Framework for Ongoing Stakeholder Engagement in Policies for Urban Freight Logistics in Singapore

by

Gabriella M. Ricart Surribas

Bachelor of Science in Industrial Engineering
University of Florida, 2012

Submitted to the System Design and Management program
in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Engineering and Management
at the
Massachusetts Institute of Technology

September 2017

Signature redacted

Signature of Author: ______________________________
Gabriella M. Ricart Surribas
Graduate Fellow, System Design and Management Program
August 18, 2017

Signature redacted

Certified by: ______________________________
Bryan R. Moser
Academic Director and Senior Lecturer, System Design and Management
Thesis Supervisor

Signature redacted

Accepted by: ______________________________
Joan S. Rubin
Executive Director, System Design and Management Program

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Abstract

While research in the urban freight field has mainly focused on evaluating regulation, stakeholder preferences prior or after a policy has been implemented, or on a single type or sub-set of agents and freight policies, the core of this thesis centers on differentiating aspects of urban freight policy design. This thesis aims to uncover how a systematic evaluation of urban freight policy design for retail malls in Singapore could weave stakeholder engagement into the policy lifecycle. This work also provides a framework for assessing the impact that a wide range of urban freight solutions could have on the different system stakeholders. System design tools, including Stakeholder Value Network (SVN) analysis and tradespace exploration, were leveraged to (1) identify key architectural aspects of urban freight policy design and (2) generate multi-dimensional policy configurations. Insight from a survey administered to retail shop owners in two large malls in Singapore as well as findings from other research on stakeholder preferences and perceptions of urban freight solutions were used to evaluate the policy configurations generated from the point of view of key stakeholders. Results and findings from this framework include policy performance patterns among configurations and stakeholders, which can be further used to drive policy decision-making and evaluate trade-offs among the system stakeholders under certain architectures. The systematic evaluation presented in this thesis revealed that according to retail shop owners, urban freight policy architectures with goods consolidation translate into higher efficiency for this group 100% of the time when compared to policy configurations without goods consolidation. Also, the results for policy efficiency as viewed by public-sector stakeholders highlighted the expense of public welfare – with average costs for incentive or subsidy-based policy architectures increasing more than three-fold compared to policies in which participation is required and two-fold compared to policies in which participation is voluntary. Future work will re-assess the urban freight policy scores with direct stakeholder participation and explore the performance of the policy architectures under different demand patterns.

Thesis Supervisor: Bryan R. Moser
Title: Academic Director and Senior Lecturer, System Design and Management

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Acknowledgments

I feel over-blessed by the outstanding support I've received from my professional and personal network through the years leading to the SDM program and during my journey at MIT.

First, I would like to express my eternal gratitude to my family, who has always provided unconditional support in all my endeavors and been the driving force behind my aspirations. Mama and Papa, no words will be sufficient to thank you for your love, support, trust, and sacrifices. I'm beyond thankful for the moral values you've instilled in us and for teaching us that with God, all things are possible and that all is under his control. All I am and all I've accomplished is in debt to you.

I would also like to express my sincere appreciation to the SDM faculty and our TA team, and most importantly, to my advisor, Bryan Moser, who patiently guided me through this self-exploration process and from the very beginning and despite his quite busy schedule, set time aside with me for enlightening discussions. I'd also like to thank Lynette Cheah and her research team at the Singapore University of Technology & Design (SUTD), for all their support and feedback throughout my thesis.

I owe a huge thank you to my boyfriend, Daniel, who has walked the SDM and thesis journey with me day by day. Thank you for keeping me sane and for your support and understanding. Thank you for cheering me up and for being a source of admiration, especially when it comes to self-discipline and commitment.

Finally, I would like to thank the SDM cohort and my MIT colleagues, a diverse group of kind and immensely talented individuals who have enriched my professional and personal values. Thank you all for your encouragement and support!

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List of Acronyms

Acronym	Definition
AHP	Analytic Hierarchy Process
AV	Autonomous Vehicle
CR	Centralized Receiving (station)
DOT	Department of Transportation, US
ERP	Electronic Road Pricing
ETC	Electronic Toll Collection
EV	Electric Vehicles
FDM	Freight Demand Management
GAIA	Geometrical Analysis for Interactive Aid
GDSM	Group decision support methods
GHG	Greenhouse Gas
GNSS	Global Navigation Satellite System
ITS	Intelligent Transportation System
ITSS	Intelligent Transportation Society Singapore
KPI	Key Performance Indicator
LB	Loading Bay
LSP	Logistics Service Providers
LTA	Land Transportation Authority, Singapore
LTG	Large Urban Freight Traffic Generators
LTZ	Limited Traffic Zone
MAMCA	Multi-Actor Multi-Criteria Assessment
MCA	Multi-Criteria Assessment
MCDA	Multi-Criteria Decision Analysis
MOT	Ministry of Transport, Singapore
SAVI	Singapore Autonomous Vehicle Initiative
SP	Stated Preferences
UCC	Urban Consolidation Center
VMT	Vehicle Miles Traveled

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1. Introduction

1.1 Motivation

Urban freight transportation is a key enabler of economic progress, enabling the flow of goods and people that fuel basically all industries. However, the rapid development of cities and population growth rates have increased the demand for urban freight, causing its unfavorable consequences to quickly surface over the last few decades. The industry's negative impacts to receive most attention include congestion, pollution, and traffic accidents, ultimately taking a toll on the urban social and economic welfare. The urban freight industry is a complex system, having multiple stakeholders with diverse and sometimes conflicting objectives. Its stakeholders include public authorities, regulatory agencies, businesses requesting (costumers) and providing (suppliers) freight transport services, their employees, suppliers of items to be transported, local citizens, among others. Freight transportation logistics has become an important aspect of urban planning and a growing concern for the industry's public and private gameplayers. Significant work has been done to develop solutions that reduce urban freight congestion, greenhouse emissions, noise, accidents, and other negative externalities, but interest on the impact that proposed solutions would have on the different system agents and how these might behave under the implementation of certain measures was dormant until a few years ago.

In 2013, Singapore's Land Transportation Authority published its "Land Transport Master Plan", highlighting the nation's emerging transportation challenges and initiatives. Through the years, most of the focus on transportation solutions in Singapore, as well as in other metropolitan regions, has been public transport due to its integral role in urban economies of connecting people to "services, amenities, and opportunities" (Singapore LTA, 2103). However, Singapore's land scarcity and growing population have drawn more attention to the concerns created by urban freight transportation. While less visible in a city's day-to-day activities, freight transport is vital to the economy, enabling the movement of goods through the supply chain. The Singapore government has more recently invested in the research and development of urban freight alternatives that have been studied and piloted in other urban settings.

Systems thinking emerged about half a century ago, and is defined in (Crawley, Cameron, & Selva, 2016) as thinking about a question, problem, or circumstance as a system – "a set of entities and their relationships, whose functionality is greather than the sum of the individual entities". This field of study explores the properties and challenges that emerge when individual parts come together to form a new phenomena. Systems thinking is therefore valuable for designing and modifying systems, and understanding their behavior or performance. In (de Weck et al., 2016), the authors outline several key aspects of the systems thinking analysis framework, which include defining the system boundaries, decomposing the system into subparts, and looking at the system from different viewpoints. This framework allows us to dissect complex systems – systems with many highly interrelated or interconnected entities (Crawley, Cameron, & Selva, 2016) – extending from functional teams in an organization, an airplane, to local urban freight logistics systems. Systems thinking includes soft and hard methods, ranging from tradespace exploration and sensitivity analysis to simulation and system dynamics, among others. By deploying systems thinking, we're able to understand better the potential risks and value of complex systems, as is the urban freight logistics system in Singapore.

The objective of this thesis is to guide the decision-making process for urban freight initiatives in retail malls in Singapore through stakeholder engagement in the evaluation of different system architectures.

1.2 Problem Statement & Research Question

Urban freight challenges and developments have motivated research for over three decades. While the objectives of most of these studies have been identifying and quantifying the negative effects of urban freight and developing alternatives to reduce or eliminate these, few had focused on the participation of system stakeholders in the development and implementation of urban freight solutions until very recently. Studies aimed at evaluating stakeholder views and preferences on urban freight challenges and solution have recognized that failure to engage system stakeholders and consider their diverse objectives has made numerous implementations unsuccessful. Valerio Gatta and Edoardo Marcucci, renowned field researchers, point out that "decision makers often adopt coarse and undifferentiated policies without reliable forecasts of effects among the agent-types impacted" (Gatta & Marcucci, 2014). Additionally, schemes that have incorporated stakeholder insight in the evaluation of urban freight alternatives have typically analyzed only a narrow set of measures, instead of considering a wide range of solution combinations and evaluating the systematic performance of these solutions with respect to different agents.

With the above considerations, we formulate the system problem statement using the "To-By-Using" framework from (Crawley, Cameron, & Selva, 2016).

Figure 1.1 | System Problem Statement

To *increase stakeholder engagement in urban freight policy decision-making*
By *generating different policy architectures and evaluating the agent-specific impacts*
Using *system architecture tools and methods*

To address this problem, we identify the research question below, to be answered by this thesis.

Figure 1.2 | Research Question

How could system design principles be used to generate and evaluate urban freight logistics solutions for different stakeholders?

Urban freight measures include parking or loading schemes, road pricing, licensing and regulation, consolidation terminals, off-hour deliveries, among others (Visser & van Binsbergen, 1999). Most studies involving stakeholders have focused on one or a few of these measures in isolation – e.g. evaluating stakeholder preferences or views on different consolidation schemes or different parking schemes, evaluating whether stakeholders would more favorably support measures that require the use of low-emission vehicles, restrict access to city areas during certain times, or require coordinated deliveries. However, assessing the system more holistically, to include the stakeholders in its boundaries and explore the broad range of potential architectures is a more novel focus. Could stakeholder views and value for urban freight measures be used to evaluate different system architectures more comprehensively and if so, would they provide more concrete evidence on the trade-offs between stakeholder objectives?

1.3 Thesis Overview

The thesis is structured as follows:

Chapter 1 – Introduction

This chapter presents the motivation for evaluating how different urban freight logistics policies could affect a select group of stakeholders. The domain of focus is also presented in this section.

Chapter 2 – Literature Review

This chapter provides a synopsis of literature review related to urban freight logistics, transportation challenges in Singapore, urban freight policies and developments, as well as research related to stakeholder considerations in urban freight policy analysis and design.

Chapter 3 – System Framing and Analysis

In this chapter, the research hypotheses and methodology are first presented. Later sections in this chapter include detailed explanation of the tools and methods essential to the research.

Chapter 4 – Discussion

This chapter captures the major findings from the model presented in the previous section. Trends in the performance of similar architectures are also discussed in this section, as well as the verification of the previously presented hypotheses.

Chapter 5 – Future Work

This chapter discusses the limitations of the methodology and model, suggesting opportunity for future research work.

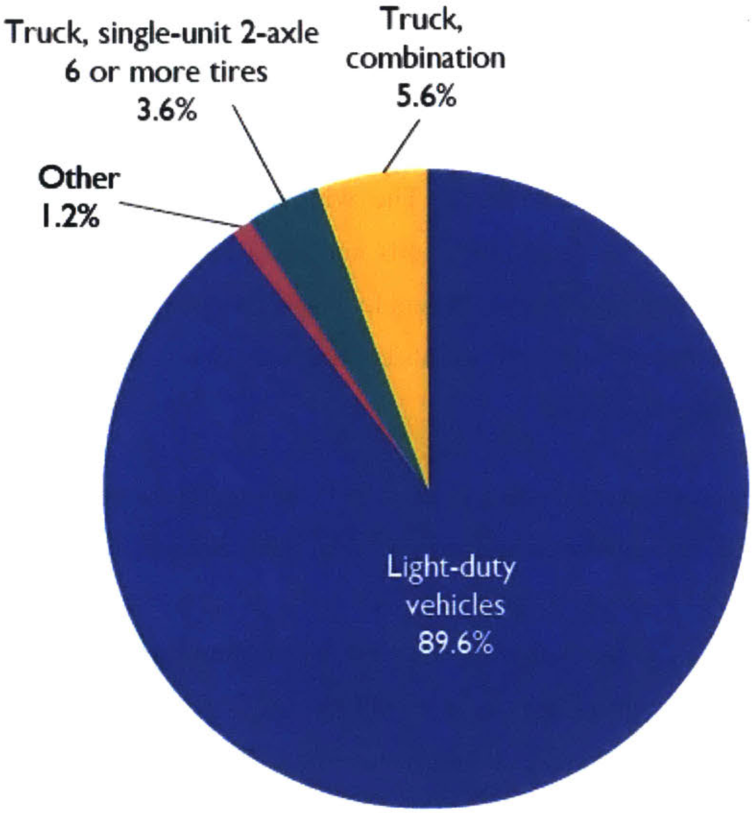
2. Literature Review

2.1 Urban Freight Logistics

The fast-paced evolution and expansion of urban areas worldwide have made urban logistics, also referred to a city logistics, a thriving field of study and a critical issue in urban planning. According to the United Nations (2014), more than 50 percent of the world's population already lives in urban settings, and the figure is expected to reach 70 percent by 2050. UN statistics from its Department of Economic and Social Affairs also report that more than 60 percent of the areas projected to become urban by 2030 haven't yet developed. The widespread urbanization has created a continuously increasing demand for consumer goods and services in these densely populated regions, which rely on the urban freight industry to get from their point of origin to their end users. As a result, the volume and value of freight shipments coming into, out of, and through urban areas has significantly increased over the years.

To establish some industry context, according to the U.S. Department of Transportation (2013), 8.6 percent of the U.S. GDP was attributed to transportation-related purchases and investments in 2013. Between 2000 and 2013, the U.S. population grew by 13 percent, while the U.S. GDP increased 24.9 percent in real dollar values during the same timeframe. While truck freight accounts for only about 9.2 percent of the highway vehicle miles traveled (**Figure 2.1**), trucks carry the most weight and value in terms of freight transport. **Figure 2.2** illustrates value and weight carried by truck freight in the U.S. during 2007 (USDOT, 2013). As captured in the charts, most goods flowing through the nation's transportation system move short distances (below 250 miles), representing 55.7 percent of the total value and 70.7 percent of the total weight of goods moved during this year. The U.S. is also an active player in world-spanning supply chains, meaning that a vast number of goods move through our transportation network to transfer between international gateways, creating additional demand for freight transportation. With international trade expected to grow 3.4 percent per year through 2040, freight demand from this segment is also expected to rise. With long-term economic growth and accelerated development of urban areas, freight transportation demand is expected to increase by 40 percent in the next 30 years. In order to satisfy the growing demand for freight transportation, cities will need to develop more efficient and sustainable urban freight logistics solutions.

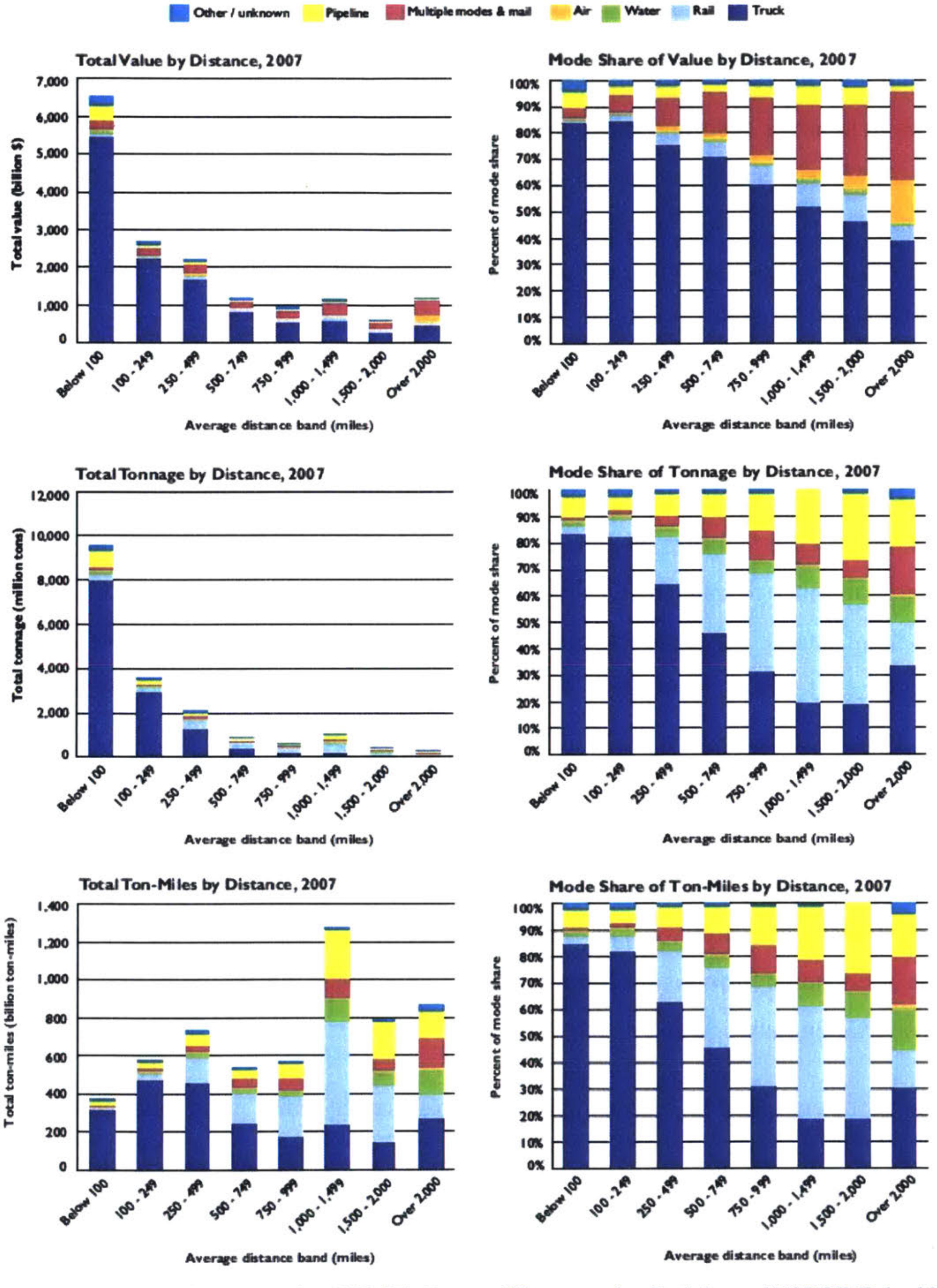
Figure 2.1 | Share of Highway Vehicle-Miles Traveled by Vehicle Type: 2013 from (USA DOT, 2015)



NOTES: "Other" comprises bus and motorcycle. "Light-duty vehicles" includes passenger cars, light trucks, vans, and sport utility vehicles. Based on a new methodology, FHWA revised its annual vehicle miles traveled, number of vehicles, and fuel economy data beginning with 2007. Information on the new methodology is available at www.fhwa.dot.gov/policyinformation/statistics.cfm. Data in this figure should not be compared to those in pre-2011 editions of *Freight Facts and Figures*.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, Industry Economic Accounts, Interactive tables, available at http://www.bea.gov/industry/index.htm as of July 2015

Figure 2.2 | Value, Tons, and Ton-Miles of Freight in the U.S. by Distance: 2007 from (USA DOT, 2015)



SOURCE: U.S. Department of Transportation (USDOT), Bureau of Transportation Statistics, and USDOT, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 3.5, 2015.

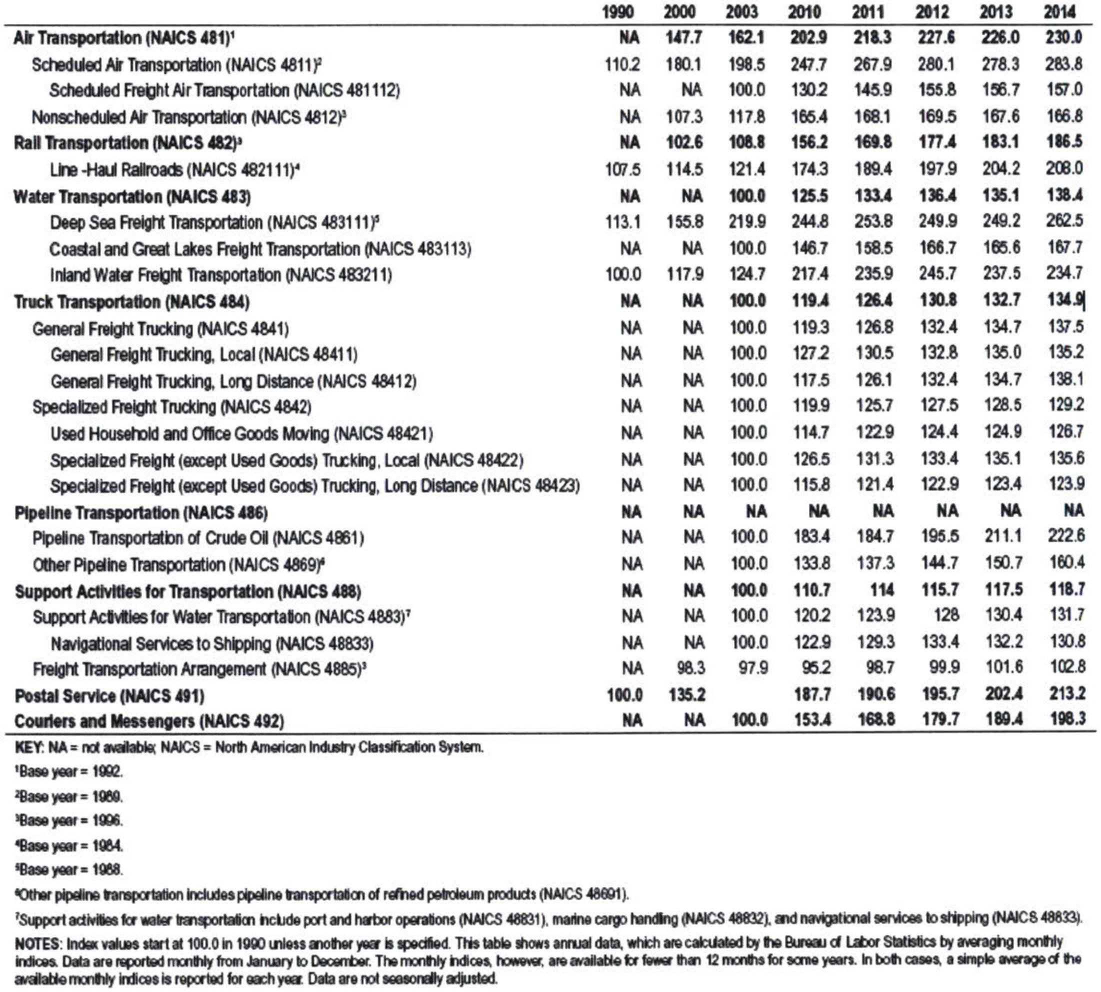
While the urban freight industry supports economic development and acts as the link between the demand and supply of almost all goods and services, its contribution comes with a handful of adverse externalities. Some of these include congestion, noise, environmental pollution, traffic accidents, among others. In addition, the rapid growth of urban freight activities also contributes to increases in logistics costs and therefore the price of goods and services as well. (Stathopoulos et al., 2011). Moreover, the urban freight transportation industry is quite fragmented, with its different players trying to optimize for their individual objectives, rather than collaborating to achieve an industry optimum. Over the past decades, transportation research groups have studied city logistics systems across the world with the objective to reduce the impact of some of the externalities associated with freight traffic and enhance their operations.

Jose Holguin-Veras is a renowned transportation engineer who has conducted substantial research on Freight Demand Modeling (FDM) and large urban freight traffic generators (LTGs). LTGs can be defined as "specific facilities housing businesses that individually or collectively produce and attract a large number of daily truck trips" (Jaller et al., 2015). LTGs include facilities such as hospitals, retail malls, government offices, commercial buildings, and universities. During previous work, Jaller et al. classified LTGs in two groups. The first group consists of buildings that house numerous independent establishments, such as commercial buildings and retail malls. The second group consists of large businesses that generate a large volume of freight traffic because of their size, e.g. universities, hospitals, etc. As previously captured, this thesis will focus on the first type of LTGs, specifically on retail mall schemes. LTGs often lack proper parking and logistics facilities, which create delays for the vehicle traffic attracted to and generated by them. These delays create environment, economic, and social costs, which can propagate through the urban transportation network.

As noted in (Ville et al., 2013), before the 1980s, urban freight traffic wasn't associated with many of the negative externalities it's tied to today, including envieronmental pullution and congestion. Over the past decades, however, these externalities have been studied to a great extent. According to the U.S. DOT (2017), congestion delays and lost fuel cost the nation USD160 billion in 2016, with truck freight account for USD28 billion, and 42 hours per year per person. What is worst, congestion is expected to increase as our population continues to grow and more people relocate to already densely populated metropolitan areas. This externality compromises the efficiency and reliability of goods' flow, which has a direct impact in our economy. Truck speed and travel time are common indicators of transportation system performance. Freight delays negatively affect these indicators en hence reduce the efficinecy of logistics operations across the transportation network. Reduced efficiencies contribute to increases in logistics costs and therefore the price of goods and services as well. (Stathopoulos et al., 2011). Some of these economic impacts are highlighted in **Figure 2.3**, which captures the increase in freight transportation services across all industries between 2010 and 2013.

Although transportation enables market development and human productivity, it also takes a toll on human life. According to the U.S. DOT, 35,092 people were killed in traffic accidents in 2014. Despite freight traffic not being solely responsible for these, it accounted for about 13.1 percent of the fatalities and 4.2 percent of the injuries associated with transportation in the U.S. during 2013. Among all traffic accidents caused by freight transport, large trucks were responsible for 88 percent of the fatalities and 95.8 percent of the freight transportation-related injuries. Other freight modes considered under these freight transportation figures in (USDOT, 2015) include railroad, water, and pipeline. The detrimental effects of urban freight on society are also observed in the changes it has caused to our environment. In the U.S., trucks are the largest contributors to freight emissions and account for most of freight energy consumption. Worldwide, urban freight is responsible for 35 percent of the world transport energy used (Ville, Gonzalez-Feliu, & Dablanc, 2013). Greenhouse gases (GHGs) are also one of the renowned side effects of transportation. Among the most popularly discussed GHGs are methane, nitrous oxide (NO_X), and carbon dioxide (CO_2). In many European cities, trucks account for 25 percent of transport-related CO_2 emissions. In French cities, this group is also responsible for 30 percent of the NO_X emissions and about 50 percent of the particulate matter emissions (Albergel et al., 2006). In the U.S., the transportation sector was responsible by about 27 percent of all GHGs emitted in 2013, only slightly surpassed by the industrial sector, which accounted for about 29 percent of these (USDOT, 2015).

Figure 2.3 | Producer Price Indices for Select Transportation Services: 1990, 2000, 2003, and 2010-2014 from (USA DOT, 2015)



	1990	2000	2003	2010	2011	2012	2013	2014
Air Transportation (NAICS 481)[1]	**NA**	**147.7**	**162.1**	**202.9**	**218.3**	**227.6**	**226.0**	**230.0**
Scheduled Air Transportation (NAICS 4811)[2]	110.2	180.1	198.5	247.7	267.9	280.1	278.3	283.8
Scheduled Freight Air Transportation (NAICS 481112)	NA	NA	100.0	130.2	145.9	155.8	156.7	157.0
Nonscheduled Air Transportation (NAICS 4812)[3]	NA	107.3	117.8	165.4	168.1	169.5	167.6	166.8
Rail Transportation (NAICS 482)[3]	**NA**	**102.6**	**108.8**	**156.2**	**169.8**	**177.4**	**183.1**	**186.5**
Line -Haul Railroads (NAICS 482111)[4]	107.5	114.5	121.4	174.3	189.4	197.9	204.2	208.0
Water Transportation (NAICS 483)	**NA**	**NA**	**100.0**	**125.5**	**133.4**	**136.4**	**135.1**	**138.4**
Deep Sea Freight Transportation (NAICS 483111)[5]	113.1	155.8	219.9	244.8	253.8	249.9	249.2	262.5
Coastal and Great Lakes Freight Transportation (NAICS 483113)	NA	NA	100.0	146.7	158.5	166.7	165.6	167.7
Inland Water Freight Transportation (NAICS 483211)	100.0	117.9	124.7	217.4	235.9	245.7	237.5	234.7
Truck Transportation (NAICS 484)	**NA**	**NA**	**100.0**	**119.4**	**126.4**	**130.8**	**132.7**	**134.9**
General Freight Trucking (NAICS 4841)	NA	NA	100.0	119.3	126.8	132.4	134.7	137.5
General Freight Trucking, Local (NAICS 48411)	NA	NA	100.0	127.2	130.5	132.8	135.0	135.2
General Freight Trucking, Long Distance (NAICS 48412)	NA	NA	100.0	117.5	126.1	132.4	134.7	138.1
Specialized Freight Trucking (NAICS 4842)	NA	NA	100.0	119.9	125.7	127.5	128.5	129.2
Used Household and Office Goods Moving (NAICS 48421)	NA	NA	100.0	114.7	122.9	124.4	124.9	126.7
Specialized Freight (except Used Goods) Trucking, Local (NAICS 48422)	NA	NA	100.0	126.5	131.3	133.4	135.1	135.6
Specialized Freight (except Used Goods) Trucking, Long Distance (NAICS 48423)	NA	NA	100.0	115.8	121.4	122.9	123.4	123.9
Pipeline Transportation (NAICS 486)	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Pipeline Transportation of Crude Oil (NAICS 4861)	NA	NA	100.0	183.4	184.7	195.5	211.1	222.6
Other Pipeline Transportation (NAICS 4869)[6]	NA	NA	100.0	133.8	137.3	144.7	150.7	160.4
Support Activities for Transportation (NAICS 488)	**NA**	**NA**	**100.0**	**110.7**	**114**	**115.7**	**117.5**	**118.7**
Support Activities for Water Transportation (NAICS 4883)[7]	NA	NA	100.0	120.2	123.9	128	130.4	131.7
Navigational Services to Shipping (NAICS 48833)	NA	NA	100.0	122.9	129.3	133.4	132.2	130.8
Freight Transportation Arrangement (NAICS 4885)[3]	NA	98.3	97.9	95.2	98.7	99.9	101.6	102.8
Postal Service (NAICS 491)	**100.0**	**135.2**		**187.7**	**190.6**	**195.7**	**202.4**	**213.2**
Couriers and Messengers (NAICS 492)	**NA**	**NA**	**100.0**	**153.4**	**168.8**	**179.7**	**189.4**	**198.3**

KEY: NA = not available; NAICS = North American Industry Classification System.

[1] Base year = 1992.

[2] Base year = 1989.

[3] Base year = 1996.

[4] Base year = 1984.

[5] Base year = 1988.

[6] Other pipeline transportation includes pipeline transportation of refined petroleum products (NAICS 48691).

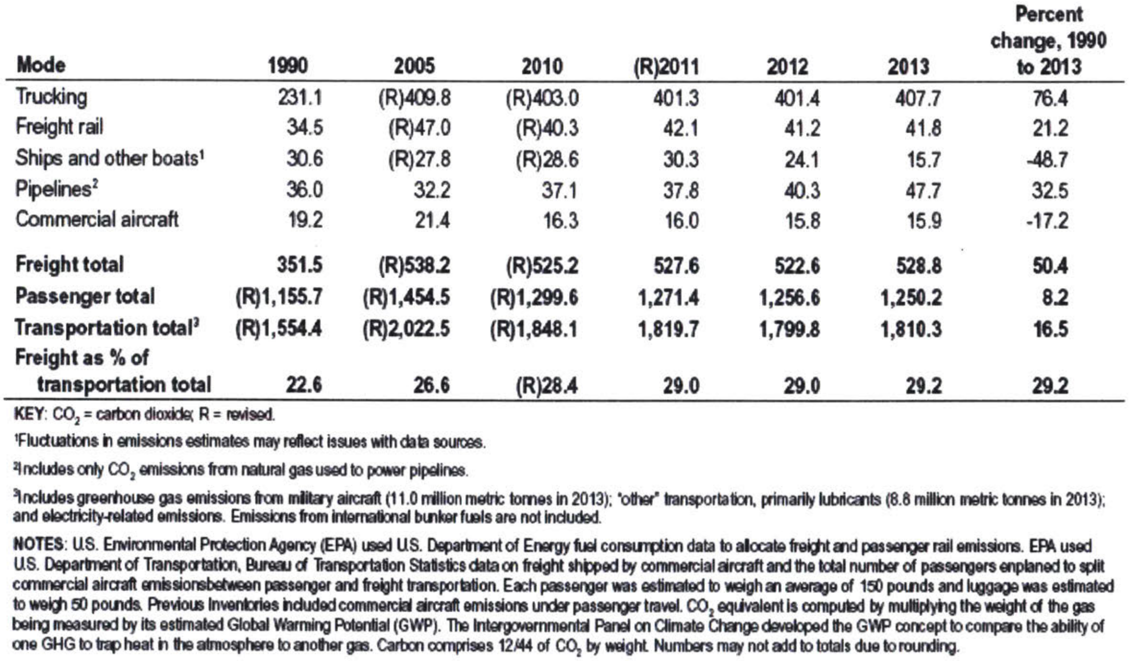
[7] Support activities for water transportation include port and harbor operations (NAICS 48831), marine cargo handling (NAICS 48832), and navigational services to shipping (NAICS 48833).

NOTES: Index values start at 100.0 in 1990 unless another year is specified. This table shows annual data, which are calculated by the Bureau of Labor Statistics by averaging monthly indices. Data are reported monthly from January to December. The monthly indices, however, are available for fewer than 12 months for some years. In both cases, a simple average of the available monthly indices is reported for each year. Data are not seasonally adjusted.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, Producer Price Index Industry Data, available at www.bls.gov/data/sa.htm as of July 2015.

Despite technology advancements in the automotive industry to reduce the environmental impact of freight vehicles, the results of these advancements have been compromised by the extensive increment in freight transport demand (Stathopoulos et al., 2011). **Figure 2.4** exposes this reality, where it can be seen that in 2013, trucks accounted for more than 75 percent of freight GHGs emissions in the U.S., followed by rail. The image also captures how CO_2 emissions from truck freight nearly doubled between 1990 and 2013, which the Department of Transportation (DOT) attributes to the boost in freight movement over the last two decades (USDOT, 2015). In (Stathopoulos et al., 2011), the authors explain that in urban settings, freight vehicles are typically responsible for 20-30 percent of total traffic emissions. It's also called out that urban freight contributes more to pollution than long-distance freight, essentially because of it's characterized by frequent short trips and numerous stops.

Figure 2.4 | U.S. Greenhouse Gas Emissions from Domestic Freight Transportation: 1990, 2005, and 2010-2013 from (USA DOT, 2015) (millions of metric tons of CO_2 equivalent)



Mode	1990	2005	2010	(R)2011	2012	2013	Percent change, 1990 to 2013
Trucking	231.1	(R)409.8	(R)403.0	401.3	401.4	407.7	76.4
Freight rail	34.5	(R)47.0	(R)40.3	42.1	41.2	41.8	21.2
Ships and other boats[1]	30.6	(R)27.8	(R)28.6	30.3	24.1	15.7	-48.7
Pipelines[2]	36.0	32.2	37.1	37.8	40.3	47.7	32.5
Commercial aircraft	19.2	21.4	16.3	16.0	15.8	15.9	-17.2
Freight total	**351.5**	**(R)538.2**	**(R)525.2**	**527.6**	**522.6**	**528.8**	**50.4**
Passenger total	**(R)1,155.7**	**(R)1,454.5**	**(R)1,299.6**	**1,271.4**	**1,256.6**	**1,250.2**	**8.2**
Transportation total[3]	**(R)1,554.4**	**(R)2,022.5**	**(R)1,848.1**	**1,819.7**	**1,799.8**	**1,810.3**	**16.5**
Freight as % of transportation total	**22.6**	**26.6**	**(R)28.4**	**29.0**	**29.0**	**29.2**	**29.2**

KEY: CO_2 = carbon dioxide; R = revised.

[1] Fluctuations in emissions estimates may reflect issues with data sources.

[2] Includes only CO_2 emissions from natural gas used to power pipelines.

[3] Includes greenhouse gas emissions from military aircraft (11.0 million metric tonnes in 2013); "other" transportation, primarily lubricants (8.8 million metric tonnes in 2013); and electricity-related emissions. Emissions from international bunker fuels are not included.

NOTES: U.S. Environmental Protection Agency (EPA) used U.S. Department of Energy fuel consumption data to allocate freight and passenger rail emissions. EPA used U.S. Department of Transportation, Bureau of Transportation Statistics data on freight shipped by commercial aircraft and the total number of passengers enplaned to split commercial aircraft emissionsbetween passenger and freight transportation. Each passenger was estimated to weigh an average of 150 pounds and luggage was estimated to weigh 50 pounds. Previous Inventories included commercial aircraft emissions under passenger travel. CO_2 equivalent is computed by multiplying the weight of the gas being measured by its estimated Global Warming Potential (GWP). The Intergovernmental Panel on Climate Change developed the GWP concept to compare the ability of one GHG to trap heat in the atmosphere to another gas. Carbon comprises 12/44 of CO_2 by weight. Numbers may not add to totals due to rounding.

SOURCE: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013, EPA 430-R-15-004 (Washington, DC: April 15, 2015), table ES-7 and Annex 3, tables A-116 and A-117, available at www.epa.gov/climatechange/ghgemissions/usinventoryreport.html as of June 3, 2015.

Urban freight has become a key aspect of our world's economy, but its unfavorable byproducts started to erupt and call for more attention over the past decades. As a result, the flow of urban goods and urban freight solutions have become the subject of city logistics studies. Eiichi Taniguchi, a distinguished expert in the field, defines city logistics as the "process for totally optimizing the logistics and transport activities by private companies with support of advanced information systems in urban areas considering the traffic environment, the traffic congestion, the traffic safety and the energy savings within the framework of a market economy" (Taniguchi et al., 1999). Urban freight is categorized as a complex socio-technical problem, having repercussions in the urban and transport system planning field, efficiency of supply chains, and social safety (Ville, Gonzalez-Feliu, & Dablanc, 2013).

2.2 Transportation Logistics in Singapore

Singapore is the third most densely populated country after Monaco and Macau (The World Bank). The city-state has an area of 719 km^2 and is home to 5.6 million inhabitants (Singapore NPTD, 2016). Its population is expected to reach 6.9 million by 2030, which explains why the nation's limited land space is expensive and its distribution a recurrent urban planning concern. Currently, 12 percent of the country's land is allotted to transportation infrastructure (roads, highways, etc.), and 14 percent is taken up by housing (Singapore LTA, 2104). With the anticipated population growth, the demand for urban space for housing and commercial purposes is also expected to rise, which would increase the demand for freight transport as well. The challenges posed by high freight transportation volumes in metropolitan regions are therefore present in Singapore's transportation system.

According to Singapore's Ministry of Transport (MOT), transportation accounts for 13 percent of the nation's energy use. Within this group, goods vehicles represent 17 percent of the vehicle population and 40 percent of the vehicle kilometers traveled (Singapore LTA, 2014), making urban freight responsible for a sizeable amount of the negative externalities associated with transportation in the region. The most notorious consequences of urban freight include congestion and environmental deterioration. While air quality in Singapore is considered acceptable, transportation is one of the mayor contributors to harmful emissions. Particulate matter, Sulphur dioxide (SO_2), nitrogen oxide (NO_X), and carbon monoxide (CO) are the most prevalent air pollutants in the region. Motorized traffic is responsible for 75 percent of air pollution and 20 percent of carbon emissions in Singapore (Singapore LTA, 2014). As far as social safety, freight transport was responsible for about 14 percent of fatal and injury road accidents in 2015 (Singapore Ministry of Trade and Industry, 2016). An additional concern of urban freight in Singapore and the rest of Asia, is the amount of own-account freight transport providers, with 90% of truck owned by individuals, the industry stands very fragmented.

The Singapore government actively works with public and private entities to address the nation's ongoing transportation challenges and maintain its international position at the forefront of technological advancements. In fact, Singapore was the first city in the world to implement an Electronic Road Pricing (ERP) system, which it established in 1998. The system was implemented to alleviate road congestion across central business districts and highways, using an open road tolling and pay-as-you-go scheme to charge vehicles entering the ERP zones during established time windows. At the time of implementation, this project cost about SGD220 million (around USD119 million[1]). According The immediate benefits from the ERP system included a reduction of almost 25,000 vehicles during peak hours, yielding a 22 percent increase in traffic speed and a 13 percent decrease in total traffic within the restricted zones (Singapore LTA, 2016). The government is currently working on the implementation of second generation ERP technology, which is expected to go live in 2020 and will use a Global Navigation Satellite System (GNSS) to replace the existing gantry system (Singapore LTA, 2013).

Additional transportation initiatives overseen and/or supported by the Singapore government include autonomous vehicle (AV) technologies, parking guidance systems, and the intelligent transport system (ITS). The Singapore Autonomous Vehicle Initiative (SAVI) has been provides a technical platform to support the research, development, and testing of AV technologies. Parking guidance systems provide real-time information about parking availability in commercial buildings across the city-state, with the objective to reduce the volume of circulating traffic in these LTGs. The ITS framework covers most of the nation's transportation network and is used to provide real-time traffic information (Singapore LTA, 2016). These and other initiatives are outlined in the "Smart Mobility 2030" strategic plan, created by the Singapore Land and Transport

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[1] Computed based on the exchange rate of USD 1.00 = 1.678 SGD, as of March 31, 1988. Source: US Government Publishing Office, https://www.gpo.gov/fdsys/pkg/GOVPUB-T63_100-35141809945353cd5a2c6d3565d5d460/pdf/GOVPUB-T63_100-35141809945353cd5a2c6d3565d5d460.pdf)

Authority (LTA) in collaboration with the Intelligent Transportation Society Singapore (ITSS). The plan aligns government and industry initiatives to better overcome transportation challengers and move toward more efficient transportation solutions. One of the four focal areas in the "Smart Mobility 2030" plan is "Green Mobility", which emphasizes the need for collaboration among key industry participants (multi-nationals, small-medium enterprises, start-ups, transportation service providers, public transport operators, etc.) and governmental and educational institutions to overcome transportation challenges (Singapore LTA, 2013).

When it comes to urban freight transport, the Singapore government has been evaluating collaborative urban logistics alternatives to improve freight deliveries in retail malls, most recently considering Central Receiving stations (CRs) and Urban Consolidation Centers (UCCs). There are about 110 urban retail malls in Singapore, each hosting approximately 114 stores. This means that more than 12,000 businesses are located in high traffic areas and they're each trying to optimize their individual supply chains, generating more than 33,000 truck trips per day (Dalla Chiara, Cheah, & Courcoubetis, 2017). Improving freight logistics at these LFGs would undoubtedly have a postivie impact on the island transportation network. In (Dalla Chiara, Cheah, & Courcoubetis, 2017), study at a local retail mall used data-driven simulation to mimic the flow of goods vechiles at the mall and evaluate the effects of a CR. The study used detailed traffic data, including arrival, parking choice and duration, and handling time to develop a parking choice model and apply simulation technology to evaluate the impact a CR would have on the queuing time for goods vehicle in the retail mall under evaluation. This study provided insight on driver behavior and the performance of a specific parking system, which enables one to understand current challenges and explore the adequate solution for these (Dalla Chiara, Cheah, & Courcoubetis, 2017) . In addtion, the study demonstrated that unless handling time at the CR is maintained below a certain level, implementing the CR would actually create longer queueing delays for goods vehicles waiting to unload/load at the CR than in a scheme with no CR. This counter-intuitive result is attributed to the parking choice of a select group of drivers, who under the no CR scheme prefer to park out of the freight parking lot (illegly) if the loading bay are is full, but under the CR scheme would choose to join the queue and take advantage of the CR, which removes the driver's need to park and handle the goods. CR pilots have also been carried out in UK and Japan in similar types of facilities.

The same research group leading the CR study summarized above is also involved the in the study of UCC schemes in Singapore to support goods distribution for retail malls. UCCs have been evaluated and implemented in Italy, Japan, and in the Netherlands. As the authors report in (Dalla Chiara, Cheah, & Courcoubetis, 2015), previous UCC research has concluded that a few factors are essential to determine the feasibilty of a UCC scheme:

1. Participation rate – There has to be a demand for the UCC service, unless a certain participation level is achieved, implententing a UCC may not be economically vaiable.
2. Existing problem – If there's an existing problem with goods transportation or distribution, agents will be more prone to accpeting the UCC policy.
3. Public support – Local government support in the form of tax breaks or incentivas has substantial influence on the successful adoption of the policy.

In their work, the supplier is the decision-maker on whether to participate in an UCC scheme or not. The study concludes with the recognition of the trade-off between the "network effect" and "congestion effect", and how these two affect the players' (supplier) behavior. The "network effect" captures a situation in which as more suppliers choose to participate in the UCC scheme, the UCC's operational cost per shipment decreases, reducing the price for the service and attracting more participants. The "congestion effect" holds that as the UCC attracts more participants, congestion will be reduced and some retailers will shift from using the UCC service to making their own shipments (or using the existing LSPs), which is less expensive than paying the UCC operator for the "last mile" delivery.

2.3 Urban Freight Patterns, Policies, and Schemes

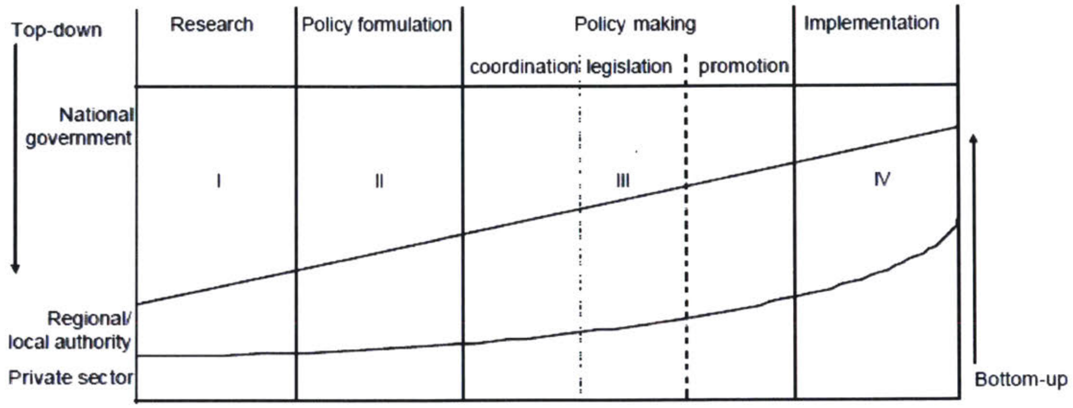
Cambridge Online Dictionary defines policy as a "set of ideas or plan of action followed by a business, government, political party, or a group of people". In general, policies are established to address issues. Through this paper you will encounter the term used as a synonym of measure or solution, and could or could not be used to refer to a government-enforced regulation. (Visser & van Binsbergen, 1999) offers an outline of urban freight public policy and planning. According to the authors, "urban freight transport is the subject of local, regional, and national policies in different policy fields, such as transportation, environmental, and economic planning". Distinguishable developments in the field of urban freight logistics have been achieved in the Netherland, France, Germany, and Japan using different approaches. The different urban freight challenges in these countries and their developments are reviewed in (Visser & van Binsbergen, 1999).

In (Ogden, 1992), the author describes urban freight transport policies as having one or more of six objectives: efficiency, economic, road safety, environmental, infrastructure, or urban structure objectives. Efficiency objectives focus on the cost and quality of urban freight services, while economic objectives are tied to business opportunities, market growth, and employment. Improvements in the efficiency of urban freight services could lead to economic improvements (e.g. reduction in price of services, increased income, etc.), therefore serving two objectives simultaneously. Environmental objectives are tied to improving the impact urban freight has on our surroundings, including air pollution, noise, and traffic accidents. Infrastructure objectives focus on improving the use and conservation of transportation infrastructure. Urban structure objectives address the preservation and reconstruction of historic buildings or architecture, and are common in many cities in Europe (Visser & van Binsbergen, 1999). In the this work, the authors point out that while the policy objectives might be attained, the costs and benefits of these might not be distributed equally among the urban freight stakeholders. This further supports the importance of understading the different groups impacted by such policies and how the policies meet their diverse and sometimes conflicting objectives.

(Visser & van Binsbergen, 1999) puts forth that policy making can occur throught a bottom-up or a top-down approach. In bottom-up approaches, policies are initiated by the private sector, whereas government initiates policy in a top-down appraoch. The authors outline five stages in the policy lifecyle: identification of the issue and research, policy formulation, policy making, and policy implementation. These stages and the bottom-up and top-down approaches are captured in **Figure**

2.5. While the lifecycle can be broken down into stages, policy planning is not a linear process. New issues could arise and new insight or technology could become available during the planning process, leading to frequent stage revisits. Due to its continuous nature, the planning process should be constantly monitored so the plan can be adjusted as new developments emerge. Ensuring stakeholder engagement and consultation throughout the entire policy planning lifecycle versus only in specific phases benefits monitoring activites as well as policy adoption (Visser & van Binsbergen, 1999).

Figure 2.5 | Combined top-down and bottom-up planning process from (Visser & van Binsbergen, 1999)



As illustrated in **Figure 2.6**, urban freight transport is a “multi-layer” system which includes regulators, supply and demand agents, and market situations or “phenomena” (Visser & van Binsbergen, 1999). The private sector is comprised of the demand and supply actors, responsible for determining the flow of goods through urban areas. Regulators oversee and have control over the flow of goods between supply and demand agents. Some measures need cooperation between the private and public sector to be successful. Examples of public measuers include toll collection measures and limited traffic zones. Private measures include loading and unloading policies for a facility, voluntary cooperation measures, and logistics information systems. **Table 2.1** captures several examples of public and private measures and strategies explained in (Visser & van Binsbergen, 1999). Research as well as previous implementations of some of these have called out policy adoption as a prime concern. In (Stathopoulos, Valeri, & Marcucci, 2011), the authors also distinguish between rule-based and incentive-based policy instruments. Depending on the policy instrument used, adoption could be supported by having regulators incentivize correct behavior or penalize negative behavior.

Figure 2.6 | Actors and regulators related to urban freight transport from (Visser & van Binsbergen, 1999)

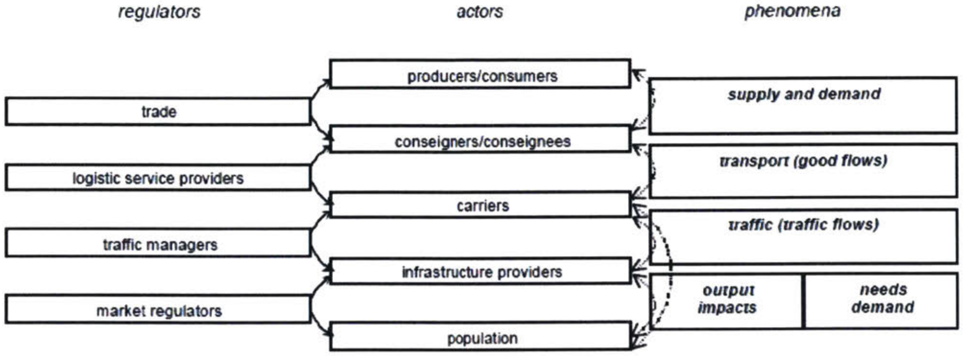
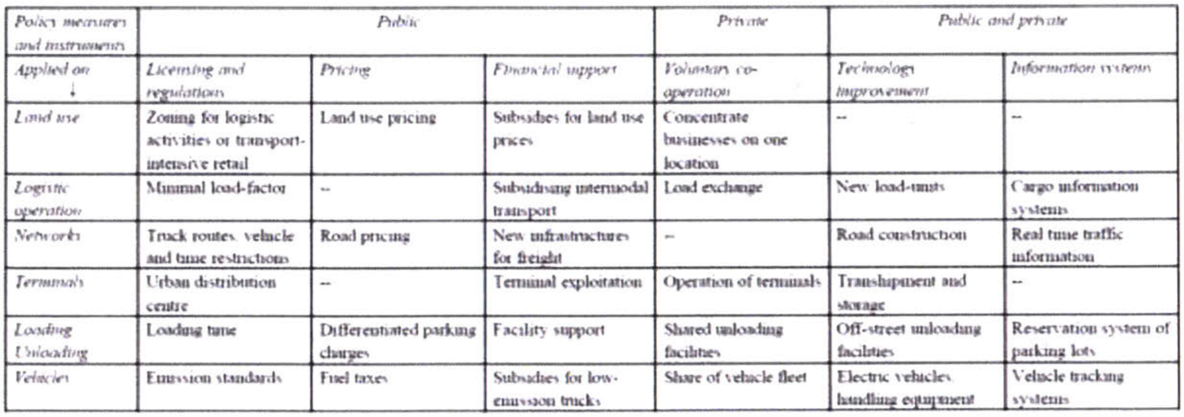


Table 2.1| Classification of public and private measures (examples) from (Visser & van Binsbergen, 1999)



Policy measures and instruments	*Public*			*Private*	*Public and private*	
Applied on ↓	*Licensing and regulations*	*Pricing*	*Financial support*	*Voluntary co-operation*	*Technology improvement*	*Information systems*
Land use	Zoning for logistic activities or transport-intensive retail	Land use pricing	Subsidies for land use prices	Concentrate businesses on one location	--	--
Logistic operation	Minimal load-factor	--	Subsidising intermodal transport	Load exchange	New load-units	Cargo information systems
Networks	Truck routes, vehicle and time restrictions	Road pricing	New infrastructures for freight	--	Road construction	Real time traffic information
Terminals	Urban distribution centre	--	Terminal exploitation	Operation of terminals	Transhipment and storage	--
Loading Unloading	Loading time	Differentiated parking charges	Facility support	Shared unloading facilities	Off-street unloading facilities	Reservation system of parking lots
Vehicles	Emission standards	Fuel taxes	Subsidies for low-emission trucks	Share of vehicle fleet	Electric vehicles, handling equipment	Vehicle tracking systems

While urban freight challenges and solutions have been prevalent since the beginning or urbanization (Visser & van Binsbergen, 1999), these have flourished as populations and demand for goods and services have increased. Some of the challenges and policies developed in Europe and Asia are highlighted below. **Table 2.2** summarizes policy differences for countries across both regions.

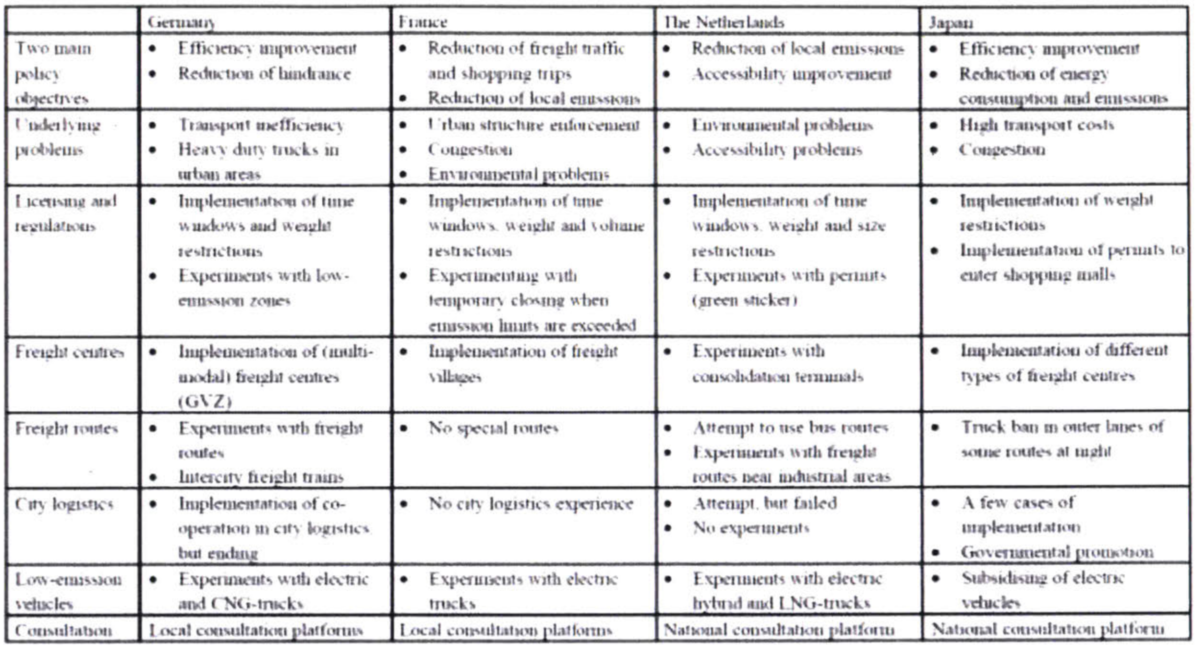
Europe

In Germany, some of the most first and most important developments were the cargo traffic centers, referred to as *Guterverkehrszentrums* (GVZs), and city logistics. GVZ policies were introduced by the national government in the 1990s with the objective of shifting road traffic to rail and ship. They have been implemented in several cities, including Augsburg, Hannover, and München, with the ambition to create inter-regional freight transport networks. City logistics policies were also introduced in the 1990s to provide joint services for delivering goods to urban areas. These policies were envisioned to reduce the amount of freight trips to city centers and therefore reduce negative externalities of freight traffic in these areas. Around the same time, collaboration between transportation and environmental agencies started to take place in France, with the objective of gathering more data on freight traffic. Throughout the nation, metro cities evaluated electric vehicles for goods deliveries, "park and ride" concepts for the delivery of urban goods, and consolidation centers in combination with vehicle size and weight restrictions. In the Netherlands, significant research on urban distribution centers (UDCs) and consolidation schemes took place in the early 1990s (Visser & van Binsbergen, 1999). The public sector was very involved in the development of such policies and while the first UDC implemenations were not successful, later ones reported promising results. Underground transport systems have also been a long-term urban freight project in the Netherlands and in 1995 a Platform Urban Distribution was put in place. The platform supports and stimulates urban freight initiatives from the public and private sector, and provides guidelines for evaluating and monitoring these.

Asia

Urban freight research gained popularity a few years after European cities turned their attention to the issue. It wasn't until 1997 that Japan implemented its first set of urban freight policies (Visser & van Binsbergen, 1999). The policies were originally designed to improve efficiency and competitiveness of japanase businesses. The plan included measures to promote co-operation among businesses (joint deliveries, delivery boxes, etc.), advanced logistics systems, shift from own-account transport services to professional carriers, and the development of ITS and Electronic Toll Collection (ETC) systems.

Table 2.2 | Differences in policies between European and Asian countries from (Visser & van Binsbergen, 1999)



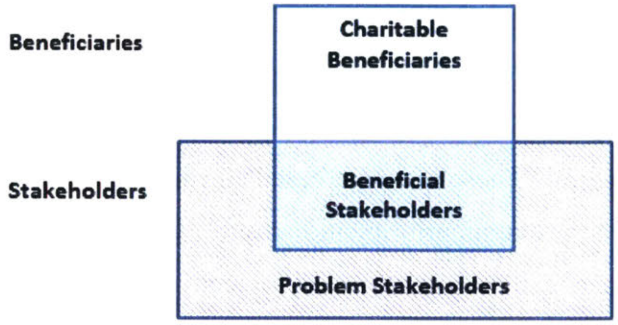
	Germany	France	The Netherlands	Japan
Two main policy objectives	• Efficiency improvement • Reduction of hindrance	• Reduction of freight traffic and shopping trips • Reduction of local emissions	• Reduction of local emissions • Accessibility improvement	• Efficiency improvement • Reduction of energy consumption and emissions
Underlying problems	• Transport inefficiency • Heavy duty trucks in urban areas	• Urban structure enforcement • Congestion • Environmental problems	• Environmental problems • Accessibility problems	• High transport costs • Congestion
Licensing and regulations	• Implementation of time windows and weight restrictions • Experiments with low-emission zones	• Implementation of time windows, weight and volume restrictions • Experimenting with temporary closing when emission limits are exceeded	• Implementation of time windows, weight and size restrictions • Experiments with permits (green sticker)	• Implementation of weight restrictions • Implementation of permits to enter shopping malls
Freight centres	• Implementation of (multi-modal) freight centres (GVZ)	• Implementation of freight villages	• Experiments with consolidation terminals	• Implementation of different types of freight centres
Freight routes	• Experiments with freight routes • Intercity freight trains	• No special routes	• Attempt to use bus routes • Experiments with freight routes near industrial areas	• Truck ban in outer lanes of some routes at night
City logistics	• Implementation of co-operation in city logistics but ending	• No city logistics experience	• Attempt, but failed • No experiments	• A few cases of implementation • Governmental promotion
Low-emission vehicles	• Experiments with electric and CNG-trucks	• Experiments with electric trucks	• Experiments with electric hybrid and LNG-trucks	• Subsidising of electric vehicles
Consultation	Local consultation platforms	Local consultation platforms	National consultation platform	National consultation platform

2.4 Related Work

While substantial work has focused on the economic and environmental impacts of urban freight policies across different cities, in depth analysis of the impact of such policies on the different stakeholders has started to take shape more recently. The effect of no or late inclusion of stakeholder analysis into policy implementation are summarized in (Macharis & Milan, 2015): "large scale or long term adoptions of urban freight policies often fail because they lack sytematic evaluation – the short and long term effects experiences by the cumulative group of stakeholders associated with the industry". Early inclusion of these agents in policy development and implementation should be a primary focuss, as adoption ultimately relies on how the new solutions or regulations address the objectives of these actors. The different view points and conflicting objectives of urban freight stkaholders should be taken into account during the urban freight policy design process (Stathopoulos et al., 2011).

The concept of stakeholder was first introduced in by R. Edward Freeman in 1984 in his Strategic Management work (Crawley, Cameron, & Selva, 2016). In (Crawley, Cameron, & Selva, 2016), the authors define stakeholders as "any and all parties touched by the system". The authors further distinguish between beneficiaries and stakeholders. They define beneficiaries as those who are affected by the system, whereas the stakeholders are those who have stake in the system (product, enterprise, policy, etc.), or affect it. The authors recognize that while the two groups are distinct, they could overlap, in which the beneficial stakeholders emerge. Beneficial stakeholders are those who affect the system and are affected by the system. As captured in **Figure 2.7**, the original two categories can be re-arranged into three categories: charitable beneficiaries, beneficial stakeholders, and problem stakeholders.

Figure 2.7 | Stakeholders and Beneficiaries from (Crawley, Cameron, & Selva, 2016)



2.4.1 Evaluation of consolidation centers in Greece

In their study of urban freight terminals for two locations in Thessaloniki, Greece, (Nathnail et al., 2016) include the stakeholders to perform a pairwise comparison of the performance of the two facilities using a Multi Criteria Assessment (MCA) framework. The goal of the study was to determine which terminal was most effective in terms of established performance criteria. The criteria along with their key performance indicators (KPIs) and weights were determined by the agents involved in the operation of the two terminals. The five criteria considered were: management policy, organizational and institutional structure, supply side performance, terminal properties, and level of services. The KPIs and their grading values were obtained from a previous project in Europe (European Research project CLOSER) as well as from the authors' prior experience in terminal performance assessment projects. The grading scale was determined based on literature review and adjusting based on stakeholders' input using the Delphi method (Nathnail et al., 2016). The numerical values for the KPIs were acquired from the terminals' annual reports and/or through input from their representatives. The weights of the individual KPIs and criterion were established through the Analytic Hierarchy Process (AHP) using input from all stakeholders for each facility, including shippers, receivers, operators, local authorities, LSPs, and several others. The AHP method for Multiple Criteria Decision Making is widely used in the transportation field. It was first structured by Saaty in the 1970s and it provides a flexible model to assist in complex decision-making processes (Nathnail et al., 2016). One of the advantages of AHIP is that it works with any type of criteria – subjective, objective, quantitative, or qualitative. One of the method's drawback is that it assumes that the criteria are additive and yields a linear model, which may not suit certain scenarios.

Table 2.3 captures a snapshot of the multi-criteria assessment framework in (Nathnail et al., 2016). Once all values were obtained, a sensitivity analysis was conducted by modifying the weight of one decision criteria at a time. These were increased and decreased by 10% to evaluate the impact the change would have to the overall prioritization results. In addition to determining which facility ranked better in performance, the study's primary objective was to use stakeholder input to guide decision-making through a consensus on geometric mean of the individual pairwise comparisons (Nathnail et al., 2016). Facility ranking results are captured in **Table 2.4**.

In conclusion, in (Nathnail et al., 2016), two specific types of urban freight logistics solutions (consolidation centers) are evaluated in terms of their performance taking account stakeholder input and using an MCA framework and the AHP methodology. While the stakeholders were able weigh in on the criteria they deemed in important to evaluate the performance of a terminal, and even rank the importance of these criteria, they were evaluating two existing urban freight logistics concepts. This study takes into account stakeholder judgement in terms of performance, which can be associated with the operation of the facilities, rather than with the policy design itself.

Table 2.3 | Multi-Criteria Assessment Framework snapshot for comparison of Port of Thessaloniki (ThPA) and Kuehne + Nage (K+N) terminals from (Nathnail et al., 2016)

Criterion	Wi	Indicator (KPI)	Description	Value (vij) ThPA	Value (vij) K+N	Grade (gij) ThPA	Grade (gij) K+N	wij
Supply side performance	20%	Employee productivity	Ratio between flows and inputs, TEU transhipped per employee and year	9324	2560	7	4	50%
		Equipment productivity	Total number of TEUs lifted per year and crane	73968	15708	7	4	50%
Terminal properties	25%	Saturation ratio (TEUs)	Ratio between actual volumes and maximum capacity (daily average,%)	66%	57%	4	5	10%
		Saturation ratio (total cargo tonnage)	Ratio between actual volumes and maximum capacity (daily average,%)	37%	50%	7	5	10%
		Expandability	Potential for expandability (% increase compared to today's capacity)	33%	10%	6	2	10%
		Distance from city centre	Number of kilometres from city centre to interchange/terminal	<2	15	10	6	10%
		Distance from commercial areas	Number of kilometres from terminal to nearest commercial centre	<5	15	10	6	10%
		Distance from industrial zones	Number of kilometres from interchange/terminal to nearest industrial zone	15	<1	6	10	10%
		Transshipment time	Time needed for loading / unloading per TEU	45 mins	60 mins	6	5	10%
		Connection and distance to primary motor-way network	Direct, indirect or no access to nearest highway and proximity	indirect (5Km)	direct (1 Km)	8	10	10%
		Connection and distance to primary railway network	Direct, indirect or no access and proximity	indirect (15Km)	direct (<5 Km)	6	10	10%
		Connection to ports	Direct, indirect or no access and proximity	direct (0 Km)	indirect (15 Km)	10	6	5%
		Connection to airports	Direct, indirect or no access and proximity	indirect (15Km)	indirect (25 Km)	6	5	5%

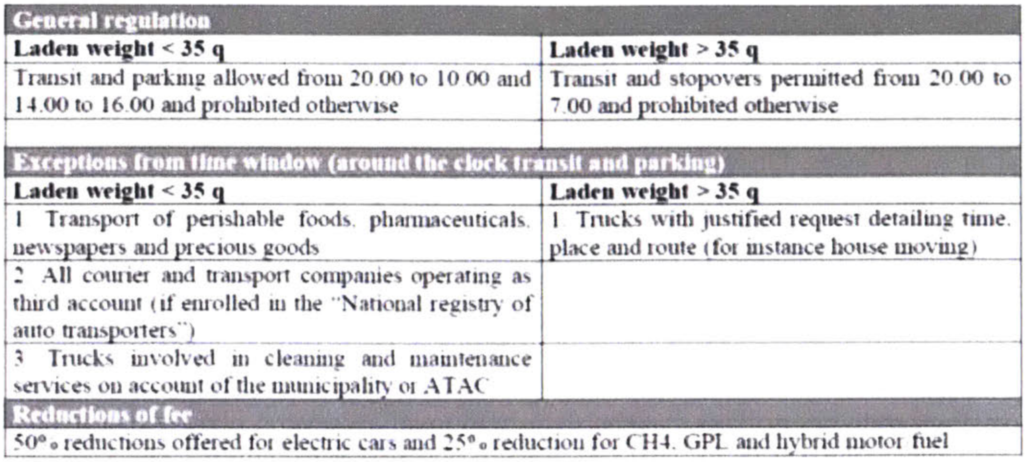
Table 2.4 | Partial and total performance indices of Port of Thessaloniki (ThPA) and Kuehne + Nage (K+N) terminals from (Nathnail et al., 2016)

Criterion	Performance index	
	ThPA	**K+N**
Management policy	2.6	5.6
Organisational and institutional structure	8.5	7.9
Supply side performance	7	4
Terminal properties	7.1	6.45
Level of service	7.9	7.2
All criteria (Total Performance Index - TPI)	**6.815**	**6.2375**

2.4.3 Stakeholder views on Urban Freight Logistics in Rome's LTZs

As in other metropolitan areas, urban freight in Rome accounts for a significant volume of the overall traffic and contributes to the city's congestion, energy use, and pollution. In Rome, the delivery of goods represents 6 percent of the total traffic volume (Comi et al. 2008). As reported in the study captured in (Stathopoulos, Valeri, & Marcucci, 2011), 25,000 goods vehicles traveled through the city's historical center in 1999. Two thirds of these vehicles were reported to complete their operations in the morning (between 7AM and 1 PM), when the area is generally more congested due to work commuters. Furthermore, the study found that about 86 percent of the goods vehicles traveling through the area were diesel-fueled and more than half committed double-parking infractions while completing their deliveries or pick-ups. Aggravating the issue is the area's business culture, in which own-account operators, also known as "*padroncini*", represent a big portion of the goods distribution service providers. Despite Rome's drop in own-account transport from 54 percent to 21 percent between 1999 and 2008, the phenomenon reaches 88 percent in some urban regions across the country, and is associated with low load factors and inefficient routing (Stathopoulos, Valeri, & Marcucci, 2011). Since the late 1980s, Rome's historical center has enforced a Limited Traffic Zone (LTZ). In (Stathopoulos, Valeri, & Marcucci, 2011), the authors explain that while the LTZ is meant to reduce own-account deliveries and lengthy parking by these and other goods vehicles, its enforcement has proven challenging due to the extensive list of exceptions to its measures. The LTZ regulation enforced in the Rome has been summarized in **Table 2.5** (Stathopoulos, Valeri, & Marcucci, 2011).

Table 2.5 | Regulatory regime for urban goods distribution in the LTZ of Rome from (Stathopoulos, Valeri, & Marcucci, 2011)



General regulation	
Laden weight < 35 q	**Laden weight > 35 q**
Transit and parking allowed from 20.00 to 10.00 and 14.00 to 16.00 and prohibited otherwise	Transit and stopovers permitted from 20.00 to 7.00 and prohibited otherwise
Exceptions from time window (around the clock transit and parking)	
Laden weight < 35 q	**Laden weight > 35 q**
1 Transport of perishable foods, pharmaceuticals, newspapers and precious goods	1 Trucks with justified request detailing time, place and route (for instance house moving)
2 All courier and transport companies operating as third account (if enrolled in the "National registry of auto transporters")	
3 Trucks involved in cleaning and maintenance services on account of the municipality or ATAC	
Reductions of fee	
50% reductions offered for electric cars and 25% reduction for CH4, GPL and hybrid motor fuel	

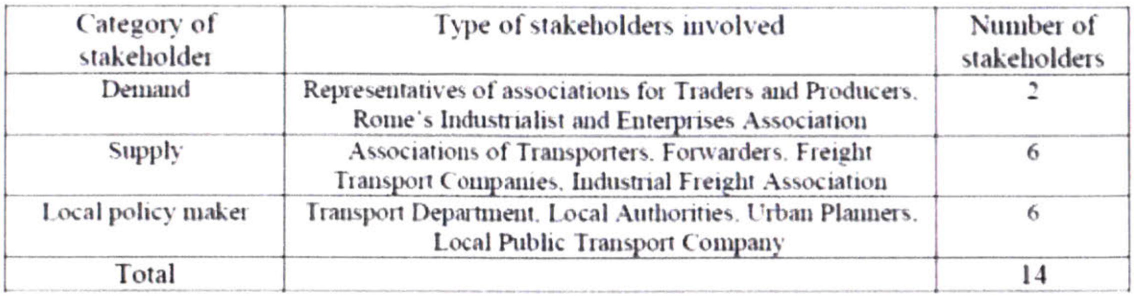
SOURCE: LTZ municipal resolution n.44 from 2007

According to the authors of (Stathopoulos, Valeri, & Marcucci, 2011), city logistics schemes aim to enhance the use of urban freight and reduce its negative impacts. They establish that it's critical that city logistics policies understand the needs of the stakeholders involved in the urban supply chain and recognize potential conflicts among these needs. Even further, the group points out that failure to study the different agents' preferences and problem perceptions could threaten the successful implementation and adoption of such policies and measures. In t(Stathopoulos, Valeri, & Marcucci, 2011), stakeholder insight is used to understand the perception of urban freight problems by the key agents in the local industry, and how different solutions might be supported by them. The research focuses on Rome's LTZ and the actors involved in its urban freight logistics.

In (Stathopoulos, Valeri, & Marcucci, 2011), the authors first distinguish between the private and public sectors in urban freight and the different types of urban freight solutions these groups implement. The private sector's decisions generate flow of goods through urban settings, whereas policy makers regulate and facilitate these flows. Typical urban freight public policies include pricing, licensing, and regulation. The authors classify policy instruments as rule-based or incentive-based. Private measures include technology investment and routing and consolidation strategies. In addition to capturing stakeholder preferences and perceptions on local urban freight challenges and potential measures, (Stathopoulos, Valeri, & Marcucci, 2011) focuses on evaluating the interaction of the system's agents. To collect input from the different agents and evaluate their interaction, the study includes stakeholder interviews and group discussions.

To explore the top issues associated with local freight transport according to main stakeholders and the policy proposals that these promote to tackle the problem, 14 system stakeholders were surveyed in two phases. Once the stakeholders were identified, they were divided into 3 main groups – transport service providers, retailers, and regulators – which are summarized in **Table 2.6**. To justify their reasoning for focusing on these three categories, the authors described these as having the most influence on the urban freight logistics chain. According to (Stathopoulos, Valeri, & Marcucci, 2011), the primary objectives of freight transport operators are reducing costs and increasing productivity. This stakeholder group involves several players that make decisions at different "stages" of the logistics game. For example, the consigner (supply category) hands the goods to a forwarder, who may hire a carrier to deliver the goods to the customer. The consigner could provide the forwarding and carrier services, but in many cases this scheme involves 2-3 companies. In addition, the driver completing the delivery of the goods to the costumer (receiver) is also a decision maker (Stathopoulos, Valeri, & Marcucci, 2011). For the receivers or retailers (demand category), top concerns include short delivery times and low inventory, which requires less warehouse space and tied up cash. It should be noted that the inventory and warehousing decisions will vary across different business profiles (types of goods, store size, etc.), which is another wide field of study. In Rome, for instance, hotel, restaurant, and catering goods make up 71% of all retailers in the LTZ area (Filippi and Campagna, 2008). These goods tend to have a short life and therefore more frequent replenishments are required, increasing the demand for freight trips in the area. The major objective of regulatory bodies (local policy maker category) is addressing social issues and costs. As it pertains to urban freight, these include pollution, noise, congestion, and land use. While city residents and customers of local businesses are affected by these negative externalities, they have little to no say in such measures.

Table 2.6 | Categories of stakeholders involved in focus group survey from (Stathopoulos, Valeri, & Marcucci, 2011)

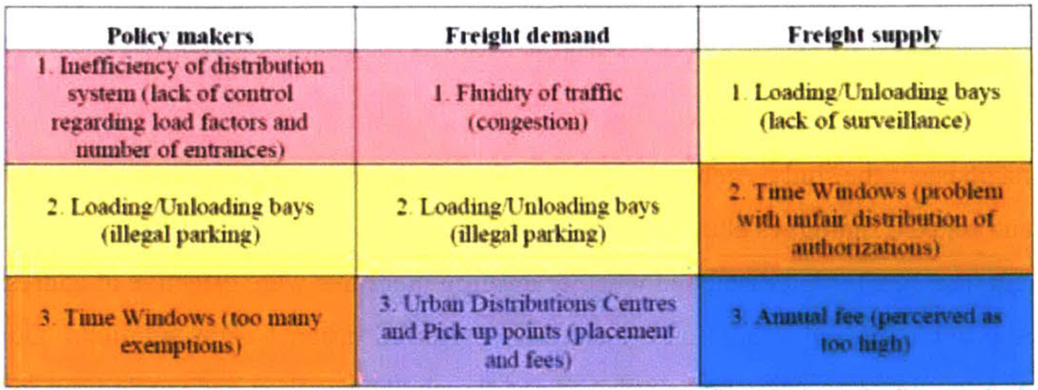


Category of stakeholder	Type of stakeholders involved	Number of stakeholders
Demand	Representatives of associations for Traders and Producers. Rome's Industrialist and Enterprises Association	2
Supply	Associations of Transporters. Forwarders. Freight Transport Companies. Industrial Freight Association	6
Local policy maker	Transport Department. Local Authorities. Urban Planners. Local Public Transport Company	6
Total		14

In the first phase of the study, each stakeholder group was interviewed separately to allow for more natural and relaxed dialogues about their own concerns and what they perceived as the problems. As a group, the agents also discussed whether existing measures were effective at addressing the problems previously highlighted and listed their preferred urban freight solutions. During the second phase, all stakeholders were gathered and the challenges they had singled out during the first phase were re-presented for further debate. At this time, the top twelve proposed policies from the first stage were also presented to the whole group to evaluate how the stakeholders related to policy proposals from other stakeholder groups.

Through the two types of group discussions, researchers were able to identify the top concerns across the entire group and those specific to each stakeholder category. They established the presence of two types of concerns about urban freight traffic – high level problems and more specific issues. High level problems were not associated with the proposed solutions and included the difficulty in data collection, the availability of real-time information on the flow of goods and freight movement, among others. The more specific concerns revolved mostly around loading bays, time window restrictions, and pricing schemes (Stathopoulos, Valeri, & Marcucci, 2011). Most stakeholders found that there were not enough loading/unloading bays, that most didn't have enough space or their location was not convenient, and that they had little surveillance. The top problem areas by stakeholder group are identified in **Table 2.7**. What this shows is that the regulatory group was most concerned with social costs and efficiency, stakeholders on the demand side expressed more concerned about the measures that impact the flow of goods (congestion, loading/unloading points, distribution centers), and stakeholders on the supply side were most concerned with measures that directly impact their operations. Supplier operations could be affected by restrictive policies (e.g. time windows, fees, etc.), and loading/unloading bay measures.

Table 2.7 | Most important problem areas by type of agent/stakeholder from (Stathopoulos, Valeri, & Marcucci, 2011)



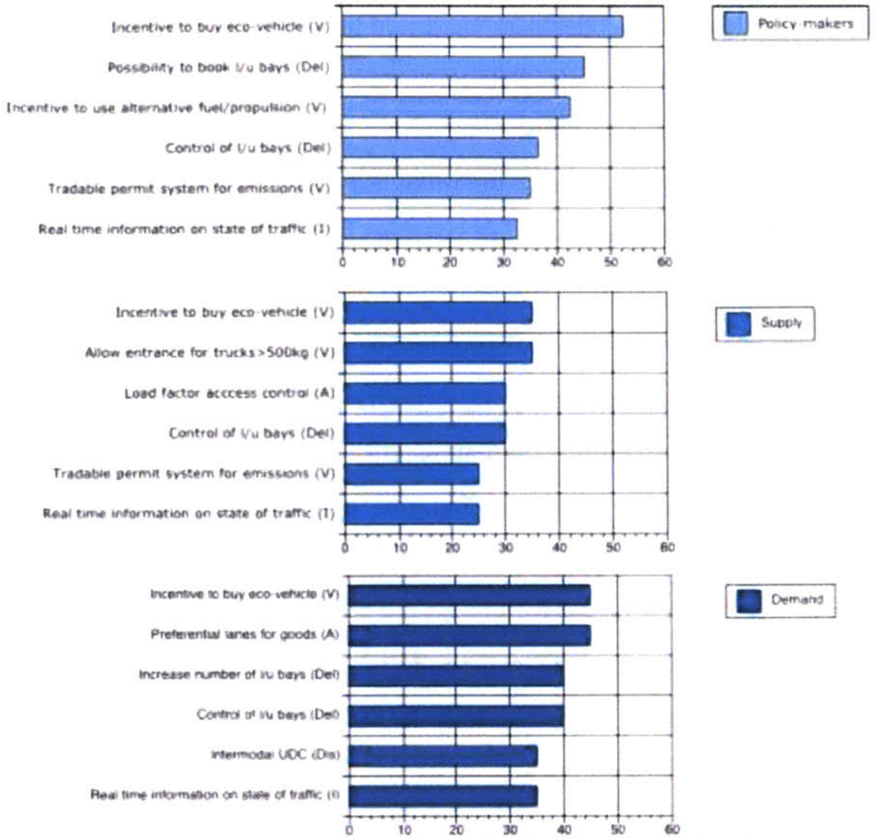
Policy makers	Freight demand	Freight supply
1. Inefficiency of distribution system (lack of control regarding load factors and number of entrances)	1. Fluidity of traffic (congestion)	1. Loading/Unloading bays (lack of surveillance)
2. Loading/Unloading bays (illegal parking)	2. Loading/Unloading bays (illegal parking)	2. Time Windows (problem with unfair distribution of authorizations)
3. Time Windows (too many exemptions)	3. Urban Distributions Centres and Pick up points (placement and fees)	3. Annual fee (perceived as too high)

Notes: * Colour indicates type of problem: pink (general traffic system), yellow (loading/unloading practices), orange (time windows), blue (access fee), lilac (UDC)

With the top problem areas well identified, the study shifts to the analysis of the proposed policies by the different stakeholder groups. The top six policies suggested by each group have been captured in **Figure 2.8**. To rank the policies, each stakeholder was given 100 points to allocate across all six suggestions. The most popular policy proposals were those that translated into least costs or behavioral adaptations and fair distribution of costs among the agents (Stathopoulos, Valeri, & Marcucci, 2011). On the other hand, policies that required joint efforts among operators or multiple agents weren't too popular among the group surveyed. For example, policies associated with the use of electric vehicles, increasing the number of loading bays, and the flow of information related to the deliveries ranked high across all stakeholder groups. Conversely, policies supporting Urban Distribution Centers (UDCs) and preferential lanes for goods vehicles received substantial support from the public sector but ranked low among private agents. The top policies were also evaluated for their level of shared support, noting that measures with unbalanced support from the stakeholders would be more difficult to successfully adopt.

The major findings from (Stathopoulos, Valeri, & Marcucci, 2011) include local urban freight problem perceptions according to different stakeholders and the level of support for the policies proposed by these. While most stakeholders identified the same issues with the area's urban freight measures, their support for the proposed policies was quite varied – some of the recommended solutions were supported by all or multiple stakeholder groups, others were only supported by one group of agents. According to the authors, the involvement of the stakeholders in the study proved quite valuable in identifying measures with unified consensus and those dismissed by distinct agents. Findings from this and similar studies would enable more effective frameworks for urban freight policy design, by allowing the stakeholders to weigh in on proposed solutions and grasp how these would be perceived and supported by them (Stathopoulos, Valeri, & Marcucci, 2011). While the approach in this study provided great insight, it was somewhat open-ended. Stakeholders freely identified problems and solutions, and did not receive any guidance on the varied alternatives for addressing urban freight challenges. Rather than informing the stakeholders on possible solutions to the area's urban freight issues and gathering their stances and preferences among those, the study relied on the stakeholders' existing knowledge about urban freight measures. The work of (Stathopoulos, Valeri, & Marcucci, 2011) demonstrates the value of stakeholder perceptions and preferences, whereas their engagement in policy design and implementation is beyond the study's scope.

Figure 2.8 | Top six policies within macro policy area per stakeholder type from (Stathopoulos, Valeri, & Marcucci, 2011



Notes: graph refers to percentage of points obtained within the given macro-area. The policy areas in parentheses are: A=Access policies. I=Information. Del=Delivery policies. Dis=Distribution system policies. V=Vehicle policies.
Source: own elaboration from focus-group surveys

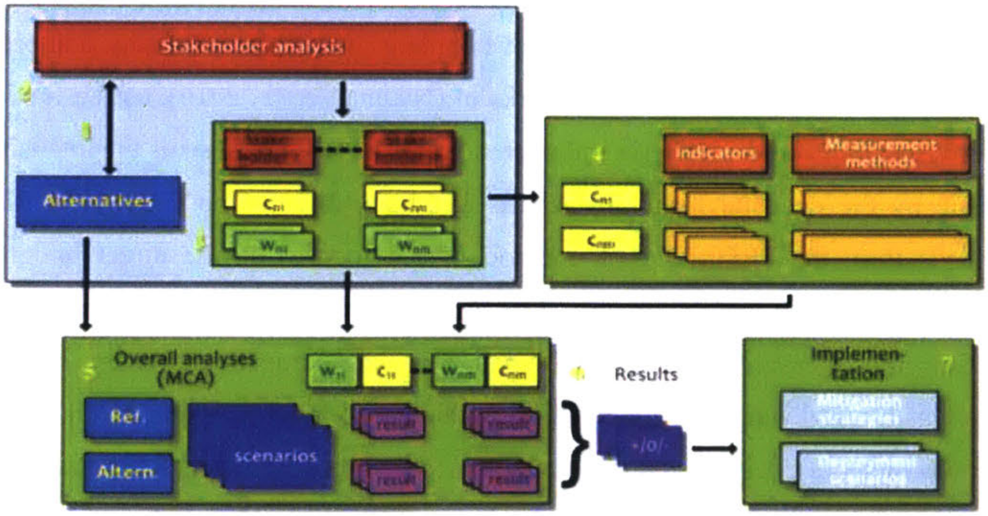
2.4.2 Using MAMCA to Evaluate Urban Freight Measures in Sweden

(Macharis & Milan, 2015) takes the MCA framework to another level in their urban freight policy study in Gothenburg, Sweden. The primary focus of this study is to involve stakeholders in the decision-making process. In this work, the authors note that "while many cities have tried the implementation of UCCs many have failed becausee not all stakeholders were taken into account when evaluating the proposed policiy and its adoption". The authors call out the need for a more comprehensive approach for evluating urban freight policies and for the inclusion of the various impacted stakeholders in this process. In (Macharis & Milan, 2015) the possibility of using the

MAMCA approach for the evaluation and implementation of urban freight solutions is discussed, using Gothenburg, Sweden as a case study. Gothenburg is the second largest city in Sweden in terms of economic activity and population density. As previously pointed out, densely populated cities are associated with high demand for goods and therefore high demand for freight transport. As a result, the city is affected by some of the negative externalities caused by urban freight and previously discussed in this chapter. In (Macharis & Milan, 2015), four alternatives were evaluated in order to improve the freight logistics services in the area: do nothing (current situation), establishing a UCC, EVs for goods distribution, and the establishment of low emission zones with restricted access.

MAMCA is an extension of the Multi-Criteria Analysis, which has been recently discussed in Section 2.4.1 (Nathnail et al., 2016). The methodology allows decision-makers to evaluate project alternatives (policies, scenarios, etc.) with respect to the different and often conflicting objectives of the stakeholders involved in the decision-making process. This methodology was developed by Cathy Macharis and widely used for decision-making problems in the transportation field. The MAMCA consists of seven steps, which have been summarized and illustrated below in **Figure 2.9** (Macharis & Milan, 2015).

Figure 2.9 | Multi-Actor Multi-Criteria Analysis Framework from (Macharis & Milan, 2015)



Step 1 – Definition of the problem and the identification of alternate solutions. Solutions

include technology, policy, scenario, etc.

Step 2 – Analysis of stakeholder objectives. This step is not included in the traditional Multi-Criteria Decision Analysis (MCDA) approach, which doesn't include input from different stakeholders.

Step 3 – Definition of criteria and weights based on stakeholder objectives and priorities.

Step 4 – Definition of indicators and measurement methods for each criterion. Through these, the performance of the different alternatives can be measured to determine how it contributes to the different stakeholders' objectives.

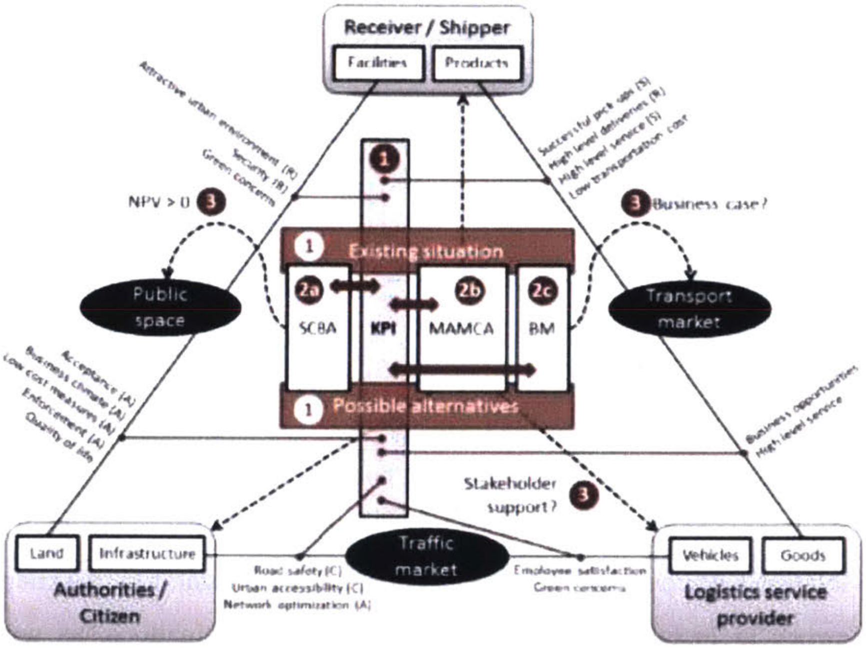
Step 5 – Analysis and ranking of alternatives. Any MCDA method can be used to evaluate the different alternatives.

Step 6 – Evaluation of MCDA results. The results include ranking of the different alternatives, as well as the advantages and disadvantages of each. The ranking results could be further evaluated using sensitivity analysis.

Step 7 – Implementation of decision. Contribution from each stakeholder group (from previous steps) not only helps in making the decision, but also on structuring the implementation plan.

In (Macharis & Milan, 2015), the AHP and PROMETHEE-GDSS methods were the MCDA methods select to evaluate the different policy alternatives (Step 5). These were selected because they allow the different stakeholder groups to develop their own criteria, weights, and preference structure. AHP, previously discussed in the works of (Nathnail et al., 2016), uses a fundamental scale for pairwise comparison of criteria and alternatives. The scale represents the intensity of the decision made by the decision maker (Macharis & Milan, 2015). The PROMETHEE-GDSS method extends from the PROMETHEE method, which focuses on the direct integration of stakeholders in the decision-making process. This is an outranking method which computes a net preference flow that measures how each alternative is outranking or outranked by the other alternatives. This method was complemented using the Geometrical Analysis for Interactive Aid (GAIA) plane, which provides a visual representation of the problem in which the alternatives and their contribution to the criteria are captured. The study's scope includes five specific stakeholders in the urban freight context: shippers, receivers, logistics service provider (LSPs), and local authorities. The authors attribute the study's stakeholder focus to the widespread interaction of these in multiple domains, which is illustrated in the stakeholder-based evaluation framework for city distribution measures in **Figure 2.10** (Macharis & Milan, 2015). In the study, the stakeholder groups were represented (role play) by students. Hence, the authors recognize that if true stakholders were involved in the study, results could be further validated and would be more objective.

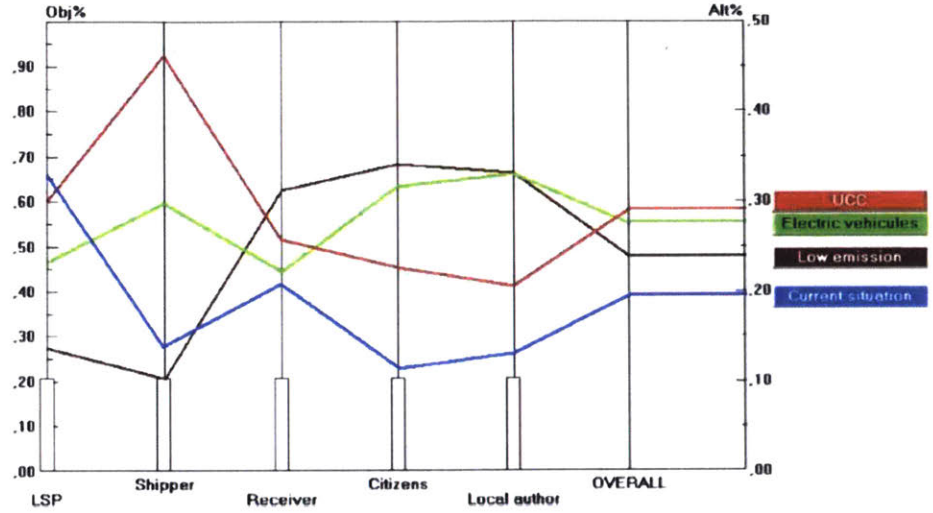
Figure 2.10 | City Distribution Multi-Actor Multi-Criteria Analysis (CD-MAMCA), setup 2012 for STRAIGHTSOL from (Macharis & Milan, 2015)



Figures 2.11-2.13 show the results from this experiment with the different approaches. The preferences for the individual stakeholders using AHP are illustrated in **Figure 2.11**, which captures how the different groups ranked the different policy alternatives. **Figure 2.12** also illustrates the stakeholders' point of view using AHP. For instance, LSPs are not supporters of the low emission zones, as this would limit the areas they have access to, and they would rather keep the current situation. Local authorities on the other hand, prefer low emission zones or EVs, and are less supportive of UCCs, a scenario in which they may have to provide incentives for it to

achieve economic viability. **Figure 2.13** captures the complete ranking of alternatives resulting from the PROMETHEE II method, suggesting that in this study, the UCC alternative received the highest preference ranking among stakeholders. It should be emphasized that the objective of (Macharis & Milan, 2015) was to capture strengths and weaknesses of the alternatives considered.

Figure 2.11 | Multi-Actor view with AHP from (Macharis & Milan, 2015)



While the methodology in (Macharis & Milan, 2015) successfully makes the different stakeholder objectives explicit and hence enable their consideration during discussions pertaining to new transportation policies and solutions, it was noted that the framework considered a limited amount of scenarios. The scenarios considered were characterized by pre-conceived policy concepts evaluated in isolation. It would be interesting to explore the possibility of expanding the robust analysis framework to include more policies and policy combinations, as well as additional stakeholders.

Figure 2.12 | The Multi-Actor GAIA plan (Macharis & Milan, 2015)

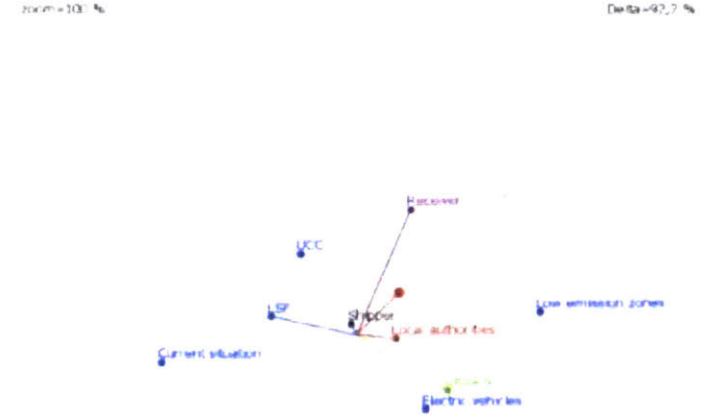
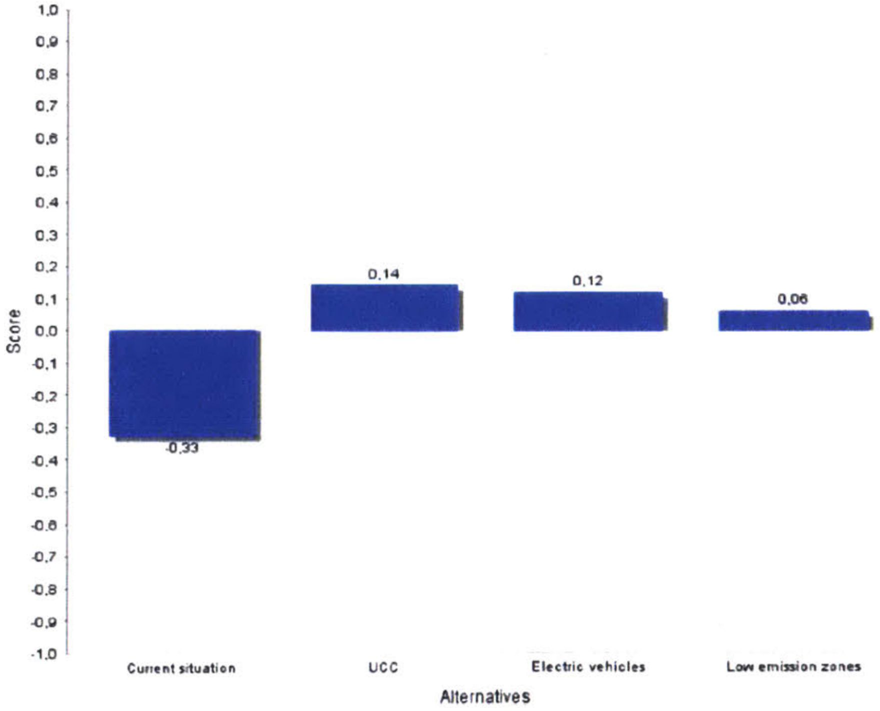


Figure 2.13 | PROMETHEE II ranking based on the net preference flow of the analyzed alternatives (actions) in D-Sight from (Macharis & Milan, 2015)



2.5 Literature Review Summary

The literature review presents an overview of the contributions and challenges posed by urban freight transportation, measures that have been studied and implemented to deal with these challenges, and urban freight research focused on stakeholder inclusion and behaviors. While urban freight transportation is essential for the urban flow of goods, its growing demand has increased the social, economic, and environmental expenses tied to it. As a result, significant attention and investments from industry stakeholders and experts have been devoted to the development of urban freight solutions and regulation over the past few decades. Some of the urban freight externalities drawing the most concern include traffic congestion, environmental pollution, noise, and traffic accidents. In Singapore, resource scarcity due to the nation's limited land area, and urban freight negative externalities have prompted the public sector to invest in transportation technologies and measures that serve to increase social and environmental safety as well as economic productivity. Among these are AV and ERP developments, as well as urban freight consolidation schemes.

The literature review also provides a synopsis on public and private urban freight measures, and on the different developments achieved by metropolitan regions in Europe and Asia. While most of the urban freight research has focused on potential regulations and measures that could alleviate its negative impacts, recently, more work has been done on urban freight stakeholder analysis and inclusion in policy design. The last section in this chapter provides background for some distinguished analyses on urban freight stakeholders. The set of policies evaluated in these studies are narrowed down based on the context and local challenges, and the focus of these is to gather stakeholder knowledge and preferences. In these studies, stakeholder insight was typically gathered before or after a policy was implemented, rather than making the stakeholders part of the policy lifecycle – weighing in in the various stages of the policy design and implementation process. In these studies, stakeholders provided their perceptions of specific policies laid out to them or suggested by them. However, most of the schemes considered in these studies are one-dimensional, whereas the approach presented in this thesis will examine multiple dimensions for developing urban freight policies and evaluate how these could impact different system stakeholders, taking into account different demand patterns. In the selected related works, methods used to collect stakeholder input and evaluate preferences include group discussions, surveys, AHP, and MAMCA.

3. System Framing and Analysis

3.1 Hypotheses

While research in the urban freight field has mainly focused on evaluating regulation, stakeholder preferences prior or after a policy has been implemented, or on a single type or sub-set of agents and freight policies, the core of this thesis centers on differentiating aspects of urban freight policy design for retail malls in Singapore. Specifically, the research focuses on the linkage of stakeholders throughout the continuous policy design lifecycle, the design and evaluation of multi-dimensional urban freight solutions, and policy design in response to demand patterns. To explore these focus areas and taking into consideration the findings and contributions from similar work discussed in Chapter 2, the following hypotheses have been drawn.

H1 | Policy configurations that include the "pre-determined" or "time window" options for the *Loading Bay Access* architectural decision will always perform better in terms of *Efficiency* for the "retailers" stakeholder group than for other stakeholders analyzed.

H2 | In terms of *Sustainability* and *Efficiency*, policy configurations with some sort of goods consolidation will always perform better than policies with no consolidation for the "LSPs" and "retailers" stakeholder groups.

H3 | Tradespace exploration for urban freight policy architectures can result in enhanced ongoing engagement of stakeholders in the decision-making process and evaluation of agent trade-offs under different scenarios.

H4 | Using a systems approach to evaluate urban freight policy designs for different demand profiles, one could identify which architectural decisions influence demand behavior and better negotiate and cater to retailers with different demand patterns.

H1 and **H2** were derived from data collected in an urban freight logistics study at two urban malls in Singapore (Dalla Chiara, Cheah, & Courcoubetis, 2017) and findings from research synthesized in Chapter 2. According to a questionnaire administered to retail shop owners at two malls in

Singapore, interruptions caused by deliveries ranked 3rd among the top 14 goods receiving related problems for the retail stores. Time windows and "pre-determined" delivery times, in the form of a parking reservation system, would provide the shop keepers more visibility into delivery times and allow them to better plan for these to avoid business interruptions. On the other hand, these architectural decision options are more restrictive for the logistics service providers (LSPs) and operators, making it less likely to improve their efficiency. **H2** was derived based on the findings from previous studies on urban freight consolidation, which reported that consolidation schemes have (1) reduced vehicle miles traveled (VMT) by freight vehicles, therefore making these solutions more sustainable, (2) improved vehicle flow at the retail malls, and (3) allowed for better use of freight vehicles through higher load factors. These results suggest that such configurations would enhance efficiency and sustainability peformance for the retailers and LSPs. **H2** assumes that a critical mass, or participation threshold, is guaranteed. As reported in numerous studies, including (Jaller et al., 2015) and (Holguín-Veras & Sánchez-Díaz, 2016), the critical mass is a crucial factor for the financial feasibility of consolidation policies. While developing these considerations, ideas for **H3** and **H4** surfaced. This thesis will focus on demonstrating the validity of **H1** and **H2**, only discussing **H3** and **H4** at a high level. The detailed discussion of these last two will follow in future work. **H3** represents the concept of a system design that has retained and ongoing linkage to its stakeholders. **H4** centers around the varying needs and objectives of the system stakeholders, further differentiating retailer types within the "retailer" stakeholder category.

3.2 Research Approach

The research approach for this thesis employs system design tools, looking at urban freight logistics for retail malls in Singapore and its stakeholders as one complex system. The tools and methods used will be demonstrated in detail in the subsequent sections, but a brief overview of these will be provided in this section.

Once the literature review was completed and the hypotheses and the system's boundaries were defined, we proceeded to do a careful analysis of the system stakeholders and their interactions, which we present in Section 3.3. The sub-set of stakeholders considered in the evaluation of the framework and their respective objectives are also thoroughly covered in this section. The stakeholder analysis is followed by a description of the architectural decisions considered in our framework for the design of policy architectures. The possible configurations considered for each decision are also presented. Architectural decisions and options were selected by decomposing the urban freight logistics system and identifying key functional and formal characteristics that have been explored individually in other studies in the field.

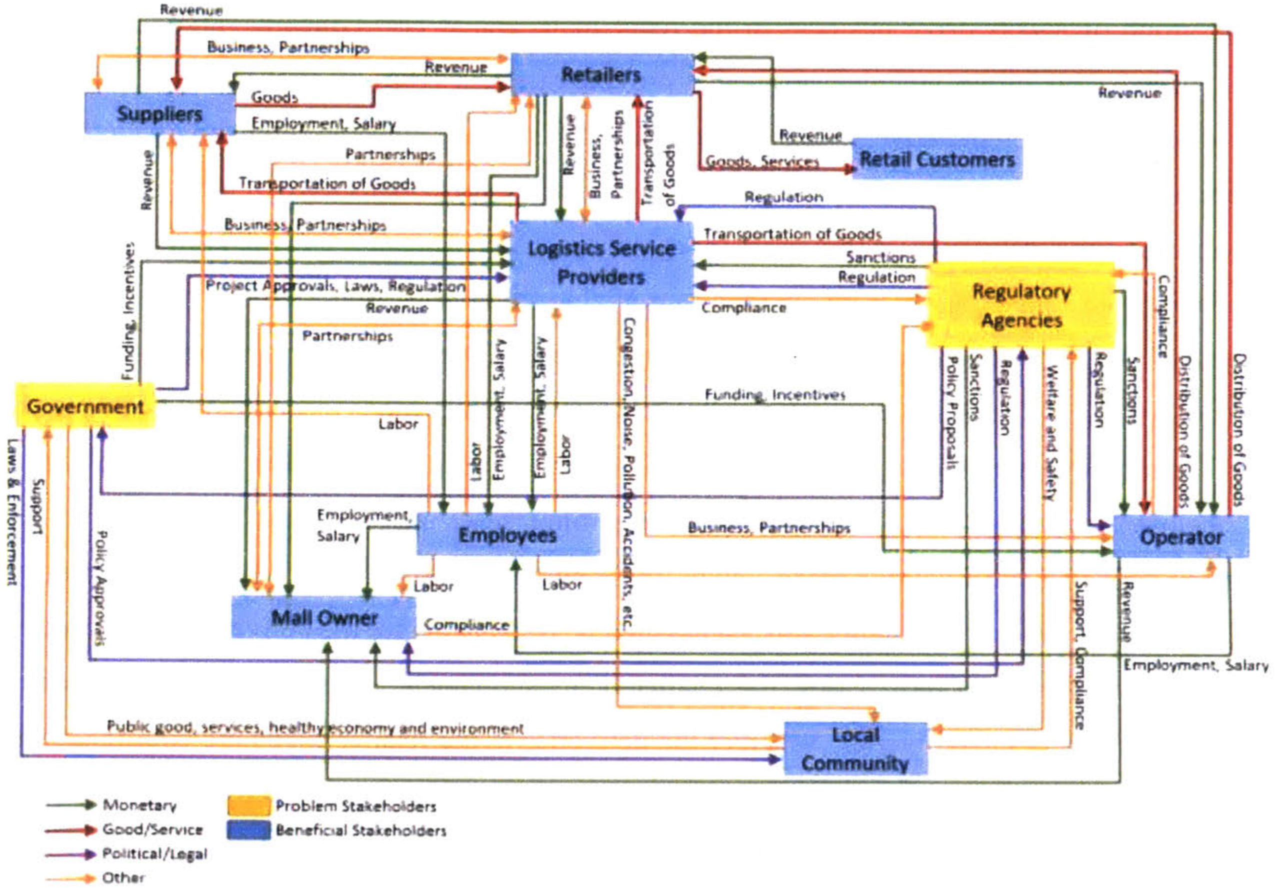
One of the differentiating aspects of this work from related research is the aim to engage stakeholders throughout the lifecycle of urban freight policy. Hence, vital lifecycle properties for urban freight policies are identified for the assessment of their emergence in different policy architectures. Different frameworks for evaluating the criteria identified are also revealed in Section 3.5, explaining how these are perceived by the different stakeholders.

From all possible combinations of the different architectural decision-options identified in Section 3.4, forty configurations are randomly selected and evaluated for their performance on cost, efficiency, and sustainability as compared to the baseline policy architecture, which is also defined in Section 3.4. Sustainability is evaluated at the systematic level, whereas cost and efficiency are evaluated for each stakeholder group. The scoring frameworks for each criterion, presented in Section 3.5, and evidence from related work and other research in the field, are used to generate multiple tradespace explorations. Tradespace analysis is conducted to identify policy trade-offs among different stakeholder groups, patterns in policy configurations, and other phenomena. With this analysis, the hypotheses presented are revisited and addressed.

3.3 Stakeholder Analysis

(Hensher & Puckett, 2004) highlights the importance of evaluating stakeholder objectives in policy design and explains that "policies that don't take into account the complex interactions within the chain may yield suboptimal outcomes, based on inaccurate projections of the likely effects". Before assessing how different urban freight policy designs impact the diverse group of agents that play in the industry, these groups and their objectives should be outlined. The Urban Freight Logistics system for urban malls in Singapore is comprised of diverse actors, including the retail shop owners, mall owners, suppliers, logistics service providers (LSPs), operators, public authorities and regulatory agencies, the local community, employees, retail shop customers, among others. The Stakeholder Value Network (SVN) in **Figure 3.1** captures these main actors and summarizes the interactions among these as value exchanges in the Urban Freight Logistics system in Singapore. Throughout this thesis we will also refer to the system's stakeholders as actors and agents, interchangeably.

Figure 3.1 | Singapore Urban Freight Logistics Stakeholder Value Network (SVN)

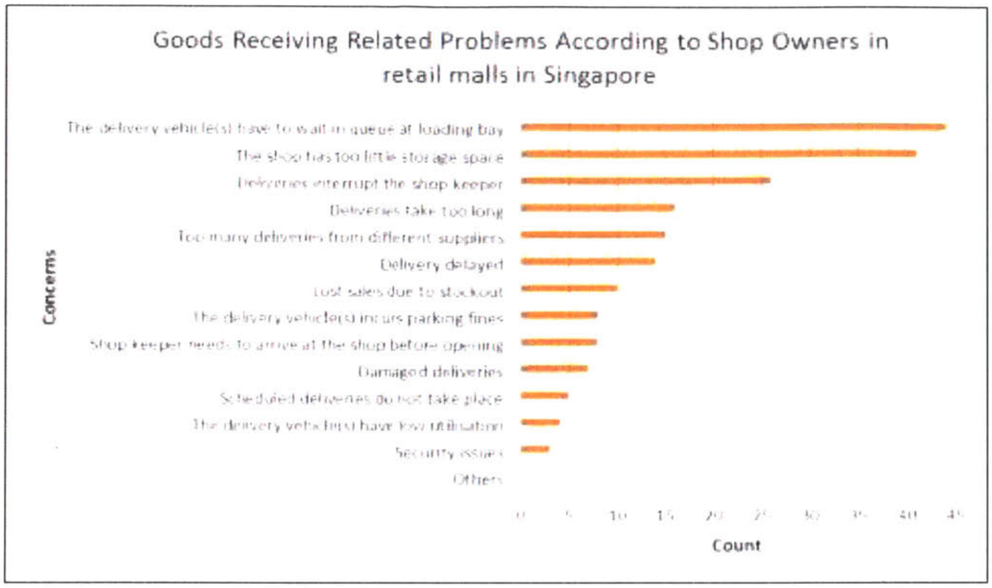


Using the stakeholder framework in (Crawley, Cameron, & Selva, 2016), the system agents have been categorized as beneficial stakeholders or system stakeholders. Beneficial stakeholders are those agents that have some input into the system and are affected by the system outputs, whereas problem stakeholders have some input into the system but they don't get anything in return from the system. As mentioned in earlier sections, this thesis focuses on the impact different policy designs would have on a select group of stakeholders – those which we have identified as key players in the supply chain. The stakeholder groups of study are the LSPs, the operators, the retail shop owners, and the government or public authorities. While in depth analysis of the impact different policy designs could have on the other actors is beyond the scope of this thesis, the framework presented could guide future research work on the complete set of system stakeholders. The sub-set of stakeholders and their objectives are defined below.

Retail shop owners

This group of agents drive business in the retail malls and is also typically referred to as the "receivers". This group includes stores that provide different types of goods and services, and therefore have different delivery needs and patterns. This group "pulls" the demand of goods from the suppliers based on customer needs and demand forecasts. The objectives of this group include having on time deliveries in order to meet their clients' demands and maximize revenues, managing store inventory effectively, and minimizing store costs. These objectives are directly impacted by urban freight logistics measures and schemes. Data collected in the study presented in (Dalla Chiara, Cheah, & Courcoubetis, 2017) captures the top goods receiving related concerns for 71 shop owners in two large malls in Singapore. These concerns have been captured in **Figure 3.2** below. According to this study, the most concerning isuses included long queues for vehicles making deliveries, little sotrage space, and business interruptions caused by deliveries. Depending on the size and type of the retailer, this agent could be responsible for the deliveries to its stores at the malls. However, in most cases, the retailer or its supplier hires logistics service providers (LSPs) to conduct the deliveries. Whether the deliveries to the retailer shops are coordinated by the retailers or their suppliers, retailers bear some of the delivery costs, directly or indirectly. As pointed out in (Stathopoulos, Valeri, & Marcucci, 2012), very little is known about the views of receivers on urban freight logistics measures and how these could impact them. Among the most popular policies studied for this group are time window regulations, which impose restriction on delivery schedules.

Figure 3.2 | Goods Receiving Concerns for retailers at malls in Singapore from (Dalla Chiara, Cheah, & Courcoubetis, 2017)



Logistics Service Providers (LSPs)

LSPs provide "door to door" delivery services to retailers and suppliers. This group includes forwarders, carriers, express service companies, drivers that work for these companies, and any other companies that provide logistics services. LSPs can be contracted by the retailers (receivers) or the suppliers, depending on the contract terms between the two parties. The primary objectives of this agent group include providing quality service to their clients, generating revenue, and managing costs. Providing a quality service to their clients can be achieved through timely delivery and careful handling of the goods. To achieve their objectives, this group works to organize freight transport efficiently, taking into consideration vehicle utilization, routing, and schedules and services specified by suppliers and receivers. One of the key challenges for this group is satisfying the sometimes conflicting service levels and delivery schedules for these two groups (Stathopoulos, Valeri, & Marcucci, 2012).

Consolidation Operators

The freight operator provides logistics services, but is differentiated from the LSPs in our analyssis, given that in the schemes considered throughout this work, this actor exclusively offers goods consolidation services. In the policy designs considered, the operator could replace LSPs during the last mile delivery of goods to the retail mall, could provide consolidation services once goods are delivered by the LSPs to a centralized receiving station (CR) at the mall, or could not be part of the urban freight logistics scheme. The objectives of this group are similar to those of the LSPs, as they provide services to suppliers and retail shop owners in schemes where the LSPs are also system agents. Operators, as we will refer to this group throughout the thesis, play a big role in urban freight consolidation policies, which have been widely studied and implemented in Europe, Japan, and recently in Singapore. A key concern for this group is the financial feasibility of goods consolidation schemes. Consolidation services translate into additional expenses for suppliers and retailers, since they still incur the goods delivery costs from the LSPs, who transport the goods to the consolidation center or to the retail mall, in the CR scheme, where additional handling services are required. Participation level and government incentives are crucial factors for evaluating the potential success of this type of measures.

Public Authorities

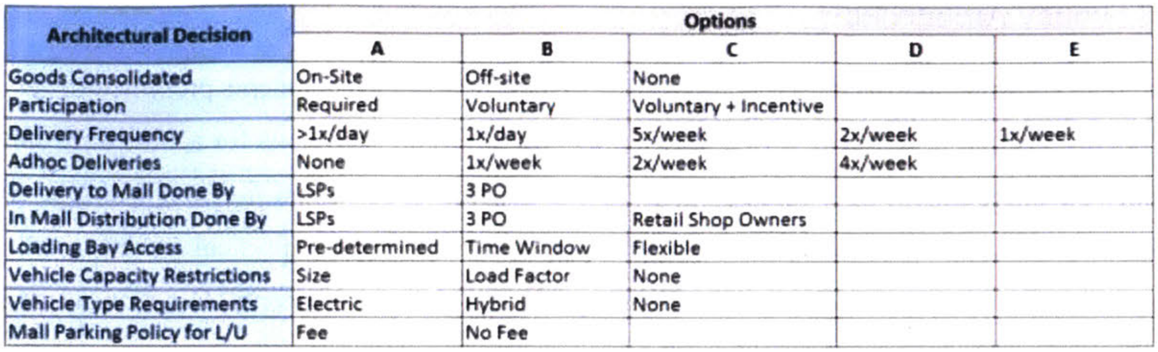
This stakeholder group, which includes regulatory agencies and the government stakeholders in **Figure 3.1**, seek the public's best interest. They are captured as problem stakeholders, because the rest of the urban freight logistics stakeholders need input from others stakeholders, but other than public support, this group doesn't get anything in return for their inputs into the urban freight logistics system. Public authorities are responsible for urban planning and regulation, they finance public infrastructure (e.g. roads, tolls, etc.), and subsidize some services. This group defines policy scenarios in which private agents operate (Stathopoulos, Valeri, & Marcucci, 2012). Their objective is to preserve and enhance the welfare of citizens, which they pursue by ensuring a strong business environment and a safe and healthy environment. Some of the conflicting needs that this group tries to meet include making the urban environment more attractive for its inhabitants, while also encouraging economic activity and development. For example, while city centers are attractive for bars, restaurants, shops, and business offices and these enhance the local economy, they also increase congestion, pollution, and noise in the area, which has a negative impact on the inhabitants. The interaction between this stakeholder group and the freight carriers or LSPs is the most studied agent interaction in urban freight stakeholder research.

most studied agent interaction in urban freight stakeholder research.

3.4 Policy Architecture

The policy design approach used in this thesis is based on tools and concepts presented in (Crawley, Cameron, & Selva, 2016). The authors offer several definitons for achitecture, among them "the embodiment of a concept" and the relationship of *form* and *function* within a given context. The authors define *form* as "what the system is", the "physical or informational embodiment" of the sytem, characterized by shape, layout, and arrangements. *Function*, as defined by the authors, is "what a system does; the activities, operations, and transformations that cause, create, or contribute to performance" (Crawley, Cameron, & Selva, 2016). Function is enabled by form. Parting from this, we evaluate multiple aspects of the form and function of the urban freight logistics system in Singapore, decomposing it into concept fragments and architctural decisions and decision options, which we then play with to generate diverse integrated concepts. We refer to these concepts as urban freight logistics policy architectures for retail malls in Singapore. The architectural decisions for this policy design exercise an their corresponding options are explained in further detail below, and include mostly *functional* decisions. Since urban freight solutions are most often concerned with processes and interactions, and their instruments (form) are more standarized, only a couple of *formal* decisions were included in the scope. Furthermore, because this thesis focuses on the impact urban freight logistics policy architectures have on different stakeholders, and for this system these are also the agents supporting the operation of the system, we determined exploring the functional aspects of the system would provide more meaningful insights.

Table 3.1 | Architectural decisions and options for Urban Freight policy design for retail malls in Singapore

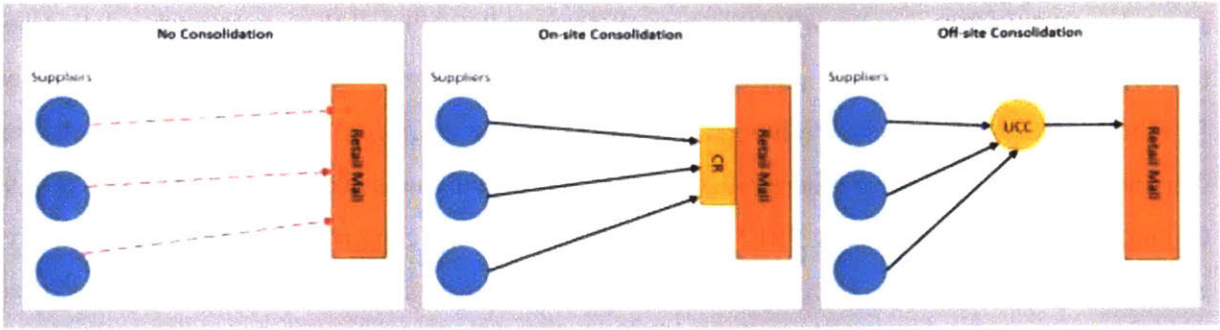


Architectural Decision	Options				
	A	B	C	D	E
Goods Consolidated	On-Site	Off-site	None		
Participation	Required	Voluntary	Voluntary + Incentive		
Delivery Frequency	>1x/day	1x/day	5x/week	2x/week	1x/week
Adhoc Deliveries	None	1x/week	2x/week	4x/week	
Delivery to Mall Done By	LSPs	3 PO			
In Mall Distribution Done By	LSPs	3 PO	Retail Shop Owners		
Loading Bay Access	Pre-determined	Time Window	Flexible		
Vehicle Capacity Restrictions	Size	Load Factor	None		
Vehicle Type Requirements	Electric	Hybrid	None		
Mall Parking Policy for L/U	Fee	No Fee			

Architectural Decision #1 - Goods Consolidated

This architectural decision captures a functional aspect of the system, determining whether goods delivered to the retail mall will be consolidated or not. Goods consolidation measures have drawn much research attention in recent year, with studies focused on Urban Consolidation Centers (UCC), Centralized Receiving Stations (CRs), and other cooperative consolidation schemes. UCCs are typically located in the outside skirts of densely populated cities and provide "last mile" delivery services to businesses located in the city center. UCC logistics services include the consolidation, storage, and transportation of goods received from LSPs for the retailers. CRs, on the other hand, are located in large urban freight traffic generators (LTGs). Under CR schemes, LSPs are still responsible for the delivery of goods to the retail mall, but the operator manages the CR to streamline loading, unloading, and distribution of deliveries within the mall. As explained in Section 3.3, the *freight operator* becomes a system stakeholder under consolidation schemes, as the third-party operator (3 PO) supporting the distribution of goods through the supply chain. The options evaluated for this decision are on-site consolidation (CR-like schemes), off-site consolidation (UCC-like schemes), or no consolidation, and have been illustrated below.

Figure 3.3 | Design options for the "Goods Consolidation" architectural decision



Architectural Decision #2 – Participation

Urban freight solutions considered in this policy design include policies implemented by public authorities as well as measures enforced by the private sector. Whether the policies are initiated and enforced by the private or public sector, the level of participation will determine how effective the policy is at reducing the negative impacts of urban freights. The *Participation* architectural decision captures whether the decision makers will require retailers and LSPs to attain to the policy, will incentivize the adherence to the policy, or will allow these agents to decide whether they will participate or not in the policy implementation. These are reflected correspondingly in **Table 3.1** by the options "required", "voluntary with incentive" (V+I), and "voluntary". To promote participation for a given policy, the public sector could provide tax-breaks to participating retailers and LSPs, subsidize some of the service provided by the freight operator in consolidation schemes, create public recognition programs, and provide discounts or one-time financial incentives to operators, mall owners, LSPs, and retailers (receivers) and suppliers (Holguín-Veras, Aros-Vera, & Browne, 2015). For the purpose of this study, it's assumed that the critical mass is achieved with all participation decision options. For this system, the critical mass is the minimum number of retailers that must participate in a policy for the policy or measure to be financially worthwhile.

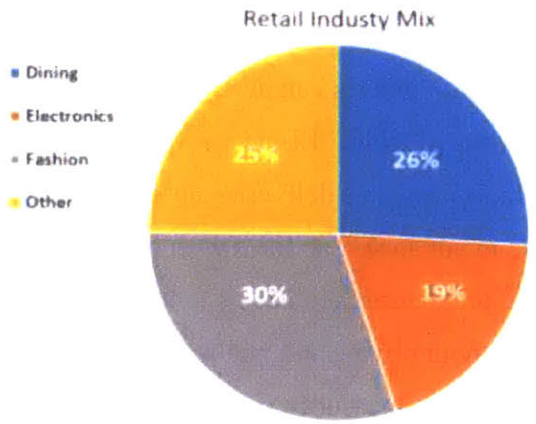
Architectural Decision #3 – Delivery Frequency

This functional architectural decision designates how often retailers receive deliveries. Under the normal or baseline scenario, retailers receive deliveries multiple times per day from their different suppliers given the nature of the system's uncoordinated supply chain. However, the frequency of deliveries under the baseline scenario is also dependent on the type of business conducted by the retail shop and their demand profile. For instance, a sports brand retail shop may receive deliveries two or three times per week from the company's distribution center, whereas restaurants and other food businesses might receive deliveries on a daily basis depending on the storage area, customer demand, and life of the items ordered. In one of the large retail malls in Singapore studied in (Dalla Chiara, Cheah, & Courcoubetis, 2017) for example, 170 stores generated 523 truck trips per day, averaging to 3.1 trips/store. Policy schemes that limit the amount of deliveries to the retails stores would seek to reduce the number of freight trips generated by the facility and therefore reduce the negative impact of these. The options considered for this decision include multiple deliveries per day, one delivery per day, five deliveries per week, two deliveries per week, and one delivery per week. It should be noted that since the retail malls include businesses with different demand profiles, policy design could include a "policy package", in which different delivery frequency options are used for businesses with different demand behaviors. For example, the 170 retail mall shops referred to in (Dalla Chiara, Cheah, & Courcoubetis, 2017) included stores in the dining, electronics, fashion, and other industries. The retail mall's store-industry break-down is illustrated in **Figure 3.4**. Based on their size, customer demand, and the nature of the goods and services they sell, different delivery frequency options could be evaluated for each group. The policy design exercise in this thesis assumes that the *Delivery Frequency* option selected for different policies is associated with a 95% service level.

Architectural Decision #4 – Adhoc Deliveries

This functional architectural decision goes hand in hand with the decision above – designating the flexibility for additional deliveries from the delivery frequency schedule selected in the prior decision. This decision allows retail shops to request additional deliveries if needed. Similar to the previous decision, a single policy may include several options for this decision, to be applied to different retail businesses based on their industry and needs. The *Adhoc Deliveries* decision has four options – no adhoc deliveries, four per week, two per week, and one per week.

Figure 3.4 | Retail mix in urban mall in Singapore from (Dalla Chiara, Cheah, & Courcoubetis, 2017)



Architectural Decision #5 – Delivery to Mall Done by

This is one of the few formal architectural decisions considered in this thesis' policy design exercise. This decision captures who brings the goods to the mall. In the baseline scenario, the different LSPs bring the goods to the retail mall. However, in off-site consolidation schemes, the LSPs haul the goods to the consolidation center and a third-party freight operator (3 PO) completes the "last mile" delivery of the goods.

Architectural Decision #6 – In-Mall Distribution Done By

Similar to the previous architectural decision, this decision determines who completes the distribution of the goods to the retail shops once the goods arrive at the mall Loading Bay (LB). Under normal conditions, the LSPs bring the goods to the mall and once there, the goods are delivered to the stores either by the LSPs or the retail shop employees. This policy design exercise evaluates policies in which the in-mall distribution service is completed by the LSP, a third-party operator (3 PO), or the retail store owner or employees.

Architectural Decision #7 – Loading Bay Access

The loading and unloading areas in facilities that generate freight traffic are referred to as loading bays (LBs). With high volumes of freight traffic, these large retail malls have recurrently congested LBs, which are typically space constrained and shared among all mall retailers. In facilities where

LB congestion issues prevail, vehicle idling times and parking violations are some of the most noticeable side effects (Dalla Chiara, Cheah, & Courcoubetis, 2017). The options considered for this architectural decision include "pre-determined", "time window", and "flexible" LB access. The baseline scenario, in which freight vehicles can access the LB at any time assuming there's no congestion, is characterized by the "flexible" LB access option. The "pre-determined" option represents schemes in which vehicles making deliveries and pick-ups in a retail mall need to determine or reserve their LB use in advance. Facilities with online parking reservation systems use this LB access measure. While pre-determined access to the LB is a popular private measure, time windows could be enforced by both private and public agents. In fact, time windows are one of the most popular urban freight logistics measures, implemented in many cities in Europe, Asia, and even in the United States. In the Netherlands, for example, about 70% of the top 100 municipalities use time windows (Quak & de Koster, 2007). Off-hour delivery schemes, evaluated in depth in (Holguín-Veras, Aros-Vera, & Browne, 2015) also fall under the "time window" option for the *Loading Bay Access* architectural decision.

Architectural Decision #8 – Vehicle Capacity Restrictions

Architectural decision #8, concerning vehicle capacity restrictions, is related to the system's form. The options considered for this architectural decision are vehicle size, load factor, and no restrictions. Typically, urban retail malls don't impose restrictions on the types of vehicles that can make deliveries to their facility, unless structural and space constraints create limits on vehicle size, height, etc. Vehicle size and load factor are used as instruments to enhance freight traffic in an area or building, with the objective of improving the utilization of vehicles that transit the area. For example, by allowing vehicles only above a certain size, the number of small trucks making deliveries is reduced, reducing the volume of freight traffic flowing through an area. As mentioned earlier, the urban freight industry in Asia is very fragmented and most trucks (90%) are owned by individuals. Load factors, while challenging to enforce, could help reduce the frequency of deliveries and therefore freight traffic, promote consolidation, and improve vehicle utilization. For example, a small retail shop that is supplied with goods by a few suppliers could have the individual suppliers make small deliveries several times per week in the baseline scheme.

However, if load factor restrictions were enforced by a mall owner or CR operator, the small retail shop could work with the few suppliers to have them make coordinated deliveries or less frequent deliveries (assuming the demand pattern permits) to abide by the load factor restrictions.

Architectural Decision #9 – Vehicle Type Requirements

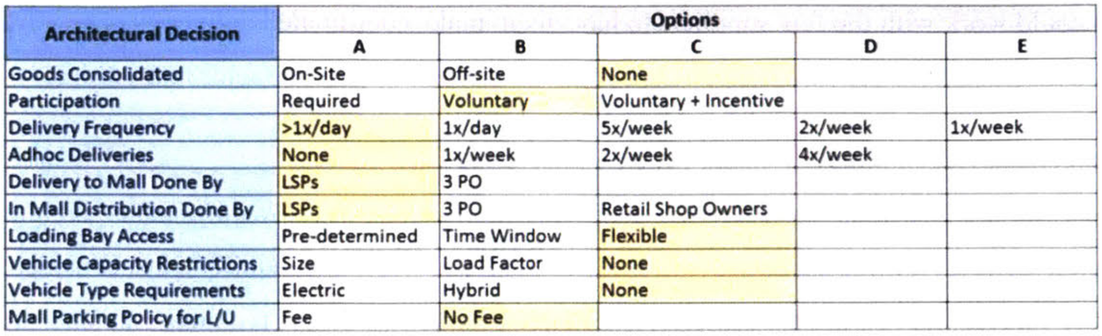
Similar to the previous architectural decision, the *Vehicle Type Requirements* architectural decision defines formal aspects of the system. The vehicle type requirements considered are electric vehicles (EVs), hybrid vehicles, and no requirements. Vehicle type requirements are used in urban freight measures that seek to reduce local emissions, know was "Low Emission Zones". However, typical urban freight logistics systems do not include vehicle type requirements policies. Electric and hybrid vehicles are more environmentally conscious than the typical fuel or diesel engine vehicles. EV runs solely on one or several electric engines, whereas the hybrid vehicle uses fuel combustion and electric power.

Architectural Decision #10 – Mall Parking Policy for Loading and Unloading (L/U)

This architectural decision describes parking logistics for freight vehicles at the retail mall. While the baseline scenario assumes no parking fee for loading and unloading activities, the other option considered is also popular among retail mall owners. The options considered for this architectural decision are employing a parking fee, and not having a parking fee ("fee" and "no fee" in **Table 3.1**). Research in this field has found that enforcing fees for loading and unloading activities reduces the amount of time the freight vehicles spend in the LB area, therefore improving vehicle flow in LBs with congestion issues, and could even reduce the freight trips attracted by the retail mall, as LSPs try to plan deliveries more effectively to reduce these costs.

Considering the architectural decisions and options above, we present the baseline scenario in **Table 3.2** below, which assumes the implementation of no urban freight logistics policy, or the "do nothing" option. While this scenario might not reflect current freight logistics in all urban retail malls, not even in Singapore, it will be the baseline for evaluation of all other policy designs generated through this study.

Table 3.2 | Options representing baseline scenario for urban retail malls in Singapore



Architectural Decision	Options				
	A	B	C	D	E
Goods Consolidated	On-Site	Off-site	None		
Participation	Required	Voluntary	Voluntary + Incentive		
Delivery Frequency	>1x/day	1x/day	5x/week	2x/week	1x/week
Adhoc Deliveries	None	1x/week	2x/week	4x/week	
Delivery to Mall Done By	LSPs	3 PO			
In Mall Distribution Done By	LSPs	3 PO	Retail Shop Owners		
Loading Bay Access	Pre-determined	Time Window	Flexible		
Vehicle Capacity Restrictions	Size	Load Factor	None		
Vehicle Type Requirements	Electric	Hybrid	None		
Mall Parking Policy for L/U	Fee	No Fee			

Note: Architectural decision-options for the baseline policy configuration are highlighted in yellow

With the architectural decisions and the associated options defined and a baseline architecture identified, we evaluate the space of configurations, in this case different urban freight policy architectures. To capture the list of the decisions and associated alternatives, we use the *morphological matrix* decision support tool. This tool was first defined by Zwicky (Crawley, Cameron, & Selva, 2016), and is a straightforward method to represent system decisions and alternatives. To manage the scope of this study, a subset of forty designs were randomly generated and selected. While the exhaustive set was not considered, designs left outside this experiment can be considered for additional developments of this work. The policy architectures generated and their associated architectural decision-option combinations are captured in the morphological matrix in **Table 3.3**. While generating these concepts, the feasibility and validity of option configurations was taken into account. In fact, we noticed that by selecting specific alternatives for certain architectural decisions, other decision-options were automatically pruned away. For instance, if the *Delivery Frequency* option selected was multiple deliveries per day, ">1x/day", all options in the *Adhoc Deliveries* decision except "none" were automatically eliminated from the set of design options. If there are no restrictions on the frequency of deliveries for the retailers, measures for exceptional or adhoc deliveries are not required. Similarly, if the freight operator, or "3 PO", option is selected for the *Delivery to Mall Done By* architectural decision, the "LSPs" option is automatically eliminated from the *In-Mall Distribution Done By* options. In policy schemes where the third-party freight operator manages the transportation of goods to the retail mall or conducts the "last mile" delivery, the LSPs leave the system when they hand-off the goods to the operator. Hence, for these types of urban freight logistics architectures, the distribution of the goods once they arrive at the mall could only be carried out by the operator or the shop owners and employees.

The architectural decisions and their respective options presented in this analysis are not meant to represent all possible decisions and options in the urban freight policy design domain for retail malls. These were selected through careful consideration and combination of different one-dimensional measures implemented in multiple cities to enhance urban freight logistics, but **Table 3.1** could be expanded to include additional decisions and options for expanded morphologies, or configurations. Of all the possible and feasible combinations of options from this table, the forty evaluated in this analysis (**Table 3.3**) were derived randomly. Other combinations were not considered for scope management purposes, but these could also prompt additional evaluation and analysis of the framework presented.

Table 3.3 | Morphological Matrix for Urban Freight Policy architectures in retail malls in Singapore

Policy Designs	Architectural Decisions & Selected Options									
	Goods Consolidated	Participation	Delivery Frequency	Adhoc Deliveries	Delivery to Mall by	In Mall Distribution	Loading Bay Access	Vehicle Capacity	Vehicle Type Requirement	Mall Parking Policy for
Baseline	None	Voluntary	>1x/day	None	LSPs	LSPs	Flexible	None	None	No Fee
01	Off-site	Voluntary	1x/day	1x/week	3 PO	3 PO	Flexible	None	None	No Fee
02	On-Site	Voluntary	>1x/day	None	LSPs	3 PO	Flexible	None	None	No Fee
03	Off-site	V + I	1x/day	1x/week	3 PO	3 PO	Flexible	Size	None	No Fee
04	Off-site	Required	1x/day	1x/week	3 PO	3 PO	Flexible	Load Factor	None	No Fee
05	Off-site	Required	1x/day	None	3 PO	3 PO	Time Window	None	None	Fee
06	Off-site	V + I	>1x/day	None	3 PO	3 PO	Time Window	Size	None	Fee
07	Off-site	Voluntary	>1x/day	None	3 PO	3 PO	Time Window	Load Factor	None	No Fee
08	Off-site	Voluntary	>1x/day	None	3 PO	3 PO	Pre-determined	Load Factor	Hybrid	No Fee
09	On-Site	Required	>1x/day	None	LSPs	3 PO	Flexible	None	None	Fee
10	On-Site	V + I	>1x/day	None	LSPs	3 PO	Pre-determined	None	Hybrid	Fee
11	On-Site	Required	1x/day	4x/week	LSPs	3 PO	Time Window	None	Electric	No Fee
12	On-Site	V + I	1x/day	2x/week	LSPs	3 PO	Flexible	Load Factor	Electric	Fee
13	On-Site	Voluntary	1x/day	4x/week	LSPs	3 PO	Pre-determined	Load Factor	None	No Fee
14	None	Required	>1x/day	None	LSPs	3 PO	Time Window	Size	None	No Fee
15	None	Required	>1x/day	None	LSPs	3 PO	Pre-determined	None	None	No Fee
16	None	Required	>1x/day	None	LSPs	LSPs	Pre-determined	None	None	Fee
17	None	Required	>1x/day	None	LSPs	Retail Shops	Time Window	None	None	No Fee
18	None	V + I	>1x/day	None	LSPs	LSPs	Flexible	None	None	No Fee
19	None	Required	1x/day	4x/week	LSPs	Retail Shops	Flexible	Load Factor	Hybrid	Fee
20	None	Required	5x/week	4x/week	LSPs	LSPs	Time Window	Size	Hybrid	Fee
21	None	V + I	>1x/day	None	LSPs	3 PO	Time Window	Load Factor	Hybrid	No Fee
22	None	Voluntary	1x/day	4x/week	LSPs	LSPs	Time Window	Size	None	Fee
23	None	Voluntary	5x/week	2x/week	LSPs	LSPs	Pre-determined	None	None	No Fee
24	Off-site	Required	>1x/day	None	3 PO	Retail Shops	Time Window	None	None	No Fee
25	Off-site	V + I	1x/day	4x/week	3 PO	3 PO	Time Window	None	Hybrid	No Fee
26	Off-site	Voluntary	5x/week	4x/week	3 PO	Retail Shops	Pre-determined	None	None	Fee
27	Off-site	V + I	5x/week	2x/week	3 PO	3 PO	Time Window	None	None	No Fee
28	Off-site	V + I	2x/week	4x/week	3 PO	3 PO	Flexible	None	Electric	Fee
29	Off-site	V + I	2x/week	4x/week	3 PO	Retail Shops	Flexible	Size	None	No Fee
30	Off-site	Voluntary	2x/week	2x/week	3 PO	3 PO	Time Window	None	Hybrid	Fee
31	Off-site	V + I	1x/week	4x/week	3 PO	3 PO	Time Window	None	None	Fee
32	Off-site	V + I	1x/week	4x/week	3 PO	3 PO	Flexible	None	None	No Fee
33	On-Site	V + I	>1x/day	None	LSPs	3 PO	Flexible	Size	None	Fee
34	On-Site	V + I	>1x/day	None	LSPs	3 PO	Time Window	None	None	No Fee
35	On-Site	V + I	1x/day	4x/week	LSPs	3 PO	Time Window	Load Factor	None	Fee
36	On-Site	V + I	1x/day	None	LSPs	3 PO	Time Window	None	None	No Fee
37	On-Site	Voluntary	1x/day	None	LSPs	3 PO	Pre-determined	None	None	No Fee
38	On-Site	V + I	5x/week	4x/week	LSPs	3 PO	Flexible	None	None	Fee
39	On-Site	Required	5x/week	4x/week	LSPs	3 PO	Time Window	Size	Hybrid	No Fee
40	On-Site	V + I	5x/week	2x/week	LSPs	3 PO	Flexible	Size	Hybrid	No Fee

3.5 Lifecycle Properties

In (de Weck et. al., 2016), the authors distinguish between the *epoch of great inventions* and the *epoch of engineering systems*. The world revolutionizing inventions of the 19th and 20th centuries were the first of their kind in different domains. The authors explain that these inventions were created simply to work and serve their primary function, and as their use became widespread their unintended consequences drew more attention. For instance, when the automobile was first introduced, congestion wasn't a concern, in fact, neither were seat belts (de Weck et. al., 2016). Only when these inventions gained popularity and these systems started to interact with other systems, did concerns and complex systems emerge. However, in the *epoch of engineering systems*, characterized by complex systems interacting with each other, the focus is the evolution of these systems over long lifetimes (de Weck et. al., 2016). Considering the "side effects and the context that establishes ground rules and constraints within which systems operate" is crucial and define a system's lifecycle properties. The authors refer to the lifecycle properties of any system as the "ilities" and formally define these as:

> *"The 'ilities' are desired properties of systems, such as flexibility and maintainability (usually but not always ending in 'ility'), that often manifest themselves after a system has been put to its initial use. These properties are not the primary functional requirement of a system's performance, but typically concern wider system impacts with respect to time and stakeholders than are embodied in those primary functional requirements."*

The scope of this thesis includes the evaluation of urban freight logistics policies for retail malls in Singapore with respect to two lifecycle properties – *Efficiency* and *Sustainability*. How these "ilities" are perceived by selected stakeholder groups is compared to their perception of cost. These properties were selected based on the main objectives of urban freight logistics measures. Research in the field has revealed that urban freight logistics measures are implemented to reduce the negative impacts of freight vehicles in cities – the most notorious being congestion, pollution, noise, and traffic accidents. Freight logistics measures that reduce these impacts can be directly associated with efficiency and sustainability improvements, which warrants their consideration. While the different stakeholder groups could perceive the efficiency of a policy quite differently, the sustainability value of a policy is defined as a systematic value. The cost criteria could also be perceived differently by the different agents. One of the findings from research on stakeholder interactions in urban freight logistics solutions is that frequently, the costs and benefits of a policy are not well balanced among the stakeholders, where a stakeholder group might incur substantial costs but not receive comparable benefits (Stathopoulos, Valeri, & Marcucci, 2012).

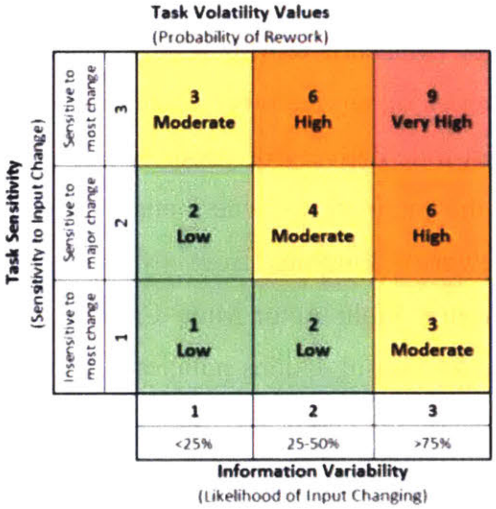
The three criteria considered – *Efficiency, Sustainability,* and *Cost* – and the frameworks used to evaluate these by the stakeholder groups are further discussed in the subsections below. For simplicity purposes, the different urban freight policy configurations generated were evaluated parting from the baseline scenario and using relative scoring and weighting for the design options and architectural decisions. Because actual stakeholders did not participate in the evaluation of architectures we present in this thesis, evidence and insight from related studies and research in which the considered stakeholders did participate were used to derive the option scores and the architectural decision weights. Future developments of this work aim to test the framework presented by having actors or agents from the stakeholder groups considered play the game and validate their scoring of options and weighting of architectural decisions in our model.

Efficiency

Efficiency is related to productivity and how resources are used to produce outputs. For this system, the efficiency of a policy may mean different things for the different stakeholder groups considered, which have differing objectives. Therefore, in this section we will provide a description of how the different agent groups considered could perceive efficiency.

In (Caplice & Sheffi, 1994), the supply chain experts expand on productivity and utilization, two popular operational measures in the freight industry. In this work, they describe productivity as "transformational efficiency", since the metric evaluates the efficiency with which a resource is converted into an activity or completes an activity. Popular measures of efficiency include the amount of time, employees, resources, and/or money invested, and the outputs (e.g. product, activities, services) produced by these. Using the concepts of efficiency presented in (Caplice & Sheffi, 1994) and the scoring model discussed in (Eppinger & Browning, 2012), we use the matrices below to generate efficiency scores for the different architectural decision-options as perceived by the LSPs and operators. The original matrix presented in (Eppinger & Browning, 2012) and reflected in **Figure 3.5**, was used in a study to derive volatility values for tasks affected by information variability. Borrowing this framework, we develop efficiency values for the different design options among our architectural decisions. The matrix in **Figure 3.6** reflects how the efficiency of a design option is calculated for the LSPs, taking into consideration vehicle miles traveled (VMT) (output) and the resources used to produce this output (input), which include freight vehicles and drivers. While the matrix in (Eppinger & Browning, 2012) (**Figure 3.5**) uses **the multiplicative values of the criteria's scores, efficiency scoring in our analysis uses the addition** of the criteria values considered. As reflected in **Figure 3.6**, policy configurations that support high VMT with few resources yield the most efficiency for the logistics service providers. These configurations are characterized by high utilization and productivity of resources – high outputs with low inputs. The architectural decision weights and decision-option scores for Efficiency as perceived by the LSPs are captured in Appendix A (**Figure A-5**).

Figure 3.5 | Task Volatility Values from (Eppinger & Browning, 2012)



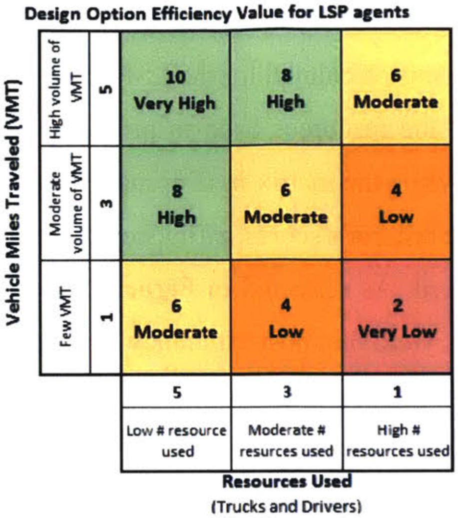
Task Volatility Values
(Probability of Rework)

Task Sensitivity
(Sensitivity to Input Change)

Sensitive to most change	3	**3** **Moderate**	**6** **High**	**9** **Very High**
Sensitive to major change	2	**2** **Low**	**4** **Moderate**	**6** **High**
Insensitive to most change	1	**1** **Low**	**2** **Low**	**3** **Moderate**
		1	2	3
		<25%	25-50%	>75%

Information Variability
(Likelihood of Input Changing)

Figure 3.6 | Efficiency scoring matrix for LSPs stakeholders



Design Option Efficiency Value for LSP agents

Vehicle Miles Traveled (VMT)		5 Low # resource used	3 Moderate # resurces used	1 High # resources used
High volume of VMT	5	10 Very High	8 High	6 Moderate
Moderate volume of VMT	3	8 High	6 Moderate	4 Low
Few VMT	1	6 Moderate	4 Low	2 Very Low

Resources Used
(Trucks and Drivers)

An assumption used for the option-specific scoring was supported by related research that also assumed that in urban freight policy scenarios where goods are consolidated – either at the mall or off-site – LSPs gain efficiency (Macharis & Milan, 2015). This assumption holds that LSPs can go off and make more deliveries or service other clients more quickly in configurations where another agent handles the last-mile delivery of goods (off-site consolidation in our framework) and/or their distribution to the retail store owners once the goods arrive at the mall (on-site consolidation in our framework). Findings from (Macharis & Milan, 2015) validate this assumption, where results from a Multi-Actor Multi-Criteria Analysis (MAMCA) indicate that LSPs have a high preference for consolidations policies. Grounded on this, our efficiency score values for options where the last-mile and/or the in-mall delivery are completed by parties other than the LSPs are higher (more efficiency) than those options in which the LSPs complete these activities. Findings from (Quak & de Koster, 2007) also provided evidence for the efficiency score values we derived for the design options for the "LSPs" stakeholder group. This study reported that LSPs have a high willingness to pay to reduce time-access restrictions and prefer policy configurations with less access restrictions. Adopting these findings, we arrive at higher efficiency scores for the LSPs in configurations with more flexible access to the loading bays, which in our framework is the only time-related architectural decision (*Loading Bay Access*). These and additional supporting facts from the literature and other work studying urban freight logistics stakeholders provided grounding for the score and weight values.

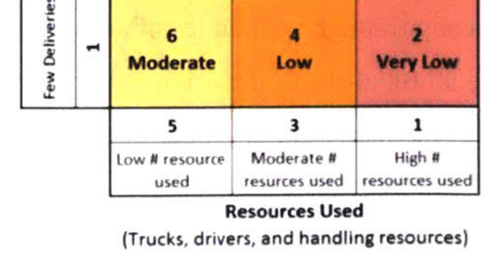
The matrix in **Figure 3.7** captures efficiency scores as perceived by the operator agents. In this study, operator efficiency takes into account deliveries fulfilled and the number of resources used to fulfill these. As previously mentioned, the operator agent only enters the system in our framework if they provide consolidation services off-site or at the retail mall. While the score matrices for the LSPs and operator agent groups are quite similar, the efficiency score tied to a particular design option could be very different for the two. This is because the two agents see efficiency in different terms and a design option that improves the efficiency for a stakeholder might reduce the efficiency for the other. The architectural decision weights and option scores for efficiency as perceived by the freight operator is captured in **Figure A-7** in Appendix A. Some evidence gathered from the literature review for these scores and weights are highlighted below. Policy configurations with no goods consolidation eliminate this stakeholder group from the evaluation of the policy's efficiency, since our definition for the freight operator assumes that he only participates if the policy architecture includes goods consolidation.

- *Participation* architectural decision: The participation level is determinant of the success of consolidation schemes (de Souza, Goh, Lau, Ng, & Tan, 2014). While our framework assumes that available design options for this decision all translate into *at least* achieving the critical mass, the greater the participation level the more viable the architecture of the consolidation policy. Our scores for the *Participation* design options reflect this by having the "voluntary" option as least efficient, "voluntary + incentive" next, and the "required' option being the most efficient for the operator. Even if the critical mass is achieved with the "voluntary" design option, incentives will increase the number of retailers participating in consolidation schemes. Finally, policies that require participation of all retailers guarantee more efficiency through economies of scale. This assumes that the operator has the capacity to service all retail stores if participation were required. Because participation is an extremely important factor for the operator, this decision has one of the highest weights.
- *In-Mall Distribution Done By* and *Loading Bay Access* architectural decisions: The study

in (Stathopoulos, Valeri, & Marcucci, 2012) reveals that policies demanding joint efforts among operators, calling out time-windows and pick-up-points, experience more resistance from the stakeholders. With this finding, we conclude that once the operator is in the scheme – meaning goods are consolidated on-site or off-site – having the in-mall distribution of goods done by someone other than the operator requires additional coordination for the operator, making such design options less efficient for this actor. Hence, the design option in which the operator completes the in-mall distribution of goods is perceived by the operator as the most efficient option for this architectural decision. Among the options available for the the *Loading Bay Access* architectural decision, options with time restrictions received lower efficiency scores from the operator based on findings from the same study.

- Weights for the architectural decisions: The *Participation, Delivery Frequency,* and *Goods Consolidated* architectural decisions received significantly more weight than the *Vehicle Type Requirements* and *Mall Parking Policy for L/U* decisions because the first three have substantial and direct impact on the criteria for determining the operator's efficiency – the amount of deliveries completed by the operator and the number of resources needed to complete these deliveries.

Figure 3.7 | Efficiency scoring matrix for Operator stakeholders



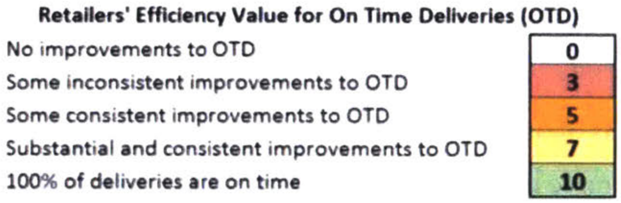
Design Option Efficiency Value for Operator agents

Deliveries	High volume of Deliveries	5	10 Very High	8 High	6 Moderate
	Moderate # of Deliveries	3	8 High	6 Moderate	4 Low
	Few Deliveries	1	6 Moderate	4 Low	2 Very Low
			5	3	1
			Low # resource used	Moderate # resurces used	High # resources used

Resources Used
(Trucks, drivers, and handling resources)

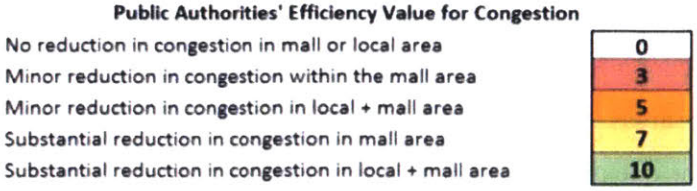
For the retailers and the public authorities, the main considerations for determining a policy's efficiency are on-time deliveries (OTDs) and congestion reductions, respectively. For these stakeholder groups, we use the relative scoring methods captured below in **Figure 3.8** and **Figure 3.9**. During the game, or implementation of the evaluation framework presented, stakeholders use these scores to assess the impact of each design option. For example, if a policy configuration includes the "off-site" option for the *Goods Consolidation* architectural decision, a retail shop owner would use the scoring framework presented in **Figure 3.8** to assess whether that option enhances their on-time deliveries (OTDs) as compared to the baseline policy scenario, in which goods are not consolidated. For each stakeholder, the individual scores for the architectural decision-options in a policy configuration are then added to obtain an overall efficiency score for the architecture. The efficiency score for each stakeholder group in the baseline urban freight policy architecture considered is captured at the end of this sub-section in **Table 3.4**. Appendix A includes additional details on the architectural decision weights and design option scores. Some of the evidence used to derive the efficiency scores for the retail shop owners and public authorities are highlighted below.

Figure 3.8 | Efficiency scoring for Retail Shop Owners stakeholder group



Retailers' Efficiency Value for On Time Deliveries (OTD)	
No improvements to OTD	0
Some inconsistent improvements to OTD	3
Some consistent improvements to OTD	5
Substantial and consistent improvements to OTD	7
100% of deliveries are on time	10

Figure 3.9 | Efficiency scoring for Public Authorities stakeholder group

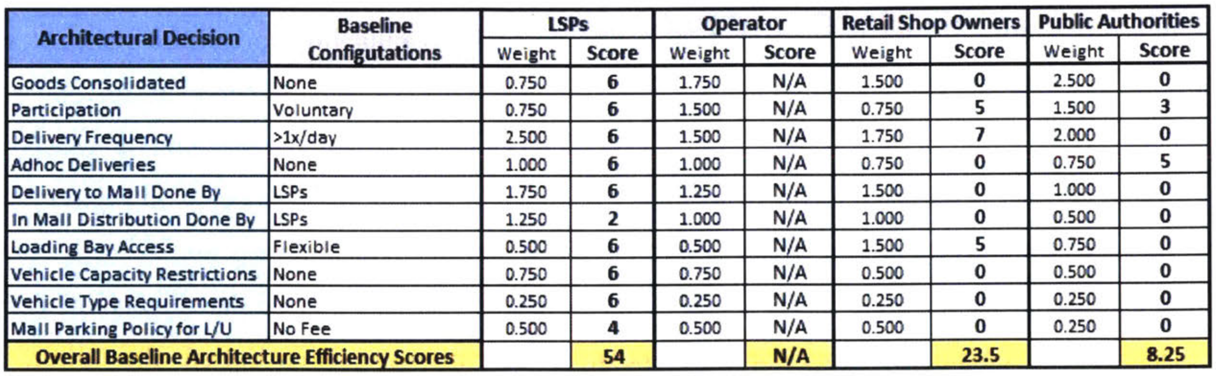


Public Authorities' Efficiency Value for Congestion	
No reduction in congestion in mall or local area	0
Minor reduction in congestion within the mall area	3
Minor reduction in congestion in local + mall area	5
Substantial reduction in congestion in mall area	7
Substantial reduction in congestion in local + mall area	10

- *Participation* architectural decision: Findings from several studies on consolidation measures reveal that typically, the public sector has to subsidize or provide incentives to the key participants in such measures: the demand agents (retail shop owners), the suppliers of goods, and the transportation service providers (LSPs) (Ville, Gonzalez-Feliu, & Dablanc, 2013). Therefore, the efficiency score values reflect that the "required" participation option is most efficient for the public authorities, since all possible participants must abide by the implemented measure, having a greater impact on congestion reduction.
- *Goods Consolidated* and *Delivery Frequency* architectural decisions: While consolidation schemes might represent additional costs for the public authorities through incentives and subsidies, these policies have been found to significantly reduce congestion in the area implemented. By reducing the number of individual carriers transporting goods, off-site consolidation schemes generate less freight trips and congestion is reduced. Therefore, the "off-site" design option for this decision is most efficient for the public sector, which in this study associates efficiency with congestion reduction. Similarly, design options that are associated with lower delivery frequencies (e.g. twice or once per week for each retailer) are also perceived by the public sector as more efficient than policy architectures with multiple deliveries per day for each retailer. Less frequent deliveries translate into less freight trips and less congestion. On the other hand, for retail shop owners, who value efficiency in terms of on-time delivery (OTD), policy architectures with frequent deliveries are perceived as more efficient. Design options with more restrictions on the frequency of deliveries therefore have lower efficiency scores for the retailers.
- *Loading Bay Access* architectural decision: As revealed in (Gatta & Marcucci, 2014), retail shop owners care a lot about access to loading and unloading areas and the probability of finding these areas free. Grounded on this, we score design options that have "pre-determined" or "flexible" loading bay access higher for the retailer's perceived efficiency. For the retailers, "pre-determined" loading bay access means that the party responsible for the delivery of the goods to the mall needs to reserve parking and the loading bay (LB) in

advance, which guarantees that they'll have access to the unloading/loading area when they arrive to the mall, making the "pre-determined" option the most retailer-efficient option for this architectural decision. The "flexible" design option, while having a lower efficiency score for the retailer, has a higher score than the "time window" design option. These relative scores are supported by the fact that LSPs making deliveries to the retailers have a higher probability of accessing LBs in flexible time-access policy designs than in time-window policy designs, which force all LSPs to make deliveries within the same time frame and decreases the probability of finding a free LB during this schedule. In many facilities, LB congestion is a prevailing concern and adding a time-window restriction could aggravate this, which explains the lower efficiency score among retail shop owners for this option.

Table 3.4 | Baseline Architecture Efficiency scores by Stakeholder group



Architectural Decision	Baseline Configutations	LSPs		Operator		Retail Shop Owners		Public Authorities	
		Weight	Score	Weight	Score	Weight	Score	Weight	Score
Goods Consolidated	None	0.750	6	1.750	N/A	1.500	0	2.500	0
Participation	Voluntary	0.750	6	1.500	N/A	0.750	5	1.500	3
Delivery Frequency	>1x/day	2.500	6	1.500	N/A	1.750	7	2.000	0
Adhoc Deliveries	None	1.000	6	1.000	N/A	0.750	0	0.750	5
Delivery to Mall Done By	LSPs	1.750	6	1.250	N/A	1.500	0	1.000	0
In Mall Distribution Done By	LSPs	1.250	2	1.000	N/A	1.000	0	0.500	0
Loading Bay Access	Flexible	0.500	6	0.500	N/A	1.500	5	0.750	0
Vehicle Capacity Restrictions	None	0.750	6	0.750	N/A	0.500	0	0.500	0
Vehicle Type Requirements	None	0.250	6	0.250	N/A	0.250	0	0.250	0
Mall Parking Policy for L/U	No Fee	0.500	4	0.500	N/A	0.500	0	0.250	0
Overall Baseline Architecture Efficiency Scores			**54**		**N/A**		**23.5**		**8.25**

Sustainability

As reported in (de Weck et. al., 2016), sustainability is one of the fastest growing lifecycle properties. The *Cambridge Online Dictionary* defines sustainability as "the idea that goods and services should be produced in ways that do not use resources that cannot be replaced and that do not damage the environment". Although sustainability planning often focuses on environmental goals, such as emissions reduction and habitat preservation, this lifecycle property encompasses economic and social sustainability goals as well. Different metrics exist to evaluate different sustainability goals, which have been summarized in **Table 3.5** (Litman, 2016).

Table 3.5 | Sustainability Goals from (Litman, 2016)

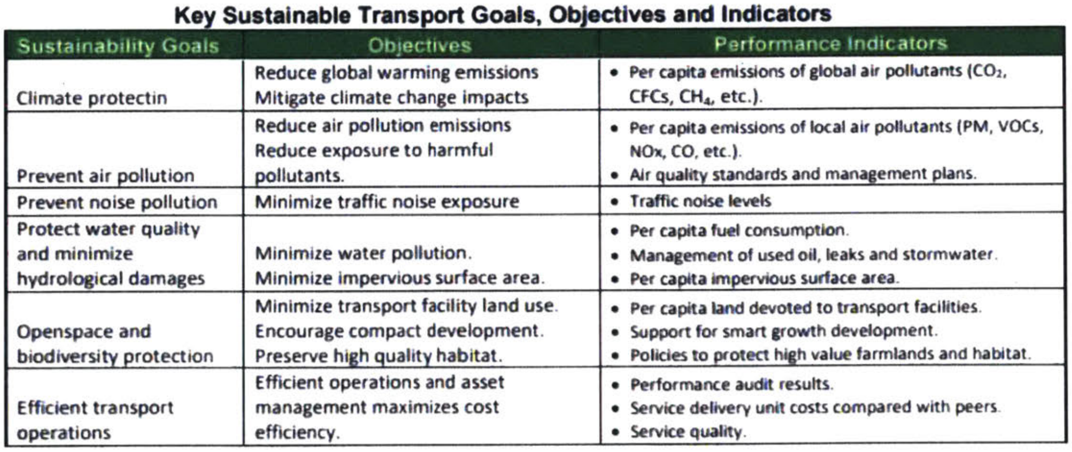
Sustainability Goals

Economic	Social	Environmental
Economic productivity	*Equity / Fairness*	Climate change prevention and *mitigation*
Local economic development	*Safety and security*	*Air, noise and water pollution prevention*
Resource efficiency	*Community development*	Non-Renewable Resource Conservation
Affordability	*Cultural heritage preservation*	*Openspace preservation*
Operational efficiency	*Public fitness and health*	Biodiversity protection
Good Governance and Planning		
Integrated, comprehensive and inclusive planning		
Efficient pricing		

While the goals across the different categories often overlap, the analysis in this thesis will focus on *environmental sustainability* exclusively. In (Quak & de Koster, 2007), the authors establish that the main objective of public authorities in the urban freight domain is to make freight transport more sustainable, describing it as one of the "most serious contributors to unsustainability in cities". Among the lifecyle properties considered in this thesis' framework, environmental sustainability is the only criteria we evaluate at a systematic level alone. We assume a policy architecture will have the same impact on environmental sustaintability for all the stakeholder groups considered. The sustainability scoring framework for the architectural design options considered in our analysis was derived using relative evaluation of the key sustainable transport goals, objectives, and indicators presented in (Litman, 2016) and summarized below in **Figure 3.6**. The scoring framework, presented in **Figure 3.7**, was simplified to include only the environmental sustainability goals most relevant to urban frieght policy in retail malls as validated by an industry researcher. To obtain the score for a particular architectural decision's option, the option is compared to the baseline option and evaluated in terms of its fulfillments of the environmental sustainability goals captured in **Figure 3.7**. The design option's scores for the different goals are added to obtain an overal score of 0-10 for each design option. The sustainability score for the baseline policy architecture is captured in **Figure 3.8** and the exact values used in the analysis for each design option's sustainability score and the architectural decision weights are illustrated in Appendix A.

Some evidence supporting our sustainability scores include findings presented in (Quak & de Koster, 2007), explaining that urban freight logistics measures that reduce vehicle miles traveled by freight trucks help trim emissions generated by this group. This led to high sustainability scores for design options in which goods are consolidated off-site, there are little or no adhoc deliveries for the retailers, and/or the delivery frequency is reduced. Policy configurations with these design options translate into the reduction of freight trips, translating into less VMT by freight vehicles and making these options more sustainable. An interesting finding and contrary to our initial perception, was the impact of time windows on local air pollution. Findings from (Quak & de Koster, 2007) revealed that time windows increase pollutant emissions, which we took into account when deriving the sustainability score for this design option. Evidence from past research validating the impact electric and hybrid vehicles have on global warming and air pollution were also taken into account for scoring the design options in the *Vehicle Type Requirements* architectural decision.

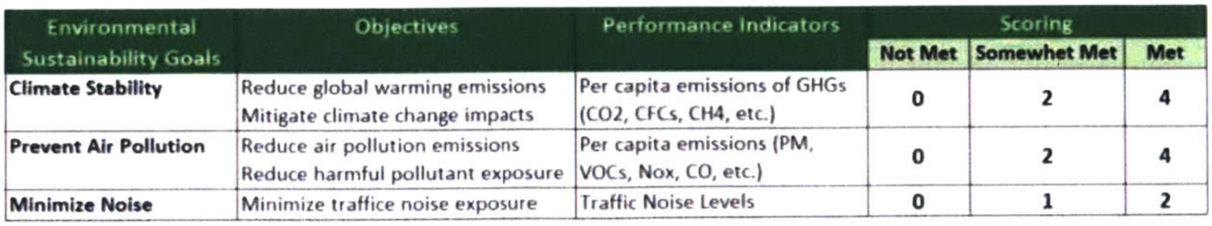
Table 3.6 | Environmental Sustainability Goals, Objectives, and Indicators from (Litman, 2016)



Key Sustainable Transport Goals, Objectives and Indicators

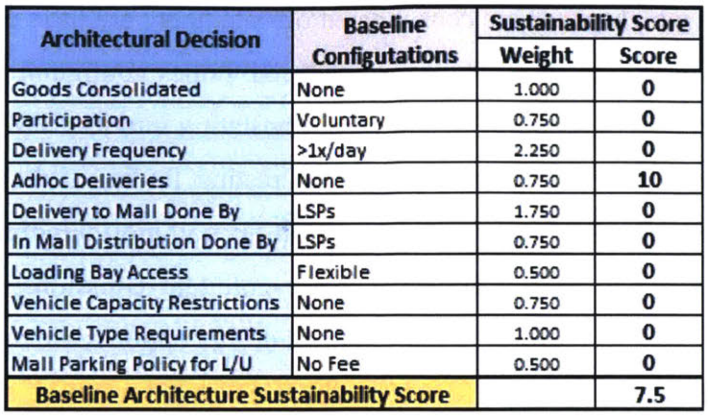
Sustainability Goals	Objectives	Performance Indicators
Climate protectin	Reduce global warming emissions Mitigate climate change impacts	• Per capita emissions of global air pollutants (CO_2, CFCs, CH_4, etc.).
Prevent air pollution	Reduce air pollution emissions Reduce exposure to harmful pollutants.	• Per capita emissions of local air pollutants (PM, VOCs, NOx, CO, etc.). • Air quality standards and management plans.
Prevent noise pollution	Minimize traffic noise exposure	• Traffic noise levels
Protect water quality and minimize hydrological damages	Minimize water pollution. Minimize impervious surface area.	• Per capita fuel consumption. • Management of used oil, leaks and stormwater. • Per capita impervious surface area.
Openspace and biodiversity protection	Minimize transport facility land use. Encourage compact development. Preserve high quality habitat.	• Per capita land devoted to transport facilities. • Support for smart growth development. • Policies to protect high value farmlands and habitat.
Efficient transport operations	Efficient operations and asset management maximizes cost efficiency.	• Performance audit results. • Service delivery unit costs compared with peers. • Service quality.

Table 3.7 | Environmental Scoring for urban freight policy architectures



Environmental Sustainability Goals	Objectives	Performance Indicators	Scoring		
			Not Met	Somewhet Met	Met
Climate Stability	Reduce global warming emissions Mitigate climate change impacts	Per capita emissions of GHGs (CO2, CFCs, CH4, etc.)	0	2	4
Prevent Air Pollution	Reduce air pollution emissions Reduce harmful pollutant exposure	Per capita emissions (PM, VOCs, Nox, CO, etc.)	0	2	4
Minimize Noise	Minimize traffice noise exposure	Traffic Noise Levels	0	1	2

Table 3.8 | Sustainability Score for Baseline Urban Freight Policy Architecture



Architectural Decision	Baseline Configutations	Sustainability Score	
		Weight	Score
Goods Consolidated	None	1.000	0
Participation	Voluntary	0.750	0
Delivery Frequency	>1x/day	2.250	0
Adhoc Deliveries	None	0.750	10
Delivery to Mall Done By	LSPs	1.750	0
In Mall Distribution Done By	LSPs	0.750	0
Loading Bay Access	Flexible	0.500	0
Vehicle Capacity Restrictions	None	0.750	0
Vehicle Type Requirements	None	1.000	0
Mall Parking Policy for L/U	No Fee	0.500	0
Baseline Architecture Sustainability Score			7.5

Cost

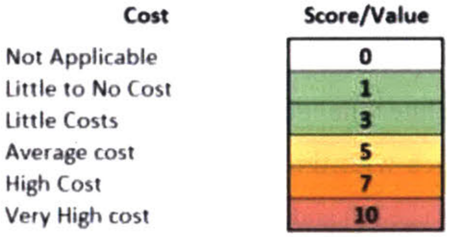
Cost is a popular metric for evaluating system architectures, as a guiding principle in project planning and financial investments is that the benefits of a project should be greater than its costs. Additionally, most if not all systems implementations, including policies, are driven by financial budgets. This criterion has multiple dimensions, including social, public, and private costs. However, in this analysis, cost will be considered as the direct monetary expense incurred by a stakeholder group. As previously mentioned, a typical concern in policy design is the distribution of costs and benefits among the system stakeholders, which in many occasions is asymmetric. For each stakeholder group, we will evaluate how implementing the options selected for all architectural decisions would affect the agent's costs as compared to the baseline scenario (**Table 3.2**). The relative cost scoring approach used for the baseline scenario and other architectural configurations is captured in **Figure 3.10** below. The cost values for the baseline architecture using this approach are presented in **Table 3.9**. The cost implications of the different architectural designs evaluated for the agents considered will be explored in more detail in the next chapter. Policy configurations with options whose cost scores are lower than those in the baseline architecture options for a system stakeholder, represent less expensive options for that agent. Conversely, options which have cost scores higher than those in baseline options, translate into additional costs for the stakeholder group under evaluation. The systematic cost score for a particular urban freight logistics policy architecture is derived by adding the cost score of each agent under this configuration. In the cost scores for the baseline architecture (**Table 3.9**), the operator agent gives a zero-cost score to the architecture because for configurations in which goods consolidation doesn't take place, we have assumed the operator is taken out of the picture, and therefore doesn't incur any costs. As previously explained in Section 3.3, the operator is a logistics service provider, but is differentiated from the LSP stakeholder group to distinguish between the types of logistics services offered by the two. The LSPs only provide transportation and handling services, while operators can provide handling, transportation, consolidation, and storage services.

The detailed cost weights and scores for the architectural decisions and their options are captured for each stakeholder group in Appendix A. Some evidence from studies and research in the industry used for deriving these scores and weights are summarized below.

- *Loading Bay Access* architectural decision: (Quak & de Koster, 2007) validates that urban freight logistics measures with timing access restrictions create additional costs for the transportation providers (LSPs) and the retailers. In many time-window scenarios, the LSP has a lot of capacity to fully load its truck(s) with many individual deliveries, but the time window restriction might not allow it to complete all deliveries within the permitted hours. In other cases, smaller LSPs don't have enough capacity and need to make several trips to make their deliveries, which may not be feasible in certain time window configurations. The missed deliveries and re-work this could generate create additional costs for these types of LSPs. Missed deliveries also translate into additional costs for the retailers.
- *Delivery Frequency* architectural decision: For the retailers, LSPs, and the operator, the greater the frequency of deliveries, the greater the cost. While the LSPs and operators incur the actual costs of more freight trips (e.g. fuel, additional employees and trucks might be needed, etc.), the increased costs for these groups will be reflected in costs incurred by the retailer for services from the transport providers.
- *Participation* architectural decision: As previously mentioned throughout the literature review, the public sector frequently subsidizes or provides incentives in policy configurations in which one or multiple stakeholders have a high costs-to-benefits ratio. Policy configurations in which retailers, LSPs, and/or suppliers are required to participate

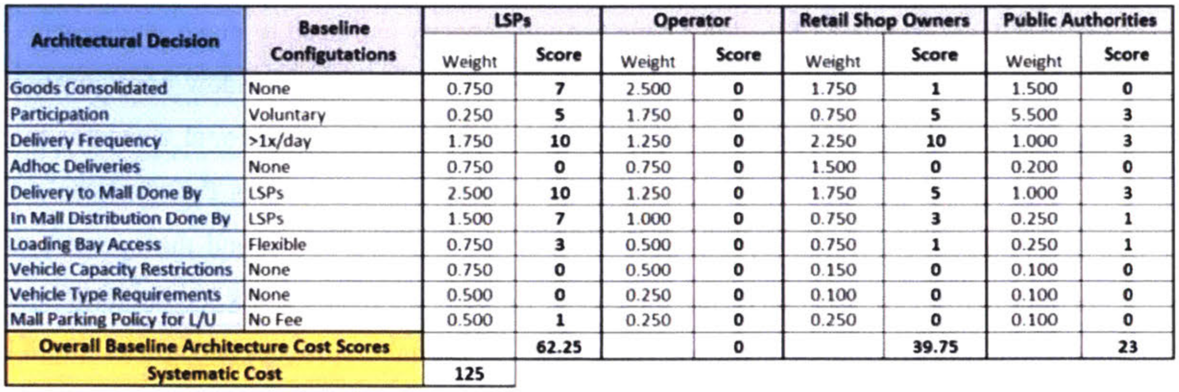
represent less costs for the public sector. However, voluntary and incentive-based policies generate substantial costs for the public agent. For the operator, "required participation" design options are less costly than voluntary and incentive-based policy architectures, since requiring participation means that the operator can shift some of its costs to its customers using pricing strategies. The "voluntary" design option is most expensive for this stakeholder group, since this design option typically yields the least participation and the operator may not be able to leverage economies of scale. With incentives, increased participation or government subsidies slightly reduces costs.

Figure 3.10 | Cost scores/values framework for Urban Freight policy architecture design



Cost	Score/Value
Not Applicable	0
Little to No Cost	1
Little Costs	3
Average cost	5
High Cost	7
Very High cost	10

Table 3.9 | Cost Scores for baseline Urban Freight Logistics configuration



Architectural Decision	Baseline Configutations	LSPs		Operator		Retail Shop Owners		Public Authorities	
		Weight	Score	Weight	Score	Weight	Score	Weight	Score
Goods Consolidated	None	0.750	7	2.500	0	1.750	1	1.500	0
Participation	Voluntary	0.250	5	1.750	0	0.750	5	5.500	3
Delivery Frequency	>1x/day	1.750	10	1.250	0	2.250	10	1.000	3
Adhoc Deliveries	None	0.750	0	0.750	0	1.500	0	0.200	0
Delivery to Mall Done By	LSPs	2.500	10	1.250	0	1.750	5	1.000	3
In Mall Distribution Done By	LSPs	1.500	7	1.000	0	0.750	3	0.250	1
Loading Bay Access	Flexible	0.750	3	0.500	0	0.750	1	0.250	1
Vehicle Capacity Restrictions	None	0.750	0	0.500	0	0.150	0	0.100	0
Vehicle Type Requirements	None	0.500	0	0.250	0	0.100	0	0.100	0
Mall Parking Policy for L/U	No Fee	0.500	1	0.250	0	0.250	0	0.100	0
Overall Baseline Architecture Cost Scores			62.25		0		39.75		23
Systematic Cost		125							

4. Discussion

4.1 Tradespace Analysis & Findings

As the authors in (Crawley, Cameron, & Selva, 2016) simply put it, "architectural wisdom is often an understanding of the trade-offs between decisions". In urban freight logistics, this entails comprehension of the trade-offs different design options create for the different system stakeholders. To evaluate the trade-offs among different urban freight policy architectures for the selected group of stakeholders, we use tradespace exploration. With the stakeholder-specific scores for the design options and each group's weights for the architectural decisions derived as explained in Section 3.5, we calculate the 0-100 sustainability, efficiency, and cost scores for each policy architecture generated. Further, we evaluate these for each stakeholder group and identify key trends, trade-offs, and important findings. Because recommending an policy architecture for each or all stakeholders is not the focus of this thesis, our tradespace analysis is not accompanied by suggestions on "optimal" policy configurations or implementations. Instead, we assess the value that this framework could provide to better understand how the different configurations impact our stakeholders.

We first look at how different urban freight policy architectures performed in terms of sustainability and cost. **Figure 4.1** shows for each policy configuration, its sustainability score and the cost implications to each stakeholder. In **Figure 4.2**, we should sustainability and cost values at a systematic level, and compare these to the baseline configuration's sustainability and cost performance. **Figure 4.1** clearly shows what several researchers referenced in earlier sections established about cost distribution among urban freight stakeholders in different schemes. Configurations in **Figure 4.1** for which the operator's costs are zero are those that do not include any type of goods consolidation measures. Since our definition of the operator is a LSP that provides consolidation services, policy architectures in which this doesn't occur take this agent out of the picture, creating no costs for him. As observed in **Figure 4.1**, while all stakeholders have a defined cost range, the costs for the public authorities seem to behave differently. This is further illustrated in **Figure 4.3**, which captures cost and sustainability performance only for this group. The different cost trends are attributed to the *Participation* architectural decision, which has the most weight for public authorities in the analysis of cost. Public agents encounter extremely high costs in urban freight policy configurations where they provide incentives and/or subsidies. The importance of this decision for determining the costs incurred by the public authorities is further highlighted by the pattern in policy configurations to the left of the baseline configuration, which is characterized by voluntary participation. All policy configurations to the left of the baseline require the participation of the retailers and/or LSPs, which represents less costs for the governmental bodies.

Figure 4.1 | Sustainability & Stakeholder Costs for Urban Freight Policy Configurations

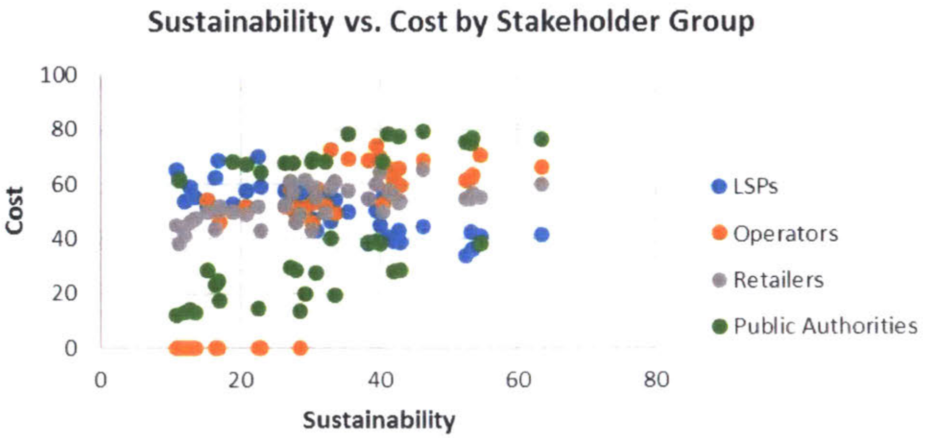


Figure 4.2 | Systematic Sustainability & Cost for Urban Freight Policy Configurations

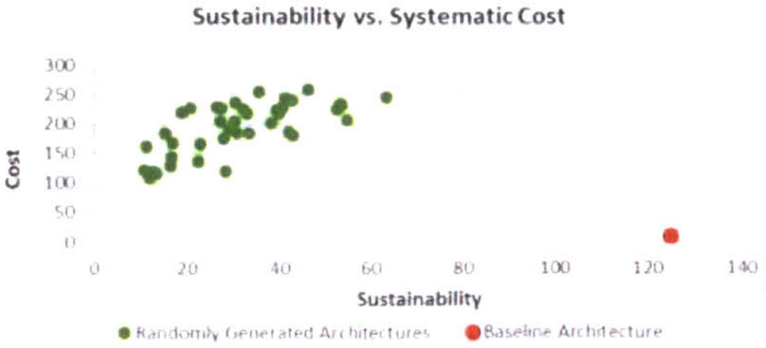
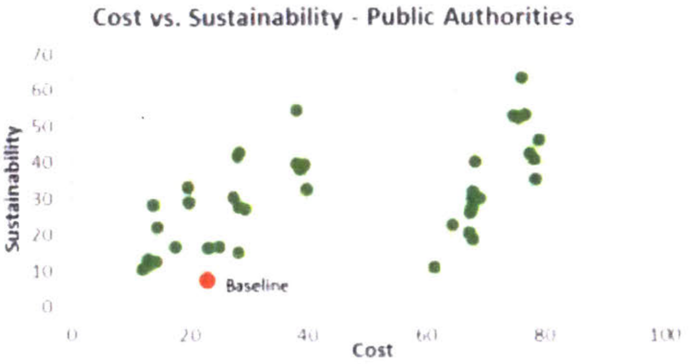


Figure 4.3 | Sustainability and Cost for Public Authorities



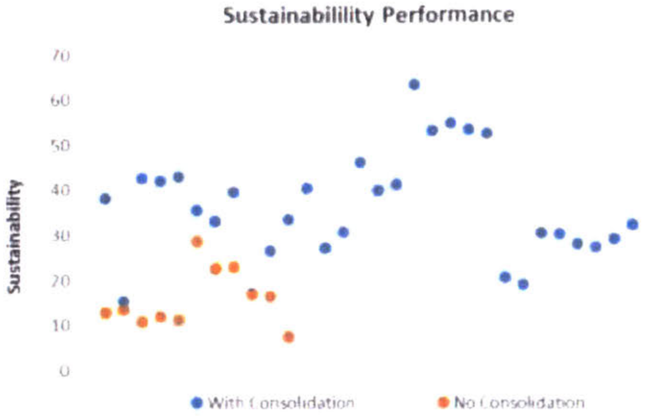
This framework could be used to assist in negotiations for urban freight policy design in scenarios where the public authorities or an organized group of private agents would like to achieve improved sustainability performance. A sustainability performance range could be defined, and policy configurations that support such performance could be further evaluated to clearly understand the cost implications to all stakeholders. Conversely, a preliminary budget for each stakeholder group could be defined and used to identify policy architectures that fall within budget constraints and improve the system's sustainability.

We now assess the part of **H2** that deals specifically with sustainability using the results presented in **Figure 4.4**.

H2 | In terms of *Sustainability* and *Efficiency*, policy configurations with some sort of goods consolidation will always perform better than policies with no consolidation for the "LSPs" and "retailers" stakeholder groups.

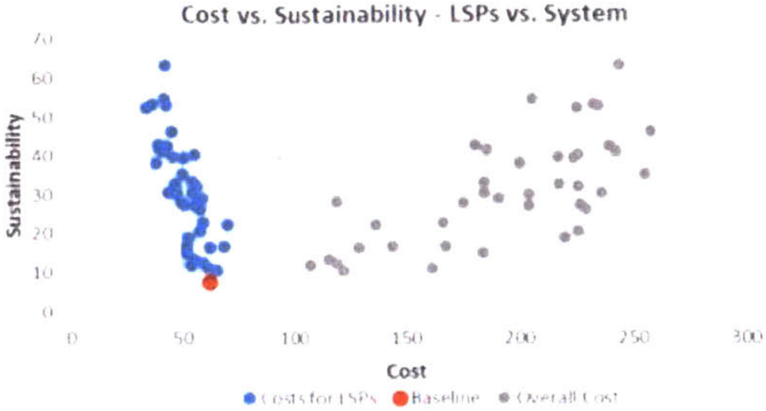
The resulting sustainability values failed to support the first part of our hypothesis that policy architectures with goods consolidation would always be more sustainable than policy configurations with no goods consolidation (H2). Out of the forty concepts randomly generated, eleven were designs with no goods consolidation. Of these eleven architectures, only six were always outperformed in terms of sustainability by the architectures with goods consolidation. Hence, 45% percent of the urban freight policy architectures considered with no goods consolidation performed better than some policy architectures that included goods consolidation.

Figure 4.4 | Sustainability for policy architectures with and without goods consolidation



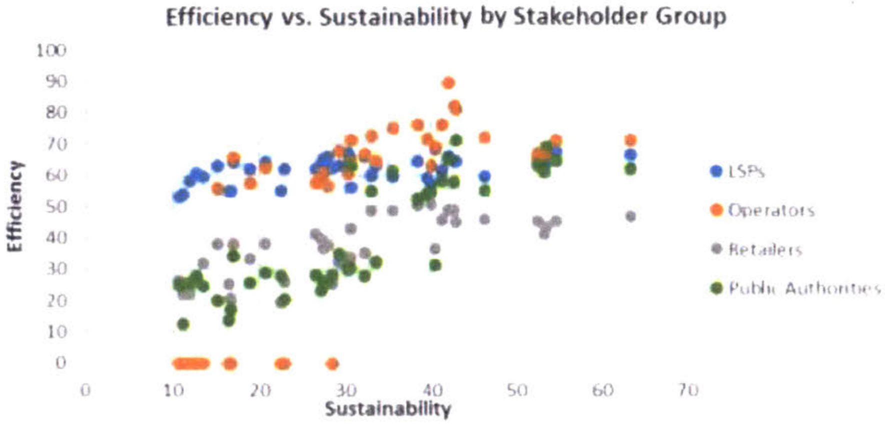
Also interesting was the tradespace of Cost and Sustainability for the LSPs, illustrated in **Figure 4.5**. Compared to the baseline, all other architectures generated performed higher on sustainability and *almost all* translated into lower costs for the LSPs. However, this doesn't mean that the more sustainable architectures were economically friendlier. In fact, the results show that the overall costs for *all* architectures significantly exceeded the baseline configuration's cost. What we see in these results is that more sustainable architectures translate into less costs for the LSPs because they limit or reduce participation and services of the LSPs, therefore reducing their costs and sometimes shifting these to other stakeholders. For example, policy architectures in which the last-mile delivery of goods is done by the freight operator remove some responsibility from the LSPs and transfer these and some of the associated costs to the operator. For the LSPs, the three freight policy architectures that are more sustainable and more expensive show a trend. All these include time windows and vehicle type or vehicle capacity restrictions, which as reported in (Gatta & Marcucci, 2014) represent significantly high costs for the LSPs and retailers.

Figure 4.5 | Cost and Sustainability for Logistics Service Providers (LSPs) and Overall system



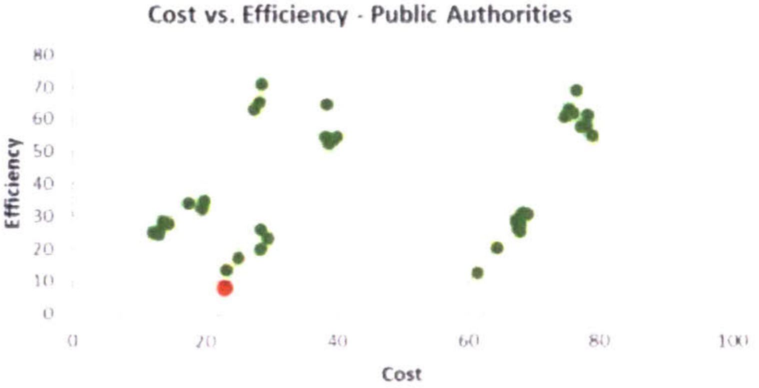
Moving on to efficiency, we present the results for efficiency and sustainability for the different stakeholder groups in **Figure 4.6**. We compare efficiency to sustainability since the latter is the only systematic criteria considered, allowing us to compare how the same architecture and sustainability value yield different efficiencies for the diverse stakeholders. As previously mentioned, policy architectures that show zero costs for the operators are those in which goods consolidation is not part of the design. Results in **Figure 4.6** indicate that while most agents have defined ranges for efficiency, the behavior of efficiency for public authorities stands out as more irregular. This behavior is attributed to the substantial reduction in mall and local congestion, which the public agents value as efficiency, produced by policy architectures where goods are consolidated off-site. All policy architectures that have high efficiency scores for this stakeholder are clustered in the middle to top-right section of the graph. Not surprisingly, these architectures also have high sustainability scores, since the off-site consolidation design reduces the amount of freight vehicles generated to the mall and city center, reducing pollution and noise side effects in addition to congestion. The architectures with lower efficiency and sustainability scores for the public sector are grouped in the bottom half of the graph. The similar behavior of the efficiency values for the LSPs and Operators, reflected in the trend of their points on the graph, can be attributed to the similarity in the services they offer and their view of efficiency, which are closely related.

Figure 4.6 | Sustainability & Stakeholder Efficiency for Urban Freight Policy Configurations



In **Figure 4.7** we capture cost and efficiency for the public sector, where we can see the two phenomena earlier mentioned – the significant gap in efficiency for configurations that have off-site consolidation of goods (top half) and those that have on-site or no consolidation design options (bottom half), and the significant gap in costs attributed to the drastic increase in costs for the public sector in policy configurations where this stakeholder group provides incentives or subsidies (right half).

Figure 4.7 | Cost and Efficiency for Public Authorities



We now assess the part of **H2** that deals specifically with efficiency for LSPs and retailers using the results presented in **Figures 4.8** and **4.9**.

H2 | In terms of *Sustainability* and *Efficiency*, policy configurations with some sort of goods consolidation will always perform better than policies with no consolidation for the "LSPs" and "retailers" stakeholder groups.

The resulting efficiency values failed to support the part of our hypothesis that policy architectures with goods consolidation would always be more efficient than policy configurations with no goods consolidation for the logistics service providers (LSPs) (H2), as illustrated in **Figure 4.8.**

Figure 4.8 | LSPs' Efficiency for policy architectures with and without goods consolidation

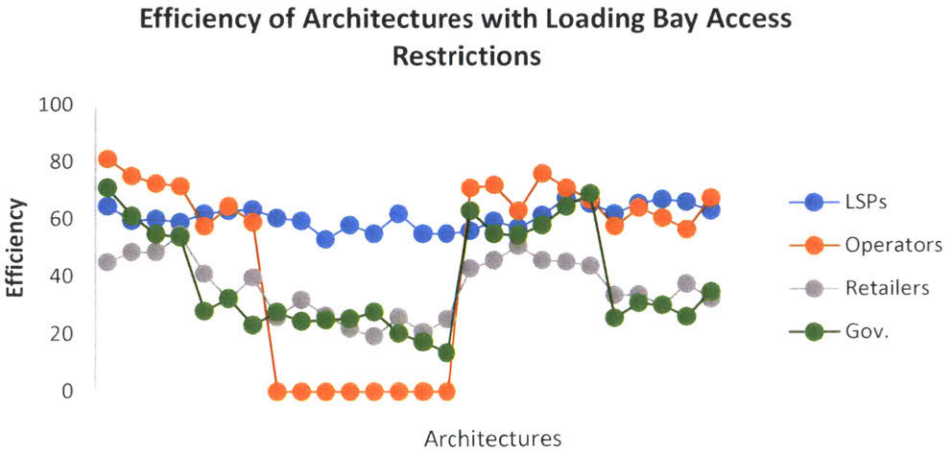
The part of H2 that consolidation design options would always be more efficient for retailers as compared with policy architectures with no goods consolidation is supported by these results. As reflected in the results in **Figure 4.9**, policy configurations with goods consolidations always outperform no-consolidation policy architectures in terms of efficiency for the retailer.

Figure 4.9 | Retailers' Efficiency for policy architectures with and without goods consolidation

Next, we present the efficiency scores with "pre-determined" and "time window" design options for the Loading Bay Access decision in Figure **4.10** to validate **H1**.

H1 | Policy configurations that include the "pre-determined" or "time window" options for the *Loading Bay Access* decision will always perform better in terms of *Efficiency* for the "retailers" stakeholder group than for other stakeholders analyzed.

Figure 4.10 | Views on Efficiency of Time-Access Restriction Policies by Stakeholder Group



The findings presented in the image above refute our hypothesis (H1). With these design configurations, rather than outperforming the other stakeholder groups in terms of efficiency, the retailers generally obtain less efficiency from the design options than the rest of the agents. The original hypothesis was grounded on the belief that more restrictive *Loading Bay Access* architectural decision-options would allow the retail shop owners to have more control over the timing of deliveries and could plan according to avoid business interruptions, which was expressed as a top concern by retailers surveyed in a big mall in Singapore. However, further analysis of research work that evaluated time access restrictions and the impact to stakeholders, including (Quak & de Koster, 2007) revealed that these stakeholders react less favorable to policy configurations with time access restrictions. One of the main concerns retailers express is few LBs and recurring congestion at the LB. Therefore, more "time window" design options are seen as less efficient by this group of stakeholders.

4.2 Conclusion

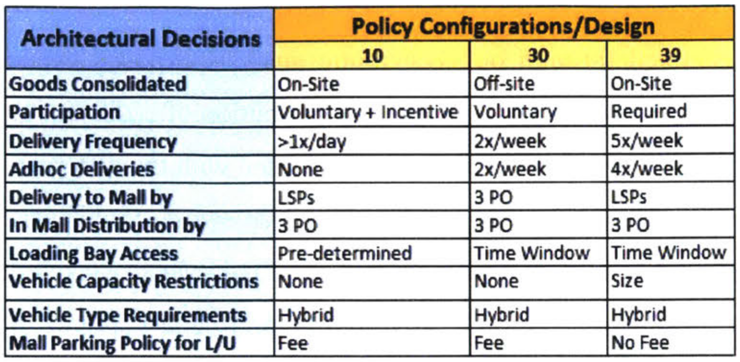
We summarize the overarching objectives and value of this thesis with the contribution from (Puckett, 2009):

> *"As the fundamentals conditioning freight travel choices change, and as the importance of implementing informed freight strategies grows for all stakeholders, it will become even more important to expand the scale of scope of freight travel behavior research. It will be no less important to enhance our ability both to represent decision-making settings faithfully, and to maximize the inferential power of the information we capture across our research applications by taking advantage of empirical developments and tools targeted at these goals"*

This thesis work explored the use of system design tools to generate multi-dimensional urban freight logistics policy architectures for retail malls in Singapore and evaluate the impact that these could have on specific system stakeholders. To achieve this, we identified key system configuration decisions and possible options using contributions from related research in the field. One of the differentiating aspects of this thesis from other work on urban freight stakeholder impacts is that this framework considers multiple urban freight logistics measures together as *one* policy architecture, whereas other studies have typically analyzed one or a few measures in *isolation*. Therefore, some of the hypotheses we formulated parting from related research that had a narrower view of the system, were refuted through the systemic analysis in this thesis. This reveals that while a certain urban freight logistics measure might be perceived to perform better on a given criteria (e.g. efficiency) for a stakeholder, combining this measure with other policy design options might affect the new policy architecture in unexpected ways. For example, when a design option that in isolation has been demonstrated to improve the efficiency of a stakeholder is combined with other design options, a new or different system behavior might emerge. This provides some explanation for the refutation of our first hypothesis (**H1**) and part of our second hypothesis (**H2**).

The results from the morphological matrix also revealed urban freight policy architectures that we have not seen explored in other work, supporting the use of this tool to further explore policy configurations. Some of these novel policy configurations are illustrated and summarized in **Table 4.1** below. To evaluate these configurations, important lifecycle properties for the stakeholders considered were identified and defined. Additionally, evaluation frameworks were developed for the assessment of the criteria by each stakeholder group. While evidence for evaluating the criteria on behalf of the different stakeholders was obtained from other research studies in the field and data available for stakeholders from the Singaporean urban freight industry, the model is built so that these evaluations are done directly by the system's stakeholders, much like playing a game. The objective of such design for the model is to inject true stakeholder values in a user-friendly and flexible framework for the high-level assessment of trade-offs among stakeholders and policy configurations.

Table 4.1 | Sample of novel Urban Freight policies obtained using policy design framework presented



Architectural Decisions	Policy Configurations/Design		
	10	30	39
Goods Consolidated	On-Site	Off-site	On-Site
Participation	Voluntary + Incentive	Voluntary	Required
Delivery Frequency	>1x/day	2x/week	5x/week
Adhoc Deliveries	None	2x/week	4x/week
Delivery to Mall by	LSPs	3 PO	LSPs
In Mall Distribution by	3 PO	3 PO	3 PO
Loading Bay Access	Pre-determined	Time Window	Time Window
Vehicle Capacity Restrictions	None	None	Size
Vehicle Type Requirements	Hybrid	Hybrid	Hybrid
Mall Parking Policy for L/U	Fee	Fee	No Fee

- *Policy Design **#10**:* LSPs drop off the goods at the mall during pre-determined time frames using hybrid freight vehicles (vehicle type restriction). The operator consolidates goods delivered by the LSPs for the retailers that choose to use the operator's in-mall goods distribution service. However, retailers are provided some type of incentive to use the operator's service. Under this policy, retailers have no restriction on the amount of deliveries they can receive.
- *Policy Design **#30***: LSPs transport the goods to a consolidation center outside the city, which is managed by the operator. Retail shop owners have the option to participate in the off-site consolidation scheme or if they prefer to maintain the baseline configuration, the individual LSPs ship their goods directly to the mall. Because retailers can only receive four deliveries per week under this policy, stores that receive many deliveries under might be motivated to join the consolidation scheme. The operator only provides its services to retailers who are willing to pay the off-site consolidation and last-mile delivery costs. Under this configuration, the operator and the LSPs delivering goods to the mall must abide by time window and hybrid vehicle requirements. Also, this policy sets strict limits on the amount of deliveries
- *Policy Design **#39**:* LSPs drop off the goods at the mall within enforced (required participation) time windows using hybrid freight vehicles that must meet certain size guidelines (vehicle type and capacity restrictions). The operator consolidates goods

delivered by the LSPs for the different retailers and streamlines the in-mall goods distribution process. Under this policy, retailers can receive up to nine deliveries per week.

The tradespaces generated through our systematic analysis exposed expected and unexpected trends and trade-offs and provided insight on the distribution of costs among the stakeholders as their efficiencies and the systemic sustainability fluctuated with the different policy architectures. With this and the model's ease of adaptability, this framework could serve to raise awareness among decision makers and system agents on the systematic versus stakeholder-specific impacts caused by specific design options not only in the preliminary policy design or evaluation discussions, but throughout the urban freight policy lifecycle.

While **H3** and **H4** were only presented in this thesis and the objective is to pursue the testing of these in future work, results from this thesis confirm that the framework presented could be leveraged and further advanced to support work centered around validating these hypotheses.

5. Future Work

The work presented in this thesis provides insight on urban freight policy design and its impact to a select group of stakeholders. The framework created could be developed further by incorporating real stakeholder input, expanding the stakeholder categories considered, incorporating retailer demand patterns, and by analyzing all feasible policy configurations for the set of architectural decisions and options considered. These advancements could enhance the model's robustness and support work to validate **H3** and **H4**, which surfaced during the development of this thesis but were set aside for upcoming research.

Firstly, validating the model with stakeholders from the urban retail mall freight logistics system in Singapore would be ideal and would be the most reliable approach for testing and developing the model further. If this were not possible, real stakeholders from a similar urban freight logistics system could also be leveraged. For each stakeholder category considered in our framework, we could have the real system stakeholders validate architectural decision weights and design option scores for the three criteria investigated in this thesis. The system stakeholders could also advice on additional architectural decisions, design options, and lifecycle properties essential to them or the overall system. Being most familiar with the system, they might be aware of additional design options for the architectural decisions already considered or even suggest the consideration of other key architectural decisions. A few additional design options that could be considered include preferential lanes for goods, real-time information on traffic, a tradable permit system for emissions, and additional variation of time windows for the *Loading Bay Access* architectural decision. Feedback from the stakeholders could also be a great way to identify other important system criteria for the agents, which we could evaluate with the enhanced model.

The framework developed could also be augmented by incorporating more or all system stakeholder categories. While only four system stakeholder groups were considered in this exploration, full inclusion of all system agents would provide a more holistic view of stakeholder trade-offs during policy design and negotiation. The scope of this work could also be expanded in terms of the number of configurations evaluated. While the forty concepts generated with the framework presented were derived through random combination of the architectural decision-options, the exhaustive list of feasible policy architectures could provide additional findings and even lead to other research questions.

The developments previously mentioned would contribute to the enhanced exploration of ongoing stakeholder engagement using system design tools (**H3**). To advance the investigation of **H4**, data on demand patterns for different types of retail businesses in a mall could be gathered. To study **H4**, the "retail shop owners" stakeholder category might need to be broken down further to distinguish among businesses with different types of demand behavior. By considering retailers with distinct demand behaviors as different stakeholders, we could more accurately capture their differing values for efficiency, cost, and other criteria. For example, a small store with little storage and high demand might view frequent deliveries as most efficient, whereas a store with lower demand might view frequent delivery policy design options as less efficient. Obtaining real insight from the retailers with different types of demand patterns would be most valuable to take **H4** further.

Appendix A: Architectural Design Scores and Weights

In this section, we illustrate the scoring and weighting values used for all architectural decisions and their options, for each stakeholder group. Since *Sustainability* was identified as a systematic lifecycle property – not varying for the different stakeholders – this one is captured first. *Cost* and *Efficiency* design option scores and architectural decision weights are then shown for each stakeholder group considered. The architectural decisions and options are first shown for reference, as the scoring illustrations will refer to the design options as A, B, C, D, or E.

Table A - 1 | Architectural Decisions and their respective Options

Architectural Decision	Options				
	A	B	C	D	E
Goods Consolidated	On-Site	Off-site	None		
Participation	Required	Voluntary	Voluntary + Incentive		
Delivery Frequency	>1x/day	1x/day	5x/week	2x/week	1x/week
Adhoc Deliveries	None	1x/week	2x/week	4x/week	
Delivery to Mall Done By	LSPs	3 PO			
In Mall Distribution Done By	LSPs	3 PO	Retail Shop Owners		
Loading Bay Access	Pre-determined	Time Window	Flexible		
Vehicle Capacity Restrictions	Size	Load Factor	None		
Vehicle Type Requirements	Electric	Hybrid	None		
Mall Parking Policy for L/U	Fee	No Fee			

Sustainability

Table A - 2 | Architectural decision weights and option scores for Sustainability

Sustainability						
Weight	Architectural Decision	Options				
		A	B	C	D	E
1.000	Goods Consolidated	4	10	0		
0.750	Participation	1	0	5		
2.250	Delivery Frequency	0	5	5	10	10
0.750	Adhoc Deliveries	10	6	5	5	
1.750	Delivery to Mall Done By	0	5			
0.750	In Mall Distribution Done By	0	5	5		
0.500	Loading Bay Access	3	0	0		
0.750	Vehicle Capacity Restrictions	1	4	0		
1.000	Vehicle Type Requirements	10	5	0		
0.500	Mall Parking Policy for L/U	2	0			

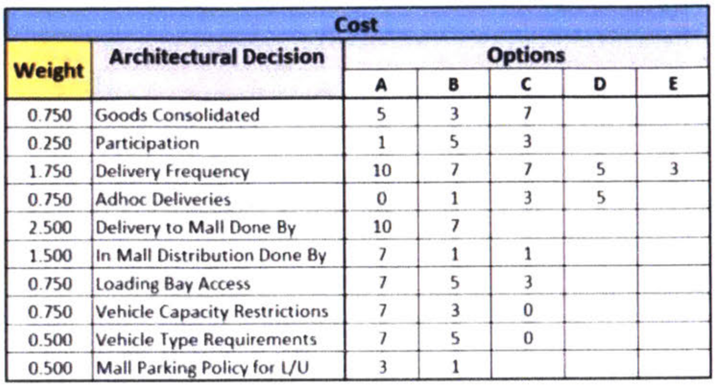
The option scores presented in **Table A-2** were obtained using the environment sustainability scoring framework explained in Section 3.5. Below are the goal-specific scores for each design option according to this framework. The 0-10 score for each option (**Table A-2**) was obtained by adding the option's values for the three environmental sustainability goals reflected in **Table A-3**.

Table A - 3 | Environmental Sustainability Goal scoring for Architectural Decision-Options

Environmental Sustainability Goal		**Options**				
		A	**B**	**C**	**D**	**E**
Goods Consolidated	Climate Stability	2	4	0		
	Prevent Air Pollution	2	4	0		
	Minimize Noise	0	2	0		
Participation	Climate Stability	0	0	2		
	Prevent Air Pollution	0	0	2		
	Minimize Noise	1	0	1		
Delivery Frequency	Climate Stability	0	2	2	4	4
	Prevent Air Pollution	0	2	2	4	4
	Minimize Noise	0	1	1	2	2
Adhoc Deliveries	Climate Stability	4	2	2	2	
	Prevent Air Pollution	4	2	2	2	
	Minimize Noise	2	2	1	1	
Delivery to Mall Done	Climate Stability	0	2			
	Prevent Air Pollution	0	2			
	Minimize Noise	0	1			
In Mall Distribution D	Climate Stability	0	2	2		
	Prevent Air Pollution	0	2	2		
	Minimize Noise	0	1	1		
Loading Bay Access	Climate Stability	0	0	0		
	Prevent Air Pollution	2	0	0		
	Minimize Noise	1	0	0		
Vehicle Capacity Restr	Climate Stability	0	2	0		
	Prevent Air Pollution	0	2	0		
	Minimize Noise	1	0	0		
Vehicle Type Requirem	Climate Stability	4	2	0		
	Prevent Air Pollution	4	2	0		
	Minimize Noise	2	1	0		
Mall Parking Policy for	Climate Stability	2	0			
	Prevent Air Pollution	0	0			
	Minimize Noise	0	0			

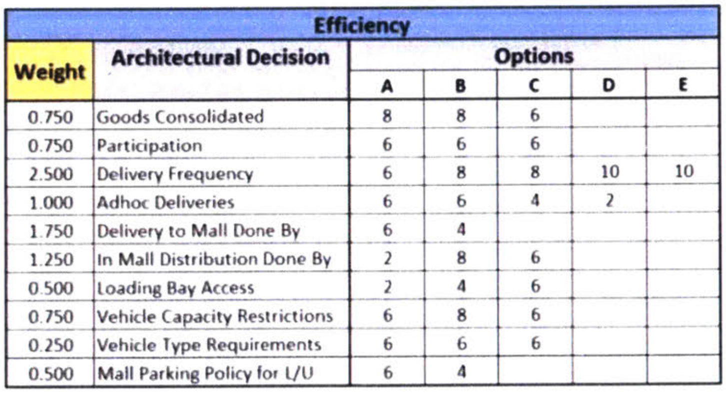
Cost & Efficiency: Logistics Service Providers (LSPs)

Table A - 4 | LSPs' architectural decision weights and option scores for Cost



Cost						
Weight	Architectural Decision	Options				
		A	B	C	D	E
0.750	Goods Consolidated	5	3	7		
0.250	Participation	1	5	3		
1.750	Delivery Frequency	10	7	7	5	3
0.750	Adhoc Deliveries	0	1	3	5	
2.500	Delivery to Mall Done By	10	7			
1.500	In Mall Distribution Done By	7	1	1		
0.750	Loading Bay Access	7	5	3		
0.750	Vehicle Capacity Restrictions	7	3	0		
0.500	Vehicle Type Requirements	7	5	0		
0.500	Mall Parking Policy for L/U	3	1			

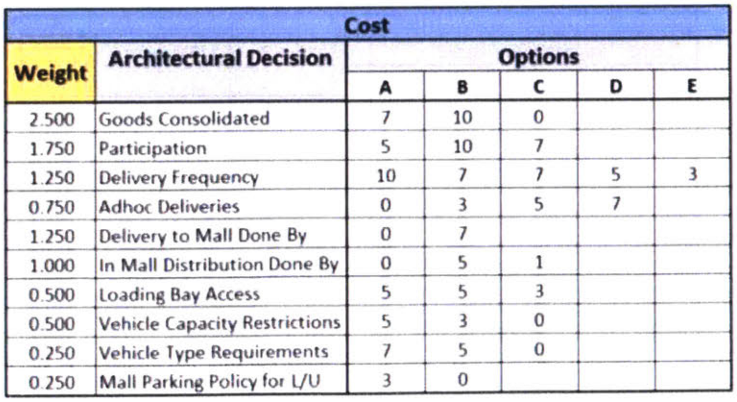
Table A - 5 | LSPs' architectural decision weights and option scores for Efficiency



Efficiency						
Weight	Architectural Decision	Options				
		A	B	C	D	E
0.750	Goods Consolidated	8	8	6		
0.750	Participation	6	6	6		
2.500	Delivery Frequency	6	8	8	10	10
1.000	Adhoc Deliveries	6	6	4	2	
1.750	Delivery to Mall Done By	6	4			
1.250	In Mall Distribution Done By	2	8	6		
0.500	Loading Bay Access	2	4	6		
0.750	Vehicle Capacity Restrictions	6	8	6		
0.250	Vehicle Type Requirements	6	6	6		
0.500	Mall Parking Policy for L/U	6	4			

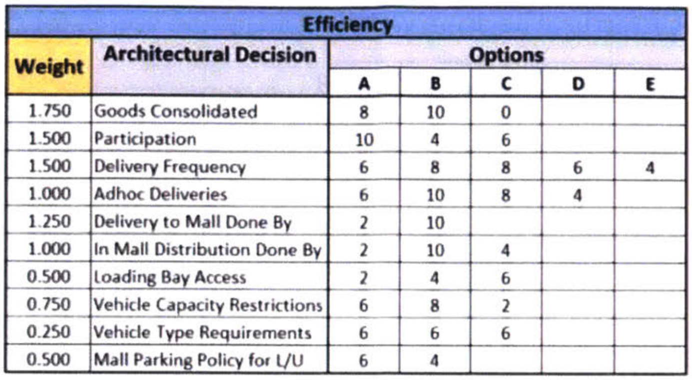
Cost & Efficiency: Freight Operator

Table A - 6 | Operator's architectural decision weights and option scores for Cost



Cost						
Weight	Architectural Decision	Options				
		A	B	C	D	E
2.500	Goods Consolidated	7	10	0		
1.750	Participation	5	10	7		
1.250	Delivery Frequency	10	7	7	5	3
0.750	Adhoc Deliveries	0	3	5	7	
1.250	Delivery to Mall Done By	0	7			
1.000	In Mall Distribution Done By	0	5	1		
0.500	Loading Bay Access	5	5	3		
0.500	Vehicle Capacity Restrictions	5	3	0		
0.250	Vehicle Type Requirements	7	5	0		
0.250	Mall Parking Policy for L/U	3	0			

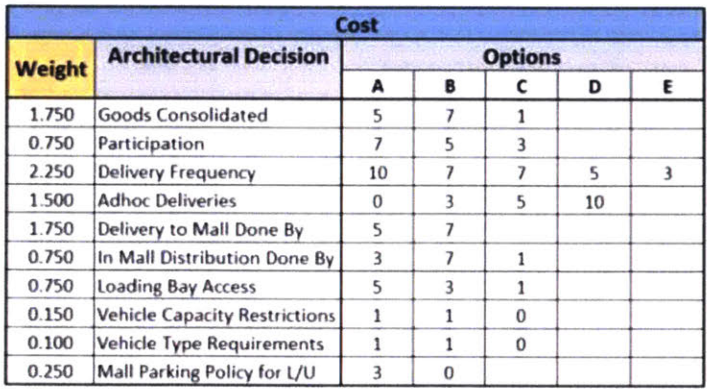
Table A - 7 | Operator's architectural decision weights and option scores for Efficiency



Efficiency						
Weight	**Architectural Decision**	**Options**				
		A	B	C	D	E
1.750	Goods Consolidated	8	10	0		
1.500	Participation	10	4	6		
1.500	Delivery Frequency	6	8	8	6	4
1.000	Adhoc Deliveries	6	10	8	4	
1.250	Delivery to Mall Done By	2	10			
1.000	In Mall Distribution Done By	2	10	4		
0.500	Loading Bay Access	2	4	6		
0.750	Vehicle Capacity Restrictions	6	8	2		
0.250	Vehicle Type Requirements	6	6	6		
0.500	Mall Parking Policy for L/U	6	4			

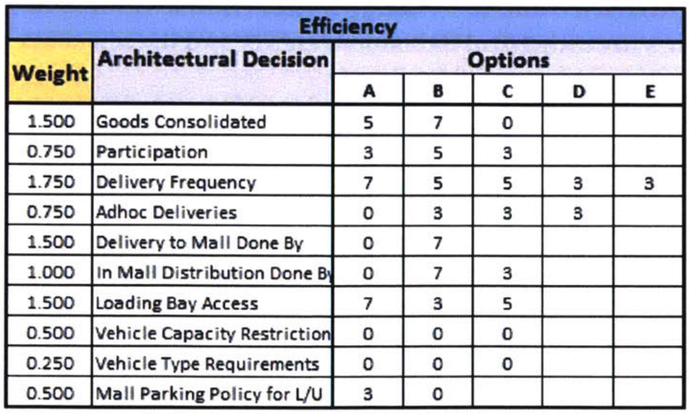
Cost & Efficiency: Retailer Shop Owners

Table A - 8 | Retailers' architectural decision weights and option scores for Cost



Cost						
Weight	**Architectural Decision**	**Options**				
		A	B	C	D	E
1.750	Goods Consolidated	5	7	1		
0.750	Participation	7	5	3		
2.250	Delivery Frequency	10	7	7	5	3
1.500	Adhoc Deliveries	0	3	5	10	
1.750	Delivery to Mall Done By	5	7			
0.750	In Mall Distribution Done By	3	7	1		
0.750	Loading Bay Access	5	3	1		
0.150	Vehicle Capacity Restrictions	1	1	0		
0.100	Vehicle Type Requirements	1	1	0		
0.250	Mall Parking Policy for L/U	3	0			

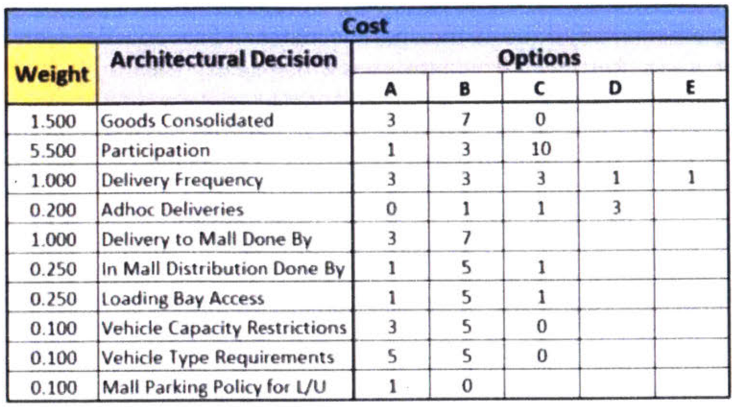
Table A - 9 | Retailers' architectural decision weights and option scores for Efficiency



Efficiency						
Weight	**Architectural Decision**	**Options**				
		A	B	C	D	E
1.500	Goods Consolidated	5	7	0		
0.750	Participation	3	5	3		
1.750	Delivery Frequency	7	5	5	3	3
0.750	Adhoc Deliveries	0	3	3	3	
1.500	Delivery to Mall Done By	0	7			
1.000	In Mall Distribution Done By	0	7	3		
1.500	Loading Bay Access	7	3	5		
0.500	Vehicle Capacity Restriction	0	0	0		
0.250	Vehicle Type Requirements	0	0	0		
0.500	Mall Parking Policy for L/U	3	0			

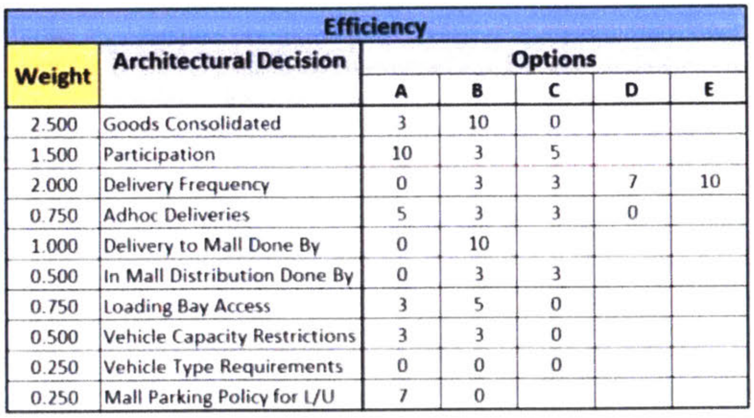
Cost & Efficiency: Public Authorities

Table A - 10 | Public Authorities' architectural decision weights and option scores for Cost



Cost						
Weight	Architectural Decision	Options				
		A	B	C	D	E
1.500	Goods Consolidated	3	7	0		
5.500	Participation	1	3	10		
1.000	Delivery Frequency	3	3	3	1	1
0.200	Adhoc Deliveries	0	1	1	3	
1.000	Delivery to Mall Done By	3	7			
0.250	In Mall Distribution Done By	1	5	1		
0.250	Loading Bay Access	1	5	1		
0.100	Vehicle Capacity Restrictions	3	5	0		
0.100	Vehicle Type Requirements	5	5	0		
0.100	Mall Parking Policy for L/U	1	0			

Table A - 11 | Public Authorities' architectural decision weights and option scores for Efficiency



Efficiency						
Weight	Architectural Decision	Options				
		A	B	C	D	E
2.500	Goods Consolidated	3	10	0		
1.500	Participation	10	3	5		
2.000	Delivery Frequency	0	3	3	7	10
0.750	Adhoc Deliveries	5	3	3	0	
1.000	Delivery to Mall Done By	0	10			
0.500	In Mall Distribution Done By	0	3	3		
0.750	Loading Bay Access	3	5	0		
0.500	Vehicle Capacity Restrictions	3	3	0		
0.250	Vehicle Type Requirements	0	0	0		
0.250	Mall Parking Policy for L/U	7	0			

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