FEASIBILITY OF INSTALLING NOISE REDUCTION TECHNOLOGIES ON COMMERCIAL VEHICLES TO SUPPORT OFF-HOUR DELIVERIES

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16. Abstract Noise is an important issue in freight delivery. In the implementation of the Off-Hour Delivery (OHD) Project, the noise problem became increasingly prominent. Effective noise control not only facilitates OHD, it also improves the community environment and drivers' physical and psychological health. In pursuit of this goal, the project team investigated existing technologies and policies on noise reduction. Technologies such as the CNG engine, electric engine, foam coating, aluminum floors, and smart reverse alarms were studied. Their advantages and disadvantages are presented. Most of these technologies are currently used in Europe, but not yet adopted by the U.S. market. To gather information from candidate vendors, requests for information were issued and responses were carefully examined. The team also collected public opinions on freight noise and field noise data. The transferability and effectiveness of noise control technologies are discussed. It was found that there is great potential for most of the technologies to be smoothly introduced into the U.S. market to effectively facilitate the OHD program implementation.			
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1. EXECUTIVE SUMMARY

Noise is an important issue in freight delivery. In the implementation of the Off-Hour Delivery (OHD) Project, the noise problem became increasingly prominent. Effective noise control not only facilitates OHD, it also improves the community environment and drivers' physical and psychological health. In pursuit of this goal, the project team investigated existing technologies and policies on noise reduction. Technologies such as the CNG engine, electric engine, foam coating, aluminum floors, and smart reverse alarms were studied. Their advantages and disadvantages are presented. Most of these technologies are currently used in Europe, but not yet adopted by the U.S. market. To gather information from candidate vendors, requests for information were issued and responses were carefully examined. The team also collected public opinions on freight noise and field noise data. The transferability and effectiveness of noise control technologies are discussed. It was found that there is great potential for most of the technologies to be smoothly introduced into the U.S. market to effectively facilitate the OHD program implementation.

2. INTRODUCTION

Impacts from freight activities are profound and complex. While the freight system is a crucial contributor to a vibrant economy, and a key determinant of quality of life, it is also a major source of fuel consumption, environmental pollution, unwanted noise and potential safety hazards. To support vibrant economies and the quality of life that citizens expect, freight activity must be incorporated into metropolitan areas in a way that maximizes its efficiency and minimizes its negative externalities.

During the 2007-2010 period, with funding from the U.S. Department of Transportation (USDOT) and the proactive participation of the New York City Department of Transportation (NYCDOT), Rensselaer Polytechnic Institute led a pilot test project aimed at increasing off-hour deliveries (OHD) between 7:00 PM and 6:00 AM. Following the success of the pilot testing project, the USDOT has funded the second phase research dealing with the implementation of OHD, which started in January 2011, led jointly by the Rensselaer team and NYCDOT.

It is estimated that when fully implemented, OHD will save all road users in Manhattan approximately 3-5 minutes per trip, and carriers about 48 minutes per delivery tour in travel time, and 1-3 hours per tour in service time. It is also estimated that OHD could lead to economic savings of $100-200 million per year, from travel time savings and pollution reduction alone. In spite of the great promise of the OHD concept, a number of important issues remain to be addressed, most notably the noise caused by commercial vehicles. With lower ambient noise levels during off hours, delivery noises can be even more noticeable, and thus disturbing. For this reason, vehicle movements in urban areas are often constrained during night-time and/or weekend periods by local "curfew" regulations, put in place to avoid noise impacts. These include delivery curfew restrictions imposed by local planning boards, and noise abatement

notices or local stakeholder agreements. Some citizens in New York City have also expressed concerns over the impacts of noise caused by OHD on local neighborhoods. Without a proactive plan to mitigate delivery noises, the large scale OHD implementation will likely cause disputes among local communities, which could threaten its viability in the long term.

It is important to identify effective noise control measures to facilitate OHD, and to improve community and neighborhood environments. In addition, truck noise reduction can help improve drivers' physical and psychological health, alleviate driver fatigue, make it easier for drivers to notice ambient noise and identify hazardous situations, and reduce bike and pedestrian-related accidents.

The goal of this study is to evaluate alternative noise mitigation strategies and technologies. To fulfill this goal, the team assessed existing noise reduction technologies, identified transferrable technologies, collected and analyzed noise data, and conducted cost and benefit analyses. The following sections describe these activities and their outputs in detail.

3. ASSESSMENT OF EXISTING POLICIES AND TECHNOLOGIES

Through a comprehensive literature review, the project team conducted a state-of-the-practice assessment of noise reduction technologies and policies that are in place for freight transportation, and in particular, trucking. This section discusses technologies and policies dealing with low noise trucks that are in place in other countries, and in domestic states and municipalities, and documented "best practice" cases.

3.1 Assessment of existing noise reduction technologies

3.1.1 Low noise engine

In terms of the noise caused by trucks, the engine remains the major source, with the gear box and brakes also causing noise during operation. The engine-related noise levels are summarized in Table 1.

Table 1 Engine Related Noise Levels

Item	Peak noise (dB)
Engine	79
Gear box	68
Brakes	72

For alternative fuels that enable low noise engines, liquefied natural gas (LNG) is proposed as a fossil fuel substitute for gasoline, which liquefies natural gas in the tank to provide energy for combustion. It is 2.4 times heavier than the compressed natural gas (CNG) engine, and 60% of the cost of diesel engine (Wikipedia, 2012). It is also environmentally-friendly, with less carbon dioxide after combustion. The estimated cost of LNG in 2012 is $1000/tpa (tonne per year). With the growing supply of natural gas and technology innovation, LNG would become

much cheaper and easier to transport. It would be one of the major sources of energy in the future (Wikipedia, 2012).

Another alternative fuel is CNG. A CNG engine emits greenhouse gas about 10% to 30% lower than vehicles operating on gasoline (Michaelis, 1996). CNG engine vehicles also have low maintenance costs and reasonable vehicle and fuel costs, as summarized in Table 2.

Table 2 Life-Cycle Greenhouse Gas Emissions and Costs For Alternative Fuel Cars

(Source: Michaelis, 1996)

Fuel	Greenhouse gas emissions in g/km CO2 equivalent				Vehicle cost ($)	Fuel cost ($/liter gasoline equivalent)	Fuel use for cost ($/100km)	Cost in excess of gasoline vehicle at cent/km
	Vehicle manu-facture	Fuel supply	Ope-ration	Total				
Gasoline	25-27	15-48	182-207	222-282	15168	0.26	7.6	0.00
CNG	29-31	5-68	130-154	164-253	16083-15600	0.18-0.24	7.27	-0.28-0.90

In addition to lower noise levels, LNG or CNG engines provide clean and sustainable energy resources for freight transportation. With increasing supplies and technology innovation, while gas prices could continue to go up, LNG and CNG prices will go down. It is likely that LNG and CNG engines will take more market share compared to gasoline engines, and become the major engine type in the future.

Other engine-related technologies include RPM limiters and incapsulation. An RPM limiter is a device fitted in the engine that prevents the engine from going beyond a certain speed limit, and could also prevent it from exceeding noise limits. Engine incapsulation is another way to minimize noise by isolating the engine in a special device. Together with CNG or LNG engines, RPM limiters and incapsulation could reduce engine-related noise to a large extent.

One thing to note is that New York State is the only state that has a moratorium on the transportation of LNG in intrastate commerce. Although LNG could be used and stored in New York, it is illegal to have LNG transported as part of the interstate commerce. And there is no sign of changing the law in the foreseen future. So although being a potentially good candidate, LNG is not to be considered for noise reduction technologies in New York.

3.1.2 Trailer and body

Another major source of truck noise comes from the trailer and truck body, as summarized in Table 3.

Table 3 Trailer and Body Noise Level

Item	Peak noise (dB)
Floor	85
Wall	74
Tailgate	83
Reversing alarm	110

Solutions for these noise sources include coatings, aluminum floors, and other materials. Foam coating has many advantages. Easily shaped and accessible, it is very light and adds almost no weight to trucks. Foam's significant sound-absorbing abilities are well known, used for sound insulation in various home and business settings. Aluminum floors keeps cargo spaces even and clean, which limits the noise made as cargoes and supplies make contact with the truck body. Compared with iron, aluminum floors are easily shaped, replaceable and durable (see Figure 1).

Figure 1 Aluminum Floor (Source: Goevaers, R., 2010)

3.1.3 Refrigeration

Refrigerated trucks have noise sources in both the engine and ventilator. The noise level of refrigerated trucks is between 69-74 dB(A). Incapsulation and cryogen refrigeration could be used to limit noise and refrigerate carbon dioxide. A refrigeration unit is shown in **Figure 2**.

Figure 2 Refrigeration Unit (Source: Goevaers, R., 2010)

3.1.4 Encouraging quiet handling behavior

In addition to the truck itself, the delivery operations of loading and unloading can also be key sources of noise, as summarized in Table 4.

Table 4 Peak Noise without Noise Reduction Technology

Activities	Peak noise (dB)
Slamming door	74
Driving up/away	67-83
Load hatch	65-92
Containers over load floor	74-85
Refrigeration kicking in	70-78
Removing onboard forklift	77-82

An effort to encourage quiet behaviors aims to reduce the noise caused from typical loading and unloading activities. For example, special loading and unloading locations can be designated to minimize possible impact from noise. Another example is the use of quiet unloading equipment, such as a hand pallet truck (Figure 3) and roll cage (Figure 4) to handle cargoes. Without these modifications, wheels, bearings and collisions can cause noise of up to 92 dB(A).

Figure 3 Hand Pallet Truck
(Source: Goevaers, R., 2010)

Figure 4 Roll Cage
(Source: Goevaers, R., 2010)

3.2 Assessment of noise control policies

In addition to low noise technologies, noise policies are needed to reduce the impact of freight noise. Various noise policies have been implemented in European countries. In the U.S., the Environmental Protection Agency (EPA) is responsible for national noise policy making. State and municipal governments make supplemental, regional or local-level noise policies. For example, Chicago, Los Angeles, Houston and New York City have their own noise policies. Noise policies in these regions are carefully studied and compared. Results would provide references for noise policy making and/or transferability.

3.2.1 Europe

Europe is the world leader for noise mitigation of freight transportation. Different approaches have been used, including noise technologies adoption, formulation of action plans, and regular evaluations of implementations. Noise is defined as "unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity" (European Parliament and Council of the EU, 2002). Based on this definition, noise level indicators L_{day} (day-noise indicator, 7:00 a.m. to 7:00 p.m), $L_{evening}$ (evening-noise indicator, 7:00 p.m. to 11:00 p.m.) and L_{night} (night-time noise indicator, 11:00 p.m. to 7:00 a.m) are defined. The calculation of L_{den} (day-evening-night noise indicator) is presented below (European Parliament and Council of the EU, 2002).

$$L_{den} = 101g\,\frac{1}{24}\left(12 * 10^{\frac{L_{day}}{10}} + 4 * 10^{\frac{L_{evening}+5}{10}} + 8 * 10^{\frac{L_{night}+10}{10}}\right) \quad (1)$$

where

L_{day}: The A-weighted average sound level over all the day periods of a year

$L_{evening}$: The A-weighted average sound level over all the evening periods of a year

L_{night}: The A-weighted average sound level over all the night periods of a year

The equation above provides a quantitative measurement of noise levels. Another distinctive feature of Europe noise regulation is that it defines noise limits for different types of vehicles, which are summarized in Table 5.

Table 5 Noise Limits in Europe

Vehicle Type	Distance	Noise level
Van	C2	75-78 dB(A)
Truck	C3	76-79 dB(A)

Besides these regulations, the PIEK program in the Netherlands sets the noise level of 65 dB(A) from 7 pm to 11 pm, and 60 dB(A) from 11 pm to 7 am for truck deliveries (Goevaers, 2010). As for the truck itself, PIEK sets a series of truck noise standards. For example, the truck driveline noise should be lower than 65 dB(A). The brake noise limit is 72 dB(A). The reverse alarm has a noise limit of 66 dB(A). The maximum noise level of all activities is 72 dB(A), which is called the "PIEK light 72 dB(A)". The certificate of "light" is given to truckers who follow noise reduction behaviors such as quiet loading and unloading. The PIEK program covers major noise reduction aspects such as noise legislation, technology, policy and measurement. The basic idea of the PIEK program is to develop solutions to noise problems in freight transportation to enable deliveries in the evening, which reduces congestion, improves efficiency and promotes sustainable transport.

The PIEK program developed the standard TNO test procedure to measure noise: two microphones are placed at 7.5 meters after and beside the vehicle to measure the door noise. Microphone positions for door measurement are illustrated in **Error! Reference source not found.**.

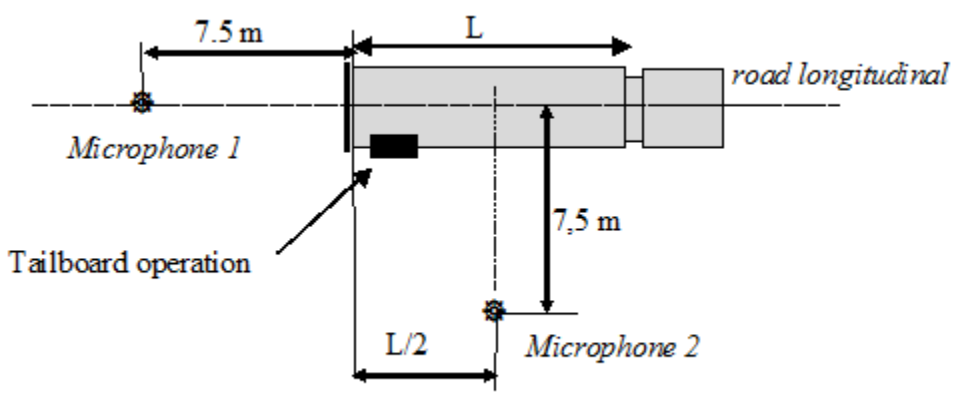


Figure 5 TNO Test for Door Noise Measurement (Source: Goevaers, R., 2010)

Noise measurements for other activities are similar. With such standard noise measurement procedures, products designed for noise reduction could also be measured in a reliable, consistent way.

3.2.2 Chicago

The noise regulations in Chicago are stated in the Chicago Environmental Noise Ordinance document. Noise is therein defined as any sound audible at at least 600 feet, or higher than 70 dB(A), when measured 10 feet away from the source. In addition, it defines a "noise-sensitive zone" as a special zone where no noise is allowed. Places such as schools, libraries and hospitals are regarded as noise-sensitive zones (City Council of Chicago, 2010).

These are the city's general noise regulations. Similar noise restrictions may well be established in freight transportation, establishing limits for the noise level of loading, unloading, driving, and dampers for off-hour deliveries between 10pm and 7am. As in the PIEK program in Europe, noise measurement procedures for trucks could also be defined. Related regulations in Chicago limits drivers to leaving a vehicle with a gross vehicle weight rating (GVWR) over 10,000 pounds within 45 meters of residential properties for longer than two minutes (City Council of Chicago, 2001).

3.2.3 Los Angeles

Los Angeles authorized the Police Department to be responsible for the enforcement of Noise Ordinances. It lists major violations in different sites covering noise levels, distance and time periods for activities near residential areas, as summarized in Table 6.

Table 6 Major Noise Violations in Los Angeles (Source: City Council of Los Angeles, 1982)

Places	Noise level	Distance	Time
Theaters and sound amplifiers	Audible	50 feet from property line	--
Construction noise	Any noise that disturb residents	500 feet for residential zone	6 pm to 8 am for residential zone
Vehicle engine	Any noise that disturb residents	Audible 150 feet from property line	--
Vehicle repair	Any noise that causes discomfort to residents	In residential zone or 500 feet therefore	8 pm to 8 am

The Los Angeles noise regulations include no specific rules on truck noise during off-hour deliveries. No exact noise levels or uniform measurement procedures are established.

3.2.4 Houston

The noise policy in Houston contains limited information on specific noise levels, distances and time periods. It sets maximum sound levels during different time periods and zones, which are summarized in Table 7.

Table 7 Major Noise Violations in Los Angeles (Source: City Council of Houston, 1997)

Places	Time period	Noise level
Residential	7 am to 10 pm	65 dB(A)
Residential	10 pm to 7 am	58 dB(A)
Nonresidential	--	68 dB(A)

Regulations from Houston contain only general information about noise levels during different periods; no specific rules on truck noise or uniform measurement procedures are established.

3.2.5 New York City

The New York City Noise Control Code Title 24, Chapter 2, Subchapter 3 prohibits persons from making unreasonable noise. The noise level limit between 10 pm to 7 am is 7 dB(A), and between 7 am to 10 pm is 10 dB(A). These noises are measured 15 feet away from the property line (The City of New York, 2005).

As in Chicago, New York City prohibits drivers from leaving a vehicle with a gross vehicle weight rating (GVWR) over 10,000 lbs, or that causes noise audible 150 feet from vehicle. The regulations on noise levels during off hours sets limits of 85 dB(A) audible 50 feet away from vehicle between 11 pm to 7 am. However, the noise level was reduced to 80 dB(A) since July 1, 2012. It also sets limits for compactor noise levels of 80 dB(A), audible from 35 feet away (The City of New York, 2005). However, New York State provides noise limits in different GVWR and speeds, which are summarized in Table 8.

Table 8 Noise Limits in New York (Source: The State of New York, 2010)

Gross Vehicle Weight Rating (GVWR) (lbs)	Noise limit		Distance
	≤35 mph	>35 mph	
≤10,000	76 dB(A)	82 dB(A)	50 feet from vehicle
>10,000	86 dB(A)	90 dB(A)	50 feet from vehicle
Compactor	80 dB(A)	80 dB(A)	35 feet from vehicle

4. IDENTIFICATION OF TRANSFERRABLE TECHNOLOGIES

Working closely with the leading designer of the PIEK program, Subcontractor Mr. Robert Goevaers, the Contractor identified further possible noise reduction technologies that could be employed to foster OHD in the City of New York. The majority of the technologies were derived from those identified previously, especially those that have been successfully implemented in other countries or states. Based on their cost and availability in the U.S. market, the Contractor assessed their transferability to the State of New York. To achieve this goal, the Subcontractor and the Contractor worked diligently to acquire information from potential noise reduction product manufacturers. As part of these efforts, the team issued an official Request for Information (RFI), and proactively reached out to noise reduction societies through conferences and meetings.

The RFI explains the purpose of the project, the information to be acquired, and contact information. The RFI was publicized through several venues, including the RPI website and email distribution (by TRB noise committee and project consultant), as well as hardcopy handouts at several noise conferences, including the *TRB* ADC40 Transportation-Related Noise and Vibration Committee summer meeting in July, and the "inter noise 2012 conference" in August. Figure 6 presents the front and back sides of the RFI handout issued at conferences.

Request For Information

Rensselaer Polytechnic Institute (RPI) is issuing a Request for Information (RFI) to gather information on noise reducing technologies to lessen the noise produced by urban deliveries in the off-hour (typically between 10PM and 6AM). These technologies may be suitable for use on trucks, trailers, shipping equipment (e.g., carts and dollies) or at the location of the delivery.

RPI and NYCDOT are working on a program sponsored by the United States Department of Transportation (USDOT) to implement an off-hour delivery (OHD) program in New York City. As part of the project, the team completed a pilot test and noted many successes including participation from major companies. Average travel speeds increased as well as savings due to a significant decline in parking tickets. With less competition for curb space, loading and unloading time also decreased. The success of this pilot phase drew the attention of several federal and state agencies including the USDOT and the US Environmental Protection Agency (USEPA). Several metropolitan areas in the United States have contacted the project team to acquire more detailed information. The USDOT is also exploring the idea of expanding this program to other areas of the country including small and medium sized cities. In general, the impacts of shifting deliveries to the off-hours are advantageous. Subsequently, the New York State Energy Research and Development Authority (NYSERDA) is supporting the research team to identify and test various noise reducing technologies in hopes to successfully implement OHD on a larger scale.

One of the major concerns, is the noise produced by these deliveries during the night. In order for this project to be successful it will be necessary to ensure the deliveries do not provide any negative impacts to communities. Through this RFI, the project team will explore the benefits that various products have for reducing delivery related noises. If your company has a product(s) that could potentially be used to reduce the noise produced by deliveries, we would like to learn more about your products and services.

To respond to the request or for additional information please visit: **http://cite.rpi.edu/off-hour-deliveries-noise/**

This RFI does not commit RPI to contract for any supply or service whatsoever. RPI will not pay for any information or administrative costs incurred in response to this RFI.
Please note that this is only an RFI – this is NOT a Request for Proposals.

Figure 6 RFI Card

Together, through literature review, phone interviews, and RFI, the contractor evaluated the effectiveness and transferability of four types of technologies: quiet drivelines, low noise body and trailer modifications, low noise components, and low noise handling equipment.

4.1 Quiet drivelines

4.1.1 Quiet tractor by DAF Trucks

Figure 7 Quiet Drivelines (Source: Goevaers, R., 2010)

4.1.1.1 The product

DAF Trucks was responsible for the undercarriage and the engine, while PD&E modified the cabin. The project began in May 2001, and the conversion was completed and tested in February 2002.

The following modifications were made:

- Since engine noise is directly linked to engine speed, the idea was to develop an engine management system that could be engaged in noise sensitive areas.
- The second partial solution is an adaptive full enclosure for the engine. The biggest problem with enclosure is engine heat, but since trucks must be driven calmly in noise sensitive areas, the temperature issue is less critical. In this situation, the cooling valves can be closed, limiting engine noise.
- Electronically controlled disc brakes were applied.
- An electronically-controlled gearbox, which is quite prevalent these days, was applied.
- PD&E-modified electronic doors and locks were installed.
- Options for a 'quiet' exhaust system that is activated on low speeds were included.
- A Susvat brake system was installed, which reduces the noise level of escaping air from the brakes.

The product has shown that it can meet the 65 dB(A) standard. In terms of the 60 dB(A) requirement, tests have indicated that the limit can be achieved under many conditions. The most difficult of these applies to accelerating from standstill, and the 60 dB(A) standard cannot be achieved in this condition..

4.1.1.2 Economic aspects

Based on the demonstrator unit built, it is difficult to determine precisely what the investment and added costs would be for the quiet tractor. Some of the necessary changes must still be made, including the enclosure. Assuming a production capacity of 1000, an added cost of 15% is estimated. The majority of the added cost is due to the automatic transmission. The product has shown that it is technically possible for engine noise to meet the 65 dB(A) criterion. However, economic feasibility remains an issue. DAF eventually decided not to introduce this vehicle to the market because it was not convinced the market was willing to pay 15,000 euro extra for these low noise features.

4.1.2 Iveco Stralis LNG low noise tractor unit

4.1.2.1 The product

Iveco made the following modifications:

- CNG engine: Instead of a diesel engine, Iveco introduced a heavy truck with 330 HP with a Compressed Natural Gas engine. Because of its lower compression, this engine is far quieter than a diesel engine.
- The next step was to deal with the distance problem; CNG has the disadvantage that it can only drive about 300 kilometres. By changing to LNG (liquefied natural gas), the distance was increased to 900 kilometres, which made the truck practical for national transport hauliers.
- Electronically-controlled disc brakes were applied.
- An electronically-controlled gearbox was applied.
- The motor management system was modified so the RPM level is limited in noise-critical areas.

All the modifications resulted in the first production truck achieving an overall noise level of 72 dB (A).

4.1.2.2 Economic aspects

Iveco's tractor unit was not inexpensive, a basic unit costing about 75,000 euro. The modification to a CNG engine costs about 15,000 euros, and adding LNG tanks requires an extra 15,000 euros. The advantage of this truck, besides its lower noise level, is that it runs on gas, which is about 15 euro cents cheaper than diesel. After a research and development period of 8 years, Iveco finally introduced a low noise tractor unit. The first year after the introduction 50 trucks were sold.

4.1.3 Mercedes Econic LNG

A year after the introduction of Iveco's, LNG tractor, Mercedes introduced a low cab LNG tractor unit, specifically designed for city distribution. The low cab is favored by drivers as they do not have to climb in the cab, and they have a better overview of what is happening in front of and on the right side of the truck. This area is very often the most problematic in terms of accidents with bicycles.

4.1.3.1 The product

- For engine, Mercedes introduced this truck with a 280 HP Compressed Natural Gas engine. It also has a version with LNG that allows a longer (900 kilometres) distance;
- The modifications on brakes, gearbox and motor management system are the same as Iveco's low noise tractor;
- Doors open with air suppression.

All of the modifications resulted in their first production truck achieving an overall noise level of 72 dB(A)

4.1.3.2 Economic aspects

The Mercedes Econic LNG costs about 40,000 euro more than a standard truck. While this is a market disadvantage, there is still interest in the truck because of its sustainable features. The first year it was introduced, 40 units were sold. The truck has been used in Amsterdam and Nijmegen, but is less suitable for long distance or highway transportation.

4.1.4 Volvo hybrid

Volvo developed this hybrid vehicle initially as a garbage collection truck. Hybrid vehicles produce less CO2 because the energy from braking is regenerated, making the frequent urban stops of a garbage truck an ideal candidate for a hybrid vehicle. After the successful introduction of its technology on garbage trucks and buses, Volvo decided to introduce it to trucks optimized for city operation. In 2012, Volvo introduced their hybrid truck to the Dutch market, and started the test cycle. In principle, a hybrid vehicle is a vehicle with two engines, in this case diesel and electrical. Having an electrical engine does not necessarily mean that the vehicle is silent. In some cases, the vehicle cannot run in full electrical mode. The diesel engine has to function as a generator to supply the electrical engine with energy. In Volvo's case, the design was to make the vehicle capable of running fully electrical.

4.1.4.1 The product

- For quiet urban transport, Volvo decided to design a vehicle capable of full electrical driving. While its distance is limited to 2 km, this is sufficient to deliver urban cargos without causing noise complaints.
- The truck's 120 KW electrical engine is very quiet because there is no combustion. This electrical engine is placed between the diesel engine and the gearbox, which means that the vehicle can be built on the standard production line, a significant advantage.
- An automatic gearbox is included.
- The motor management system is also modified to limit the RPM level.
- Equipped with a 'silent mode' button, the driver can press this to operate the vehicle in full electric mode.
- It is capable of an overall noise performance, in full electric mode, of under 72 dB(A)

4.1.4.2 Economic aspects

The price of this vehicle is not yet known; it is only available for lease. The Volvo hybrid is expected to expensive, but about 20% of its fuel cost can be cut compared to a diesel engine. Overall, this technology seems to be economically viable. The market is waiting for a tractor version.

4.1.5 Renault Max City Electric

In 2011 Renault introduced to the market their first fully electrical truck, specifically designed for urban deliveries of small quantities.

4.1.5.1 The product

- Fully electric, and very quiet, it is the first small truck that meets the toughest PIEK requirement of 65 dB(A) without any modification..
- Its operation range of 150 kilometres is more than sufficient to operate the in the centre of a city. If cargos have to be delivered in the suburbs, this range may not be sufficient.
- Quite heavy; because of the battery package the truck's basic weight is 4500 kilogram.
- A manual gear box is included, which makes the most noise of the entire vehicle.
- Very quiet brakes are installed, but not specifically modified to make the 65 dB (A) level.

4.1.5.2 Economic aspects

The Renault Max City Electric costs about 90,000 euro, compared to a standard diesel propelled truck (30,000 euro). While the additional cost is fairly high, there are also savings due to the low vehicle operation costs.

4.1.6 Electronic Speed Limiter' (ESL) by Groeneveld

Drive noise comes from the engine, transmission and brakes, and is largely determined by speed and RPM. Electronically limiting speed and RPM is therefore one option for limiting noise, particularly when commercial vehicles drive up and drive off. Two companies were involved in finding out to what extent intelligent speed/rev limiters result in noise reduction. This section focuses on the ESL product by Groeneveld.

4.1.6.1 The product

The ELS product was initially developed to limit extreme driving behaviour. Suitable for delivery and cargo vehicles, tests in late 2002 showed that the product can also contribute to noise reduction during acceleration based on tests done in late 2002 The 60 dB(A) standard can be achieved with light delivery vehicles fitted with a limiter. Detailed test results are given in Table 9, below.

Table 9 Tests Results

Vehicle	Constant speed	Accelerating
Mercedes Vito	-3 dB(A)	-12 dB(A)
Mercedes Sprinter	-3 dB(A)	-9 dB(A)
Mercedes Atego	-4 dB(A)	-7 dB(A)

4.1.6.2 Economic aspects

The price of electronic rev/speed limiters varies. The second generation of limiters is more expensive, but also more attractive to fleet managers. Not only does it comply with PIEK, it also results in considerable fuel and maintenance savings for the vehicle. However, for heavier delivery vehicles, installing a limiter alone is not sufficient; engine insulation is also required.

4.1.7 Intelligent speed limiter by Ecodrive/Ecocargo

In addition to Groeneveld, ProfSave brought two products to the market. In short, for lighter delivery vehicles, the 60 dB(A) standard can be achieved using a limiter. In terms of noise in heavier vehicles, the 65 dB(A) standard can be achieved, but not the 60 dB(A) standard.

4.1.7.1 The product

4.1.7.1.1 Ecodrive

Ecodrive is a speed rev limiter (second generation) that penalizes the driver for exceeding the limit. Research in four test situations has shown that the intelligent speed limiter by Ecodrive contributes significantly to making trucks quieter. The results are given in Table 10 below.

Table 10 Speed Limiter Results for Trucks Fitted with Ecodrive Limiter

Vehicle	20 km/h (constant)	Braking	Reversing	Accelerating
Mercedes Vito	60	60	56	67
Mercedes Sprinter	62	65	56	63

Clearly, light commercial vehicles under 3.5 tonnes can achieve the PIEK standards for loading and unloading in the evening, except when accelerating. Ecodrive does not meet the night standard. The limiter can be fitted to new vehicles, but is also well-suited to retrofitting.

4.1.7.1.2 Ecocargo

A project was started in 1999 to develop a third generation limiter for delivery vehicles and light trucks up to 12 tonnes. The limiter takes effect sooner than the moment the established top speed or top RPM is reached. It measures the gear, and then calculates whether the limits will be exceeded, and if so, the limiter takes effect immediately. The advantage is that action is taken during the process leading to the limit being exceeded, not just when the limit is reached. It is expected that this will bring compliance with the PIEK standard closer. Of the five vehicles

tested (VW Caddy, VW Transporter, MB Vito, MB Transporter, MB Atego), the Sprinter and the Atego do not meet the requirements for the evening and night, and the Caddy is not yet suitable for night.

The following tables show the results of the maximum sound levels.

Table 11 Sound Levels without Ecocargo

Vehicle	20 km/h (constant)	Braking	Reversing	Accelerating
VW Caddy	66	65	58	69
VW Transporter	60	59	58	66
Mercedes Vito	60	57	55	68
Mercedes Sprinter	65	63	55	74
Mercedes Atego	77	72	66	81

Table 12 Sound Levels with Ecocargo

Vehicle	20 km/h (constant)	Braking	Reversing	Accelerating
VW Caddy	61	59	58	62
VW Transporter	58	59	58	60
Mercedes Vito	59	57	55	59
Mercedes Sprinter	59	57	54	66
Mercedes Atego	71	68	66	70

4.1.7.2 Economic aspects

The price of electronic rev/speed limiters varies greatly. The limiter is on the Ministry of Finance's list for energy investment deductions (EIA), and fuel savings of 10 percent proved feasible during a pilot project.

4.2 Low noise body and trailer

4.2.1 The VOC vehicle with 'quiet' structure

There are many types and sizes of trucks. Vehicles less than 7.5 tonnes actually consist of two components: the motor vehicle and the structure. Making the structure quieter was the focus of the 'VOC Whisper Truck' project.

Figure 8 Low Noise Body (Source: Goevaers, R., 2010)

4.2.1.1 The product

The project consists of innovations in a series of components. Because the final result of the project had to be a 'quiet' distribution vehicle, the assistance of VOC and Booi Carrosseriën was sought. The integrated 'quiet' distribution vehicle was successfully presented as the Whisper Truck in early February 2000, at the RAI commercial vehicles exhibition. The structure of the Whisper Truck meets the standard for night distribution, which is < 60 dB(A). 'Quiet' solutions were achieved for the floor, walls, doors, ceiling and taillift.

The following components were modified:

- floor, fitted with noise-absorbing material;
- ceiling, fitted with noise-absorbing foam;
- walls, fitted with rubber bumper strips;
- taillift, fitted with a noise-reducing layer whereby a coating is applied and hollow spaces are filled by spraying; also, the hydraulic system includes low-noise pump;
- hinges and locks, modified;

4.2.1.2 Economic aspects

The quiet version modifications of the structure add about 15% to the truck cost. While these solutions are also suitable for retrofitting, the added cost of modification for retrofits is higher. The VOC vehicle already showed in 2000 that a 'quiet' solution can be built for the structure that meets the PIEK standard of 60 dB(A). It should be noted, however, that the solution built is subject to wear through intensive use, which reduces noise performance. As a result, research into greater floor durability has begun.

4.2.2 Quiet refrigerated trailer, Post-Kogeko

The Post-Kogeko refrigerated trailer has shown in technical and economic terms that the 60 dB(A) standard is feasible. All incorporated solutions to make a refrigerated trailer 'quiet' are now available at a limited added cost.

Figure 9 Quiet' Refrigerated Trailer (Source: Goevaers, R., 2010)

4.2.2.1 The product

A 'quiet' refrigerated/freezer city trailer was built together with Booi Carrosseriën, Thermo King and Hoek Loos, for the Post-Kogeko transport company. New to this city trailer is its use of a refrigeration system using CO_2 as the refrigerant (a cryogenic refrigeration system). This system, by Thermo King of the US, ensures that the peaks for the refrigeration system remain below 60 dB(A). Recycled CO_2 is used rather than the customary burning of a petroleum product, so that the refrigeration process does not create new CO_2. Research abroad has shown that the balance is tipping in a positive sense towards less CO_2 emissions. A conventional diesel-powered unit produces more CO_2 than is released by CO_2 refrigeration. The project has shown the technical feasibility of the cryogenic refrigeration system, and when used on a large scale, this new technology will contribute to reducing the greenhouse effect. The system appears to score better than the conventional product (diesel-powered) in various aspects.

In addition to the modified refrigeration, the floor and walls of the vehicle have a special coating to reduce noise pollution. The taillift has been modified, and the vehicle is also fitted with a 'quiet' reversing signal.

4.2.2.2 Economic aspects

- The added cost of a 'quiet' version of the refrigerated truck is less than 10 percent.
- The economic lifespan of trailers is 6 -10 years; the technical lifespan can be as long as 12 years.

- In daily use of the trailer, no cost differences were indicated during the practical test for all parts, except the refrigeration machine.
- The refrigeration machine is more expensive to purchase, but cheaper to run. The cheaper refrigeration machine, however, does not compensate for the added cost of the 'quiet' city trailer.

4.2.3 Quiet Trailer, Schmitz Cargobull

Schmitz Cargobull, Carrier and Mariba have developed a 'quiet' refrigerated trailer to limit noise pollution.

4.2.3.1 The product

Schmitz Cargobull's contribution is aimed at two parts of the trailer: the floor and the wall. The biggest challenge was developing a 'quiet' floor.

Finding the right foundation was an interesting task. A completely smooth floor presents little friction, hence little noise when containers are rolled over it. A smooth floor, however, has a major disadvantage. When the floor is wet, there is a high risk of slipping.

The solution was found in an aluminum floor with slots cut into it lengthwise. Aluminum is smooth, and therefore low-noise. The slots ensure that the floor does not become slippery, so that people and cargo can maintain a grip on the floor.

The wall also plays a part in noise production in that rolling containers collide with the side walls. Schmitz Cargobull has fitted the wall with a sandwich wall, or plastic protective layer, to enclose noise production.

The floor is not only low-noise, it also complies with occupational health regulations. The floor and wall are suitable for all types of trailers, not only refrigerated trailers.

4.2.3.2 Economic aspects

The cost of this product is not entirely known, but expected to be reasonably low.

4.3 Low noise components

4.3.1 Taillifts Dautel, Dhollandia, Mariba, STAMA

Virtually all trucks used for urban distribution are equipped with taillifts to allow the driver to unload goods quickly at the location. The roller stops of a standard taillift indicate a PIEK load of 93 dB(A), indicating great potential for noise control. Making the taillift quieter proved quite possible. One aspect requiring attention is wear and tear, particularly of the cast floors, which reduces noise performance.

Figure 10 Low Noise Components (Source: Goevaers, R., 2010)

4.3.1.1 The product

'Quiet' taillifts have been developed by Dautel, Dhollandia, Mariba and STAMA. The modifications made by the manufacturers are comparable.

- Since the *electric motor* powering hydraulic operation of the taillift often exceeds the PIEK standards, insulating the motor is a solution.
- The lines of the *hydraulic pump* used to control the taillift often cause PIEK standards to be exceeded. Insulating and securing these lines in several locations reduces noise considerably.
- *The surface of the taillift*, which is usually steel with a non-skid layer, can be given an extra noise-absorbing coating. Because the taillift is usually hollow, it also acts as a sound-box.
- The *roll-off limiter* on the taillift also causes PIEK standards to be exceeded, so rubber bumper strips can be fitted to the taillift surface.
- When the taillift is *opened*, specifically on contact with the road, the PIEK standard may also be exceeded. The solution is to fit rubber on to the edge of the taillift.
- Finally, *closing* the taillift and contact with the body can be noisy; rubber bumper points help lessen this noise.

4.3.1.2 Economic aspects

There is little difference in the prices of the various brands of taillifts, and the cost of 'quiet' taillift modifications add about 10-15 percent.

4.3.2 Electric roller door

Vehicles used for urban distribution are often equipped with a roller door that is less than ideal in terms of noise control. Just before closing, the roller door's weight causes it to close at

some speed, resulting in considerable noise. This section focuses on the electric roller door developed by Transport Load Systems. In the future, hauliers will increasingly choose electric roller doors over non-electric versions; the electric version is quieter, safer and better in terms of occupational health.

4.3.2.1.1 The product

The electric version of the roller door slows it down when it reaches the maximum opening point, and also when it falls shut. This results in much less noise during loading and unloading, a noise of 57 dB(A), well below 60 dB(A) standard. The electric roller door also has added value in terms of safety. The door stops immediately when it encounters resistance, e.g., if a hand or package is in the closure. Quieter and safer, the roller door is CE approved, and complies better with occupational health directives than does a standard roller door.

4.3.2.1.2 Economic aspects

An electric roller door is more expensive than a conventional roller door. This cost difference may be offset by some advantages, such as low noise, ease of use, and occupational-health compliance.

4.3.3 Floor coatings

Contact between rolling containers and the floor of the truck during loading and unloading is another major source of noise.

4.3.3.1 The product

4.3.3.1.1 DVN Click-it floor (composite floor)

- One ‘quiet’ solution for finishing the floors and walls of the truck body comes from DVN of Zutphen. The product is called ‘Clickit’ and offers an alternative to conventional floor systems. A floor usually starts as a steel or aluminum frame to which a wooden floor is mounted. This is labor-intensive, takes up space, and results in many kilogrammes of extra weight.
- The Clickit system consists of sections made of composite materials, which combine the strong properties of various materials. DVN has built a finish for the floor that is ‘quiet,’ strong and light, and is in compliance with hauliers’ requirements for durable bodies.
- The system is not intended to replace aluminum, steel or wooden structures. It is a good alternative where there are strict demands in terms of reducing loading and unloading noise, and/or saving weight. The floor meets the 60 dB(A) PIEK standard.

4.3.3.1.2 KCN coating (spray coating)

- The plastic floor coating by Kunststof Coatings Nederland is effective to make loading and unloading quieter in residential areas. The coating is a protective layer of plastic that can be applied to various foundations, from steel and aluminum, to wood

and polyester. A layer of half a centimetre is enough to protect the floor, as well as to absorb sound.

- In this system, two liquid plastic components are heated separately and combined under pressure in a spray gun. A chemical reaction occurs immediately, forming the coating. The immediate mixing and short reaction time results in a very robust, solid coating. The material's high density ensures that sound waves are absorbed, so noise caused by rolling and sliding over the floor remains below, 60 dB(A). The floor is moisture and UV-proof, resistant to many chemicals, and meets HACCP and ARBO standards.

4.3.3.1.3 Zepro floor (poured coating)

- Zepro wanted to develop a 'quiet' floor that also had low rolling resistance, durability, and met HACCP requirements. Their choice of material is a two-component system with a polyurethane base that is highly noise-absorbent, temperature-resistant and resistant to acids, salt solutions, etc.
- In practice, however, some users find the coating susceptible to wear when they apply it to an incorrect foundation (one for which it is not recommended).

4.3.3.1.4 Ruco Industries Rucoating (poured coating)

- RUCO Industries has been producing floor coatings for the transport trade for some time. Measurements by Cintec in 2001 showed that these coatings are important in reducing noise during loading and unloading. Encouraged by these results, RUCO continued to develop 'quiet' floor coatings, with Rucoating as the final product. Noise level measurements have the following results at present:

Driving forklift over tread plate	83 dB(A)
Driving a forklift over a smooth metal plate	69 dB(A)
Driving a forklift over a tread plate with Rucoating	60 dB(A)

- Applying Rucoating to the taillift means that manoeuvring the cargo is quieter by 19 dB(A) on average.

4.3.3.1.5 Rhiwa Carfloor 'quiet' floor (poured coating)

- Rhiwa was one of the first manufacturers to actively start work on noise control. They provided the floor for the 'Whisper Truck,' previously discussed.
- To create a 'quiet' floor, both the hot spray process and manual application are used, and a rough top layer is achieved by incorporating rubber granules in the top layer. This process results in a floor that is well below 54 dB(A).

4.3.3.1.6 Rhino Linings noise-absorbing floor coating (spray coating)

The last floor to be described here is the noise-absorbing floor coating by Rhino Linings. This floor coating is applied in a spray process, which adheres well and provides an airtight and watertight seal for the coating. The most suitable coating for goods transport is Tuff Stuff, with a

hardness of 90 Shore. The coating reduces noise by 25 dB(A). The manufacturer claims that the floor will adhere to virtually all foundations, which makes it very suitable for retrofitting applications.

4.3.3.2 Economic aspects

A coated floor is obviously more expensive than a non-coated one. Prices vary greatly for each solution described, because of the difference in function and durability. Hauliers have a wide range of 'quiet' floors to choose from. Adhesion and durability of the floor coatings must be reviewed further.

4.3.4 Quiet reversing alarm system

Many trucks are equipped with reversing signals to warn bystanders of a manoeuvring truck. The warning signal produces a standard 110 dB(A). There are several solutions to replace this warning system. Here are two of them: the Groeneveld warning system (Greensight), the GrootJebbink rearview systems.

4.3.4.1 Greensight reverse warning signal

Figure 11 Greensight reverse warning signal (Source: Goevaers, R., 2010)

4.3.4.1.1 The product

The Greensight system by Groeneveld works with a detection system at the rear of the truck. The sensors use triangulation to determine the distance between the object and the vehicle, which gives the driver very precise and reliable information. The driver has a compact display in the cabin that uses light signals and sounds to warn of obstacles and people outside of the driver's field of vision.

As soon as an obstacle is within three metres during reversing, the display will show blinking LED lights. A built-in buzzer in the cabin will also sound, with the volume of the sound depending on the distance of the object to the vehicle.

4.3.4.1.2 Economic aspects

Using a 'quiet' reversing system is considerably more expensive than the well-known beep. On the other hand, these 'quiet' systems are considerably safer, and will contribute to a decrease

in accidents and damages. The system is a good solution for detecting obstacles and people behind a truck without creating as much noise.

4.3.4.2 GrootJebbink reversing alarm

The characteristic beep noise carries over a large distance. In residential areas especially, this is considered irritating. GrootJebbink has developed some 'quiet' reversing alarms, suitable for various situations.

4.3.4.2.1 The products

The reversing alarm has a list of different products. They are introduced below.

4.3.4.2.1.1 Night Silent

This alarm has a special night setting that meets the standard of 60 dB(A). During the day, the normal volume is audible; the 'quiet' alarm is intended for night use. In terms of international transport, this alarm also meets the Austrian legal standard for reversing alarms for trucks larger than 7.5 tonnes.

4.3.4.2.1.2 Smart Alarm

This is a self-regulating alarm. A built-in microphone function measures ambient sound. If there is no significant ambient sound, the alarm produces a sound meeting the 60 dB(A) standard. If ambient sound increases, the volume of the alarm also increases. Residents therefore do not have their sleep disturbed, while during the day, when there are many people in the street, the beep clearly warns that the truck is reversing.

4.3.4.2.1.3 BBS-Tele

This alarm has different characteristics because it uses broadband sound technology to ensure that the sound mutes itself. It is audible at a limited distance from the vehicle, but residents do not hear it because the alarm works at a 90-degree angle, instead of the standard 360 degrees. This means that bystanders immediately know where the sound is coming from, and which vehicle will be reversing.

4.3.4.2.1.4 UltraSone radar sensors

With this alarm, sensors detect the blind spot behind the vehicle when it is reversing. If someone is standing within three metres behind the vehicle, the reversing alarm will automatically engage, and the brake may be activated automatically. The driver will also see the person on the audiovisual display. The UltraSone is not susceptible to water, snow, mud or noise, which makes it very suitable for construction machines and shovels.

4.3.4.2.2 Economic aspects

A 'quiet' reversing system is more expensive than the well-known beep. On the other hand, these 'quiet' systems are considerably safer, and will contribute to a decrease in the number of accidents and amount of damage.

4.3.5 Carrier diesel refrigeration

Various 'quiet' refrigeration systems have been developed. Carrier opted to make conventional diesel-powered refrigeration 'quiet' using enclosure with noise-absorbing material.

4.3.5.1 The product

The noise of a transport refrigeration machine comes from three sources:

- Ventilation (required to extract heat from the cargo area);
- Compressor vibration and noise;
- Drive vibration and noise;

To eliminate noise, Carrier developed a refrigeration system in which the components are configured separately from the refrigeration power source. The diesel engine is usually attached at the top of the front of the truck, on the bulkhead. In Carrier's solution, the diesel engine is mounted separately, under the trailer. There is more space available under the trailer for optimal insulation of the engine. The free space around the diesel engine can thereby be used for absorbent material and attenuators. After modification, the refrigeration system meets the standard of 60 dB(A). The solution is such that retrofitting is unfortunately not an option.

The refrigeration is therefore simply powered by a separate diesel engine, a proven and reliable source of propulsion. The diesel engine runs at the most efficient speed, so that emissions meet environmental requirements and fuel consumption is minimal. An additional advantage is that the diesel engine mounted under the trailer is now more easily accessible for periodic maintenance.

This 'quiet' refrigeration also benefits the driver. The noise from the refrigeration system is less disruptive when the driver sleeps in the cabin at night, because it is under the trailer and better insulated instead of being above the cabin. The refrigeration system is also available in two or three components.

4.3.5.2 Economic aspects

- The added cost of this solution is about 40 percent of a standard truck.
- A major advantage of the 'Carrier Concept' is that it guarantees 24-hour delivery to the haulier.

The solution developed by Carrier, and the refrigeration systems described below, give hauliers a wide range of choices in 'quiet' refrigeration. Carrier's refrigeration system was introduced in 2003, and sells well.

4.3.6 Thermo King cryogenic transport refrigeration

Conventional refrigeration systems contain a diesel engine that is the source of the refrigeration unit's noise. Noise is not the only disadvantage; conventional refrigeration systems

with combustion engines emit substances that harm the environment. An alternative is to use cryogenic refrigeration systems, which use cooled gas. This section discusses the Thermo King refrigeration system, which uses cooled CO_2 gas.

4.3.6.1 The product

The most important difference compared to conventional refrigeration for trucks is that the products are refrigerated with CO_2. When oil is refined at Pernis, CO_2 is captured and purified. The cold gas is atomised in the cargo space of the truck, refrigerating the products. This means the desired temperature in the cargo compartment can quickly be re-established after unloading.

Thermo King has developed a transport refrigeration unit without a diesel engine. The absence of the diesel engine reduces noise by 20-30 dB(A), and Thermo King's application meets the 60 dB(A) noise standard.

An additional advantage of a cryogenic refrigeration system is its high refrigeration capacity. which means the quality and shelf life of refrigerated and frozen products remains optimal. Cryogenic refrigeration therefore has technical and social benefits.

4.3.6.2 Economic aspects

- The refrigeration machine is more expensive to purchase but cheaper in practice, as the machine requires virtually no maintenance.
- In addition to the cost of purchase of the refrigeration machine, a filling station must also be installed at the place of business

4.3.7 Tire mufflers

Tire noise stays with drivers throughout their shifts, which can be annoying to both drivers and passengers, and may lead to driving interference. One way to avoid the noise going through the cabin is to put a foam layer inside the tire behind the tread. It does not have any effect on normal driving, but does reduce noise.

4.3.7.1 The product

Tire mufflers aim to reduce noise from the tires going through the cabin during driving. The company or driver puts a 20mm thick layer of polyurethane foam inside the tire behind the tread which muffles noise coming from the tread as it rolls on the road surface.

The performance varies by type of vehicle, speed, and road surface. It is estimated the muffled tire can help reduce the noise going into the passenger compartment by as much as 9 dB absolute. The foam layer has no effect on vehicle handling, gasoline mileage, or load capacity.

4.3.7.2 Economic aspects

The foam tire muffler is a relatively cheap material, so the cost of adding tire muffler should be acceptable to drivers. It is easily produced, shaped and installed, and requires no specific

technology. So the cost of adding tire muffler should be acceptable to drivers. The tire muffler has already been tested and adopted in several automobile companies. It is a practical and promising product to reduce noise, but whether it could be used in trucks needs to be further studied.

4.3.8 Solar based auxiliary power unit

Solar energy harnesses energy from the sun. It is clean, safe, resource-rich and environmentally friendly, and has tremendous potential to become the major human energy source in the future. Consequently, countries around the world are paying special attention to developing solar-based technologies. Solar-based auxiliary power units (APU) have been developed to provide power assistance to trucks in the form of safety lighting, no-idle HVAC, life gate systems, and refrigeration. These products have less dependence on gasoline combustion, so solar-based APUs reduce fuel consumption, engine maintenance costs, and greenhouse gas emissions.

4.3.8.1 Product

Solar-based auxiliary power units (APU) can be used for a variety of products, such as:

Safety lighting: to supply power for safety lights on light duty road construction and service vehicles.

No-idle HVAC: eliminates fuel consumption from diesel-powered APU's, or the engine alternator to charge batteries. Reduces additional load on engine alternator, resulting in reduced fuel use and engine maintenance costs, and reduces fuel consumption by eliminating engine idling

Lift gate systems: supplies power to stand-alone lift gate batteries, reducing the demand from the engine alternator. This results in reduced fuel consumption, and longer battery life.

Refrigeration: supplies power to keep cold-plate storage systems charged, or to run evaporator fans while in operation. Extends daily range, reduces fuel consumption and reduces system maintenance costs.

Figure 12 Safety lighting

Figure 13 No-idle HVAC

Figure 14 Lift gate systems

Figure 15 Refrigeration

Source: eNow Solutions. (2013)

4.3.8.2 Economic aspects

With their use of solar energy, and less dependence on gasoline combustion, solar-based APUs reduce fuel consumption, engine maintenance costs, and greenhouse gas emissions. It is estimated that by using solar-based APUs, the total costs avoided for idling would be around $8,000 per year per truck. Tax savings from solar idling reduction equals around $7,746 per year. A more detailed APU comparison is summarized in Table 13 below.

Table 13 APU Costs Comparison

	Diesel APU	Battery APU	Class 8 Truck	eNow APU
Fuel cost				
Gallons per hour	0.35	0.25	1.25	-
Hours per day	7.00	7.00	7.00	7.00
Days per year	250.00	250.00	250.00	250.00
Cost per gallon	$4.00	$4.00	$4.00	$4.00
Total	$2,450.00	$1750.00	$8750.00	-
Equipment cost				
Gross equipment cost	$9,500.00	$9,000.00	-	$11,367.00
Less incentives	$1,600.00	$1,600.00	-	$3410.10
New equipment cost	$7,900.00	$7,400.00	-	$7,956.90
First year cost				
New equipment cost	$7,900.00	$7,400.00	-	$7,956.90
Fuel cost	$2,450.00	$1750.00	$8750.00	-
Maintenance cost	$500.00	$500.00	$1,500.00	-
Total	$10,850.00	$9,650.00	$10,250.00	$7,956.90
Daily cost				
1st year cost	$10,905.00	$9,332.00	$9,947.00	$8,400.00
Daily cost	$43.62	$37.33	$39.79	$33.60

4.4 Low noise handling equipment

4.4.1 Hand pallet truck

A hand pallet truck is used to load and unload pallets. The hand pallet truck is not powered, but is equipped with a hydraulic mechanism to lift the pallet. Research initially focused on identifying the sources of noise and the transmission routes for vibration. The hand pallet truck was then made quieter. The same approach was used for an electric pallet truck. The project has shown that a hand pallet truck and an electro pallet truck can remain within the 60 dB(A) standard. Both products have been in production since October 2004. It is now a matter of waiting for the next market demand.

4.4.1.1 The product

While riding with and without a load, the hand pallet truck produces noise with values that vary from 81 to 87 dB(A). On further examination, some parts proved to be acting as sound-

boxes, and the wheels proved to contribute considerably to the high noise levels. The values were not much different for the electro pallet truck.

A 'quiet' version of the hand pallet truck was first measured and was not yet optimized for noise control. The values were between 70 and 75 dB(A). BT succeeded through this project in keeping the hand pallet truck and the electro pallet truck under 60 dB(A). The hand pallet truck was made 'quiet' by installing softer wheels, eliminating play and removing the rumble from the plate material, among other measures. Similar measures were taken with the electro pallet truck and a dimensioned pump was used. In early versions, noise performance proved to be highly dependent on regular maintenance, yet the latest models are less sensitive to these maintenance factors.

4.4.1.2 Economic aspects

- The 'quiet' hand pallet truck is about 50% more expensive than the standard version.
- The manufacturer is aiming to increase the base price by about 10%. This will not be within reach until it can be delivered ex works, and there must be a bigger market for the 'quiet' solution.
- The situation is slightly different for the electro pallet truck. The added cost is higher in absolute terms, but more favourable in relative terms. The price difference is some 38% for single piece production. If ex works delivery is possible, the price will be about 15% higher than for the conventional version.

4.4.2 Silent Roll container Container Centrale

Rolling containers are used to supply shops quickly and efficiently. Research was carried out on how these can meet the noise control standard. While there are no technical limitations on the use of 'quiet' rolling containers, in view of the huge number of rolling containers in circulation, it would be an expensive undertaking to replace all conventional rolling containers with 'quiet' versions.

4.4.2.1 The product

Various modifications have led to the low noise roll containers. First, new noise-absorbing wheels were developed. The sound of a moving empty rolling container also appears to be a problem. The most important noise sources are the metal parts that vibrate during movement and transmit vibrations to the entire frame.

Applying noise-absorbing materials between the metal parts achieved very good results. Finally the noise that occurs when the containers are nested was studied. To counteract the noise, the roll container has rubber bumpers on nesting contact points. This significantly reduces noise production.

4.4.2.2 Economic aspects

In technical terms, the solution can be adapted on new trucks or as a retrofit. In economic terms, only the new truck installation solution is feasible.

4.5 Potential manufactures in the U.S. providing noise reduction technologies

In order to acquire information about low cost noise reduction technologies available in the U.S. market, the Request for Information (RFI) has been distributed through many venues, including email lists of professional organizations, conferences, and the Subcontractor's network in Europe. Seven companies have provided information in response to the RFI, as summarized below (Company name and contact information have been removed in the report, but are available upon request).

4.5.1 Company A: Broadband Sound Alarm

Products: 3 different self-adjusting, white sound back up alarms
SA-BBS-107 Self-Adjusting Heavy Duty (87-107 dB)
SA-BBS-97 Self-Adjusting Medium Duty (77-97 dB)
SA-BBS-97HV Self-Adjusting Electronic Forklift (77-97dB)

Level of noise reduction: Continually adjusts to 5-10 dB above ambient; bbs-tek alarms make a "ssh, shh, shh" sound instead of the shrill beep of a traditional tonal alarm

How product works to limit noise: Wide frequency spectrum broadband sound rather than the more familiar strident tonal alarm; sound is confined to the danger area.

New or Retrofit? Can be installed on trucks, busses, and refuse vehicles

Costs:

Hardware	$75-$125 (US dollars)
Installation	
Operation/Maintenance	
Total	

Certifications: SA J994 certified, PIEK, Quiet Mark

Warranty: Life-time warranty

Merits: Wide frequency range; sound confined to where you need it; dust and waterproof – can be steam-cleaned or pressure hosed.

Limitations: Units need to be carefully placed to point directly to the hazard area (line of sight can't be blocked)

4.5.2 Company B: Electric Truck Mounted Forklift

Products: Hiab Moffett Electric Truck-Mounted Forklifts (E-series)

Noise level: Maximum of 60dB(A)

How product works to limit noise: The Hiab Moffett E2 comes with the latest AC electric motor technology. The hydraulic components are driven by a silent helical gear pump and all operator controls comprise of programmable electric steering with hand lever for forward / reverse drive via an electric throttle pedal. Boasting the latest lithium-ion battery technology the E-Generation excels with low noise levels and smooth performance.

New or Retrofit? The forklift can be mounted on any truck

Costs:

Hardware	N/A
Installation	
Operation/Maintenance	
Total	

Certifications: All meet Dutch PIEK certification (emits less than 60 dB at 7.5 m from the sound source) except the Trolley which is currently being tested The E2 has been nominated and short listed for the prestigious SV Innovation Award, reinforcing the importance of innovation in the transport sector.

Warranty: Life-time warranty

Merits: E2 model has a lifting capacity of 1200kg (2640 lbs)

Limitations: Maximum capacity is 400 kg (880 lbs)

Where used: 40 countries worldwide – large presence in Western Europe and the US

4.5.3 Company C: "Blueeze" Indirect Truck/Trailer Refrigeration

Products: blueeze ™ – Liquid Nitrogen Truck/Trailer Refrigeration System

Noise level: Testing at 7m showed a volume of 70 dB or less

How product works to limit noise: cooling system based on indirect cooling with liquid nitrogen

New or Retrofit? Both

Costs:

Hardware: $30,000-$50,000 depending on configuration - new or retrofit both possible
Installation
Operation/Maintenance
Total

Certifications: PIEK

Warranty: N/A

Merits: Very quiet cooling system does not run on diesel, and there are no CO2 emissions. The system is modular and easy to integrate. Low maintenance costs. Higher refrigeration performance available in certain configurations.

Limitations: Supply station is required for nitrogen refueling. Local service providers are needed in for regular maintenance, and occasional repairs.

Where used: 10 locations in Eurpose,1 in the US (California)

4.5.4 Company D: CENTADRIVE

Products: Centadrive® - a remote-controlled shutter door system with near silent operation

Noise level: The noise level of the Centadrive®system is more than 20dB lower than the standard system. In subjective terms this equates to the Centadrive system being less than a quarter of the perceived loudness compared to the standard system.

How product works to limit noise: The remote-controlled shutter door system operates quietly and avoids any door slamming noises. Fitted into the roof space and activated by a handy remote-control key fob, the Centadrive® Unit electronically controls the up and down movement of a dry- freight shutter door.

New or Retrofit? Can be installed on trucks, new or old. Powered directly from the vehicle's 24 volt battery, the system has been designed for fast, simple installation, with minimal wiring required. Easily installed into new builds or as retrofit upgrades9fitted into the roof space and activated by a remote-controlled key fob).

Costs:

Hardware	$2,000	New/Retrofit
Installation		
Operation/Maintenance		
Total		

Certifications: Unknown

Warranty: Unknown

Merits: Improved delivery cycles, Improved fuel efficiency, Improved payload potential, Allows out-of-hours deliveries, Improved security, Addresses key Health & Safety issues, Easy to use - with Integrated safety features, Easily installed into new builds or as retrofit upgrades, Reduced maintenance costs

.

Limitations: Unknown

Where used: United Kingdom and Germany

4.5.5 Company E: Whisper Plus Sound Kit for Self Powered Truck Refrigeration Unit

Products: Whisper Plus Sound Kit for Self Powered truck Refrigeration Unit

Noise level: Reduction in noise is 2-3 dB for this kit.

How product works to limit noise: unknown

New or Retrofit? The sound kit can be kit on any refrigeration system.

Costs:

Hardware	$300 (US dollars)
Installation	
Operation/Maintenance	
Total	

Certifications: Unknown

Warranty: Unknown

4.5.6 Company F: Back Up Alarm Reduction

Products: Back-up alarm reduction

Noise level: Unknown.

How product works to limit noise: Intelligently reduces occurrences and/or volume of Back-Up Alarms when unnecessary

New or Retrofit? Can be new or easily fitted to trucks.

Costs:

Hardware	$1000 (US dollars)
Installation	
Operation/Maintenance	
Total	

Certifications: Unknown

Warranty: Unknown

Merits: Reduces the loudest source of noise during overnight deliveries

Limitations: Unknown

Where used: Unknown

4.5.7 Company G: Rolling Carts

Products:

CC Euro Rollcontainer for efficient picking, packing, & distribution of consumer products
CC Euro Rolly - for distribution of cardboard displays and crates
CC Euro Trolley - for display and distribution of horticultural products
Cc Euro Low Noise Dolly - low-noise ¼ pallet in galvanized steel (capacity 440 lbs)
CC Euro Low Noise Rolly - low-noise ½ pallet in galvanized steel (capacity 880 lbs)

Noise level: Maximum of 60dB(A)

How product works to limit noise: Low noise rubber wheels on carts of various sizes and weights. Some decks are hot dipped galvanized steel and others are steel reinforced plastic.

New or Retrofit? New carts are available for sale or as part of a rental service agreement. Low noise wheels are not sold separately.

Costs:

Hardware	$75-$125 (US dollars)
Installation	
Operation/Maintenance	
Total	

Certifications: All meet Dutch PIEK certification (emits less than 60 dB at 7.5 m from the sound source) except the Trolley which is currently being tested

Warranty: Unknown

Merits: Can be handled manually or with automated lifting equipment, nestable/stackable when not in use, can be loaded at distributor and rolled directly to retail display floor, fits standard European modular packing units, temperature ranges -22°F to 158°F

Limitations: Maximum capacity is 400 kg (880 lbs)

Where used: 40 countries worldwide – large presence in Western Europe and the US

5. DATA COLLECTION AND ANALYSIS

5.1 Survey on residents' concerns over noise issue

After discussion with New York City Department of Transportation, information regarding residents' concerns over OHD noise were mainly collected through focus group study on community board members, and were also derived from the Plan 2040 Public Survey.

Interestingly, all concerns over freight-related noises seemed to center on freight rail at this stage, especially freight rails that transport waste and scrap. Truck-related noises do not seem to be as concerning as freight rail in New York City. Some of these comments are:

"*The increased use of the rail yards in western Queens; in western Queens especially. With the city's increased reliance on rail for its solid waste transfer program and freight shipments, the engine switching and idling activities that seem to take place at all hours of the night throughout the early morning. The noise and air pollution diminish the quality of life at the rail yards of residential neighbors...*"

"Freight rail lacks new technology that is cleaner, quieter, and safer. Burdens from rail include diesel emissions from old, high-polluting Tier 0 locomotives, noise and seismic effects from old equipment and tracks, foul odors, vermin and other pest species, pollution of air, water, and land, and open cars of garbage and unsightly rail property in residential areas..."

"Communities that live with freight rail around Fresh Pond Terminal need noise abatement--for the noise of engines, brakes, couplings, and rails. Hours of operation must be addressed--through coordinated passenger and freight rail improvements, alternative classification yards, and marine transportation use..."

Although the survey seems to imply that truck noises are not the major concern for the public at this moment, it is still important to monitor truck noises, and take proactive measures to ensure that residents' quality of life and environmental justice are not negatively impacted by OHD.

5.2 Noise monitoring and visits

The Contractor further conducted field noise data collection during several deliveries in Manhattan to fully understand the noise profile during off-hour deliveries, and to identify effective components in noise control.

Gristedes Grocery Stores agreed to participate in the Off-Hour Delivery Program. Ambient noise and delivery noise to the following locations were collected, as shown in Table 14.

Table 14 Noise measurement visit information

Store No.	Address	Visit Time	Comments
1445	2704 Broadway (103St.)	10:35 PM	• Noise measurements during delivery operations
1403	907 8th Avenue & 54th Street	10:10 PM	• 5 minutes of ambient noise at corner of 26th St and 8th Avenue
1441	307 West 26th Street & 8th Avenue	9:45 PM	• 2 minutes of ambient noise at entrance of 26th St off-street loading dock • 5 minutes of ambient noise at corner of 26th St and 8th Avenue

The following describes preliminary data collection efforts during visits to these stores.

5.3 Site GRI-1445: Commercial Area

This Gristede store is located at the intersection of Broadway and 103rd St., with an entrance at Broadway. Figure 16 shows the delivery truck parked at the corner. Various instances of the delivery process were recorded, from the pick-up of pallets using an electric handcart inside the truck, while using the lift, and then moving from the back of the truck to the store's entrance. In addition, the process of breaking up the pallets and transporting them to the inside of the store using manual carts was recorded.

Figure 16 Freight Delivery at Store's Entrance

Monitoring Information Summary:			
Site visit ID:	GRI-1445-01	Pre- or Post-OHD	Pre
Date:	03/04/2012	Time:	10:35 PM
Analyst	Miguel Jaller	Purpose:	Pre-switch monitoring plan
Data Collected:	Pictures and delivery truck/operations noise data before switch to OHD		
Data Profile:	Noise data collection at intersection – Figure 17 Start Time 04-03-2013,22:38:46 End Time 04-03-2013,22:47:51 Max 88.80 @04-03-2013,22:43:37 dBA Min 54.50 @04-03-2013,22:47:44 dBA Average 65.76 Noise data collection while moving pallets on the sidewalk –Figure 18 Start Time 04-03-2013,22:50:50 End Time 04-03-2013,22:54:30 Max 81.10 @ 04-03-2013,22:54:14 dBA Min 53.70 @ 04-03-2013,22:52:46 dBA Average 63.63 Noise data collection while truck is departing – Figure 19 Start Time 04-03-2013,23:07:36 End Time 04-03-2013,23:10:44 Max 87.40 @ 04-03-2013,23:10:34 dBA Min 52.90 @ 04-03-2013,23:09:16 dBA Average 64.78		

Figure 17 shows the data collected during a few delivery cycles from truck to store's entrance. The large spikes correspond to the moments when the metal rollers of the electric handcart hit the ground (when moving from the sidewalk to the street level).

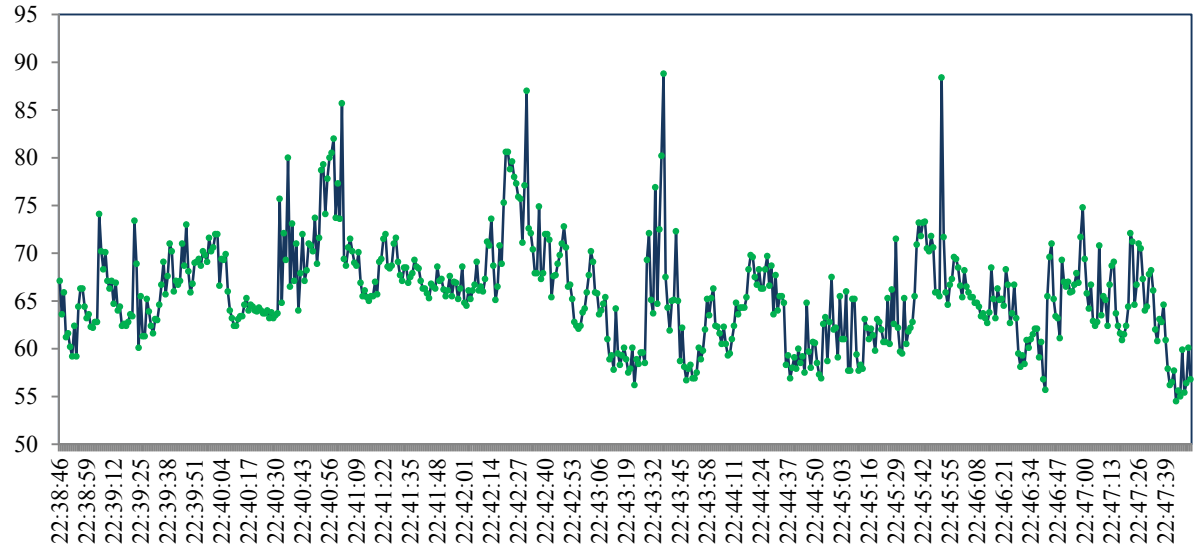


Figure 17 Noise data collection at intersection

Figure 18 shows other instances of the delivery process, when moving from the corner to the store's entrance. The different spikes also correspond to vibration and metal friction.

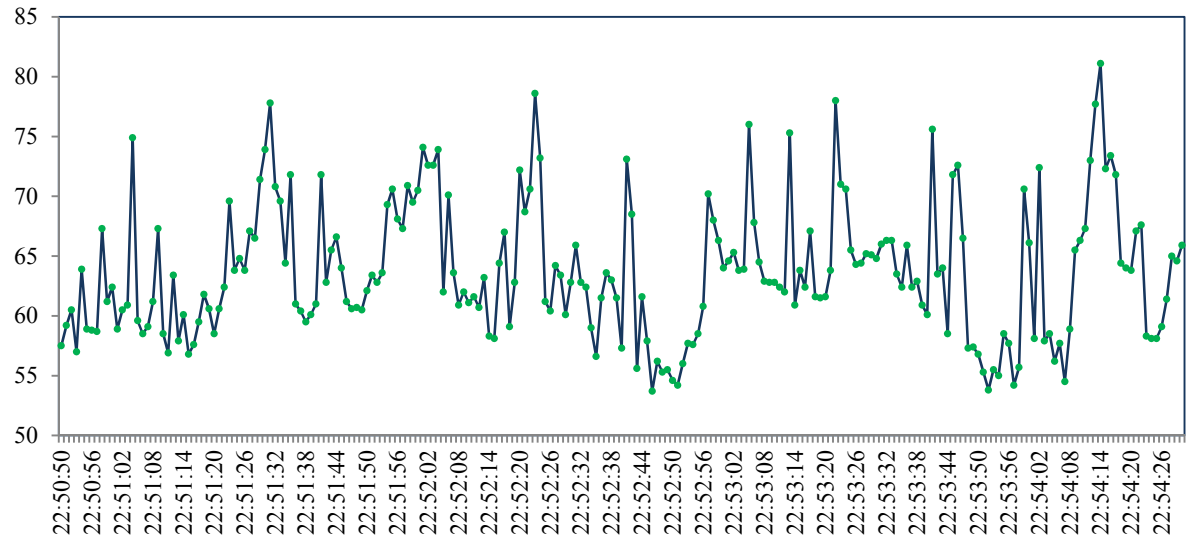


Figure 18 Noise data collection while moving the pallets

Figure 19 shows the data collected for the truck departure. The first spike is due to vehicular traffic. The interval from 23:09:49 on corresponds to the time when the engine was turned on, and the truck started departing.

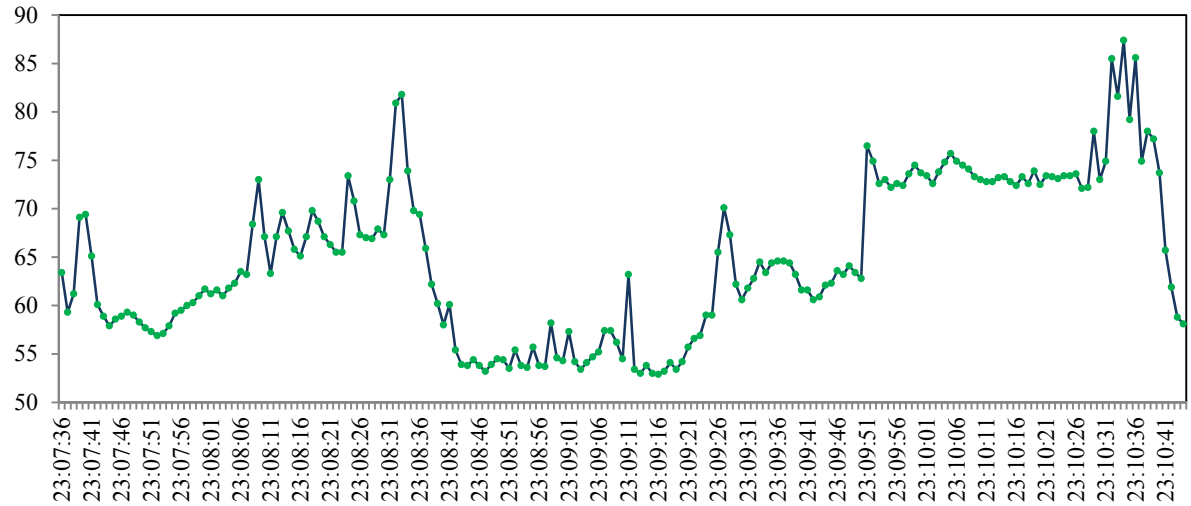


Figure 19 Noise data collection for truck departure

5.4 Site GRI-140: Commercial Area

This store is located at the intersection between 8th Ave. and 54th St., with an entrance over 8th Ave. Figure 20 shows the store location, and the pallets of deliveries left by the truck on the sidewalk. These pallets were then broken down and carried inside the store using a manual kart.

Figure 20 Store Location Between 8th Ave and 54th St.

On 8th Ave. there is a bike lane, and on-street parking conveniently located in front of the store's entrance. Figure 21 shows the parking restrictions.

Figure 21 On-street parking restrictions

Figure 22 shows the data collected at the intersection of 54th St. and 8th Ave. A couple of large trucks were observed during the time interval.

Monitoring Information Summary			
Site visit ID:	GRI-1403-01	Pre- or Post-OHD	--
Date:	03/04/2013	Time:	10:10 PM
Analyst	Miguel Jaller	Purpose:	Pre-switch monitoring plan
Data Collected:	Pictures and ambient noise data		
Data Profile:	Noise data collection at intersection-Figure 22 Start Time 04-03-2013,22:12:33 End Time 04-03-2013,22:17:28 Max 83.10 @04-03-2013,22:15:38 dBA Min 60.60 @04-03-2013,22:14:53 dBA Average 68.32 Comments: This store is located at the intersection of Broadway and 103rd St., with entrance at Broadway. Various instances of the delivery process were recorded from the pick-up of pallets using an electric handcart inside the truck, while using the lift, and then moving from the back of the truck to the store's entrance. In addition, the process of breaking up the pallets and transporting them to the inside of the store using manual carts was recorded.		

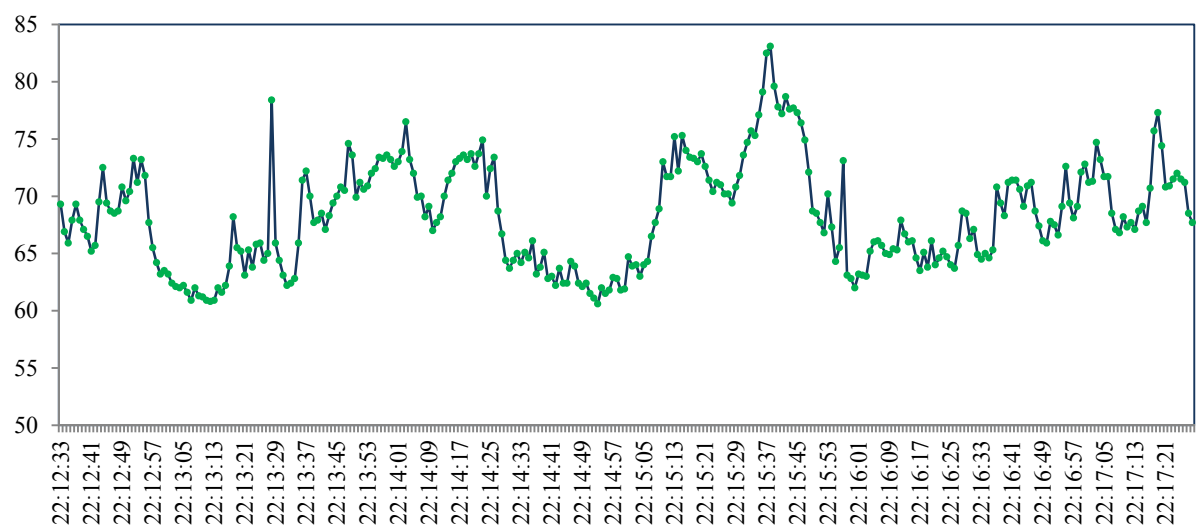


Figure 22 Noise data collection at intersection

5.5 Site GRI-1441: Commercial Area

This location is at the corner of 26th St. and 8th Ave, with an entrance on 26th St (see Figure 23). At the time of the visit, there was a noticeable difference between the vehicle traffic flows between those traversing 26th St. and 8th Ave. Figure 24 shows the parking restriction in front of the store's entrance, and the intersection design. Along 8th Ave. there is a bike lane and on-street parking.

Figure 23 Store Location Between 8th Ave and 26th St.

Figure 24 Intersection design and parking restriction

Additionally, this location has an off-street loading dock located on 26th St.

Figure 25 Off-street loading dock

Figure 26 shows the noise data collection in front of off-street loading dock: Noise spikes are due to larger vehicles passing by.

Monitoring Information Summary			
Site visit ID:	GRI-1441-01	Pre- or Post-OHD	--
Date:	03/04/2013	Time:	09:45 PM
Analyst	Miguel Jaller	Purpose:	Pre-switch monitoring plan
Data Collected:	Pictures and ambient noise data 2 minutes of ambient noise at entrance of off-street loading dock on 26th St 5 minutes of ambient noise at corner of 26th St and 8th Avenue		
Data Profile:	Noise data collection at loading dock-Figure 26 Start Time 04-03-2013,21:53:57 End Time 04-03-2013,21:58:59 Max 76.80 @ 04-03-2013,21:57:18 dBA Min 58.70 @ 04-03-2013,21:57:35 dBA Average 66.84 Noise data collection while moving pallets on the sidewalk-Figure 27 Start Time 04-03-2013,21:51:01 End Time 04-03-2013,21:53:04 Max 75.50 @ 04-03-2013,21:51:41 dBA Min 53.40 @ 04-03-2013,21:51:23 dBA Average 57.89		

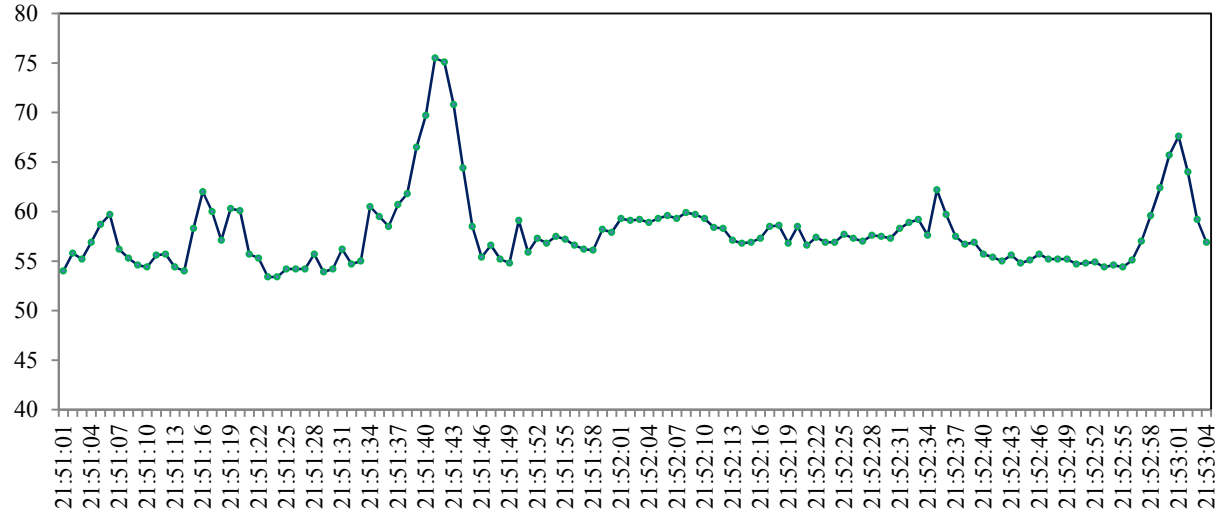


Figure 26 Noise data collection at loading dock

Figure 27 shows the data collected at the corner. Here again, spikes correspond to larger vehicles. As discussed, the average noise level at the intersection is higher than at 26th St, due to more vehicular traffic on 8th Ave.

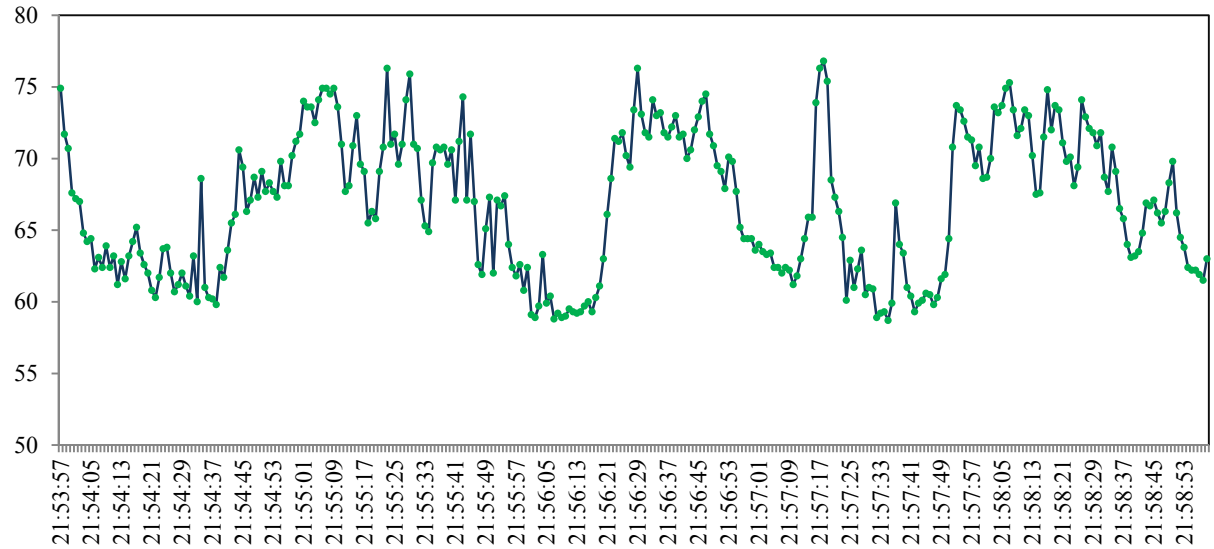


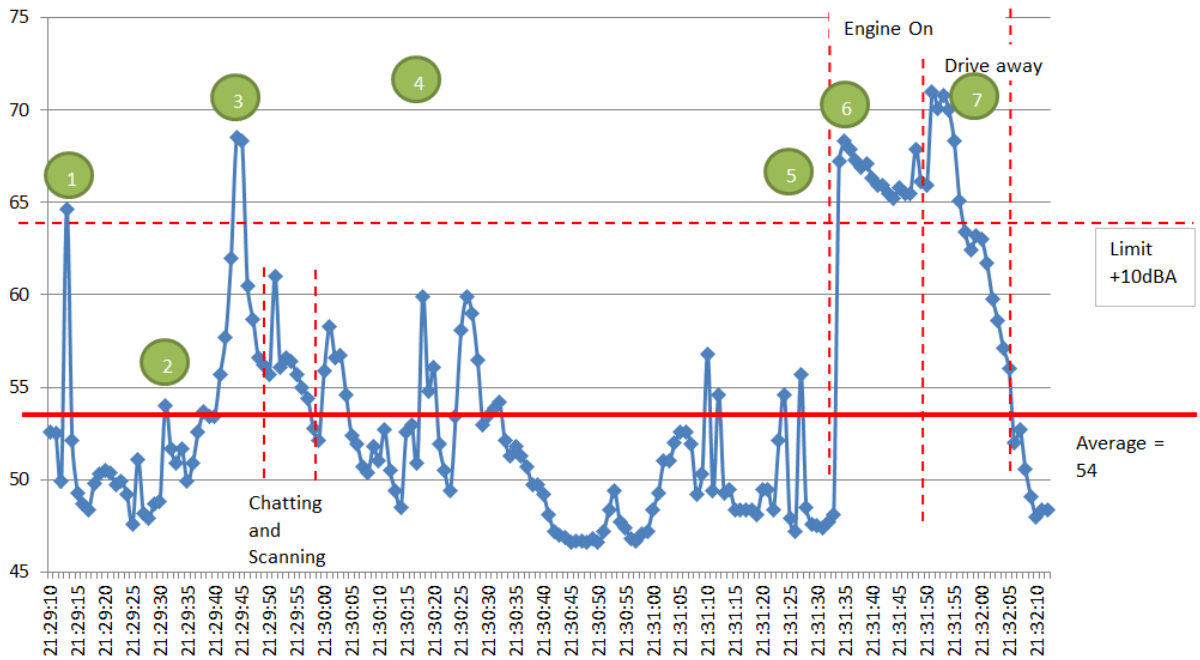
Figure 27 Noise data collection at corner

5.6 Site FS-T01: Residential Area

To provide enough geographic diversity, truck delivery noise (before mitigation measures) was monitored at another location that is mostly residential.

Monitoring Information Summary			
Site visit ID:	FS-T01	Pre- or Post-OHD	Pre
Date:	10/04/2012	Time:	9:29 PM
Analyst	Miguel Jaller	Purpose:	Noise Test
Data Collected:	Pictures and Noise data collection from truck delivering at night at a residential area		
Data Profile:	Noise data collection at intersection Start Time 10-04-2012,21:29:10 Max 71.00 @ 10-04-2012,21:31:51 dBA Min 46.60 @ 10-04-2012,21:30:45 dBA Average 54.09 Sample Rate 1		

From the noise profile, one notes most noises are under 75dB(A), with the peak noises at: slamming door, starting engine and accelerating. The noise control of the last two sources would need to rely on quiet engine technologies, while the first could be addressed with driver education and quiet body components.



1

Slamming Door

2

Metal noise Inside

3

Car passing through

4

Clossing back door

5

Driver closes front door

6

Starts Engine

7

Accelerates and drive away

6. COST BENEFIT ANALYSIS

The project team investigated current methods of CBA and studied their applicability on the project. Cost benefit analysis (CBA), sometimes called benefit–cost analysis (BCA), is a systematic process for calculating and comparing the benefits and costs of a project, decision or government policy. CBA has two purposes:

- To determine whether an investment/decision is sound (justification/feasibility); and
- To provide a basis for comparison with other projects. This is done by comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs, and by how much.

For this project, the potential benefits of noise reduction may include:

- Lower noise to drivers
- Less disturbance of surrounding neighborhoods/citizens
- Off-hour delivery
- Energy efficiency
- Emission reduction
- Freight delivery efficiency
- Cost saving

Similarly, the potential costs of noise reduction consist of:

- Installation and set-up cost
- Transition and training cost
- Maintenance cost
- Subsidy cost
- Research and development cost
- Potential social cost

One way to evaluate these benefits and costs is to convert them to monetary values. Benefits are measured by the willingness of individuals to pay. Costs are calculated as the amount of compensation required to exactly offset negative consequences. There are two common ways to measure willingness to pay. First, it is relatively easy to value the direct benefits. For example, the noise reduction technology may help raise fuel efficiency by 5%, the total fuel cost would decrease by 5%. In other words, direct benefits could be easily measured in terms of monetary value. Another approach is to observe how much people are willing to pay for goods that have an environmental quality component. WTP is an effective way to measure the social benefit and cost. In practice, there are two common ways to measure WTP: revealed preference (RP), and stated preference (SP). RP collects data from people's actual choice behavior. SP provides questionnaire for respondents to gather hypothetical choices of how much money, for example, would they willing to pay to carry out noise reduction technology or off-hour delivery. The advantage of SP is that, since the analyst controls the decision variables, all decision makers will use the same set of variables (not perceived). SP questionnaires are very efficient in using

information, and can easily be integrated into a discrete-choice modeling framework. However, the SP approach could not easily represent market constraints.

Limited by time and budget, and considering the fact that the precise initial cost and maintenance costs are not disclosed for most of the technologies, the quantitative cost benefit analysis based on WTP is difficult. Therefore, this study adopts a multi-criteria approach and instead of accurately translating all benefits and costs into monetary units, summarizes benefits and costs using visual cues, so that "---" means very bad, "0" is neutral, and "+++" means very good. When quantitative values are available, the values are also presented. The cost benefit analysis is thus summarized, below.

Table 15 Benefits and Costs Summary

Cate-gory	Item	Costs	Benefits
Quiet Drivelines	'Quiet' tractor by DAF Trucks	•15,000 euros (-)	•Lower noise
	Iveco Stralis LNG	•Initial cost 75,000 euros (---) •Maintenance cost (-)	•Reduction of noise (++) •Reduction of fuel costs about 300 euros/year (+) •Reduction of air pollution (++) •Improvement of quality of life (++)
	Mercedes Econic LNG	•40,000 euros(--)	•Lower noise (++) •Reduction of fuel costs about 300 euros/year 300 (+) •Reduction of air pollution (++) •Improvement of quality of life (++)
	Volvo hybrid	--	•Less CO2 and low noise(++) •Reduction on fuel about 20% (++) •Reduction of air pollution (++) •Improvement of quality of life (++)
	Renault Max City Electric	•90,000 euros(---) •Build charge station(---)	•Very low noise: 65 (++) •Reduction of air pollution (++) •Sustainable and environmental friendly(+++)
	Electronic Speed Limiter' by Groeneveld	•Varies (---)	•Limit noise (+++) •Reduction of air pollution (++) •Sustainable and environmental friendly(+++)
	Intelligent speed limiter, Ecodrive/Ecocargo	•Varies (--)	•Lower noise(++) •Reduction on fuels about 10% (+)
noise body,	The VOC vehicle with 'quiet' structure	•Added initial cost of 15% (--)	•Low noise (++) •Less abrasion and longer life cycle

Cate-gory	Item	Costs	Benefits
	Quiet' refrigerated trailer, Post-Kogeko	•Added initial cost less than 10%(--)	•Low noise (++) •Less abrasion and longer life cycle(++)
	Quiet Trailer, Schmitz Cargobull	--	•Noise reduction (++)
Low noise components	Taillifts Dautel, Dhollandia, Mariba, STAMA	•Added initial cost of 10-15% (--)	•Low noise loading/unloading (++) •Raise loading/unloading efficiency(++)
	Electric roller door	•More expensive than conventional roller door (-)	•Low noise (++) •Convenient maneuvering (+)
	Floor coatings	•More expensive than a non-coated one (-)	•Reduce noise (++) •Less abrasion and longer life cycle (++)
	Greensight reverse warning signal	--	•Warning signal (+)
	GrootJebbink reversing alarm	•More expensive than a beep one (-)	•Low noise (+) •Smart alarm (+) •UltraSone radar sensors(+)
	Carrier diesel refrigeration	•Added initial cost of 40% (---)	•guarantees 24-hour delivery(++) •low noise (++)
	Thermo King cryogenic transport refrigeration	•more expensive to purchase but cheaper in practice (-)	•Low noise (++)
	Tire mufflers	--	•Lower noise going through the cabin(++)
	Solar based auxiliary power unit	•5,840 euros	•Gas saving (++) •No maintenance cost (++) •No greenhouse emission (++)
Low noise handling equipment	Hand pallet truck	•50% more expensive than the standard(---)	•Low handling noise(++) •Less abrasion and longer life cycle(++) •Raise handling efficiency(++)
	Silent Roll container Container Centrale	--	•Low noise(++) •Less abrasion and longer life cycle(++)

7. CONCLUSIONS

The project team investigated thoroughly existing technologies on noise reduction. Technologies such as foam coating, CNG engines and aluminum floor are introduced, and their characteristics are described in detail. In addition, transferrable technologies such as LNG engines, electric vehicles and reverse alarm are carefully studied to assess the merit of the application of such potential noise reduction technologies in the U.S. Their advantages and

disadvantages are discussed in detail. To gather information from candidate companies, a request for information was sent, and responses carefully studied. After that, the project team started collecting real noise data and conducting analyses. In the end, cost and benefit analyses were performed for potential noise reduction technologies.

Major noise reduction technologies are summarized, and their cost/benefits are carefully compared. However, to implement these technologies in New York City, further research needs to be done. Comprehensive pilot tests need to be carried out, and impacts should be carefully evaluated. This report provides an important reference tool to the implementation of noise reduction technologies in New York City.

8. ACKNOWLEDGEMENT

The support from NYSERDA and NYSDOT on this project has partially enabled the in-depth noise technology and policy assessment, which is an integral part of the Off-Hour Delivery Program (sponsored by U.S Department of Transportation; Project name: RITARS-11-H-RPI: Integrative Freight Demand Management in the New York City Metropolitan Area: Implementation Phase). Part of the content on the noise technology and policy investigation in this report is thus also presented in the Off-Hour Delivery Program Final Report.

9. REFERENCES

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