MULTI-CRITERIA MULTI-STAKEHOLDER DECISION ANALYSIS ON URBAN FREIGHT SUSTAINABILITY INITIATIVES

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DECLARATION

I hereby declare that this thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

GE DONGLIANG

19 AUGUST 2013

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LIST OF SYMBOLS & ABBREVIATIONS

AHP	Analytical hierarchy process
α_{mn}	Metric of an alternative on criterion n for Stakeholder m
CEA	Cost-effectiveness analysis
CO_2	Carbon dioxide
CO	Carbon monoxide
C_{mn}	Criterion n of Stakeholder m
EIA	Economic impact analysis
ICT	Information and communication technology
HC	Hydrocarbon
JIT	Just-in-time
MCDA	Multi-criteria decision analysis
MCMSE	Multi-criteria multi-stakeholder evaluation
MCMSDA	Multi-criteria multi-stakeholder decision analysis

MECE	Mutually exclusive and collectively exhaustive
NO_X	Nitrogen oxides
NTD	Night-time delivery
PIA	Private investment analysis
PM2.5	Particulate matters of 2.5 microns in diameter or smaller
PM10	Particulate matters of 10 microns in diameter or smaller
PPP	Public-private partnership
SCBA	Social cost-benefit analysis
SH	Stakeholder
TOE	Tons of oil equivalent
TEP	Tons equivalent petrol
UCC	Urban consolidation centre
UFT	Urban freight transport
UFS	Urban freight sustainability
UGM	Urban goods movement
VOC	Volatile organic compound
W_{mn}	Weight of criterion n for Stakeholder m

EXECUTIVE SUMMARY

Urban freight transport is a backbone of a city's economic activities. As its social, environmental and economic impacts become increasingly significant and in some cases alarming, cities and countries around the globe have been taking initiatives to counteract the undesired impacts of urban freight transport and to promote sustainable development. Both infrastructural and organisational measures, such as licensing, road pricing and urban consolidation centres, are widely discussed and implemented in both the developed and developing countries. However as options for sustainability initiatives increase in number and many of them experience dysfunction or failure, policy makers are constantly faced with challenges to make the right decision of which initiatives to adopt.

The research work is dedicated to a deep understanding of main characteristics of urban freight sustainability (UFS) initiatives and key leverages for right decision. Multiple criteria and multiple stakeholders are the two major leverages identified upon thorough analysis. UFS initiatives should be able to cope with all three aspects of the environmental-economic-social sustainability triad. With any of the

three missing in the objectives, the decision is liable to fail. Meanwhile, only considering multiple criteria is not sufficient for a successful implementation. Specifically incorporating all stakeholders in the decision process is a decisive step.

The thesis answered this challenge by combining and adapting the traditional multi-criteria decision analysis and the multi-criteria multi-stakeholder project evaluation methodology to specifically consider the stakeholders in the decision model. A four-initiative case study is carried out to verify the applicability of the methodology.

CHAPTER 1

INTRODUTION

1.1 Economy, Energy and Freight Transport

The human beings have been increasingly dominant on the planet Earth, ever since they started standing on its feet around 200,000 years ago. As the only species being capable of making and using tools and communicating with its congeners, they quickly developed, from a simple labour-driven society in the prehistory, into an extremely sophisticated modern one in which we live now.

The beginning of industrial revolution since the early 19th century, the start of fossil resource exploitation, the invention of train, automobile, aeroplane, the industrialisation of food and other consumer goods production, among other industrial activities, have pushed the human dominance and its activity frontiers even further. For almost two centuries, the world economic activities that have been skyrocketing in an extravagant way have been putting a strain on the energy the world has to offer in an unprecedented manner (*c.f. Figure 1.1*).

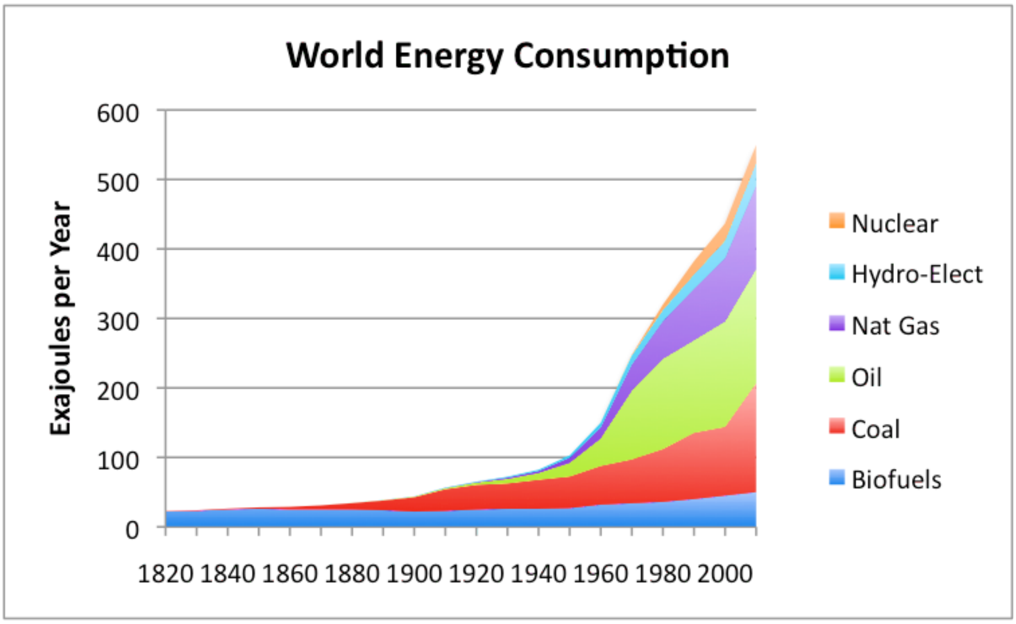

Figure 1.1 World energy consumption (Smil, 2012)

Freight transport, as a necessary component of most economic activities, has played a significant role in the human society development. The development of vehicle and transport systems has served and keeps serving as a backbone in supporting smooth conduct of most economic activities. Freight transport in particular is a major contributor in the transport industry. Especially with the arrival and the growth of globalisation, the role that freight transport served as in the world economy has also risen substantially. A relatively recent research by the European Environment Agency (EEA, 2010) has demonstrated that economic activities are in a clear correlation with the intensity and volume of goods flow to a large extent (*c.f. Figure 1.2*).

The world has seen continuously rising freight transport since decades, along with the growth of global GDP. Rapid urbanisation which took place in the developed world in the late 19th century and 20th century has lead to a real phenomenon of urban goods transport, with soaring

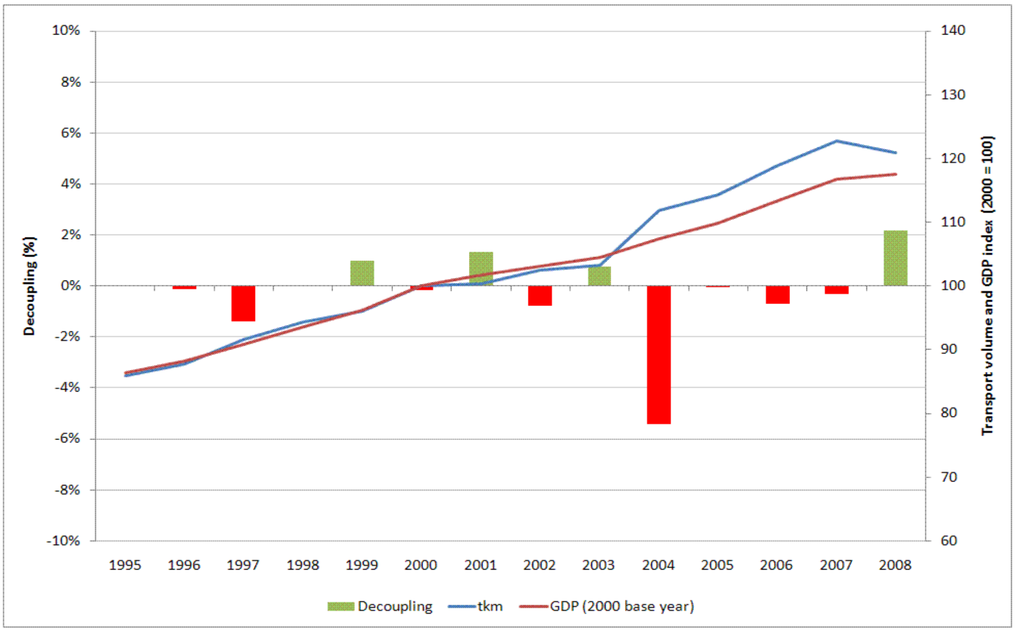

Figure 1.2 EU trend in freight transport demand & GDP (EEA, 2010)[1]

urban freight vehicle numbers constantly hitting records (Dablanc, 2012). Urban freight transport and the sustainability issues it imposes on the cities have attracted much attention in recent years (Allen et al., 2000).

1.2 Urban Freight Transport and Sustainability

1.2.1 Significance of Urban Freight Transport

Urban freight transport (UFT), along with other city logistics operations, in general refers to the activities of delivering and collecting goods in town and city centres (Allen et al., 2000). UFT can be sometimes referred to as "city distribution" or "city logistics"[2], since it is concerned with a set of activities, including transportation, goods loading and unloading, goods storage, stock management, reverse logistics (i.e. waste and returns) as well as door-step delivery services.

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[1] Tkm is stands for tonnage-kilometer. Vertical bars stand for the decoupling or the difference between grow in GDP and in transport. Green indicates faster growth in GDP than in transport while red indicates stronger growth in transport than in GDP.
[2] Section 2.1 contains a full list of equivalent or similar names.

As is shown in Figure 1.2, freight transport is greatly related to most economic activities, supporting all the aspects of human societies. Cities, in developed countries or developing countries, remain a major player in the global economy. Even with the trend of suburbanisation in certain part of the developed countries, most commercial activities remain largely with the urban areas(Dalanc, 2011).

The growing significance of urban freight transport and logistics is related to increased population and sustained economic growth in urban areas (COST321, 1997). Goods transport in cities represents from 10 to 18 per cent of road traffic. As the majority of the population in developed countries lives in urban and suburban areas, a significant portion of goods and other deliveries is despatched to these areas, which results in an increased demand for urban freight transport. Furthermore, as urban freight transport deals primarily with the distribution of goods at the end of the supply chain, many deliveries tend to be made in small loads and in frequent trips, thus resulting in many vehicle kilometres.

Because of the substantial importance that urban freight transport manifests in urban economies, it has virtually become an indication of the city's competitiveness and economic liveliness. Indeed, an efficient and highly competitive freight transport system can support many aspects of the city, including urban lifestyle, environment, and most of all, industrial and commercial activities and contributes to the competitiveness of the city concerned (Anderson et al., 2005). At the same time, it is by nature a major industry and an important part of the economy as well, both in terms of the wealth it generates and the number of jobs it ensures (Allen et al., 2000).

1.2.2 Sustainability of Urban Freight Transport

In most urban areas around the world, especially in the developed countries, cities are characterised by their high density in population and high demand consumption for goods and serices. Meanwhile, the transport infrastructures are by nature bounded with limited possibilities of physical extension for the cities. This specificity leads to a dilemma between demand and limitations of the urban environment, which has resulted in significant problems associated with urban freight transport. The most frequently discussed problems are, among others, air pollution, fuel consumption and energy waste, greenhouse gas emission, health, safety, traffic congestions, noise nuisance et cetera.

As environmental conditions aggravate and its issues attract much attention around the world, firstly in the developed world some years ago following by the emerging countries (especially Brasil, Russia, India and China), the social awareness of sustainable development and environment protection has been constantly rising. Along with other environmental issues, the sustainability of urban freight transport are being increasingly questioned and have attracted much attention both from the academic world and from the corporate arena. In most cases, environmental problems are interrelated with and lead to both economic and societal ones. Thus, the negative impacts are in general multi-dimensional, which affect and challenge economic, social and environmental sustainabilities, with the last being the most worrying.

Indeed, the environmental impact of UFT can be tremendously significant and undermining, both in terms of pollution and energy consumption. UFT is widely acknowledged to be far more polluting than long-distance freight transport, due to multiple reasons, such as short delivery distances, frequent trips and stops, low speed under traffic congestions, as well as higher average age of vehicles, et cetera. In fact, in the context of the European Union, and more specifically in Dijon, France, UFT is responsible for up to 60 per cent of PM10, more than one third of nitrogen oxides (NO_X), one fourth of carbon dioxides and one fifth of carbon monoxide (LET, 2006; *c.f. Table 1.1*). The situation is not less, if not more, severe in the developing countries. According to research conducted by Lozano (2006), out of total 3,500 tons of PM2.5 emitted in the City of Mexico in 2002, a striking level of 71 per cent traced back to freight vehicles. In terms of energy consumption, urban freight vehicles account for an important portion as well. For example, in Dijon, France, freight vehicles are responsible for up to 26 per cent of total road traffic-related consumption of total equivalent petrol (TEP) (Dablanc, 2009).

Besides environmental impact, the sustainability issues of UFT extend to social and economical spheres of urban areas, with all three aspects interrelated to each other. Environmental issues are related to areas such as health, safety, comfort of residents (e.g. noise nuisance, et cetera.). These problems have significant impacts on the well-being of a nation or a city by decreasing the quality of life of citizens and through detrimental effects on health. Urban freight transport and logistics operations systems that experience poor performance or complete dysfunction (e.g. frequent and severe traffic congestions) can be a brake for an urban area's economic competitiveness due to their low efficiency and poor effectiveness (Allen et al., 2000).

Table 1.1 Transport pollutant emissions in Dijon, France (LET, 2006)

Emission (kg/hour)	CO	NO_X	HC	PM10
All Traffic	1124	312	166	15
Private Cars	894	173	122	5
Urban Freight Transport	225	113	41	9
Freight in Transit	5	26	3	1
Proportion of Freight in Urban Transport Emission	**20%**	**36%**	**25%**	**60%**
Proportion of Freight and Transit in Urban Transport Emission	20%	45%	27%	67%

1.3 Urban Freight Sustainability Initiatives and Challenges

1.3.1 Urban Freight Sustainability Initiatives

For many years freight transport has not been concerned as much as passenger transport. The subject of urban freight transport (UFT), including other closely related topics in the domain, has been largely underestimated by researchers and planners (Anderson et al., 2005). It is sometimes regarded as a "marginal issue" of passenger transport and often studied in an inappropriate manner or to an insufficient extent, without taking into account specificities of freight transport (Melo, 2011).

Its rising activities and impact on the urban areas (*c.f. Section 1.2*) have resulted in more dedicated research since some years and brought about numerous actions taken primarily, but not exclusively, by governmental organisations (Quak, 2008). Countries and cities all over the world are making effort to counteract the undesired impacts of urban freight transport, both from managing the demand side of transport (e.g. road pricing) and from expanding capacity supply aspect (e.g. urban infrastructural development). All these efforts are in general referred as urban freight sustainability (UFS) initiatives.

A significant variety of UFS initiatives have been invented and developed along the years, especially in the more developed countries such as those in the European Union and Japan. Conventional methods, such as licensing and regulation, have been widely discussed and many implementations are taking place all over the globe. Novel UFS initiatives, including night-time delivery (NTD) policy or urban consolidation centres (UCC), also attract much attention. Governments and local authorities therefore have a wide range of choices when they are faced with undesired impacts of UFT and decide to address those issues.

1.3.2 Challenges of UFS Initiatives

Although UFS initiatives are widely available to assist local transport authorities in fighting against the side-effects of UFT and numerous initiatives are being carried out around the globe by policy makers, whether at a local or national level, they are constantly confronted with multi-dimensional problems and frequently challenged by the uncertainty of their decisions.

Among the significant number of UFS initiatives that have been taken around the world, most initiatives remain costly, with some achieving well their goals, whereas many others generate either poor results or complete failure disappointing policy makers. Many of them ended with being far under performance, dysfunctional or a complete ineffectiveness. Reasons for failure may vary, such as poor execution, incoherent implementation, et cetera (Melo, 2011).

However, one of the common reasons for failure for UFS initiatives is the lack of a specific and well-adapted methodology and a rigorous decision-making process for policy makers to choose the UFS initiatives that are the most appropriate and adapted to the city and its context (Macharis, 2004). In fact, governments and authorities have difficulties deciding which approach to adopt, when inundated with numerous choices provided or proposed by multiple parties, including governments from local level to national level, public or private transporters, the public in general, transport scholars and professionals.

A well-rounded methodology is therefore needed for the process of decision-making when the policy makers are faced with multiple choices of UFS initiatives.

1.4 Research Objectives

The research aims to contribute to the decision analysis of policy makers when an UFS initiative is to be chosen and to help decision makers make better-informed decisions and thus they can expect better results of their decision-making.

Based the above introduction of circumstances and challenges, the research objectives are as follows:

- **Understanding of UFS initiatives.** Conduct an in-depth research on UFS initiatives in order to gain a better understanding of their common traits and specificities, and identify key leverage for UFS initiatives decision-making. A thorough understanding of UFS initiatives is a necessary basis for the thesis. Results of detailed UFS are presented in depth in the forthcoming chapter. The references cited in the thesis are from sources both in English and in French.

- **Decision Analysis Model.** Develop and tailor a methodology, or alternatively a decision analysis model, on the decision analysis and decision-making under the situation where decision maker, in this case the transport authority in general, is faced with multiple UFS choices.

- **Case study.** Conduct a case study with a specific city with a given set of UFS options, based on necessary assumptions and data gathered, to apply the decision analysis model developed in the thesis.

1.5 Outline of Thesis

Chapter 1 introduces the background information, presents the origin of problems and challenges followed by research objectives, as well as outline of the thesis.

Chapter 2 presents in the first place the results of in-depth study of UFT impacts, followed by a detailed investigation of past and current

UFS initiatives around the world to obtain a better understanding of the circumstances under which UFS decisions are made. The chapter concludes with key findings of leverage in the UFS initiatives decision analysis.

Chapter 3 comprises the results of a comprehensive study on classical and recent decision analysis methodologies, presents the methodology developed in the thesis, and then reasons why the methodology is well aligned with the research objectives.

Chapter 4 presents in detail the case study on the City of Paris, with application of the methodology that is developed in Chapter 3, including necessary assumptions, problem specification, model application, results and analysis.

Chapter 5 concludes the research thesis by presenting the key conclusions, as well as important recommendations and outlooks for future research.

CHAPTER 2

URBAN FREIGHT SUSTAINABILITY INITIATIVES: REVIEW AND CATEGORISATION

2.1 Introduction

This chapter starts by providing a clear overview of urban freight transport (UFT) including specific definition of UFT and its challenges. Secondly, the chapter presents in detail the results of in-depth study of UFT impacts and the urgency of initiatives. Thirdly, a detailed investigation of past and current urban freight sustainability (UFS) initiatives around the world is carried out to obtain a better understanding of the circumstances under which UFS decisions are made. Finally, the chapter concludes with key findings of leverages in the UFS initiatives decision analysis that are crucial in the decision model development later presented in Chapter 3.

2.2 Urban Freight Transport

2.2.1 Definition of Urban Freight Transport

It is important to clarify the definition of urban freight transport. From its linguistic composition, urban freight transport can be understood immediately and perceived to be all transports related to freight in an urban environment. In the context of this thesis, urban freight transport needs to be defined in an exact manner for the purpose of academic rigour.

Urban freight transport (UFT) is defined in various ways by different researchers under different circumstances or in different areas of the world. Definitions can differ by term, scope and level of precision. Despite certain level of differences, similar terms are often used interchangeably. Following is a list of the frequent terms:

- City distribution
- City logistics
- Urban freight logistics
- Urban freight transport
- Urban goods distribution
- Urban goods movement
- Urban goods transport

A very brief definition was proposed by Ogden (1992) who defined urban goods movement (UGM) as “the movement of things to, from, within and through urban areas”. More elaborated definitions appeared along the years, as the research progressed in the domain. OECD (2003) defined urban goods transport as follows:

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

A more detailed version of definition was proposed by Allen et al. (2000) that urban freight transport should include the following three elements:

> "(1) all types and sizes of goods vehicles and other motorised vehicles used for (core) goods collections and deliveries at premises in the urban area; (2) all types of goods vehicle movements to and from urban premises including goods transfers between premises, ancillary goods deliveries to urban premises, money collections and deliveries, waste collections and home deliveries made from urban premises to customers; (3) And service vehicle trips and other vehicle trips for commercial purposes which are essential to the functioning of urban premises".

In 2011, Dablanc defined urban freight transport as "all goods movements generated by the economic needs of local businesses" including "all deliveries and collections of supplies, materials, parts, consumables, mail and refuse that businesses require to operate". In this case, household deliveries via e-commerce are also considered[3]. However, two specific cases are not included, which are private trips performed by individuals or households to acquire goods ("private shopping trips") and freight vehicles that pass through the city without serving any business or household in the city (through traffic). As it is the latest and the most specific and relevant version, the definition of Dablanc (2011) is adopted in the thesis.

[3] E-commerce in many parts of the world is not only worth considering, but also actually stands for a significant portion of UFT (Dablanc, 2009).

2.2.2 Recent Trends in Urban Freight Transport

While UFT are faced with sustainability issues since decades, recent changes in various aspects of the human society have made the issues more difficult to deal with. The changes owe mainly to the increasing globalisation of trading activities, increasingly complex supply chain and inventory management and lastly suburbanisation.

First of all, the increasingly globalised economy, for example outsourcing of production, has contributed to the rising quantity of freight movement. UFT usually comprises the last portion of goods transportation or, in certain cases, the first part. This "last mile" specificity results in a direct relationship between the global trade volumes with UFT activeness. In other words, when an international trade volumes increase with the globalisation, UFT volumes increase accordingly (Himanen et al., 2004).

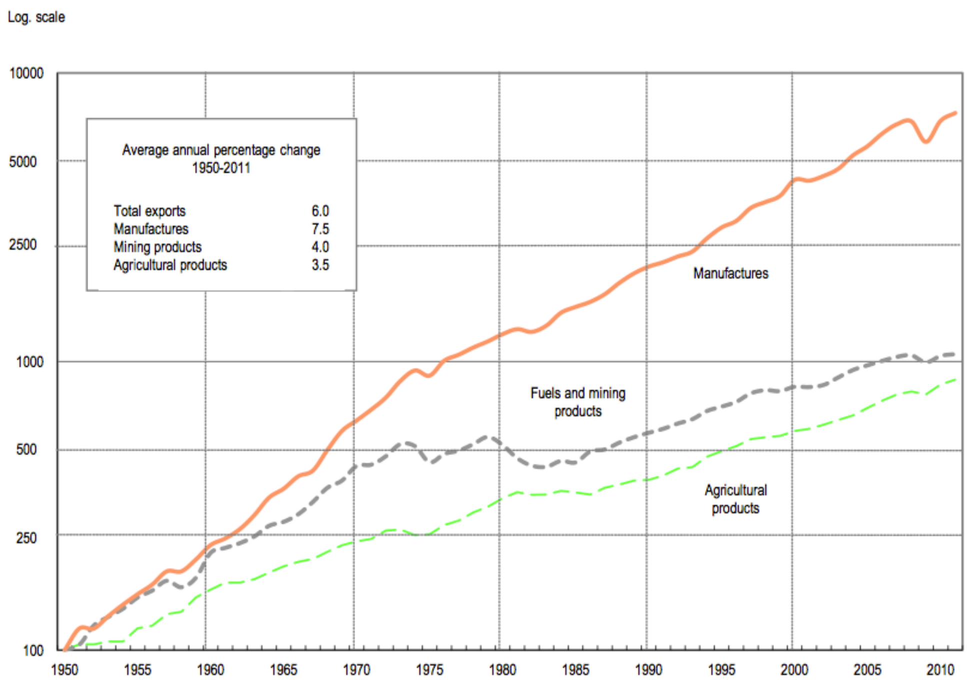

Figure 2.1 World trade volume by major product groups (WTO, 2012)

Secondly, urban commercial activities are evolving rapidly and major changes are threatening the sustainability of UFT. Due to fierce business competition and rising rental price, most businesses are increasing frequency of releasing new products and product variety as well. This has directly resulted in increased freight deliveries (LET et al., 2006). Moreover, businesses start to convert more inventory space for commercial use and this has resulted in shrinking inventory size and more frequent deliveries. Just-In-Time (JIT) is increasingly adopted by businesses, which again increases the freight transport. The market of express mail and courier services is also expanding in an unprecedented way. All the above factors are challenging the sustainability of UFT (Dablanc, 2007).

Lastly the suburbanisation in some of the developed countries is another hurdle. Increasing number of people start living in the suburbs while keeping their professional activities within the city centre. This has resulted in a substantial rise in traffic that in turn added to the difficulty of freight transport efficiency. Anderson et al. (2005) believed that the increasing congestion and decreasing city accessibility is one of main obstacles of high levels of efficiency in urban freight transportation.

Banister et al. (2000) and Visser et al. (1999) concluded that increasing physical infrastructure has its own limits and cannot solve the problems all the time, but building more roads sometimes could even result in less road capacity available for freight transport. That is where comes the importance of UFT initiatives which are often more subtle yet more effective than pure physical infrastructural changes.

2.3 Sustainability of Urban Freight Transport

2.3.1 Overview

Urban freight transport (UFT) is of great importance to a city in many ways, supporting urban lifestyles, serving and retaining industrial and trading activities, and contributing to the competitiveness of the city (Anderson et al., 2005). First of all, it meets many vital basic needs of the city such as bringing food, consumer goods and also waste disposal and recycling (Ogden, 1992). Secondly, efficient UFT is essential to the economic liveliness and serves as a pillar function for industrial, trading and other activities, such as retailing tourism and leisure, which are essential to economic prosperity and thus the competitiveness of the city concerned (Munuzuri et al., 2005; Allen et al., 2003). To add to its importance, the UFT industry provides tens of thousands of jobs and is on its own a key element of the service sector that is becoming increasingly important to the urban economy (Browne, 1999; Browne and Allen, 1999).

However, UFT has demonstrated intrinsic conflicts with other aspects of urban functioning. Indeed, in most urban areas around the world, especially in the developed countries, cities are characterised by their high density in population and high demand consumption for goods and services. The transport infrastructures are by nature bounded with limited possibilities of physical extension for the cities. This specificity leads to a dilemma between demand and limitations of the urban environment, which has resulted in significant problems associated with urban freight transport.

The negative impacts that UFT could bring to an urban environment can be so influential that they virtually affect all aspects of people life and can substantially undermine the overall quality of life. In general, the impacts, despite being interrelated and interdependent, are classified as three categories:

- Impact on environmental sustainability
- Impact on economic sustainability
- Impact on social sustainability

All the above three aspects, sometimes named as the “sustainability triad” (Quak, 2008), contribute to the overall liveability of the city and the well-being of its inhabitants. They are to be reviewed individually in the coming sections.

2.3.2 Environmental Sustainability of UFT

In terms of impacts on environmental sustainability of a city, there are three major concerns, namely air pollution, green house gas emission and energy and fuel consumption. Three impacts intertwine and exert a multi-dimensional influence on the urban environment, quality of inhabitants’ life, the city’s economic competitiveness, and much more. As the concept of sustainable development increasingly attracts attention, the sustainability of current UFT situation is widely questioned.

Air pollution. In fact, in terms of air pollutants, carbon monoxide (CO), nitrogen oxides (NO_X) and particulate (mainly PM10 and

PM2.5)[4] are the major concerns, and thus the main targets for research. In fact, despite the relatively smaller population of freight vehicles as opposed to passenger vehicles, they contribute a significant percentage of air pollutants. Over one fifth of CO, one third of NO_X, and half of particulates matters emitted in the transport are from freight vehicles (mainly trucks and vans) in today's major cities (Dablanc, 2009; LET et al., 2006; *c.f. Table 2.1*).

Particulate matters. Particulate matters have become a major concern in recent years, both in the developed countries and the developing ones. In a typical medium-sized city in European Union, it is found that an astonishing level of 60 per cent of PM10 is emitted by freight vehicles (LET, 2006; *c.f. Table 2.1*). In the greater Mexico area, 71 per cent out of the 3500 tons of PM2.5 emitted by transport was from freight vehicles (Lozano, 2006).

Greenhouse gas emission. As the issue of global warming and over emission of green house gas became an serious concern for many countries, especially in the developed world, its emission is also widely monitored. As a matter of fact, one fourth of CO_2 emission trace back its source to freight transport vehicles in major European cities (Dablanc, 2009).

Energy and fuel consumption. In terms of energy consumption, freight transport is also responsible for a large portion. The survey results are equally percussive. For example, in Dijon, France, it has been recorded and calculated that freight transport consumes 26 per

[4] Volatile organic compounds (VOCs) are also one of researched pollutants, yet less frequently.

Table 2.1 Environmental impact of freight transport (LET, 2006)

Emission (kg/hour)	CO	NO_X	HC	PM10
All Traffic	1124	312	166	15
Private Cars	894	173	122	5
Urban Freight Transport	225	113	41	9
Freight in Transit	5	26	3	1
Proportion of Freight in Urban Transport Emission	20%	36%	25%	60%
Proportion of Freight and Transit in Urban Transport Emission	20%	45%	27%	67%

cent of total transport-related TOE[5] (LET et al., 2006). There are also other transport-related activities or phenomena that consume indirectly non-negligible amount of energy and fuel, such as vehicles tyres and other products.

2.3.3 Economic Sustainability of UFT

Secondly, an inefficient UFT situation can largely affect the city's economic sustainability. Economic sustainability impacts of UFT refer to the overall influence of UFT that are related to financial or economical factors, for individuals, corporates, and the society as a whole. The low efficiency of UFT in many parts of the worlds are reflected mainly by two factors: low load factor and high number of small operators, both of which combine to lead to an inefficient UFT

[5] TOE stands for "tons of oil equivalent", the amount of energy released by burning one ton of crude oil. TEP (total equivalent petrol) is an alternative term.

system, especially in many developing countries.

For society as a whole, they can refer to inefficient usage or waste of energy or other type of resources. Transport inefficiency is directly linked to the waste of energy, such as excessive fuel consumption during traffic congestions. LET (2006) showed that more than one fourth of TOE is related to freight transport. Especially in the case of urban freight transport, many vehicles tend to have a relatively high average age, which leads to further fuel consumption (Dablanc, 2009). Poor road conditions including traffic congestions reduce the city's accessibility and hence negatively impact the city's economic performance (Ogden, 1992). In cities and areas that are traditionally tourists' destinations, poor transport situation can substantially affect the city's attractiveness and eventually impact the city's economic sustainability to a certain extent.

Table 2.2 Number and size of freight operators in Mexico City (Dablanc, 2009)

Size of Companies	Number of Companies	Percentage
Very small operators (1 to 5 vehicles)	79,254	83.5%
Small operators (6 to 30 vehicles)	13,413	14%
Medium-sized operators (31-100 vehicles)	1,619	2%
Large operators (more than 100 vehicles)	465	0.5%
Total	94,751	100%

Table 2.3 Urban freight transport vehicle usage indicator in Medan, Indonesia (Sato & Kato, 2006)

Size of Operator	Frequency of Vehicle Usage (per week)	Average Load Factor
Less than five employees	2.11	29%
More than five employees	2.43	76%

Inefficient and unreliable freight transport can also result in low performance in the business sector. Poor traffic condition can easily decrease journey reliability, delivery punctuality and the overall service quality, which may result in customer loss and market loss (Quak, 2008). High number of small operators and low load factor are two of the major challenges to UFT efficiency for many countries and cities in the worlds. For example, in the Metropolitan of Mexico, there are 79,254 small freight transport operators (with 1-5 vehicles) compared to 465 large operators (with more than 100 vehicles) (Dablanc, 2009; ; *c.f. Table 2.2*). In general, small companies are much less competent in term of load factor control and delivery route optimisation. For instance, small operators (with less than five employees) have an average load factor of only 29 per cent as opposed to 76 per cent of large operators for the city of Medan, Indonesia (Sato and Kato, 2006; *c.f. Table 2.3*).

2.3.4 Social Sustainability of UFT

Impacts of UFT on social sustainability generally refer to any impact that is related to people in a given urban environment. These impacts are becoming increasingly important in UFT-related discussions, especially in the developed countries where people in general participate more in the public decision-making processes. These impacts are found in a wide range of aspects in people's lives, among which safety, health, convenience, comfort, et cetera. Major negative impacts include safety issues (injuries, death) due to traffic accidents, health problems (illness, death) as a consequence of air pollution, noise pollution, inconvenience and discomfort due to traffic congestion, overall deteriorating quality of life due to transportation infrastructure construction, accompanied green space loss, decrease of city's attractiveness et cetera (Dablanc 2009; LET et al., 2006; Quak, 2008).

2.4 Urban Freight Sustainability Initiatives

2.4.1 Overview

Freight transport was during a long period not researched as much as passenger transport (Himanen et al., 2004). The subject of urban freight transport (UFT), including other closely related topics in the domain, has been largely underestimated by researchers and urban planners (Anderson et al., 2005). UFT was in some cases regarded as a subset issue of passenger transport and often studied in an inappropriate manner or to an insufficient extent, without taking into account specificities of freight transport (Melo, 2011).

Because of the rising activities, significant impacts and pervasive issues (*c.f. Section 2.3*) that UFT brings on the urban areas all over the globe, be it in the developed countries or developing one, more dedicated research have been conducted since some years and more actions are being taken, primarily yet not exclusively, by various governmental organisations (Quak, 2008). Countries and cities all over the world are making effort to counteract the undesired effect of urban freight transport, both from managing the demand side of transport (e.g. road pricing) and from expanding capacity supply aspect (e.g. urban infrastructural development). All these efforts are in general referred as urban freight sustainability (UFS) initiatives.

Spearheaded by developed countries such as those in the European Union and Japan, a important variety of UFS initiatives have been created and developed along the years, among which some are relatively conventional and others are more novel and creative. Conventional methods, such as road pricing or licensing and regulation, have been widely discussed and many implementations are taking place all over the globe. Novel UFS initiatives, including night-time delivery (NTD) policy or urban consolidation centres (UCC), also attract much attention. Governments and local authorities therefore have a wide range of choices when they are faced with undesired impacts of UFT and decide to address those issues.

2.4.2 Challenges of UFS Initiatives Decision

Although UFS initiatives are widely available to assist local transport authorities in fighting against the undesired impacts of UFT and numerous initiatives are being constantly carried out around the world by policy makers, be it at local or national level, they are constantly confronted with multi-dimensional problems and frequently challenged by the uncertainty of their decisions. First of all, many initiatives remain costly, either financially or in terms of other resources such as human resources and time, which could be constraining to initiatives' successful implementation and operation. Secondly, among the significant number of UFS initiatives that have been taken around the world despite many success cases, many others end with either disappointing results, far below satisfying performance, dysfunction or complete failure, which give policy makers huge challenge. Dablanc (2011) said that UFS Initiatives are rising in quantity but not in quality, in other words, the rate of successful implementation is not rising. There exist various reasons for failure, such as poor execution, incoherent implementation, et cetera (Melo, 2011).

Macharis (2004) argues that one of the common reasons for failure for UFS initiatives is the lack of a specifically designed methodology and a rigorous decision-making process for policy makers to choose the UFS initiatives that are the most appropriate and adapted to the city and its context. In fact, governments and authorities have difficulties deciding which approach to adopt, when inundated with numerous choices provided or proposed by multiple parties, including governments from local level to national level, public or private transporters, the public in general, transport scholars and professionals (Dablanc, 2007).

A prerequisite of successful UFS initiative is a clear understanding of the panoramic view of options and the context where situates the decision-maker. A clear understanding of all the initiatives that have been developed along the year around the world is therefore essential. Based on the understanding of UFS initiatives, a well-rounded methodology is thereafter needed for the process of decision-making when the policy makers are faced with multiple choices of UFS initiatives.

2.4.3 Methodology of UFS Initiatives Study

It is therefore of great importance to conduct a comprehensive study and examination on the current situation of all initiatives to date. It is obviously impossible to study all the initiatives, yet a reasonable number of them with a significant variety of nature can validate them on the eligibility of representing the population.

In order to obtain a comprehensive profile of initiatives, the author has reached to different sources and parties for information and assistance. The initiatives reviewed are firstly from various recent research papers across different continents, proceedings of conferences (especially those of OECD and the European Conference for Ministers of Transport) and recently published books in the area.

Secondly some initiatives are also from some projects of Metis Consulting, a management consulting firm based in Paris and specialising in the supply chain management and operational performance, and the City of Paris. A visit to the Monoprix Railway Intermodal Terminal organised by MINES ParisTech (formerly École Nationale Supérieure des Mines de Paris) also helped in the understanding of relative matters.

2.5 Specificities of UFS Initiatives

2.5.1 UFS Initiatives – A Categorisation

After a detailed review and analysis, we developed a categorisation framework to classify the initiatives, based on the observation of the sample profiles. In order to cover all initiatives, the categorisation was designed and realised to be mutually exclusive and collectively exhaustive (MECE). We first distinguish three classes of initiatives in term of initiators: "Class 1 - Public" initiatives that are launched by governmental organisations; "Class 2 – Private" initiatives which are primarily initiated by private companies, mostly in the transport sector; and finally "Class 3 - Public-Private Partnership (PPP)" initiatives which are realised under the partnership of public and private bodies.

In each of the classes, initiatives are categorised as 'Organisational initiatives' or 'Infrastructural initiatives'. This sub-categorisation also respects the MECE principle. Organisational initiatives are the ones that do not involve any physical modification of the existing systems and reply purely on rearrangement of current organisation. A typical example of Organisational initiatives would be 'road pricing' that aims at redistributing the road capacity over the time by changing its supply and demand pattern. Infrastructural initiatives, by definition, involve necessarily physical modification or addition of existing infrastructure, mainly those related to the freight transport. The most common infrastructural initiative is the road network development. A less common yet more recent one is the urban consolidation centre (details of which will be covered in the coming sections).

For the purpose of convenience, we denote "Organisational initiatives" as Category A and Category B for "Infrastructural initiatives". As

Category B initiatives in general involve physical modification and construction, they usually tend to be more expensive, more time-consuming and more risky than Category A initiatives.

In category 1-A, the most common initiatives are 'Licensing and regulation', 'Road pricing', and 'Parking and loading'. Category 1-B includes 'Road network development' and 'Underground logistics system'. In the privately driven initiatives, 2-A contains 'Carrier cooperation', 'Vehicle routing improvement' and 'Transport auction', while 2-B is represented by 'Technological vehicle innovation'. Finally in Class 3 (Public-Private Partnership), 3-A includes 'Night-time delivery policies' and 'Standardisation of loading units' and 3-B includes 'Urban consolidation centre' and 'Intermodal transport'. Under each of the categories, the most common initiative types are listed in the Table 3.1.

Table 2.4 Categorisation of UFS initiatives

Initiator	Category	Initiatives
Class 1 Public	A Organisational	Licensing and regulation Road pricing Parking and loading
	B Infrastructural	Road network development Underground logistics system
Class 2 Private	A Organisational	Carrier cooperation Vehicle routing improvement Transport auction
	B Infrastructural	Technological vehicle innovation
Class 3 Public-Private Partnership (PPP)	A Organisational	Night-time delivery policies Standardisation of loading units
	B Infrastructural	Urban consolidation centre Intermodal transport (Monoprix)

2.5.2 Research Landscape on UFS Initiatives

Spearheaded by European countries and cities, followed by Japan and the USA, initiatives designed to counteract the negative impacts of urban freight transport grew since the last decades from a few pilot projects into a common scene across the globe. Not only the central governments, but also governments at all levels from counties to provinces are taking actions (Dablanc, 2007). Many other actors of the society also stay very active, from private companies in the transport sector to researchers and specialists in the universities and various other institutions.

Observing the research landscape, there have been several clear trends, with most of them focusing on quantitative analysis and microscopic studies, with very often a focus on a local situation. Night-time delivery, urban consolidation centre, last-mile delivery are some examples of the most researched topics. The following are some of the most recent research tentative.

Gevaers et al. (2011) analysed the characteristics and typology of last-mile logistics that are specifically related to e-commerce, researching and discussing on the impact of last-mile delivery complications. They discussed the substantial rise in cost and time at the last-mile delivery due to time windows and diversity brought by small quantity orders, and how various initiatives can potentially optimise last-mile efficiency and reducing cost. This research is primarily a focused study of a given scenario that is the last-mile logistics, in a microscopic scale as well.

With due recognition to the above research efforts, it is noticed that there is a general lack of panoramic view of the initiatives, and how the decisions are taken in order to be successful. The following section of intends to take up the challenge with a in-depth study of current initiatives, and an well-rounded analysis on the factors that make an initiative successful with the help of a framework to be presented as well.

2.5.3 Challenges and Leverages of UFS Initiatives

2.5.3.1 Challenges as Phenomena

Understandably, most influential initiatives are driven by government or their agencies. Government-initiated measures are in general taken with specific objectives. Among the objectives, we could distinguish three mainstream objectives, which are environmental sustainable development, social sustainable development, and economic sustainable development. Naturally, many measures are implemented with synergy leading to multiple effects. A project that is intended to improve a city's accessibility is also like to facilitate economic activities to a certain extent (May and Taylor, 2002). However, synergy may not the case all the time. In fact, one of the major challenges with policy making in the urban areas is conflicting interests and objectives, primarily among various stakeholders. These difficulties are reflected in multiple dimensions.

Inadequate information. Firstly, inadequate information for the project and for the future evolution of the project is one major obstacle for policy makers. As argued previously, a major mission or challenge for policy makers is trade-off between UFT benefits and sustainability impacts. As pointed out by Visser and Van Binsbergen (1999), obtaining complete information about the exact extent of UFT impacts or, costs in certain cases, which makes the mission to decide how far to push an UFS initiative intangible and subtle. This in turn leads to a certain level of risk of failure for projects.

Conflicting interests. Secondly, even if hypothetically the decision maker has complete information over the initiatives' negative impacts and benefits, the nature of UFT puts the decision maker in a difficult position to determine the most suitable initiatives. As Macharis (2004) asserted, the conflicting interests and objectives of different stakeholders remain so strong that making a decision for policy maker sometimes seems impossible.

2.5.3.2 The Real Challenges

The above nature of UFT results in two complicating facts.

Multiple criteria. Firstly, there are conflicting factors within the impacts of UFT. That is "introducing new policies to alleviate one environmental impact of urban freight movement can result in worsening the others" (Browne and Allen, 1999). Secondly, there are intrinsic conflicts among the triad of sustainability, namely environmental, economic and social sustainabilities. As Anderson et al. (2005) pointed out, in UFS initiatives, more criteria need to be considered than typical UFT facts such as transportation costs, delivery quality, et cetera. A typical project aimed at reducing the number of freight vehicles and improving environmental sustainability would necessarily challenge the economic pillar of the sustainability triad. Other projects such as night-time delivery that help create a fluid traffic conditions may possibly hinder people's quality of life because of the noise nuisance generated throughout the operations during the night.

Multiple stakeholders. A UFT problem eventually comes down as a collective problem for all stakeholders. This critical leverage that is the multi-stakeholder characteristics has been unconsciously ignored by many transport authorities. Incomplete or no consideration of stakeholders can results in severe counterproductive consequences when tailoring and implementing UFS initiatives, as is proven by numerous past experiences.

"Evil transporter". One common mistake is neglecting local transporter as a stakeholder. In fact, transport authorities in many countries, even in democratic nations, tend to resort to enforcing and determined approach when it comes to solving UFT problems by adopting and enforcing regulations (OECD, 2003). It has been noticed that urban freight transporter are deemed, by local authorities, as a "problem-maker" to be "fighted against" rather than an active stakeholder who can actually contribute to the overall situation (Dablanc, 2007; Quak, 2008).

As a consequence, when formulating the UFS initiatives, the interests of local freight transporters are far from defended. In other words, local authorities often implement an UFS initiative to promote economic and social sustainability of the city, at the cost of sacrificing freight transporters. This in turn leads to increased transport costs, affected delivery quality (including timeliness and lead time) and complicated delivery procedures (if numerous regulations are imposed). All these consequences would be eventually passed down to the end consumers, who are the public and whose interests were defended by the UFS initiatives but finally are lost. Such cases of missing critical stakeholders not only happen in developing countries, but also in the developed world. According to Dablanc (2007), in a certain French urban area, more than 30 different restrictions on freight vehicles are imposed which directly leads to a complex delivery procedure and poor delivery quality. Therefore, specifically taking all stakeholders into considerations is critically important to the successful functioning of UFS initiatives and to achieve desired results.

Proactive approach. Concerning UFT problems, most authorities tend to be in reactive state rather than adopting a proactive approach. They react to various situations and problems, such as severe traffic congestions, by creating temporary solution. Few of them actually have well-rounded long-term transport policy plan. Incompetent expertise from local transport authorities is one of the major reasons (Allen et al., 2000). Partially caused by the passive attitude of local authorities, their approach to problems tend to be only capable of temporarily solving a "superficial" problem rather than capturing the root cause and providing an impactful solution.

2.6 Summary on UFS Initiatives Challenge

As is reviewed and investigated by the above sections, despite tremendous efforts from all parts of society, be it from the government, the corporate players, the public, urban freight transport is faced with severe and multi-dimensional challenges that awaits immediate action. It is shown that UFS initiatives decisions are not only multi-criteria decisions, but also multi-criteria multi-stakeholder decisions.

Multiple criteria. The criteria to make the UFS initiatives are not only multiple, but also conflicting. Criteria are mainly based on the "triad of sustainabilities" – environmental, economic and social sustainabilities. To achieve satisfying results, a UFS initiative is ideal to incorporate criteria from all three dimensions of the triad, instead of focusing on the one or two and completely leave the others.

Multiple stakeholders. Besides the multi-criteria specificity, the main hurdle to the UFS initiative decision-making process turns out to be the stakeholders and their frequent conflicting interests. Most decisions taking place around the world today lack specific and effective methodology and hence their actions are subject to significant uncertainty which ultimately leads to project dysfunction and eventual failure. Specifically considering the criteria of stakeholders is therefore of critical importance. The following chapter is dedicated to the research and development of a specific methodology that adapts to the specific requirements of a UFS initiative decision-making process.

CHAPTER 3

MULTI-CRITERIA MULTI-STAKEHOLDER DECISION ANALYSIS

3.1 Overview

This chapter is dedicated to quest and development of a specific methodology that adapts to the specific requirements of a UFS initiative decision-making process, as are examined in the previous chapter, namely the specificities of multiple criteria and multiple stakeholders. The research target is focused on the project evaluation and decision analysis methodologies.

There exist a wide range of project evaluation methodologies, often times in engineering-related domains, which involve a typical decision-making process. There are a number of classical engineering project-evaluation and decision analysis methodologies. The most relevant ones in the context of urban freight sustainability (UFS) initiatives include the cost-effectiveness analysis (CEA), the economic impact analysis (EIA), the social cost-benefit analysis (SCBA), and the multi-criteria decision analysis (MCDA).

Despite being applicable and effective under certain circumstances, the classical project-evaluation and decision analysis methodologies are subject to several important shortcomings, among which stakeholder incorporation is a critical one. The failure of specifically incorporating different and often conflicting points of view from various stakeholders causes frequent disputes and controversy (Anderson et al.; *c.f. Section 2.5.3.2*). The absence of a capable and appropriate methodology for the decision-making process is therefore indispensable for avoiding eventual failure or dysfunction of many projects.

The key problem the current research is faced with is the decision analysis in an urban freight sustainability initiatives context, in which every actor in the society is a team player, i.e. a stakeholder. The stakeholders include the transporter sectors, the employees, the citizens, the government and its various agencies, et cetera. Therefore, a well-defined approach to take into account all stakeholders is an absolute necessity to the decision-making process and a key element to the ultimate success of the implemented initiative.

This chapter presents an in-depth examination of project-evaluation and decision analysis methodologies; in particular the multi-criteria decision analysis (MCDA) and multi-criteria multi-stakeholder analysis (MCMSA). In the second part, we introduce the adapted MCMSDA methodology and reason why the adapted MCMSDA is an appropriate approach for the urban freight sustainability initiatives context. Lastly, the model components, structure, and various stages of the adapted MCMSDA methodology are presented in detail, before continuing with the case study in the next chapter.

3.2 Classical Decision Analysis and Project Evaluation Methodologies

There are several classical methodologies that are widely adopted for initiative decision analysis and project evaluation, such as CEA, EIA, SCBA, and MCDA, et cetera. They are examined here for the purpose of understanding the available methodologies and their applicability to the UFS initiatives.

CEA. The *cost-effectiveness analysis* involves a direct comparison of the ratio of "effects" or benefits over costs of two or more projects. It is applicable and effective in the context where the objective of the initiative or the project is directly correlated to the financial return or the financial objective is the only or dominant criterion. The drawback of CEA is that it restrains many of the criteria into the sole financial criterion, which is far too narrow as a criterion for most projects and decisions in the world today. In the modern world where financial concerns remain non-negligible, decision-making tend to involves many more factors, such as the environmental sustainability issues which are usually a counteracting factor vis-à-vis the financial interests (Gold et al., 1996). Given the multi-criteria specificity of UFS decision-making context, it is hence inapplicable and ineffective.

EIA. The *economic impact analysis* is usually applied to estimate or predict the economic contribution of a specific project or initiative to a given country or region (Weisbrod and Weisbrod, 1997). The economic contribution is often an equivalence of economic growth (usually measured by gross domestic product), or other economic indices such as the number of employments the project would create, the amount of tax income it would generate et cetera. In the case of UFS initiatives, far more criteria are to be considered besides economic contribution. As a matter of fact, it only supports one “leg” of the environmental-economic-social sustainability triad of UFS initiatives (*c.f. Section 2.3.1*). EIA is therefore not an appropriate approach to adopt for the UFS initiatives decision-making.

SCBA. The *social cost-benefit analysis* is another project assessment tool that is used to be applied in an urban development context. SCBA methodology not only considers the financial impact of the project, but more importantly the impacts on environmental and social aspects, including factors such as air pollution, carbon emission, energy consumption, safety, et cetera (Pollock, 2013). The usual practice of SCBA is to transform most of these factors cited above into “prices’, which is often questioned of its accuracy and justifiability. Meanwhile, being focused on the interests of the society as a whole, SCBA fails to take various stakeholders into consideration, which makes it an ineligible methodology for the context of UFS initiatives decision analysis.

MCDA. *The multi-criteria decision analysis* is another important and frequently employed decision-making methodology. As its name suggests, MCDA methods are capable of incorporating multiple criteria, making a “fair” judgment on the situation and hence leading to a more balanced decision, compared the previous methodologies. However, because of the specificities of UFS initiatives, the effectiveness of MCDA methodology is also challenged. Due to its importance, MCDA is reviewed and examined in an separate section (*c.f. Section 3.3*).

3.3 Classical Multi-Criteria Decision Analysis

3.3.1 Concept of Stakeholders

The concept of stakeholders was originally introduced by the corporate world, when companies were faced with increasing social pressures to incorporate more employees' interests and viewpoints (Williamson, 1991). The original definition of "stakeholders" was very restrained to the business world or organisations as well. One of the earliest definitions of "stakeholder" by Freeman (1984) was "the individuals or the groups of individuals that can influence the objectives of an organisation or can be influenced by the objectives". Another early definition by Banville et al. (1998) was as restrained, if not more, as that of Freeman, where the stakeholders are restrained to the ones who have a direct influence on the decision-making process. This definition is completely incompatible with the context of urban freight sustainability initiatives, where the public, with normally restricted influence on the decision-making process, is the major stakeholder that is subject to significant influence by most decision made.

Therefore, a stakeholder, in the context of UFS initiative, should rather be defined as anyone who is liable to have an influence and who is liable to be influenced by the impact of a decision and the final results of the decision, in the short term as well as in the long term (Grimble and Wellard, 1997). For example, the forthcoming generations on the Earth are actually stakeholders, under this definition, of an urban development project or initiative.

The clear and appropriate definition of stakeholder is of substantial importance, because it directly influences the methodology to adopt and its effectiveness. If a methodology, such as a classical MCDA, defines the stakeholders in a very restrained manner, the results of the decision-making are liable to be very biased as well. The lack of specific and comprehensive inclusion of stakeholders in a classical MCDA methodology is discussed in the next section.

3.3.2 Classical MCDA methodology

Although there are many varieties of MCDA methods that are specifically designed to cope with a certain problem or decision, they share some common traits to large extent. In a typical MCDA methodology, there are necessarily the following five main phases: problem specification, alternatives development, development of criteria analysis and evaluation, followed by final synthetic evaluation and implementation (Nijkamp et al., 1990). This well-defined procedure does enable a classical MCDA methodology to include various points of view from multiple stakeholders, yet in a non-specific manner (*c.f. Figure 3.1*). In other words, the roles of stakeholders are not specifically incorporated in the decision-making process.

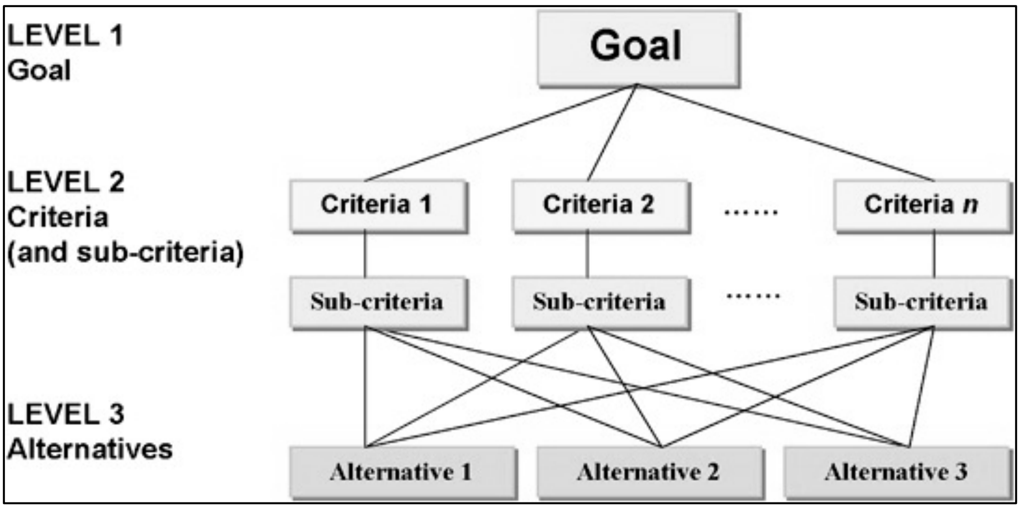

Figure 3.1 A typical MCDA process with AHP method

Therefore, it has its clear limitations, especially in the context of an urban development initiative such as a UFS initiative.

Missing specific stakeholder incorporation. There are specifically two major limitations. The classical MCDA methodology is designed to make a decision among multiple alternatives with consideration of various criteria. However, in spite of being able to consider different stakeholders' criteria, traditional MCDA is not capable of specifically considering multiple stakeholders and incorporating their often-conflicting interests in a clearly defined manner (*c.f. Figure 3.1*). Therefore, in the case of UFS initiatives, a traditional MCDA method is not ideal to be applied to make the decision.

"Common interests". Secondly, most MCDA methods were designed and developed within a single organisation or firm, incorporating viewpoints from various stakeholders yet in the view of a "common interest" (Alvarez et al., 2010). The classical MCDA is usually applied to a decision-making process within an organisation or a company. Therefore, despite different arguments or even conflicting points of view, there is always an ultimate "goal" (*c.f. Figure 3.1*), and the ultimate goal of the group is always to bring more benefits or more specifically profits to the company or the organisation. It is however not applicable to the case of an UFS initiatives where the "common interest" often does not exist and a decision is based on a trade-off of interests among stakeholders.

Therefore, a classical MCDA approach is challenged when confronted with a situation such as the UFS initiative decision-making. The missing specific stakeholder incorporation and the restraint on a “common interest” are its major limitations. The factor of stakeholders needs to be considered specifically and in a better-defined way. Objectives of various stakeholders are all to be taken into account. The methodology to be presented in the next section is intended to alleviate these limitations.

3.4 Multi-Criteria Multi-Stakeholder Evaluation

In recent years, as decision-making processes involve more stakeholders that have conflicting interests, the roles of stakeholders are becoming increasing important and critical in numerous cases. Integration of all stakeholders’ interests into the decision-making process often becomes critical to the success implementation of a decision, especially when the decision is made on a public project.

The multi-criteria multi-stakeholder evaluation (MCMSE) was originally designed to evaluate the feasibility of a single project, instead of a multiple-choice decision, at the Department of MOSI, Vrije Universiteit Brussel. Despite the fact that UFS initiatives decisions are concerned with multiple choices and MCMSE only deals with an evaluation on a single project, there are two major contributions from this methodology. The first contribution of the original MCMSA is that, unlike a classical MCDA methodology, it specifically incorporates various interests of all stakeholders and measures them in a clearly defined and structured manner. Secondly, unlike methodologies such as CEA or EIA that are based on numerical evaluations, MCMSA makes non-numerical evaluations possible within the methodology which is a invaluable feature, as in many cases criteria and preferences of stakeholders are not numerical.

However, being originally designed to evaluate a single project, it does not consider multiple choices, which is the case of UFS initiatives and which is possible with MCDA. Therefore, by combining the multiple-choice capacity of MCDA and the stakeholder-incorporating ability of MCMSE, the research intends to propose a solution to make the multi-choice decision in the context of urban freight sustainability (UFS) initiatives. It is named as the adapted multi-criteria multi-stakeholder decision analysis.

3.5 Adapted Multi-Criteria Multi-Stakeholder Decision Analysis

3.5.1 Introduction

Based on MCDA and MCMSE methodologies, this section is dedicated to the illustration of the adapted multi-criteria multi-stakeholder decision analysis (MCMSDA) model specifically dedicated to urban freight sustainability (UFS) initiatives decision-making. Establishing a decision model such as the MCMSDA starts with a clear understanding and a decomposition of the defined problem, including the alternatives, the criteria, the constraints of each criterion, the relationships between the criteria, et cetera. The section will start by introducing the model components – the key elements of the model, followed by an in-depth explanation of the model structure. Subsequently, the various stages of analysis process is presented, before continuing with the case study in the next chapter.

3.5.2 Model Components

Alternatives. Alternatives are the first to be defined in clear and comprehensive manner. In the UFS initiative context, they refer to the prospective initiatives that the authority plans to investigate. The convenience of MCMSDA method is that adding more alternatives along the process is relatively simple. Due to limited knowledge that some local transport authorities have, especially in some developing countries, the prospective alternatives envisioned by the authorities may not be necessarily appropriate. During the discussions with the stakeholders including the experts, it is possible to add or eliminate certain alternatives, if needed.

Stakeholders. Stakeholders, as defined in the section 3.3.1, are the ones who is liable to have an influence and who is liable to be influenced by the impact of a decision and the final results of the decision, in the short term as well as in the long term. In a UFS initiative context, they should often include the transport sector, the public, the employee of transporters, et cetera.

Criteria. The criteria refer to the objectives of the stakeholder groups or the interests they would like to defend. Each of them have different interests. They are to be identified and defined in a mutually exclusive and collectively exhaustive (MECE) manner, which means all the interests are to be identified and they should not overlap with each other.

Weights. While a single stakeholder has multiple criteria, criteria are different in terms of the degree of importance. The stakeholders are to allocate his fixed sum of weights (for example 100 points) to each of the criterion in specific manner. Weights can be adjusted in a simple manner along the analysis.

Metrics. Metrics are the factors that allocated for alternatives vis-à-vis the criteria, as an indicator of the influence of alternatives on the criteria, be it very positive, positive, neutral, negative, or very negative. They can be subsequently transformed into an evaluation matrix in order to aggregate the results and execute synthetic analysis for all criteria and alternatives.

3.5.3 Model Structure

The adapted multi-criteria multi-stakeholder decision analysis (MCMSDA) method for UFS initiatives specifically incorporates stakeholders into the decision model and integrates them in the whole decision-making process. MCMSDA is designed in the way so that it incorporates all important elements, including all alternatives (or scenarios), the impact of stakeholders, various criteria (or objectives) of stakeholders and weights they attach to each criterion, et cetera. All the above elements are either quantifiable or transformed into a scale before being integrated in the final synthetic analysis.

The methodology includes two main parts, namely the model development part and the synthetic analysis part (*c.f. Figure 3.2*). In the first part, alternatives, stakeholders, criteria and metrics are defined and gathered to establish the model. Based on the model, the second part will generate an evaluation matrix and the model will then generate a ranking of the alternatives, thereby provide the decision maker an insight of the overall situation, which leads to final decision and implementation (*c.f. List of Symbols & Abbreviations* for variables).

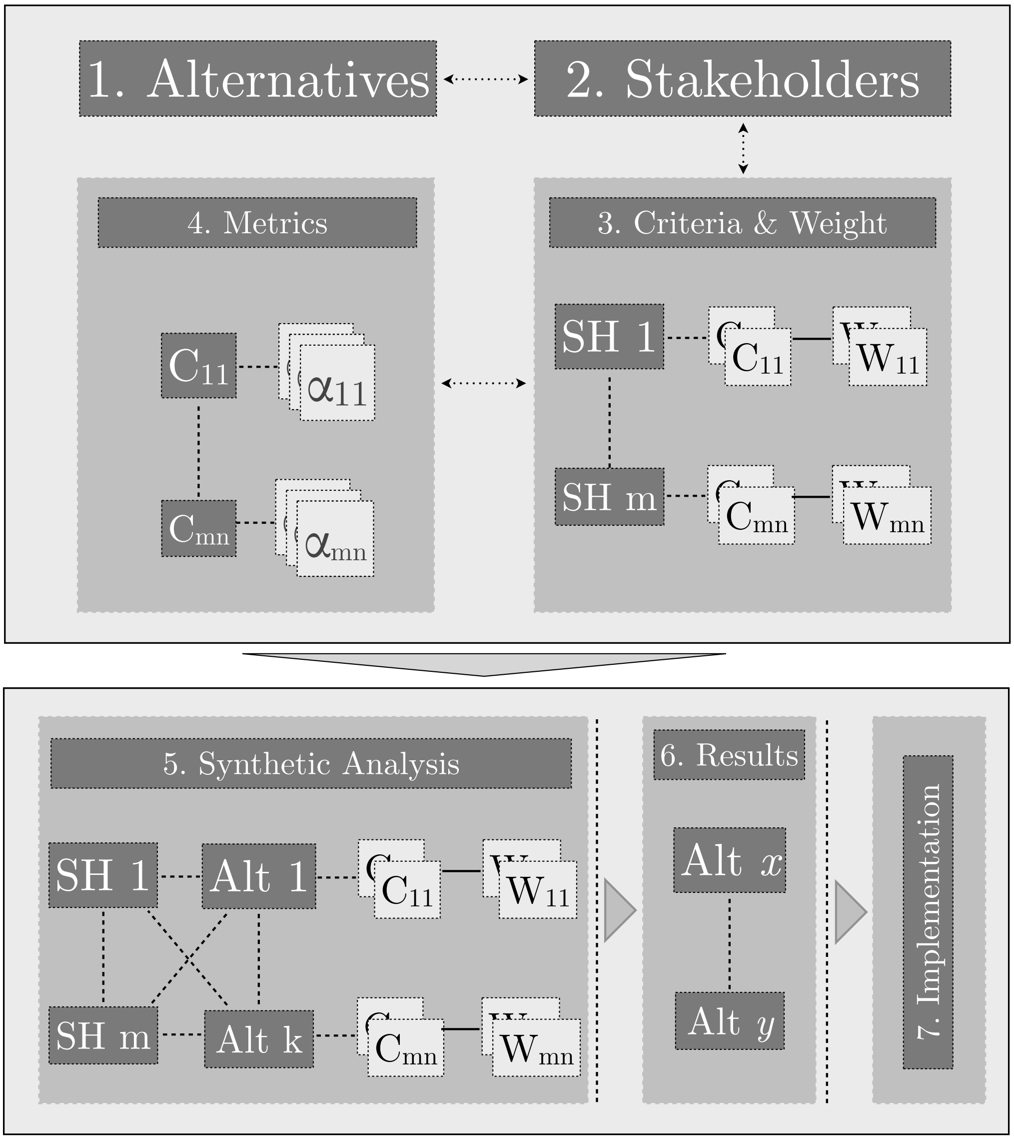

Figure 3.2 An adapted MCMSDA model based on MCDA & MCMSE

3.5.4 Stages of MCMSDA Model

The MCMSDA model that is specifically adapted to the case of UFS initiatives decision-making should contain the following seven stages. The first four stages constitute the model development. The next two stages are the synthetic analysis and decision-making stages, while the last stage is the implementation of the UFS initiative (*c.f. Figure 3.2*). This section is dedicated to illustrating each of the seven stages.

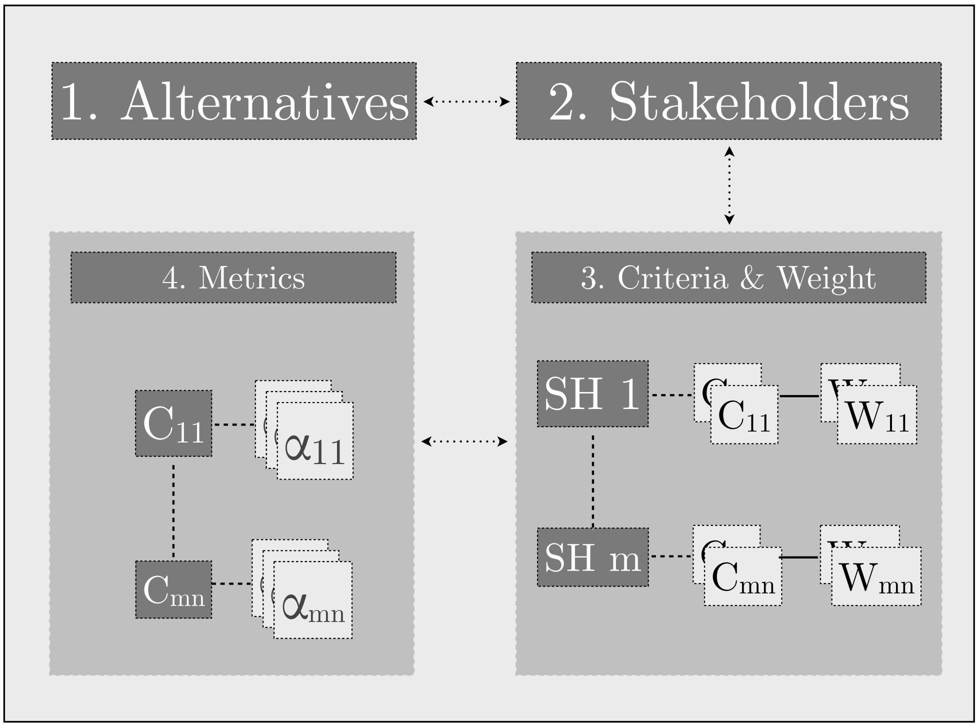

Figure 3.3 MCMSDA stage 1-4: model development

Stage 1: Alternatives Definition

The first step of MCMS decision analysis is to exhaustively identify and to clearly define all possible alternatives, which should be a straightforward move. It is where the decision maker identifies all the alternatives that need to be considered. In the case of UFS initiatives, it can be initiatives proposed by different stakeholders. It can be any of the initiatives that are reviewed in the previous chapters. It is possible to add or eliminate certain alternatives if necessary.

Stage 2: Stakeholders Identification and Investigation

The second stage involves the identification and a thorough analysis of all stakeholders. Stakeholders are the ones on whom the UFS initiative will have impact, be it financial or not[6]. A complete identification of

[6] Section 3.3.1 contains more information on the definition of stakeholders.

stakeholders and a detailed understanding of interests and objectives of every stakeholder is a key to the success of the MCSM decision-making. All their objectives are to be identified and taken into consideration in the whole process.

Stage 3: Criteria and Weights Definition

The third step is to define criteria of each stakeholder and allocate weights to each of the criteria.

The criteria are the objectives of stakeholders, or alternatively, the interests that each stakeholder would like to defend for him. The criteria identification process demands an effort so that the identification is exhaustive and comprehensive. After criteria definition, weights are to be allocated to each criterion. The weights are the importance that the stakeholders attach to each of the criteria. In general, a classical approach to tackle the weight allocation problem is by distributing a total of 100 points to all criteria (Nijkamp et al., 1990).

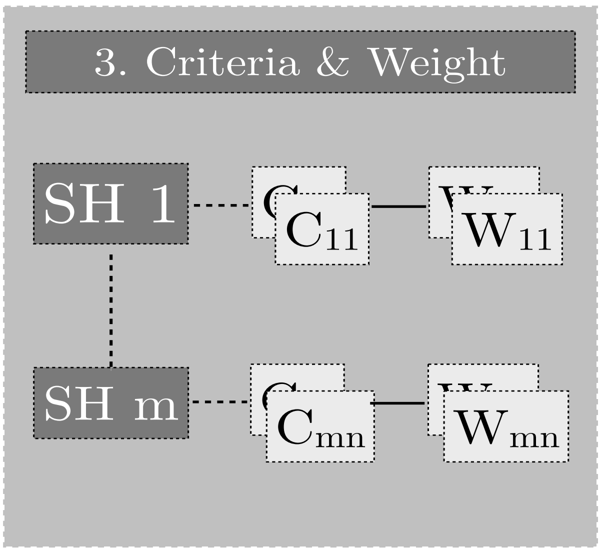

Figure 3.4 MCMSDA stage 3: Criteria and weight definition

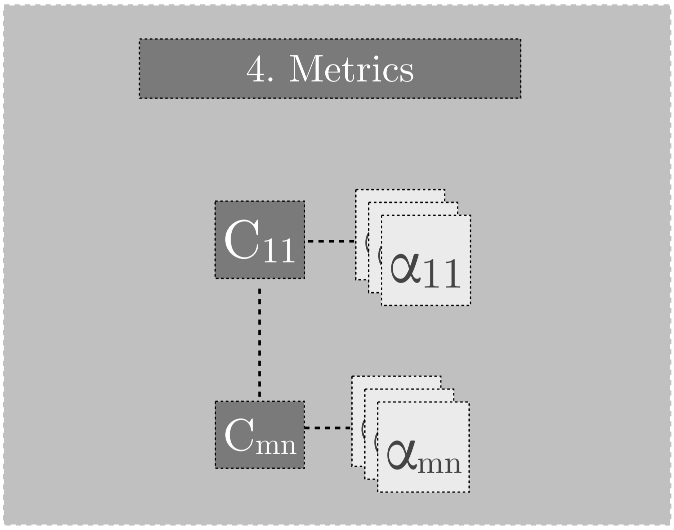

Figure 3.5 MCMSDA stage 4: Criteria quantification by metrics

Stage 4: Criteria Quantification

In the fourth phase, for one stakeholder after another, the alternatives will be examined according to the previously determined criteria in order to decide its impact or contribution to each criteria or objective of stakeholders. The impact could be significant or negligible, desired or undesired, positive or negative. The impact is to be shown by an allocation of metrics to each of them (*c.f.* α *in Figure 3.5*).

The metric can be defined in various manners. In general, it should be a direct reflection of the scale to which the alternative has impact on the criteria. The metric should also reflect whether the impact is positive, neutral or negative (Nijkamp et al., 1990). With these requirements, the metrics are in general likely to be in numbers, although exceptions can be considered.

Stage 5: Synthetic Analysis and Ranking

The fifth stage involves an integral analysis of stakeholders and alternatives. With the criteria, weights and metrics ready, alternatives

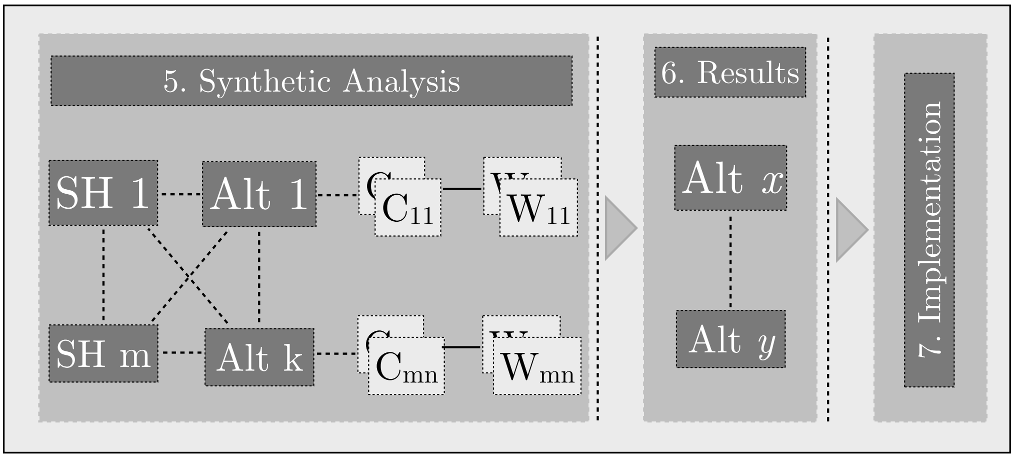

Figure 3.6 MCMSDA stage 5-7: Synthetic analysis and ranking

are examined vis-à-vis their criteria and a ranking of alternatives can be generated for each stakeholders.

Many methods are available for the analysis and determination of the ranking. The Analytical Hierarchy Process (AHP) method in this case is a suitable choice, which was adopted by other researchers as well. By adopting the AHP method, the alternatives under go a pairwise comparison, after which a weight can be calculated and allocated to each alternative.

Stage 6: Final Results and Analysis

In Stage 6, upon completion of analysis for individual stakeholders, a synthetic analysis is carried out and a final ranking of alternatives is generated. The final ranking also depends on the weights of each stakeholder. Either all stakeholders carry the same weight, but in certain cases, they can carry different weights, too.

In the real world, many of the criteria, metrics and weights tend to be subjective. Their actual value in the analysis process may in certain cases impact the final results. Therefore, an impact analysis is necessary for the whole methodology, in order to see if the final results changes significantly with variation of certain parameters.

One of the main contributions of MCMS decision analysis is the revelation of critical stakeholders and their criteria, which is usually valuable information for the decision maker.

Stage 7: Deployment

The final stage is the implementation phase.

Theoretically, the decision can be made over the multiple alternatives previously proposed, after the previous steps of analysis. Certainly, in an actual case, the decision may be subject to various factors, such as administrative procedures, negotiation among stakeholders, et cetera.

Once the decision is made, the decision maker can then proceed with the implementation of the final alternative, in this case an proper urban freight sustainability initiative.

The next chapter will be dedicated to a case study on the UFS initiatives by applying this methodology. Detailed methodology procedure is demonstrated as well.

CHAPTER 4

CASE STUDY

4.1 Introduction and Problem Definition

4.1.1 Overview

The current chapter is dedicated to a case study to apply the MCMSDA methodology studied the previous chapters. The purpose is firstly illustrate the methodology more in detail and secondly to verify the premise that the methodology is well adapted and applicable to the decision-making under urban freight sustainability (UFS) initiatives.

A problem is designed for the City of Paris, France. Although it is a hypothetical case and based on certain assumptions, the core of the problem is the same to one in reality – a multi-criteria and multi-stakeholder decision dilemma. Similar problems are challenging from local to central authorities in many cities around the globe, be it in the developed or developing world. Due to resource constraints, the current case study is conducted based on necessary assumptions that we made in order to proceed with the analysis.

4.1.2 Problem Definition

As presented in the previous chapters, the major objective for the current research is to propose a solution to the decision-making, or decision analysis, of UFS initiatives, when the decision maker is faced with multiple alternatives where multiple stakeholders have different and often conflicting objectives. MCMSDA methodology is therefore tested in the case study of Paris.

Why Paris? The main reason of choosing Paris as the research target is that the city of Paris has a clear separation with its suburbs (*c.f. 5.1*). In other words, the city centre exists in a clearly defined area, as opposed to other cities such as London where the city centre contour is much less clear. In terms of problem definition, the latter would pose problems for the research.

Figure 4.1 City of Paris and its suburbs (Source: Mairie de Paris site)

The details of the hypothetical case study problem are as follows.

The transport authority of the City of Paris is faced with the following potential action plans to tackle the negative impacts generated by urban freight transport (UFT), especially by the heavy freight vehicles in the city. They would like to see the feasibility or the popularity of these initiatives among various stakeholders.

Below are the proposed UFS initiatives.

1. Urban Consolidation Centres

Under this proposition, multiple urban consolidation centres (UCC) would be constructed and operated at the rim of the city, while trucks above certain sizes would be completely forbidden to enter the city. The goods that are to be delivered to the city centre are bound to make transshipment and are transported by a common carrier agreed by all stakeholders and operated under multi-lateral collaboration. In this case, the role of transporters within the City will be taken either by the City Authority or a common transporter designated upon agreement of all transporters.

The main advantage of UCC is firstly to completely eliminate from the city centre the heavy freight vehicle that are have high impacts on traffic conditions and environmental qualities. Secondly, because of the transshipment and consolidation processes, the load factor of the freight vehicle within the city would be much higher than the case without UCC. With the two advantages, the traffic conditions and environmental indices are likely to improve. There are however drawbacks of this initiatives as well. The pros and cons are to be analysed more in details in the next section.

2. Implementation of night-time delivery in the city

This second initiative would allow the large trucks (within a certain tonnage range to be defined by the Authority and other stakeholders) to enter the city during the night to carry out the delivery. The convenience of this initiative is that it completely eliminates or substantially reduce the freight vehicles' presence during the day time where traffic volume is high. Traffic conditions and environmental conditions are likely to improve substantially.

Meanwhile, in order to counteract the noise nuisance of trucks during the quiet hours, transporters are required to install noise cancelling or diminishing devices to decrease the truck noise level to a predefined level, which would generate additional costs for transporters. Alternatively, the transporters can use special quiet vehicles, which however are likely to be even more costly than the noise-cancelling device. More details are covered in the coming sections.

3. Road pricing for freight vehicles

In the third alternative, road pricing is proposed to be imposed for freight vehicles entering the city. Price would vary depending on the time of the day and the traffic conditions, as well as the type of vehicle, for example vehicle sizes and emission levels. The aim is to impose higher prices to dissuade freight vehicles that are either large in size or heavily polluting in terms of pollutant emission, from entering the city, especially during peak hours. The potential contribution of road pricing mainly come from regulating and improving the traffic and thereby improve other aspects of the “sustainability triad” (*c.f. Section 2.3.1*) as well.

In terms of feasibility, it is technologically possible to discriminate heavy freight vehicles from others and impose a higher price, by installing a regulated device in each heavy vehicle and charge them via a wide range of ICT (information and communication technology) options available nowadays. An example of such implementation could be the Electronic Road Pricing (ERP) system that is employed city-wide in Singapore, where vehicles are charged of different rates based on vehicles types (Menon and Chin, 2004).

4. Load factor control

The last initiative is aimed at limiting the number of empty or partly loaded freight vehicle in the city. All freight vehicles are to be controlled and are required to fulfill a load factor standard upon entering the City. Upon successful implementation, this measure would bring effective benefits to the traffic conditions and the environment (Kjaersgaard and Jensen, 2004).

However, a major challenge is the enforcement process. Setting up controlling points are likely to be costly both in terms of human resources and in terms of infrastructure. Secondly, the controlling process is likely affect the traffic as well, as the vehicle would have to stop by the checking points and the checking points could therefore become a “bottle neck” for the whole traffic (Kjaersgaard and Jensen, 2004).

4.1.3 Assumptions of the Case Study

Due to resource constraints, the case study is carried out with limited available information accessible in the research literature and from certain partners, including certain projects of Metis Consulting based in Paris.

In terms of available alternatives, the actual problem and the UFS alternatives the target city have may vary significantly depending on their approach and circumstances. The current research case study is for experiment purpose only.

In a real MCMSDA, stakeholders are in general interviewed by the decision-maker for the purpose of collecting their viewpoints, et cetera. In the current research case study, the viewpoints and preferences are based partially on assumption and partially on available literature resources. Yet the function and validity of the methodology can equally be shown with these assumptions, which would be demonstrated shortly in the upcoming sections of this chapter.

4.2 Application of MCMSDA: Results and Analysis

The application of MCMSDA on the case of Paris is directly based the methodology designed in Chapter 4 and follows strictly the various stages (*c.f. Figure 3.2*).

4.2.1 Stage 1: Alternatives Definition

After a clear definition of the problem, the alternatives have already defined as above. They are hereby named as follows:

- Alternative 1: Urban Consolidation Centre

- Alternative 2: Night-time delivery
- Alternative 3: Road pricing for freight vehicles
- Alternative 4: Load Factor Control

4.2.2 Stage 2: Stakeholders Identification and Investigation

The objective of Stage 2 is to identify all stakeholders that have an interest or interests, be it financial or not, in the decision to be taken[7]. Through a thorough analysis of the circumstances, the following stakeholders are identified.

The Transporters

The transporters are naturally the first ones to be affected, in either a facilitating or challenging way. In this case, they are not only the delivery companies (the truck owners), but also other related logistics companies, therefore the transport sector as a whole.

As they are the main "target" in the measure to be taken in the context, the decision would have significant impacts on various aspects of these companies, for example, the delivery time, delivery frequency, fleet management, salary cost, client relationship management, additional regulatory charges (for the case of road pricing), et cetera. Therefore, the transport sector is an important stakeholder. For simplification purpose, they are referred as "the transporters" here in the case study.

The Consignees

The consignees, namely the receivers, are also liable to be largely affected by the decision in the context. As the main target of UFS

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[7] C.f. Section 3.3.1 for more information on the definition of stakeholder

initiatives are the (heavy) freight vehicles in the case study, the consignees refer to the local businesses in the city. Individual receivers are neglected for simplification purpose. The initiative to be taken is likely to affect the delivery time of the day, delivery frequency, the delivery timeliness, and possibly the cost of the delivery service. Therefore, the consignees are one of the important stakeholders.

The Public

In this case, as the objectives of the general public and the authority (the government) are in general consistent and aligned, they are considered as one single stakeholder.

UFS initiatives usually trace back their origins to the public, because of their concerns on the social, environmental and economic sustainability of the city. Hence the initiative in the context would have a direct impact on them. The result of the measure taken will affect them from multiple perspectives, from safety, to health, to the quality and attractiveness of the environment they live in, to traffic conditions they experience on a daily basis, to their quality of life as a whole, et cetera. Therefore, the public is a major stakeholder.

The Employees

The employees, as a stakeholder, refer to people who work for either the transporters or the consignees. Although there are certain common interests between the transporters, the consignees and the employees, many specific concerns of the employees are different.

As the employees are the ones who directly execute the freight delivery and reception processes, the changes due to the new initiative are to have multiple impacts on their life, including their time of work, safety, health, salary, stress et cetera.

4.2.3 Stage 3: Criteria and Weights Definition

The objective of Stage 3 is to firstly identify specifically the criteria, namely the objectives, of each stakeholder group, and secondly assign an appropriate weight to each of the criteria according to the specific circumstance under which each stakeholder group is situated.

Through a thorough analysis, the specific criteria for each stakeholder are identified as follows. The weights distribution will be integrated with the subsequent stages, namely the criteria quantification and synthetic analysis.

4.2.3.1 The Transporters

Total delivery costs. The total delivery costs affect at the same time the profitability of the transporter and the best price that can be offered to their customers (i.e. the consignees). This criterion includes delivery cost and potential additional cost due to the implementation of the alternative, for example additional charges in the case of Alternative 3 Roading pricing.

Customer relationship. Transporters would naturally wish to maintain a healthy and growing relationship with their customers to maintain profitability. The measure to be taken is likely to affect some aspects of the delivery, which in turn has impact on the satisfaction of their customers.

Technical viability. Some of the alternatives may be technically easier to realise and execute than others. For example, in the case of Alternative 2 Night-time delivery, it is technically more complicated to execute than some other alternatives.

Organisational viability. Organisational viability refers to the question of how easy it is to implement the initiative and organise it in an efficient and effective manner. For example, in the case of Alternative 1 Urban consolidation centre, it is organisationally more complicated to make transshipment at the rim of the city than to delivery the goods directly to the customers' premises.

Employee management. Having satisfied and motivated employees is a key to success for any business, so it is to the transport sector. Different initiatives may have different impact on their employees. For example, Alternative 2 Night-time delivery would make a significant impact on the involved employees' lives.

4.2.3.2 The Consignees

Delivery price. The first concern for the consignees, naturally, is the financial concern. Lower delivery price is always attractive for the consignees. The regulatory measure to be taken is likely to affect the delivery price to a certain extent.

Delivery quality. This aspect including delivery lead time, punctuality, frequency, price et cetera. Delivery quality is therefore directly influenced by the initiative to be taken. For example, if the Urban Consolidation Centres (UCC) were implemented, it would possibly affect the delivery lead-time and even punctuality, as most goods would have to undergo an additional step of transfer. This criterion applies to other initiatives as well.

Customer relationship. In many cases, the consignees are local businesses located in the city, thus customer satisfaction is an important factor. Customer satisfaction is directly related to and to a large extent influenced by the delivery quality, including the punctuality, lead time, et cetera.

Goods safety. The goods safety is another concern of consignees, which is also subject to the influence of the initiatives in the context. For example, if the night-time delivery were implemented, there would be potential concern for goods' safety in the case where the consignee is not present when delivery happens during the night.

Employee management. This criterion is similar to that of the previous stakeholder - the transporter (*c.f. 4.2.3 the transporter*s).

Pleasant urban environment. This criterion matters mainly because of the fact that the consignees here are local business owners. Initiatives to be chosen would affect more or less the urban environment. Having heavy vehicles passing by periodically during the day or not does have an impact to some extent the shopping experience for the business owners' customers.

4.2.3.3 The Public

Pleasant urban environment. This criterion is similar to the case of the consignees (*c.f. 4.2.3 the consignees*). In this case, it may also include the following two sub-criteria. *Level of noise nuisance*. Freight vehicles have in general more impact on noise nuisance level than passenger vehicles (Dablanc, 2007). A policy such as the night-time delivery could possibly affect substantially this criterion. *Level of pollutants.* Freight vehicles are also responsible for an important part of pollutant emission in the city (*c.f. Figure 2.1*). The number of freight vehicle, especially the heavy freight vehicles, has a direct correlation with the level of pollutant emission in the city.

Traffic safety. Traffic safety is obviously a concern of the public. The number of heavy freight vehicles circulating on the city's road network has a direct relationship with the level of traffic safety the public experience (OECD, 2003).

Traffic condition. Having a smooth traffic or not makes a significant difference in people's life and transport experience. Freight transport, especially the heavy vehicles, has a non-negligible impact on the traffic conditions.

Efficient urban goods distribution. As the final consignees of urban goods distribution are people in the society, an efficient urban goods distribution has a direct impact on most people's life and various experiences in the city. It is therefore an important factor to consider.

Public expenses of projects. As certain projects would involve public expenses, the public expense incurred by the initiative is an important factor as well.

4.2.3.4 The Employees

Safety. Safety is the first concern of all. It is by far the most important factor to consider as for employees. A policy such as the night-time delivery has a potential impact on the employees' safety concerns, as there could be possible safety implications for driving the night, or working for the consignees during the night.

Health. Health as a factor plays its role from two ways. Firstly it is affected by the work itself, which similar to the previous criterion. For example, working at night or during the day may have a possible influence on their health condition. Secondly, health is also, in the long term, related to the quality of urban environment, especially the air condition, which in turn is related to the freight transport.

Salary. Salary is another concern. Some initiatives may have more impact on the salary than others. But it is in general a concern for employees of the transporters, as well as of the consignees.

Social life. Social life is an important part of employees' concern. In the case of night-time delivery, the employees' working hours may easily become incompatible with those of their family and friends and therefore affect their social lives.

Stress. Stress is directly related to the level of how much employees enjoy their work. This variable could affect to certain extent the performance of transporters and the consignee business. Although it is not among the most important criteria such as the salary or health, it is a criterion not to be missed.

4.2.4 Stage 4: Criteria Quantification

4.2.4.1 Metrics Definition

The mission of the fourth stage is turning qualitative objectives of each group of stakeholders into quantitative criteria and metrics to prepare for further analysis. It includes mainly weights distribution among criteria for each group of stakeholders and allocating, one stakeholder after another, metrics, or indicators, of importance to each alternative vis-à-vis each criteria.

For each stakeholder, a total weight of 100 points is allocated to each criterion. For experimentation purpose, assumptions are made upon the allocation. In real cases, face-to-face interviews with stakeholders are necessary to obtain the real preference to determine the weights.

Afterwards, each alternative is examined vis-à-vis the criteria of all stakeholders and metrics, i.e. a score, of preference are allocated to each alternative for all criteria. The scores are indicators of the extent to which the alternatives influence a certain criteria, from being very positive to very negative. The score is given as an integer from -2 to +2. They will be subsequently transformed in the forthcoming stage, in order to be applied to the analytical hierarchy process (AHP). The scores are hereby defined as follows (*c.f. Table 4.1*).

Table 4.1 Metrics and influences conversion

Metrics	Influences
+2	Very positive
+1	Relatively positive
0	Neutral (No influence)
-1	Relatively negative
-2	Very negative

4.2.4.2 Metrics Assignment

In this section, stakeholders are to be examined one by one vis-à-vis the alternatives. The weights and the metrics are allocated as follows, one stakeholder after another. It is to be noted that the metrics and weights are allocated based on literature and reasoning judgment. Their values can be adapted to a real case upon a relatively easy modification of parameters.

1. The transporters

Criteria weights. As a business, the primary concern for the transporters is the financial impacts of an action. Thus, total delivery cost is the most important criterion, followed by customer relationship and organisational viability, and lastly technical viability and employee management.

Metrics for alternatives.

- *Total delivery costs.* Alternative 2 – night-time delivery can help carriers substantially save delivery cost mainly by rising the vehicle load factors, optimising delivery route and saving delivery time (Quak, 2008). Alternative 4 – Load Factor Control, similar to the last one, help save delivery cost to a certain extent. While the other two alternatives are likely to lead to higher costs.
- *Customer relationship.* Alternative 2 brings at the same time positive and negative impacts to this criterion. While possible lower price can be offered to the customer, night-time delivery is likely to cause certain degree of inconvenience for the customer

as well. The three other alternatives are rated as slightly negative, because of their related impacts on the delivery price or delivery lead-time.

- *Technical viability.* Alternative 2 is liable to pose a technical challenge to the transporters, as they would be required to operate vehicles in a much more silent environment. The other alternatives are not concerned in this criterion.
- *Organisational viability.* Alternative 1 – Urban consolidation centres (UCC) is the most challenging one in terms of organisation. Reconsolidating freight at the rim of the city and redelivering them via another vehicle directly add another step in the supply chain and create more organisational challenge (Allen et al., 2000). Alternative 2 on the other hand is facilitating in terms of organisation because delivering when there is no traffic at all is much easier as compared to a congested traffic. Alternative 3 and 4 both pose challenges as well.

Table 4.2 Criteria quantification for the Transporters

Criteria	Weights	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Total delivery costs	40	-1	+2	-1	+1
Customer relationship	20	-1	0	-1	-1
Technical viability	10	0	-1	0	0
Organisation al viability	20	-2	+1	-1	-2
Employee management	10	+1	-1	0	-1

- *Employee management.* Alternative 1 leaves the delivering part within the city to other carriers and thus is a positive initiative for employee, as they are not longer responsible for the most challenging part in the city. Alternative 2 would oblige the employees to drive at night, which is a very negative aspect, however it is slightly alleviated by the fact that driving at night is much easier than during the daytime. Alternative 3 has no impact on employees, whereas Alternative 4 causes slight inconvenient to employees as they would have to stop the vehicle for load factor control and possibly join a long queue in front of the control point (Kjaersgaard and Jensen, 2004).

2. The Consignees

Criteria weights. Similarly to the transporters, as a business, the primary concern for the consignees is also the financial impacts of a change. Therefore, delivery price is the most important criterion, followed by delivery quality, customer relationship. Goods safety, employee management and pleasant urban environment is slightly less important.

Metrics for alternatives.

- *Delivery price.* As Alternative 1 – UCC add another process to the supply chain, the total delivery price is likely to augment the delivery price. Alternative 2 and 4 help to slightly decrease the delivery costs and thus are likely to decrease to a certain extent delivery price. Alternative 3 only increases costs for the transporters, and thus prices in the long term should slightly increase.

Table 4.3 Criteria quantification for the consignees

Criteria	Weights	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Delivery price	25	-1	+1	-1	+1
Delivery quality	20	0	0	-1	-1
Customer relationship	20	-1	0	-1	-1
Goods safety	15	0	-1	0	0
Employee management	10	0	-2	0	0
Pleasant urban environment	10	+2	+2	+1	+1

- *Delivery quality.* For **Alternative 1,** with the implementation of UCCs, there are both positive and negative impact vis-à-vis the consignees. On the one hand, because of improvement in traffic condition upon elimination of heavy freight vehicles, the substituting smaller trucks are likely experience less traffic congestions leading to more accurate time. On the other hand, because the freight vehicles in the case of Alternative 1 are shared vehicles among different transporters, the service quality is unlikely to reach the same level as compared to the traditional. For example, if an additional delivery is needed, with the existence of UCC, the unplanned delivery lead-time is likely to be longer. Therefore the overall delivery quality is set to be 0. Similarly for **Alternative 2**, if it were implemented, night-time delivery ensures better timeliness for delivery, thanks to smoother traffic conditions during the night. However, for some consignees, receiving goods during the night may affect normal conduct of their business. For example, in the case of supermarkets, some chilled goods need to be delivery in the morning (Devine, 2011). With the above constraints, the overall impact on delivery quality is therefore neutral, i.e. 0. Alternative 3 and 4 both have a potential negative impact on the delivery timeliness.

- *Customer relationship.* Alternative 1, Alternative 3 and 4 could affect customer relationship negatively because of their impact on delivery timeliness. Alternative 2 has basically no influence on this criterion.
- *Goods safety.* This criterion only concerns Alternative 2 where deliveries are carried out during night and goods safety is subject to a potential negative impact.
- *Employee management.* This criterion, too, only involved Alternative 2. Employees would be obliged to work at night to receive the goods, which to many is a very negative impact.
- *Pleasant urban environment.* All four alternatives are positive to urban environment, where Alternative 1 and 2 are likely to have more impactful results than 3 and 4, as they eliminate a substantial portion of freight vehicles from the city's traffic.

3. The Public

Criteria weights. For the public, the overall quality of urban environment is definitely the primary concern, followed by traffic safety, traffic conditions. Public expenses are another concern, especially in the developed countries, as some initiatives may cost much more than

Table 4.4 Criteria quantification for the public

Criteria	Weights	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Pleasant urban environment	30	+2	+1	+1	+1
Traffic safety	20	+1	+2	+1	+1
Traffic condition	20	+1	+2	+1	+1
Efficient urban distribution	10	+1	+1	0	0
Public expenses	20	-2	0	0	-1

others. Lastly, an effective goods distribution concerns everyone; as the goods are in the end delivered to people that form "the public".

Metrics for alternatives.

- *Pleasant urban environment.* All alternatives contribute to this criterion. Alternative 1 is likely to create the best results as it eliminates all the other freight vehicles except the common carrier. Alternative 2 also generates very good results, however, because night-time delivery may in certain cases affect the quality of residents because of some level of noises, it is assigned as "+1".
- *Traffic safety.* All alternatives contribute.
- *Traffic condition.* Similar as the above criterion.
- *Efficient urban distribution.* Alternative 1 and 2 contribute positively, and 3 and 4 have no substantial impact.
- *Public expenses.* Alternative 1 would cost a considerable sum of public expenses to build and operate the UCCs. For Alternative

3, the revenue later generated would compensate the initial setup fee. For Alternative 4, it is relatively more complicated and costly to control the load factor than to charge vehicles wireless (the case of Alternatives 3).

4. The employees

Criteria weights. Salary, safety and health are almost equally important to employees in most cases (Quak, 2008). Social life and stress are another equally important criteria.

Metrics for alternatives.

- *Safety.* All initiatives are likely to contribute to a better traffic and working condition and thus improve safety, except Alternative 2 where employees would be obliged to work during the night, which has a potential danger on safety.
- *Health.* Similar to last criterion. Alternative 2 has a negative impact on employees' health conditions.
- *Salary.* Most alternatives would not affect employees' salary, except Alternative 2 where they would work at nighttime and are likely to have more salary to a certain degree.
- *Social life.* Social life is also mainly affected by Alternative 2 where employees have an "incompatible" timetable compared to their family or friends.
- *Stress.* Alternative 1 reduces stress for employees as they skip the difficult part of city centre traffic. Night-time work, despite of potential safety concerns, imposes less stress as there are less traffic as well. Alternative 4 may lead to long queuing time and checking time at the load factor control station and add stress.

Table 4.5 Criteria quantification for the employees

Criteria	Weights	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Safety	25	+1	-2	+1	+1
Health	20	0	-1	0	0
Salary	25	0	+1	0	0
Social life	15	0	-1	0	0
Stress	15	+2	+1	0	-1

4.2.5 Stage 5: Synthetic Analysis and Ranking

This section is dedicated to the synthetic analysis of the alternatives and stakeholders, based on the weights and metrics allocated during the Criteria Quantification stage in the last section. They are to be transformed into evaluation matrix. For each stakeholder, a ranking of preferred alternatives is generated. Subsequently, upon an integral analysis, a final ranking of alternatives will be obtained.

4.2.5.1 General Principles

a. AHP and Degree of Preference

AHP is employed as the decision-making method. The metrics of importance that are allocated to each criteria undergo a pairwise comparison and are allocated in a degree of preference from 1 to 9, based on the difference of metrics allocated to them previously. The degrees of preference are defined following a typical analytical hierarchy process (AHP) manner as follows (Saaty, 2001).

Table 4.6 AHP conversion for metrics

Degree of Preference	Metrics Difference	Definition (Explanation)
1	0	Equally preferred: two elements contribute equally to the objective
3	1	Moderately preferred: experience and judgment slightly favour one element over another
5	2	Strongly preferred: experience and judgment strongly favour one element over another
7	3	Very strongly preferred: experience and judgement very strongly favour one element over another
9	4	Extremely preferred: the evidence favouring one element over another is of the highest order of affirmation

The intermediate judgments of 2, 4, 6 and 8 can be used if necessary. The reciprocal judgments are interpreted as follows: if, for example, A is judged to be moderately preferred to B, the pairwise comparison between A and B is 3, implying the pairwise comparison between B and A is 1/3. A series of software are available for AHP application. As the data sets are within a certain limit, Microsoft Excel is employed as the main tool.

b. AHP Process

The AHP method is repeatedly applied to each of the stakeholder groups. For each stakeholder, the calculating process starts from pairwise comparison of alternatives for each criterion, where degrees of preference are used and a ranking of preference is generated. Upon completion of pairwise comparison for all criteria, a final ranking of all alternatives is generated with consideration of criteria weights.

Table 4.7 AHP - Pairwise comparison for the transporters' criteria 1[8]

Alt	1	2	3	4	Geometric Mean[9]	Normalised Weight
1	1.00	0.14	1.00	0.20	0.411	0.068
2	7.00	1.00	7.00	3.00	3.482	0.580
3	1.00	0.14	1.00	0.20	0.411	0.068
4	5.00	0.33	5.00	1.00	1.699	0.283
				Sum	6.003	1

Table 4.8 AHP Results for the Transporters

Alt/Crit	1	2	3	4	5	Weighted Average
1	0.068	0.126	0.219	0.077	0.490	0.139
2	0.580	0.379	0.073	0.659	0.084	0.455
3	0.068	0.126	0.219	0.192	0.219	0.135
4	0.283	0.126	0.219	0.077	0.084	0.184
Criteria Weight[10]	0.4	0.2	0.1	0.2	0.1	

For example, for the Transporters' first criterion – "total delivery cost", alternatives undergo pairwise comparison and normalised weights, that is the Transporters' preferences on 4 alternatives vis-à-vis the criterion "total delivery cost", can be obtained by AHP method (*c.f. Table 4.7*). After pairwise comparisons for all criteria, the alternative preferences of the Transporter can be generated (*c.f. Table 4.8*)[11]. Similar processes are executed for the other three stakeholders.

4.2.5.2 Preliminary Results

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[8] *c.f.* Table 4.2 and Table 4.6.

[9] The geometric mean of a data set $\{a_1, a_2, \ldots, a_n\}$ is given by:

$$\left(\prod_{i=1}^{n} a_i\right)^{1/n} = \sqrt[n]{a_1 a_2 \cdots a_n}.$$

[10] *c.f.* Table 4.2.

[11] All calculations details are included in Appendices.

AHP process is applied to each of the stakeholder groups. The following are the results for the four groups of stakeholders.

Stakeholder 1: The transporters.

Analysing the results, it can be quickly observed that the transporters have a very high preference on Alternative 2 (night-time delivery) over other alternatives (up to 45.8%). Alternative 4 (load-factor control) is slightly more preferred than the other two initiatives. Alternative 1 seems be the least preferred.

Observing the criteria and respective weights for the transporters, "total transport costs" is the priority in their concerns, followed by "customer relationship" which is a direct reflection of total delivery quality (including delivery lead time, delivery punctuality, emergency reactiveness, et cetera.). Among the four alternatives, only Alternative 2 has a potential cost decrease, whereas the rest three options would all generate more costs. Therefore, the results correspond well to the observation for Stakeholder 1 - the Transporters.

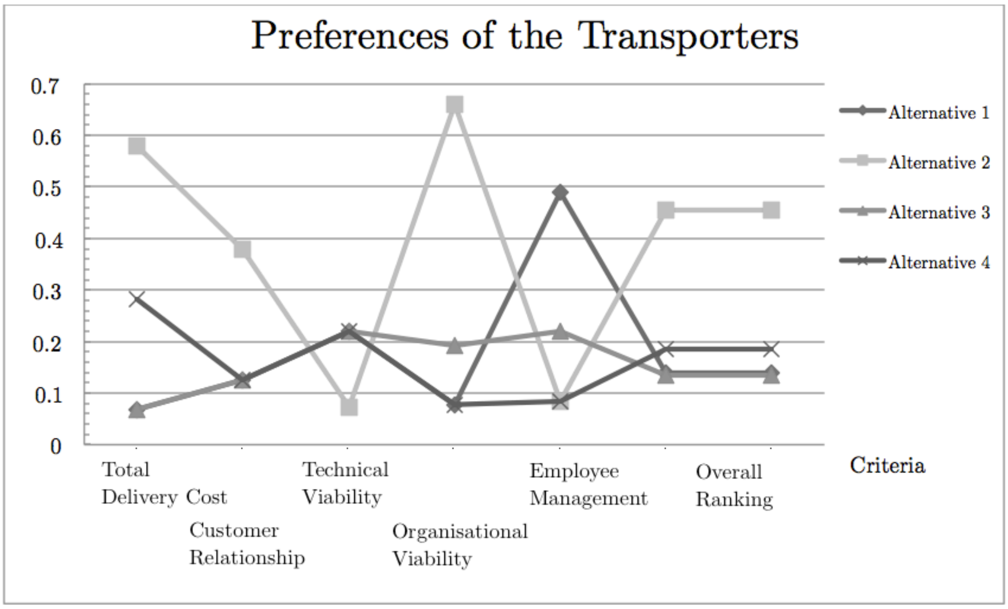

Figure 4.2 Preliminary results: preferences of the transporters

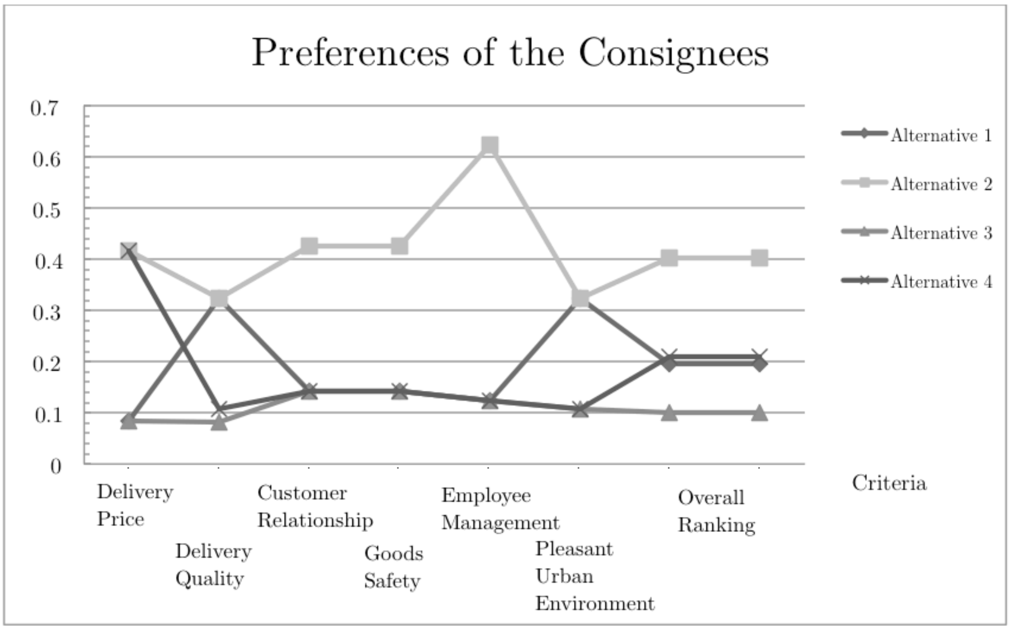

Figure 4.3 Preliminary results: preferences of the consignees

Stakeholder 2: The consignees.

For Stakeholder 2, Alternative 2 is also highly preferred (40.1%), though slightly less than the case of Stakeholder 1. Alternative 1 and 4, being both near 20%, are almost equally preferred, while Alternative 3 is the least preferred.

Observing the criteria of Stakeholder 2, the consignees are concerned primarily about delivery price and delivery quality. Although Alternative 2 would bring some level of inconvenience to certain consignees, the possible low price and quickly delivery during the night make Alternative 2 (night-time delivery) stand out of the four initiatives. Therefore, the result for Stakeholder 2 (the consignees) is consistent with the observation.

Stakeholder 3: The public.

The preferences of Stakeholder 3 the public is less absolute than other stakeholders. Alternative 2 is still the most preferred with a preference

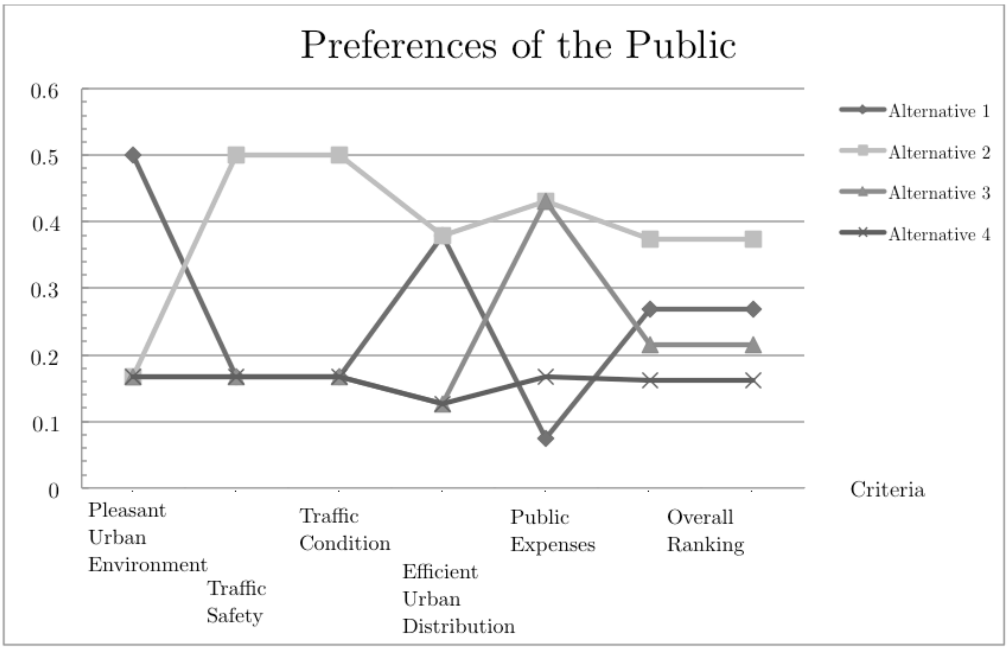

Figure 4.4 Preliminary results: preferences of the public

of 37.4%. Alternative 1, with a result of 26.9%, is also supported by the public. Road pricing and load factor are respectively 21.5% and 16.2%.

The concerns of the public are relatively evenly distributed among the criteria, such as “pleasant urban environment”, “traffic safety”, “traffic conditions”, “public expenses”, et cetera. Although Alternative 1 is likely to bring about the most significant improvement to the environment, which is the biggest concern of the public, it is also the most expensive initiative (*reference*). Alternative 2 contribute significantly to the environment and is much less costly in terms of public expenses, which results in the first place for the public. Alternative 3 and 4 are more costly than Alternative 2 and are likely to contribute less the environment, which explains their low ranking. The result of Stakeholder 3 is coherent with the observation as well.

Stakeholder 4: The employees.

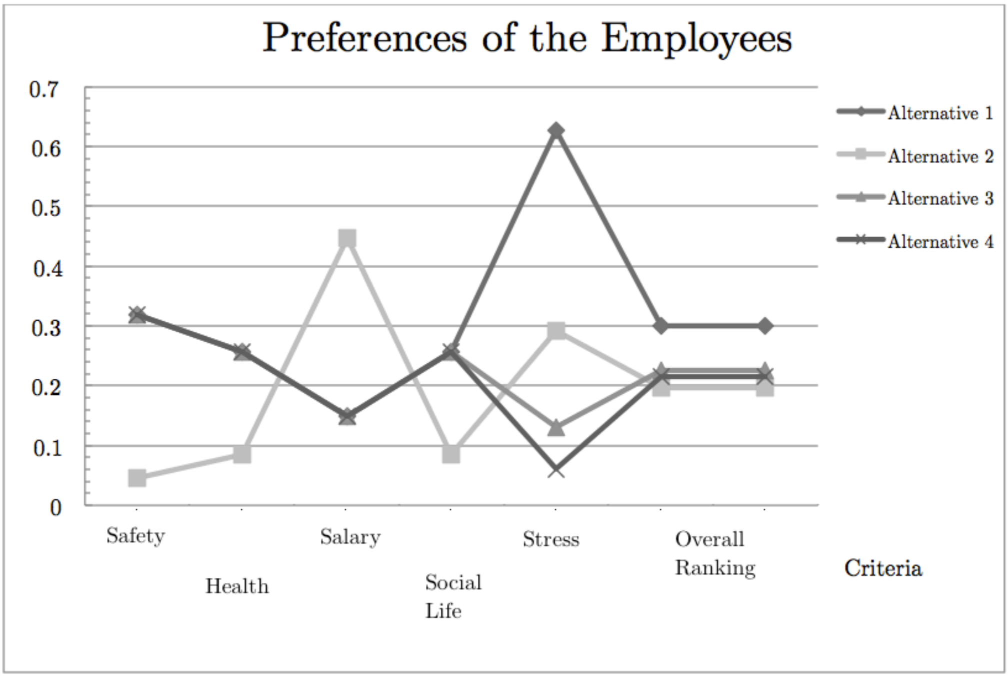

Figure 4.5 Preliminary results: preferences of the employees

The employees' highest preference turns out to be Alternative 1 Urban Consolidation Centres (approximately 30%). Their preferences vis-à-vis the other three initiative are almost equal, which are respectively 19.7%, 22.6%, 21.6%. Looking into the criteria of the employees, their primary concerns are "health", "safety", and "salary". Although Alternative 2 is likely to provide additional salary opportunities for workload during the night, the finance incentive is weakened by related health, safety and other concerns incurred by night-time delivery. Despite absence of finance incentive, Alternative 1 is preferred by the employees, especially the ones of transporters, mainly because they do not experience traffic congestions and related stress in the city. Hence, the result for Stakeholder 4 is consistent with observation as well.

4.2.6 Stage 6: Final Results and Analysis

4.2.6.1 Final Results with Equal Stakeholders

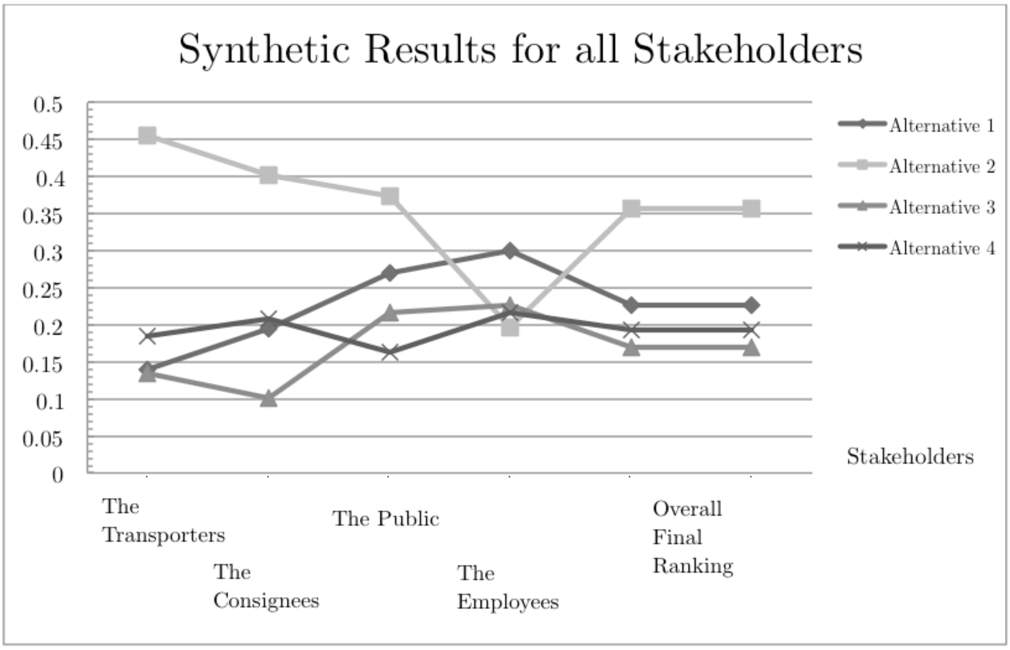

Figure 4.6 Final results with equal stakeholders: overall ranking

In this case study, equal weights for stakeholders are employed to general final results. However, in a real case, weights of stakeholders can vary substantially from country to country.

With the above assumption, integrating the results of all stakeholders, a final ranking for alternatives can be generated as follows. Among the four choices, Alternative 2 - Night-time delivery is the most preferred (35.8%), followed by Alternative 1 - UCC (22.3%), Alternative 4 Load factor control (19.4%), and Alternative 3 Road pricing (17.1%).

4.2.6.2 Stakeholder Sensitivity Test

Stakeholder Weights. To fully integrate the preferences of all stakeholders, an important factor is to be considered, that is the weights of each stakeholder. As is suggested in the previous section, the weights of stakeholders could vary from case to case.

A sensitivity test is therefore carried out to observe if the result substantially changes while stakeholders' weights vary. As is shown in

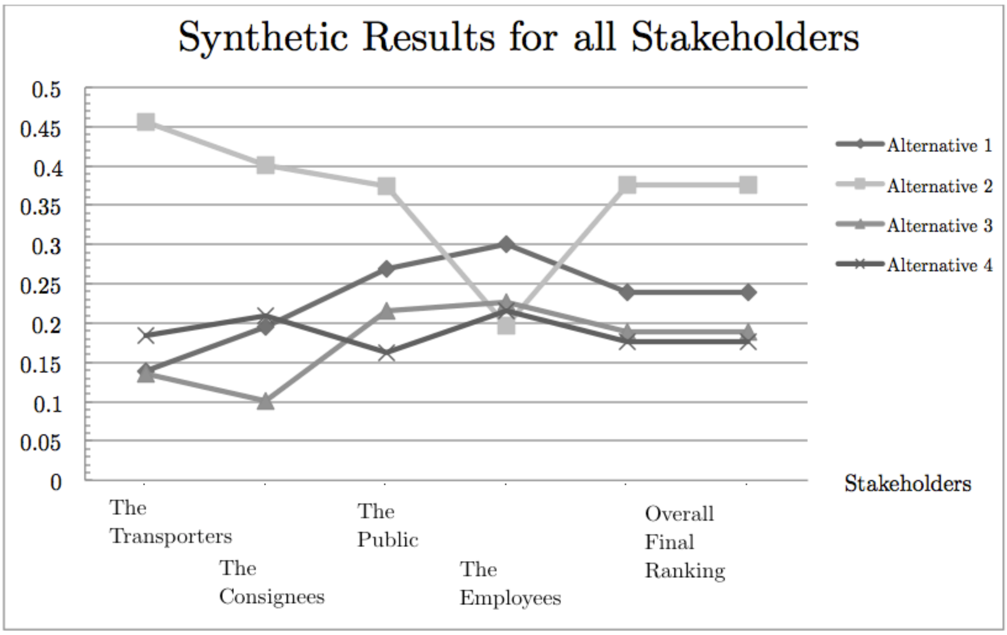

Figure 4.7 Stakeholders weights sensitivity test

Figure 4.7, when the Public is assigned 60% of total weights, the results stayed relatively stable as compared to the previous case. Alternative 2 is again by far the most preferred option.

4.2.6.3 Results Analysis

With various weights for all stakeholders, the results suggest that Alternative 2 – Night-time delivery is the most preferred UFS initiatives. The final result is understandable, as it is financially the most economical and environmentally the most efficient initiative, although it is not without challenges[12].

4.2.7 Stage 7: Deployment

After the previous six stages of examination and analysis, the final choice stands out. The rest of the mission is to deploy the UFS initiative. Observation and supervision are needed along the progress of

[12] Devine (2011) carried out an in-depth research on the challenge of night-time delivery, in which noise management and consignee reception are the biggest challenges.

implementation to ensure the initiative is aligned with the reality. If any unforeseen circumstances appear, adjustment of the initiative could be necessary (Quak, 2008).

CHAPTER 5

CONCLUSIONS

5.1 Concluding Remarks

Along the years, the dilemma of urban freight transport (UFT), being at the same time of critical importance in supporting a city's lives and economy and a "trouble-maker" of a city, has challenged generations of transport authorities, carriers and researchers around the globe, and the challenge will certainly continue. Focused on how policymaking can make more sound choices when faced with multiple urban freight sustainability (UFS) initiatives, the research achieved its objectives with the following key findings.

5.1.1 Key Leverages in Urban Freight Sustainability

Understanding UFS initiatives. Chapter 2 carried out an in-depth examination of current UFS initiatives including a detailed classification of current initiatives. It revealed that, from an initiator point of view, there are three types of initiatives that are respectively public-driven, private-driven and under public-private-partnership.

From the nature of the initiatives, there are main two types of them, namely infrastrutural and organisational.

Multiple criteria - "Sustainability Triad". The environmental-economic-social sustainability triad is one of the key factors to consider when taking actions in UFT-related initiatives. Focusing on one or two of the triad does not fix the problems and often creates more of them (*c.f. Section 2.5*). Sole suppression of the "evil" transporters, while bringing direct environmental benefits, is a direct threat to the economic "leg" of the triad.

Multiple stakeholders. Besides the multi-criteria specificity, the main hurdle to the UFS initiative decision-making process turns out to be conflicting stakeholders. Lack of specific incorporation of stakeholders in the UFS initiative decision-making process ultimately leads to project dysfunction and eventual failure. Specifically and separately considering the criteria of stakeholders is of critical importance.

5.1.2 Multi-criteria Multi-stakeholder Decision Analysis

Being only capable of consider multiple criteria but not specifically multiple stakeholders makes traditional multi-criteria decision analysis (MCDA) methods unsuitable for UFS initiative decision context.

The adapted multi-criteria multi-stakeholder decision model based on MCDA and MCMSA is an effective tool to cope with UFS initiative choices (*c.f. Figure 3.2*). It precisely defines the stakeholders at an early stage of the decision process and thereby comprehensively incorporates various criteria from stakeholders. Apart from being able to include stakeholders, another two advantages make it a power tool. Firstly, alternatives and criteria can be added or eliminated along the process, which is a substantial convenience. Secondly, weights of stakeholders are an easily adjustable parameter. This specificity empowers the policy maker to personalise the decision-making by adapting to their local specificities. Places like Western Europe may allocate more weights to the public stakeholders, whereas in many Asian countries such as Singapore, the authorities may tend to outweigh other stakeholders.

5.1.3 Results of Case Study

The case study on the City of Paris chose four of the most efficient UFS initiatives as candidates for decision-making. The study demonstrates that MCMSDA is effectively an applicable tool when the policy maker is faced with UFS initiative decision dilemma.

5.2 Future Research

5.2.1 Further Development of MCMSDA

Multiple Rounds of MCMSDA Application. When a decision is made and a specific alternative is chosen, the decision maker could apply the MCMSDA methodology for another round to decide on which specific configuration of the alternative to adopt. For example, if the night-time delivery is chosen as the best alternative, another round of MCMSDA can be carried out to determine specific time range of the night-time delivery by creating different scenarios with different time ranges, for example between 7pm to 6am, or between 8pm to 12am, et cetera.

Breakdown of criteria into sub-criteria. Breaking down certain criteria into more specific sub-criteria is likely to improve the accuracy of the entire methodology. For example, delivery quality can be decomposed into delivery lead-time, delivery punctuality, emergency reactiveness, et cetera.

5.2.2 Real-world Project

Future research, in case conditions permit, could carry out a real-world project testing the methodology, under partnership with relevant transport authorities and other stakeholders. Carrying out a real-world project can serve both as a potential improvement opportunity for the methodology and a support for the local policy makers.

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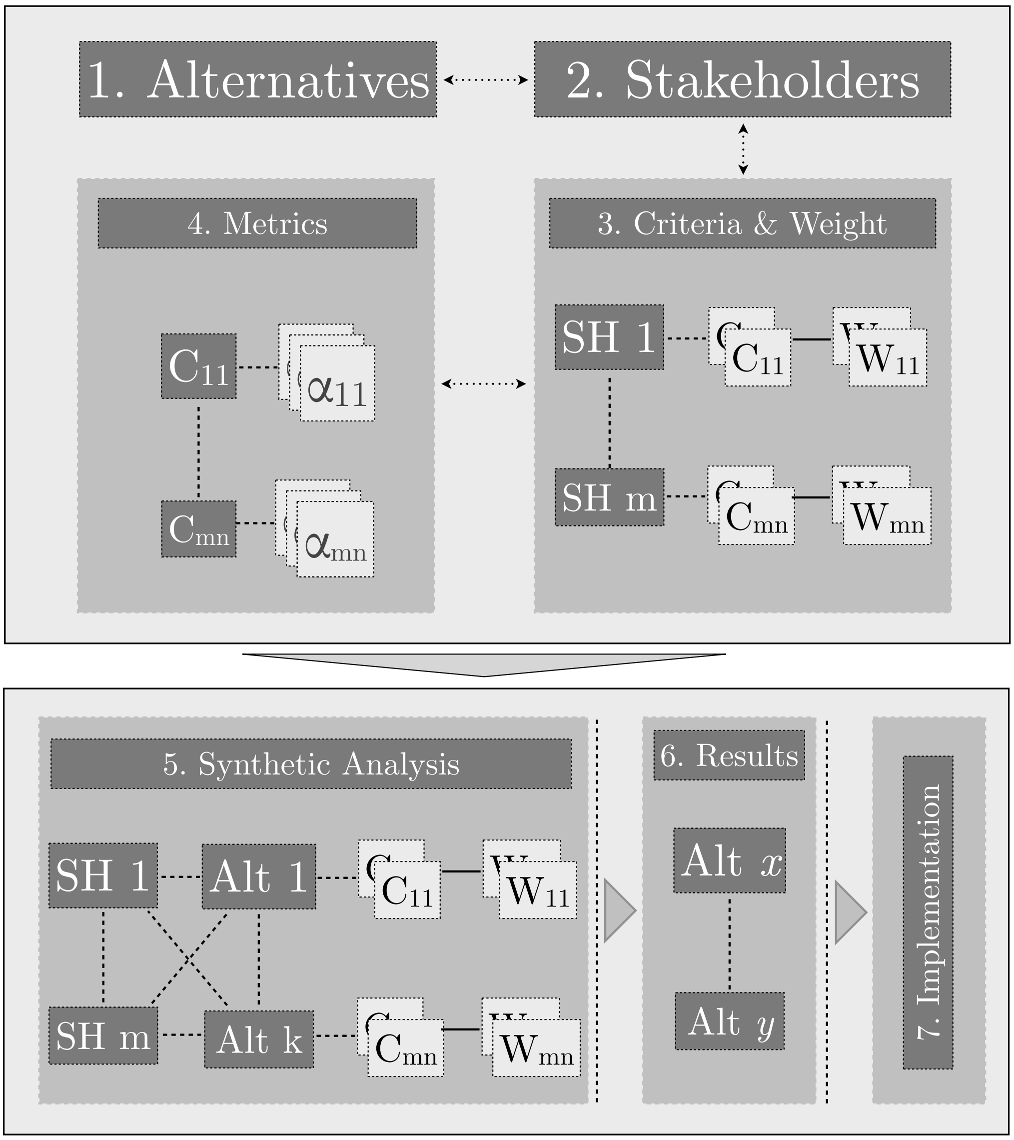
APPENDICES

A.1 MCMSDA Model, based on MCDA & MCMSE



A.2 AHP Calculation Processes

A.2.1 Detailed Results for the Transporters

Table A.1 Pairwise comparison for the transporters' criteria 1[13]

Alt	1	2	3	4	Geometric Mean[14]	Normalised Weight
1	1.00	0.14	1.00	0.20	0.411	0.068
2	7.00	1.00	7.00	3.00	3.482	0.580
3	1.00	0.14	1.00	0.20	0.411	0.068
4	5.00	0.33	5.00	1.00	1.699	0.283
				Sum	6.003	1

Table A.2 Pairwise comparison for the transporters' criteria 2

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	0.33	1.00	1.00	0.760	0.127
2	3.00	1.00	3.00	3.00	2.280	0.380
3	1.00	0.33	1.00	1.00	0.760	0.127
4	1.00	0.33	1.00	1.00	0.760	0.127
				Sum	4.559	1

Table A.3 Pairwise comparison for the transporters' criteria 3

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	3.00	1.00	1.00	1.316	0.219
2	0.33	1.00	0.33	0.33	0.439	0.073
3	1.00	3.00	1.00	1.00	1.316	0.219
4	1.00	3.00	1.00	1.00	1.316	0.219
				Sum	4.387	1

[13] *c.f.* Table 4.2 and Table 4.6.

[14] The geometric mean of a data set $\{a_1, a_2, \ldots, a_n\}$ is given by:

$$\left(\prod_{i=1}^{n} a_i\right)^{1/n} = \sqrt[n]{a_1 a_2 \cdots a_n}.$$

Table A.4 Pairwise comparison for the transporters' criteria 4

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	0.14	0.33	1.00	0.467	0.078
2	7.00	1.00	5.00	7.00	3.956	0.659
3	3.00	0.20	1.00	3.00	1.158	0.193
4	1.00	0.14	0.33	1.00	0.467	0.078
				Sum	6.049	1

Table A.5 Pairwise comparison for the transporters' criteria 5

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	5.00	3.00	5.00	2.943	0.490
2	0.20	1.00	0.33	1.00	0.508	0.085
3	0.33	3.00	1.00	3.00	1.316	0.219
4	0.20	1.00	0.33	1.00	0.508	0.085
				Sum	5.275	1

Table A.6 AHP results for the transporters

Alt/Crit	1	2	3	4	5	Weighted Average
1	0.068	0.126	0.219	0.077	0.490	0.139
2	0.580	0.379	0.073	0.659	0.084	0.455
3	0.068	0.126	0.219	0.192	0.219	0.135
4	0.283	0.126	0.219	0.077	0.084	0.184
Criteria Weight[15]	0.4	0.2	0.1	0.2	0.1	

[15] *c.f.* Table 4.2.

A.2.2 Detailed Results for the Consignees

Table A.7 Pairwise comparison for the consignees' criteria 1[16]

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	0.20	1.00	0.20	0.447	0.083
2	5.00	1.00	5.00	1.00	2.236	0.417
3	1.00	0.20	1.00	0.20	0.447	0.083
4	5.00	1.00	5.00	1.00	2.236	0.417
				Sum	5.367	1

Table A.8 Pairwise comparison for the consignees' criteria 2

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	1.00	3.00	3.00	1.732	0.323
2	1.00	1.00	3.00	3.00	1.732	0.323
3	0.33	0.33	0.33	1.00	0.439	0.082
4	0.33	0.33	1.00	1.00	0.577	0.108
				Sum	4.480	1

Table A.9 Pairwise comparison for the consignees' criteria 3

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	0.33	1.00	1.00	0.760	0.142
2	3.00	1.00	3.00	3.00	2.280	0.425
3	1.00	0.33	1.00	1.00	0.760	0.142
4	1.00	0.33	1.00	1.00	0.760	0.142
				Sum	4.559	1

Table A.10 Pairwise comparison for the consignees' criteria 4

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	0.33	1.00	1.00	0.760	0.142
2	3.00	1.00	3.00	3.00	2.280	0.425
3	1.00	0.33	1.00	1.00	0.760	0.142
4	1.00	0.33	1.00	1.00	0.760	0.142
				Sum	4.559	1

[16] *c.f.* Table 4.3 and Table 4.6.

Table A.11 Pairwise comparison for the consignees' criteria 5

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	0.20	1.00	1.00	0.669	0.125
2	5.00	1.00	5.00	5.00	3.344	0.623
3	1.00	0.20	1.00	1.00	0.669	0.125
4	1.00	0.20	1.00	1.00	0.669	0.125
				Sum	5.350	1

Table A.12 Pairwise comparison for the consignees' criteria 6

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	1.00	3.00	3.00	1.732	0.323
2	1.00	1.00	3.00	3.00	1.732	0.323
3	0.33	0.33	1.00	1.00	0.577	0.108
4	0.33	0.33	1.00	1.00	0.577	0.108
				Sum	4.619	1

Table A.13 AHP results for the consignees

Alt/Crit	1	2	3	4	5	6	Weighted Average
1	0.083	0.323	0.142	0.142	0.125	0.323	0.195
2	0.417	0.323	0.425	0.425	0.623	0.323	0.401
3	0.083	0.082	0.142	0.142	0.125	0.108	0.101
4	0.417	0.108	0.142	0.142	0.125	0.108	0.209
Criteria Weight[17]	0.3	0.3	0.1	0.1	0.1	0.1	

[17] *c.f.* Table 4.3.

A.2.3 Detailed Results for the Public

Table A.14 Pairwise comparison for the public's criteria 1[18]

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	3.00	3.00	3.00	2.280	0.500
2	0.33	1.00	1.00	1.00	0.760	0.167
3	0.33	1.00	1.00	1.00	0.760	0.167
4	0.33	1.00	1.00	1.00	0.760	0.167
				Sum	4.559	1

Table A.15 Pairwise comparison for the public's criteria 2

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	0.33	1.00	1.00	0.760	0.167
2	3.00	1.00	3.00	3.00	2.280	0.500
3	1.00	0.33	1.00	1.00	0.760	0.167
4	1.00	0.33	1.00	1.00	0.760	0.167
				Sum	4.559	1

Table A.16 Pairwise comparison for the public's criteria 3

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	0.33	1.00	1.00	0.760	0.167
2	3.00	1.00	3.00	3.00	2.280	0.500
3	1.00	0.33	1.00	1.00	0.760	0.167
4	1.00	0.33	1.00	1.00	0.760	0.167
				Sum	4.559	1

Table A.17 Pairwise comparison for the public's criteria 4

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	1.00	3.00	3.00	1.732	0.380
2	1.00	1.00	3.00	3.00	1.732	0.380
3	0.33	0.33	1.00	1.00	0.577	0.127
4	0.33	0.33	1.00	1.00	0.577	0.127
				Sum	4.619	1

[18] *c.f.* Table 4.4 and Table 4.6.

Table A.18 Pairwise comparison for the public's criteria 5

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	0.20	0.20	0.33	0.340	0.075
2	5.00	1.00	1.00	3.00	1.968	0.432
3	5.00	1.00	1.00	3.00	1.968	0.432
4	3.00	0.33	0.33	1.00	0.760	0.167
				Sum	5.036	1

Table A.19 AHP results for the public

Alt/Crit	1	2	3	4	5	Weighted Average
1	0.500	0.167	0.167	0.380	0.075	0.270
2	0.167	0.500	0.500	0.380	0.432	0.374
3	0.167	0.167	0.167	0.127	0.432	0.216
4	0.167	0.167	0.167	0.127	0.167	0.163
Criteria Weight[19]	0.3	0.2	0.2	0.1	0.2	

A.2.3 Detailed Results for the Employees

Table A.20 Pairwise comparison for the employees' criteria 1[20]

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	7.00	1.00	1.00	1.627	0.318
2	0.14	1.00	0.14	0.14	0.232	0.045
3	1.00	7.00	1.00	1.00	1.627	0.318
4	1.00	7.00	1.00	1.00	1.627	0.318
				Sum	5.112	1

[19] *c.f.* Table 4.4.

[20] *c.f.* Table 4.5 and Table 4.6.

Table A.21 Pairwise comparison for the employees' criteria 2

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	3.00	1.00	1.00	1.316	0.257
2	0.33	1.00	0.33	0.33	0.439	0.086
3	1.00	3.00	1.00	1.00	1.316	0.257
4	1.00	3.00	1.00	1.00	1.316	0.257
				Sum	4.387	1

Table A.22 Pairwise comparison for the employees' criteria 3

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	0.33	1.00	1.00	0.760	0.149
2	3.00	1.00	3.00	3.00	2.280	0.446
3	1.00	0.33	1.00	1.00	0.760	0.149
4	1.00	0.33	1.00	1.00	0.760	0.149
				Sum	4.559	1

Table A.23 Pairwise comparison for the employees' criteria 4

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	3.00	1.00	1.00	1.316	0.257
2	0.33	1.00	0.33	0.33	0.439	0.086
3	1.00	3.00	1.00	1.00	1.316	0.257
4	1.00	3.00	1.00	1.00	1.316	0.257
				Sum	4.387	1

Table A.24 Pairwise comparison for the employees' criteria 5

Alt	1	2	3	4	Geometric Mean	Normalised Weight
1	1.00	3.00	5.00	7.00	3.201	0.626
2	0.33	1.00	3.00	5.00	1.495	0.293
3	0.20	0.33	1.00	3.00	0.669	0.131
4	0.14	0.20	0.33	1.00	0.312	0.061
				Sum	5.678	1

Table A.25 AHP results for the employees

Alt/Crit	1	2	3	4	5	Weighted Average
1	0.318	0.257	0.149	0.257	0.626	0.301
2	0.045	0.086	0.446	0.086	0.293	0.197
3	0.318	0.257	0.149	0.257	0.131	0.226
4	0.318	0.257	0.149	0.257	0.061	0.216
Criteria Weight[21]	0.25	0.2	0.25	0.15	0.15	

A.2.4 Final Sythetic Results for All Stakeholders

Table A.26 Final sythetic results for all stakeholders

Alt/SH	Transporters	Consignees	Public	Employees	Weighted Average
1	0.139	0.195	0.270	0.301	0.226
2	0.456	0.401	0.374	0.197	0.357
3	0.135	0.101	0.216	0.226	0.170
4	0.184	0.209	0.163	0.216	0.193
Stakeholder Weight[22]	0.25	0.25	0.25	0.25	

A.3 Additional Information

Table A.27 Registered freight vehicles in Buenos Aires (Dablanc, 2009)

Own account transport	**318,211**	**Third account transport**	**108,168**
Light trucks	289,120	Light trucks	32,639
Medium and heavy trucks	20,230	Medium and heavy trucks	37,712
Tractors	2,172	Tractors	10,321
Trailers	6,689	Trailers	27,496

[21] *c.f.* Table 4.5.

[22] Weights of stakeholders can adjusted for different results and sensitivity test.