do not allow for collaboration, hence the costs are equal to traditional delivery costs. An overview of when consolidation is possible is given in appendix E.
Table I.4: Traditional coalition costs in example

<table>
<thead>
<tr>
<th>Coalition</th>
<th>Last-mile</th>
<th>Last-metre</th>
<th>Recycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>FO1</td>
<td>4.03</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>R1</td>
<td>0.00</td>
<td>3.03</td>
<td>0.00</td>
</tr>
<tr>
<td>WG</td>
<td>8.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>FO1, R1</td>
<td>4.03</td>
<td>3.03</td>
<td>0.00</td>
</tr>
<tr>
<td>FO1, WG</td>
<td>12.03</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>R1, WG</td>
<td>8.00</td>
<td>3.03</td>
<td>0.00</td>
</tr>
<tr>
<td>FO1, R1, R2</td>
<td>4.03</td>
<td>7.05</td>
<td>0.00</td>
</tr>
<tr>
<td>FO1, R1, WG</td>
<td>12.03</td>
<td>3.03</td>
<td>0.00</td>
</tr>
<tr>
<td>N</td>
<td>15.05</td>
<td>7.05</td>
<td>0.00</td>
</tr>
</tbody>
</table>

The most complex sub-coalition to determine is FO1, R1 — this is because consolidation volumes are intersections of the volume sets of FO1 and R1. The additional trips needed to deliver non-consolidated freight to the WSC also adds complexity. In this case the consolidated volume on the last-mile and last-metre is: \( V_{1,1,1}, V_{1,2,1} \). This requires an extra last-mile trip because \( T_{1,1} \) also carries volume for a non-participating retailer \( (R_2) \). Because the Westfield group does not participate the loading bay opportunity aspect is excluded from the last-mile cost. Shrinkage in the last-mile is also partially consolidated — 2 units are consolidated (thus 0.5% shrinkage) and 1 unit follows that traditional path (thus 0.5% shrinkage).

The last-metre is not completely consolidated as a non-participating freight operator FO2 also delivers to R1 — this requires a pickup by the retailer which is less efficient (and 1% shrinkage). Costs of FO1, R1, R2 are determined in a similar way, only now they do not require extra last-mile trips as all retailers are collaborating.

The other sub-coalitions do not have the added complexity of added last-mile trips or mixed consolidation / traditional last-metre deliveries. The Westfield Group allows the decoupling of the last-mile and last-metre process. That means: the processes can be fully consolidated if the involved players join with the Westfield Group. Adding the Westfield Group also adds Recycling revenue and potentially reduced loading bay opportunity cost.

The table I.5, the single asterisk (*) represents a strange shift: last-mile costs are lower with more players. This is because consolidating FO2’s trips reduces the loading bay opportunity cost more than it adds variable WCC costs, hence a net costs drop. In the table the double asterisk (**) the difference in cost can be explained by the fact that singleton coalition \( (R1) \) cannot consolidate the last-metre process and FO1, R1 can (partially) consolidate the last-metre process.

I.5 Example: Benefit game

Using the benefit game definition from section 7.3, the benefit game from table I.6 is obtained. It is obvious that more benefit is obtained in bigger coalitions (because more can be consolidated).
Table I.5: Consolidated coalition costs in example

<table>
<thead>
<tr>
<th>Coalition</th>
<th>Last-mile</th>
<th>Last-metre</th>
<th>Recycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>FO1</td>
<td>4.03</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>R1</td>
<td>0.00</td>
<td>3.03**</td>
<td>0.00</td>
</tr>
<tr>
<td>WG</td>
<td>8.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>FO1, R1</td>
<td>8.02</td>
<td>3.52**</td>
<td>0.00</td>
</tr>
<tr>
<td>FO1, WG</td>
<td>12.53</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>R1, WG</td>
<td>8.00</td>
<td>3.27</td>
<td>-0.15</td>
</tr>
<tr>
<td>FO1, R1, R2</td>
<td>6.52</td>
<td>7.04</td>
<td>0.00</td>
</tr>
<tr>
<td>FO1, R1, WG</td>
<td>12.52*</td>
<td>3.27</td>
<td>-0.15</td>
</tr>
<tr>
<td>N</td>
<td>11.53*</td>
<td>6.28</td>
<td>-0.25</td>
</tr>
</tbody>
</table>

By definition the game is superadditive (due to the super additivity cover) and thus the Shapley value is individually rational and in the core.

Table I.6: Obtainable benefits of sub-coalitions in example

<table>
<thead>
<tr>
<th>Coalition</th>
<th>Last-mile</th>
<th>Last-metre</th>
<th>Recycling</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>FO1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>R1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>WG</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>FO1, R1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>FO1, WG</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>R1, WG</td>
<td>0.00</td>
<td>0.00</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>FO1, R1, R2</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>FO1, R1, WG</td>
<td>0.00</td>
<td>0.00</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>N</td>
<td>3.53</td>
<td>0.77</td>
<td>0.25</td>
<td>4.55</td>
</tr>
</tbody>
</table>

I.6 Example: Shapley Allocation

For this example the Shapley value is computed using the benefit game. It can be seen that the more expensive FO1 obtains a higher benefit of consolidation than the cheaper FO2. It can be seen that the allocation to the retailers is about the same. This is because the benefit obtained by retailers is relatively small and they are important to support the freight operators consolidation effort — the high-level process "last-mile" has the most benefit.
Table I.7: Shapley allocation in example

<table>
<thead>
<tr>
<th>Coalition</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FO1</td>
<td>1.2</td>
</tr>
<tr>
<td>FO2</td>
<td>1.2</td>
</tr>
<tr>
<td>R1</td>
<td>0.37</td>
</tr>
<tr>
<td>R2</td>
<td>0.35</td>
</tr>
<tr>
<td>WG</td>
<td>1.4</td>
</tr>
</tbody>
</table>

I.7 Example: Transfer Payments

Using the traditional costs, the consolidated costs and the benefits the transfer payments can be determined. These are the payments between players so that all players pay what they should based on the benefit allocation. A player should pay traditional costs minus benefit - the difference between this and the actual consolidation costs for the player is what they should pay/receive. This is shown in table I.8. The total consolidation cost needs to be paid for by the players in that segment. For this example half of last-mile consolidation costs are allocated to freight operators and half of the last-metre consolidation costs are allocation to retailers.

Table I.8: Transfer payments in example

<table>
<thead>
<tr>
<th></th>
<th>FO1</th>
<th>FO2</th>
<th>R1</th>
<th>R2</th>
<th>WG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Costs</td>
<td>4.03</td>
<td>3.02</td>
<td>3.03</td>
<td>4.02</td>
<td>8.00</td>
</tr>
<tr>
<td>Allocated benefit</td>
<td>1.21</td>
<td>1.21</td>
<td>0.37</td>
<td>0.35</td>
<td>1.40</td>
</tr>
<tr>
<td>Consolidation Costs</td>
<td>3.76</td>
<td>3.76</td>
<td>3.14</td>
<td>3.14</td>
<td>3.75</td>
</tr>
<tr>
<td>To Receive</td>
<td>0.95</td>
<td>1.95</td>
<td>0.48</td>
<td>-0.53</td>
<td>-2.85</td>
</tr>
</tbody>
</table>

I.8 Example: Sensitivity of trip grouping

In the simplified example the effect of grouping is examined. This is done by shifting trips from FO1 to FO2 (and reverse). This keeps the total benefit, obtained by the grand coalition N, constant. The analysis is done to determine if the Shapley value can be used when grouping trips and retailers — grouping is done in the case of the WSC. The simplified example allows for a more intuitive shift in groups.

In figure I.1, five scenarios are shown to illustrate the changes in Shapley value. Two important conclusions can be drawn from this: (1) Shifts in freight operator grouping does not significantly effect retailer allocation (the effects are only minor) and (2) The Westfield Group becomes significantly larger if the grouping is changes. The second conclusion can be explained by the way the benefit game is formulated and how the Shapley value is calculated. In the base situation the allocation of FO1 and FO2 is about equal. Indicating both players are just as important in
obtaining benefit, this suggests that both players are needed for last-mile consolidation to work. Once one group gets bigger, the other player does not have enough trips/volume to overcome the high WCC fixed costs (on its own). This means: less sub-coalitions which will choose for last-mile consolidation and thus the Westfield Group is relatively more important in the sub-coalitions that do use last-mile consolidation — hence: $WG$ gets more allocation and the freight operators (as a whole) get less.

This will also work the other way around. If the $FO$ group is split into more players, more sub-coalitions will be choosing last-mile consolidation. This means the $WG$ will get less allocation by the Shapley value.

Fig. I.1: Sensitivity to Shapley allocation to group shifts in example
Appendix J

Extra sensitivity analysis

J.1 Changes in variable consolidation costs

If the variable consolidation costs increases, the benefit of consolidation will decrease for the high-level process the cost belongs to. This is illustrated in figure J.1. The variable cost is driven by volume in both situations. As discussed in section 8.2.4, an increase in variable centre cost can mean that the game is no longer super additive. This is the case if the variable cost of adding one volume unit is higher than in the consolidated situation. If the WCC variable cost increases to approximately £6.50 (+10%), the articulated vehicles have lower variable cost in the traditional supply chain, hence: not super additive. Similarly if the last-metre variable cost increases to approximately £17.5 (+60%), Zone 3 has a lower variable cost in the traditional supply chain.

It can be seen in figure J.1 that for last-metre an increase of that magnitude does not effect superadditivity because the traditional supply chain is cheaper. For the last-mile segment only a small increase is needed. In the Shapley allocation within the truck group, articulated vehicles get a negative allocation around £6.5/cage-eq until £7/cage-eq (after this amount the last-mile process uses the traditional supply chain. Negative allocations are not individually rational. The Shapley allocation for player types can be found in figure J.2.

J.2 Loading bay opportunity costs

This sections discusses changes in loading bay opportunity costs. When examining the benefit graph it becomes clear that loading bay opportunity is an integral part of last-mile consolidation success. If everything else is kept equal the minimal loading bay opportunity should be £4800(per
two months). Of course higher opportunity costs (which could be the case in new shopping centres), increase the last-mile benefit substantially. Increases in this opportunity effect only the Westfield Group and the trucks.

J.2.1 Shrinkage effect

The effects of shrinkage/breakage reduction is examined in this section. This is done by increasing the total shrinkage of the last-mile and the traditional last-metre — this is not done separately because this would yield the same effect as examined several times in previous sections. When increasing the shrinkage for the entire supply chain it is expected that the Shapley allocation will linearly change for all players (in the same way). This is shown by figure J.3.