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TNO report

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Emissions of mobile machinery at Dutch container terminals

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Contents

1 Introduction

In 2009 TNO developed the EMMA model to calculate the emissions from mobile machinery for the Dutch emission inventory. This model calculates emissions from mobile machinery based on annual machine sales, emission standards and use profiles, corrected by annual fuel use. Although the model contains reach stackers used at container terminals for an unknown share of the total number, it did not yet include other mobile machinery used at these sites. Mobile machinery typically found at container terminals are: reach stackers, empty handlers, straddle carriers, tug masters, forklifts and automated guided vehicles. These machines are used to transfer containers from container ships to a storage location or another mode of transportation.

In this project, the historical emissions (1990-2014) of all mobile machinery used at Dutch container terminals (from now on referred to as MMCTs) have been calculated and added to the EMMA model as a new emission source. Furthermore, the emissions have been geographically distributed over the respective Dutch container terminals. In order to avoid double-counting of emissions, reach stackers have been removed from the EMMA model. The findings of this project can also be used in the future to calculate annual emissions from MMCTs.

2 Goal of the project

The goal of this project was to estimate the emissions of several key substances by mobile machinery at Dutch container terminals, and to geographically distribute these emissions between these sites. To achieve this goal, the following data were required:

a) A composition of the fleet of mobile machinery used (number of machines, power, year of manufacture, service life);
b) Energy requirement for container handling;
c) Emissions per energy unit for different mobile machines (emission factors);
d) Annual number of container handlings in the Netherlands;
e) Distribution of container handlings over different container terminals.

To improve the continuity of the emission results it was attempted to use data sources that are periodically available where possible.

2.1 Deliverables

The following products have been delivered through this project:

a) An Excel model in which the annual emission factors for MMCTs are calculated per activity unit (number of TEU containers handled) and combined with annual activity data to calculate the annual emissions of several substances;
b) An Excel model containing the coordinates of Dutch container terminals and the number of container handlings per terminal. These are used to calculate the share of the respective terminals in total emissions and thus geographically distribute the emissions;
c) A description of the aforementioned models in chapter 3 of this report;
d) An overview of the results generated by this project in chapter 4 of this report;
e) Instructions on future actualization of the data and emissions results in Appendix A of this report;
f) A chapter in the methodology report of the Task Force on Transportation.

3 Model and data description

3.1 Mobile machinery fleet

In 2010, DCMR (Joint Environmental Protection Agency Rijnmond) did a study into the emissions of mobile machinery at several container terminals at the port of Rotterdam, which included a survey into the mobile machinery present (Okkerse & de Gier, 2010). In the study, over 460 machines and their year of manufacture were reported. For this project it was assumed these were all machines with a category 5 diesel engine (130–560 kW). Furthermore, it was assumed that, on average, 20% of MMCTs are smaller; 10% with a category 3 engine (37–75 kW) and 10% with a category 4 engine (75–130 kW). This resulted in an average machine fleet in 2010, including years of manufacture.

The EMMA model uses a scrap-function to estimate the number of machines that fail and are taken out of service every year, based on the age and average service life of the machines (Hulskotte & Verbeek, 2009). The same function was used in this project to estimate the number of machines taken out of service in subsequent years (after 2010). It was assumed that the small and medium sized machines (category 3 and 4) have an average service life of 9 years and the large machines (category 5) have an average service life of 15.5 years. Based on the assumption that every machine taken out of service is replaced by a new machine of similar size, an extrapolation of the composition of the machine fleet to 2020 was made.

This method could not be used to estimate the composition of the average machine fleet before 2010. To estimate the composition of the machine fleet in the year 1990 the assumption was made that 35% of machines were manufactured before 1981 and 65% of machines were manufactured between 1981 and 1990. The machine fleet in the year 2000 was assumed to consist for 45% of machines manufactured between 1981 and 1990, 45% of machines manufactured between 1991 and 1999, and 10% of machines manufactured later than 1999.

3.2 Energy requirement container handling

From the DCMR report, it could be derived that the handling of containers costs approximately 4.5 litres of diesel per TEU (Twenty feet Equivalent Unit) container at a typical container terminal in 2010. This value is slightly higher than the value of 3.9 litres/TEU for a conventional container terminal which is reported by Oonk (2009). The value of 4.5 litres/TEU was used for this study, and is likely on the high end. Using the average diesel use per delivered kWh of the machine fleet in 2010, this diesel use was converted to a measure of delivered energy/TEU. The resulting value of 14.5 kWh/TEU was kept constant over the model time range (1990–2020).

The model also includes the handling of empty containers at storage depots, for which an alternative energy requirement is used. Based on fuel use data from individual container depots in the port of Rotterdam provided by DCMR (Wester, 2016), it was estimated that the fuel requirement for handling empty containers is approximately three times lower than for the handling of loaded containers. This results in a value of 1.5 litres/TEU for the handling of empty containers.

3.3 Emission factors

The EMMA model contains emission factors for several substances in g/kWh linked to existing engine categories and emission standards. These emission factors are based on the emission standards for non-road vehicles of the EU, available online (Dieselnet, 2015). For this study, several emission factors were updated based on more recent sources (Dieselnet, 2015; Helms et al., 2010). These emission factors can be found in Table 1. The emissions of $PM_{2.5}$ and $EC_{2.5}$ are calculated as a fraction of total PM emissions. The fractions can be found in Table 2. The emission of other substances is determined only by the amount and type of fuel used. Emission factors (in g/MJ) for these substances are present in the EMMA model and were used in this project to determine yearly emission factors based on the fleet composition (relevant for fuel efficiency). These emission factors can be found in Table 3.

The EMMA model also contains a list of years of implementation of the emission standards for different machine types. This list was also updated according to the most recent data available (Dieselnet, 2015). An overview of implementation years can be found in Table 4. The annual emission factors for SO_2 can be found in Hulskotte & Verbeek (2009).

Table 1: Emission factors for non-road diesel engines, (g/kWh)

Engine size	**Emission standard**	**Emission factor**				
		NOx	**PM**	**CO**	**HC**	**Fuel**
Category 3 (37–75 kW)	<= 1980	7.7	1.8	6.0	2.4	290
	1981–1990	8.6	1.2	5.3	2.0	275
	1991–Stage I	11.5	0.8	4.5	1.5	260
	Stage I	7.7	0.7	2.2	0.6	260
	Stage II	5.5	0.36	0.75	0.25	260
	Stage IIIa	3.8	0.36	0.075	0.014	260
	Stage IIIb	3.3	0.025	0.075	0.014	260
	Stage IV	2.1	0.025	0.075	0.014	260
Category 4 (75–130 kW)	<= 1980	10.5	1.4	5.0	2.0	280
	1981–1990	11.8	1.0	4.3	1.6	268
	1991–Stage I	13.3	0.4	3.5	1.2	255
	Stage I	8.1	0.63	1.5	0.4	255
	Stage II	5.2	0.27	0.75	0.25	255
	Stage IIIa	3.3	0.27	0.075	0.014	255
	Stage IIIb	3.0	0.025	0.075	0.014	255
	Stage IV	0.4	0.025	0.075	0.014	255
Category 5 (130–560 kW)	<= 1980	17.8	0.9	2.5	1.5	270
	1981–1990	12.4	0.8	2.5	1.0	260
	1991–Stage I	11.2	0.4	2.5	0.5	250
	Stage I	7.6	0.48	1.5	0.3	250
	Stage II	5.2	0.18	0.75	0.25	250
	Stage IIIa	3.3	0.18	0.075	0.014	250
	Stage IIIb	1.8	0.025	0.075	0.014	250
	Stage IV	0.4	0.025	0.075	0.014	250

Table 2: PM2.5 and EC2.5 fractions of PM emissions

Substance	Fraction of PM emissions
$PM_{2.5}$	0.95
$EC_{2.5}$	0.48925

Table 3: Diesel emission factors, (g/MJ)

Substance	Emission factor
CO_2	74.3
N_2O	0.0006
NH_3	0.000234
Metals diesel combustion	0.000000958431

Table 4: Implementation years for emission standards

Emission standard	Year of implementation		
	Cat. 3	Cat. 4	Cat. 5
<= 1980	N/A	N/A	N/A
1981–1990	1981	1981	1981
1991–Stage I	1991	1991	1991
Stage I	1999	1999	1999
Stage II	2004	2003	2002
Stage IIIa	2008	2007	2006
Stage IIIb	2012	2012	2011
Stage IV	2015	2015	2014

Based on the fleet composition in every year, the average emission factors in g/kWh could be calculated for 1990, 2000 and 2010–2020 for the respective substances. It was assumed that the emission factors between 1990 and 2000, and 2000 and 2010 developed linearly between these years.

3.3.1 TAF factors

During actual use, the emissions of machines and vehicles may deviate from the emission factors measured under controlled testing circumstances. The U.S. Environmental Protection Agency has done a study into the emissions factors of machines under rapidly changing (transient) loads (EPA, 2004). The results were expressed in TAF factors, which indicate the average deviation of actual emissions from the emission factors measured in standard test cycles. These TAF factors are used in the EMMA model to adjust the emission calculations for mobile machinery and were also implemented in the calculations done in this study. For this study, it was assumed that the "high" TAF profile applies to the large (cat. 5) machines, and the "Backhoe/loader" profile applies to the small and medium (cat. 3 and 4) sized machines. The applicable TAF factors are shown in Table 5. A complete list of TAF factors can be found in Hulskotte & Verbeek (2009).

Table 5: TAF factors for relevant machine profiles

TAF type	NOx	PM	CO	HC	Fuel
Backhoe/loader	1.05	2.07	2.66	2.23	1.16
High	0.95	1.23	1.53	1.05	1.01

3.4 Container handlings in the Netherlands

Historical data on the number of container handlings in the Netherlands was requested from the Dutch Statistical Agency (CBS). CBS provided data on maritime container transport for the years 2009–2014, further specified to several key ports (Moritz, 2015; Sijstermans, 2015). Data on total maritime container handlings in the Netherlands before 2009 was not available at CBS.

Additionally, CBS provided data on inland container handlings per municipality in the Netherlands from 2011 to 2014 (Pouwels, 2015). The maritime and inland container handlings were added together to calculate the total number of container handlings. The result is shown in Table 6 for the years 2011–2014. Only ports with more than 250,000 container handlings over these four years are shown separately.

Table 6: Number of containers handled in Dutch maritime and inland ports, (TEU)

Municipality	**2011**	**2012**	**2013**	**2014**
Alphen aan den Rijn	146,771	161,616	158,183	180,045
Amsterdam	241,052	255,890	242,109	231,476
Groningen	79,922	99,543	81,096	1,873
Hengelo	103,031	93,265	103,172	103,727
Hertogenbosch, 's-	109,883	99,207	96,955	94,507
Meppel	89,116	99,782	69,222	69,855
Moerdijk	282,647	207,641	155,925	179,637
Nijmegen	87,362	70,764	78,195	102,260
Rotterdam	14,440,548	14,690,842	14,387,566	15,232,405
Sittard-Geleen	121,211	106,323	106,542	110,278
Terneuzen	106,622	116,694	98,507	73,621
Tilburg	57,456	59,100	73,097	65,759
Utrecht	106,753	80,101	104,888	113,567
Venlo	53,357	58,665	86,956	107,333
Venray	78,532	84,125	86,521	128,809
Vlissingen	62,534	98,909	97,706	102,599
Other municipalities	561,526	582,146	710,156	881,993
Total	16,728,323	16,964,613	16,736,796	17,779,744

To estimate the total number of container handlings from 1990 to 2010, a complete time series for container handlings in the port of Rotterdam was used (Port of Rotterdam, 2015). The average ratio of total container handlings and container handlings in the port of Rotterdam between 2011 and 2014 was multiplied by the number of container handlings in the port of Rotterdam to get the total number of container handlings from 1990 to 2010. The complete time series can be found in the results chapter.

Since 2015, several container terminals (APM Terminals Maasvlakte II and Rotterdam World Gateway) are fully electric. The estimated number of container handlings at these terminals is subtracted from the total handlings before calculating the total MMCT emissions in the Netherlands.

3.5 Emissions calculation

3.5.1 Emissions NOx, PM, CO and HC from diesel combustion

The emissions of NOx, PM, CO and HC are dependent on the amount of energy delivered, the specific engine design and size, and the variation in the engine load. The calculation is as follows:

Formula 1
Emission = Activity data x Energetic efficiency x Emission factor x TAF factor

Where:
- Activity data is the number of containers handled (TEU);
- Energetic efficiency is the required energy per container handling (kWh/TEU);
- Emission factor is the average emission factor which is dependent on the engine size and year of construction (emission standard) (g/kWh);
- TAF factor is the adjustment factor applied to the average emission factor to correct the deviation from the average use of this type of machine due to varying power demands (./.).

3.5.2 Emissions SO_2, CO_2, N_2O, NH_3 and metals from diesel combustion

The emissions of SO_2, CO_2, N_2O, NH_3 and metals are only dependent on the amount and type of fuel used. The calculation is as follows:

Formula 2
Emission = Activity data x Energetic efficiency / Fuel efficiency x Fuel energy content x Emission factor

Where:
- Activity data is the number of containers handled (TEU);
- Energetic efficiency is the required energy per container handling (kWh/TEU);
- Fuel efficiency is the required fuel per energy delivered (g/kWh);
- Fuel energy content is the amount of energy per unit of fuel (MJ/kg);
- Emission factor is the average emissions factor (g/MJ).

3.5.3 Emissions $PM_{2.5}$ and $EC_{2.5}$

The emissions of $PM_{2.5}$ and $EC_{2.5}$ are proportional to the emissions of PM.

Formula 3
Emission = Emission PM x $PM_{2.5}$ or $EC_{2.5}$ fraction

Where:
- Emission PM is the PM emission calculated with formula 1;
- $PM_{2.5}$ or $EC_{2.5}$ fraction is the average fraction of $PM_{2.5}$ or $EC_{2.5}$ that is emitted per unit of PM.

3.6 Distribution of emissions over container terminals

To geographically distribute the total emissions over the Dutch container terminals, the share of every terminal in total container handlings was estimated. Given limited data availability, this distribution was based on the average number of container handlings per municipality in 2011–2014. Only municipalities with more than 100,000 handlings in the period 2011–2014 were included. The resulting 28 municipalities accounted for approximately 99% of all container handlings in the Netherlands. The distribution was assumed to be similar for earlier years but can be updated in the future if additional data become available.

For the port of Rotterdam, responsible for approximately 87% of container handlings in the Netherlands, recent data on the container capacity of terminals and depots was available on their website (Port of Rotterdam, 2016). For other Dutch container terminals, data on container handlings was gathered from the website of Inland Links (Inland Links, 2015). Both sources also offered data on the number of cranes, empty handlers and reach stackers present, and the quay length and plot size of the individual terminals.

When comparing data from these two sources for terminals in Rotterdam, it appeared that for container terminals, the actual number of container handlings was on average only 81% of total capacity listed by the port of Rotterdam (i.e. maximum handling capacity was not fully used). For the container depots, the number of handlings was 13 times higher than listed depot storage capacity (i.e. one storage spot can be used for multiple containers during one year). These average factors were used to correct the container capacities of terminals and storage depots for locations where no data on number of handlings was available from Inland Links.

Four large container terminals in Rotterdam did not have their capacities listed in the port of Rotterdam source. However, these terminals were all owned by one company which listed the total number of container handlings on their website (ECT, 2015). Based on the plot size, quay length and available machinery at these terminals, the total number of handlings by this company was distributed over these four terminals.

For the terminals in Amsterdam, additional data on container handling shares per terminal were requested at the port of Amsterdam (van Breemen, 2015). For the terminals in Moerdijk, the distribution was done relative to the plot area, quay length and available machinery at the terminals. For the two terminals in Vlissingen and two terminals in Terneuzen, the shares were assumed to be equal for lack of actual data on container handlings.

To calculate the share of emissions from each terminal, each location specified by CBS was first given its relative share based on the container handling data from CBS (e.g. Rotterdam 87%, Moerdijk 1.2%). Then, the shares of individual terminals at these locations were multiplied with share of the location to calculate the shares of the individual terminals in total container handlings in the Netherlands. For container depots, the share was lowered by two thirds to account for the reduced energy requirement for empty container handling. Fully electric terminals were given a share of 0%. The shares in container handlings are assumed to be proportional to the emissions from mobile machinery at these locations.

4 Results

The most important results of this project are presented here. Table 7 shows the resulting emission factors of the MMCTs over time for the respective substances.

Table 7: Resulting average emission factors, (g/kWh)

Year	NOx	PM	CO	HC	SO_2	CO_2	N_2O	NH_3	Metals
1990	13.54	1.24	5.03	1.62	0.967	862	0.007	0.003	0.00001
1991	13.30	1.21	4.99	1.57	0.974	859	0.007	0.003	0.00001
1992	13.06	1.17	4.95	1.51	0.971	855	0.007	0.003	0.00001
1993	12.82	1.13	4.91	1.45	0.967	852	0.007	0.003	0.00001
1994	12.59	1.09	4.87	1.39	0.937	849	0.007	0.003	0.00001
1995	12.35	1.05	4.83	1.34	0.907	846	0.007	0.003	0.00001
1996	12.11	1.01	4.78	1.28	0.904	843	0.007	0.003	0.00001
1997	11.87	0.97	4.74	1.22	0.900	840	0.007	0.003	0.00001
1998	11.64	0.93	4.70	1.17	0.897	837	0.007	0.003	0.00001
1999	11.40	0.90	4.66	1.11	0.894	834	0.007	0.003	0.00001
2000	11.16	0.86	4.62	1.05	0.891	831	0.007	0.003	0.00001
2001	10.76	0.82	4.38	0.98	0.889	830	0.007	0.003	0.00001
2002	10.35	0.78	4.13	0.91	0.887	828	0.007	0.003	0.00001
2003	9.95	0.74	3.89	0.85	0.886	826	0.007	0.003	0.00001
2004	9.54	0.70	3.65	0.78	0.884	825	0.007	0.003	0.00001
2005	9.14	0.66	3.41	0.71	0.882	823	0.007	0.003	0.00001
2006	8.73	0.62	3.17	0.64	0.100	822	0.007	0.003	0.00001
2007	8.33	0.58	2.93	0.57	0.056	820	0.007	0.003	0.00001
2008	7.92	0.54	2.69	0.50	0.013	819	0.007	0.003	0.00001
2009	7.52	0.50	2.45	0.43	0.013	817	0.007	0.003	0.00001
2010	7.12	0.46	2.20	0.36	0.005	816	0.007	0.003	0.00001
2011	6.74	0.44	2.00	0.33	0.005	816	0.007	0.003	0.00001
2012	6.04	0.41	1.69	0.28	0.005	810	0.007	0.003	0.00001
2013	5.58	0.36	1.47	0.24	0.005	804	0.006	0.003	0.00001
2014	5.23	0.33	1.32	0.21	0.005	800	0.006	0.003	0.00001
2015	4.77	0.29	1.16	0.19	0.005	796	0.006	0.003	0.00001
2016	4.09	0.24	0.95	0.16	0.005	788	0.006	0.002	0.00001
2017	3.57	0.20	0.79	0.13	0.005	782	0.006	0.002	0.00001
2018	3.16	0.17	0.68	0.11	0.005	777	0.006	0.002	0.00001
2019	2.85	0.15	0.59	0.10	0.005	772	0.006	0.002	0.00001
2020	2.54	0.13	0.52	0.09	0.005	766	0.006	0.002	0.00001

Figure 1 visualizes these emission factors for NOx.

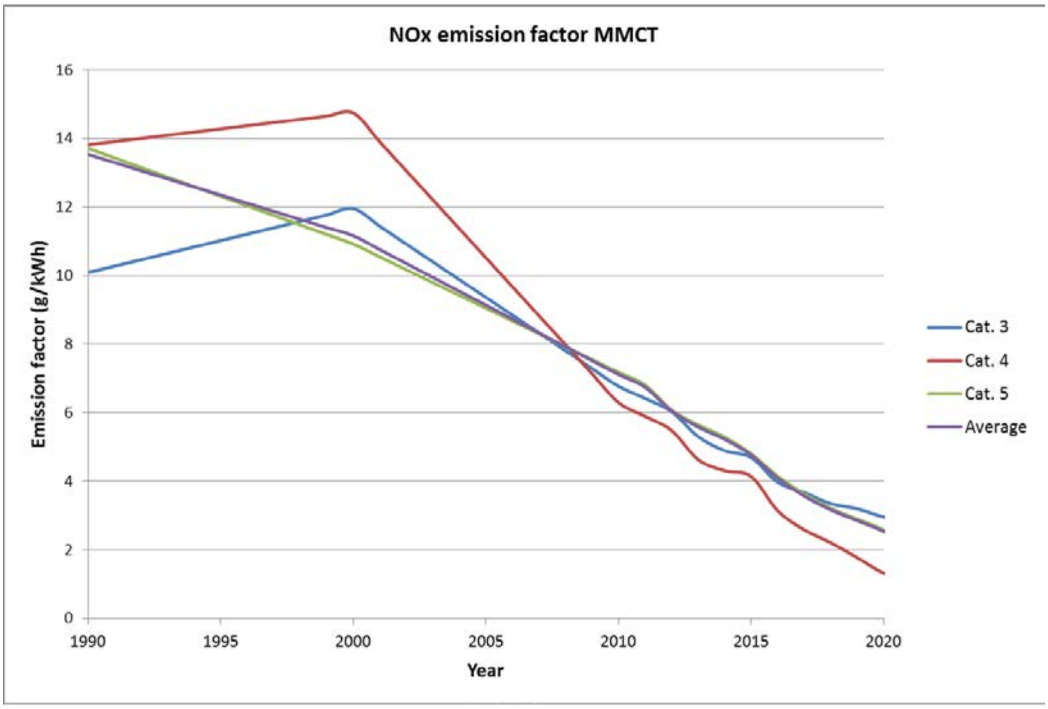

Figure 1: NOx emission factors for MMCTs, 1990–2020

Figure 2 shows the annual number of container handlings in the Netherlands.

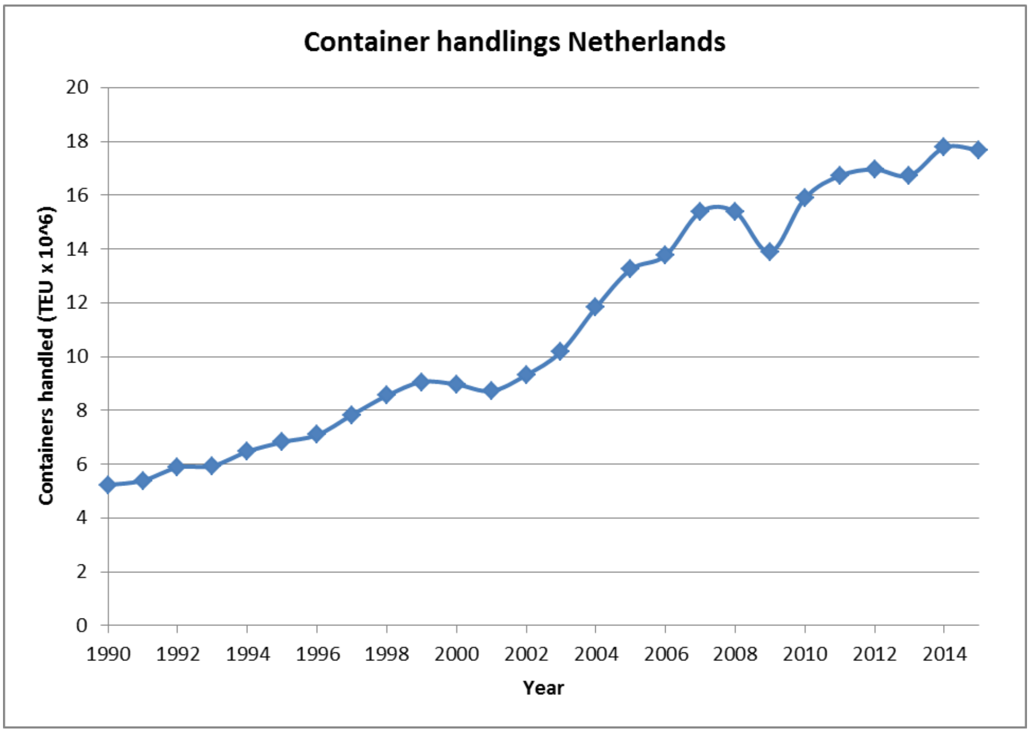

Figure 2: Container handlings in the Netherlands, 1990–2015

Table 8 and Table 9 show the resulting annual emissions from MMCTs.

Table 8: Annual emissions from MMCTs, (kg/y)

Year	NOx	CO	PM	HC	SO2	CO2
1990	931,529	346,417	85,632	111,718	66,534	59,293,535
1991	944,248	354,454	85,601	111,211	69,171	60,959,079
1992	1,011,395	383,332	90,356	116,864	75,168	66,244,106
1993	1,002,969	383,915	88,234	113,571	75,651	66,669,341
1994	1,072,730	414,808	92,850	118,896	79,861	72,390,932
1995	1,109,545	433,546	94,404	120,211	81,490	76,040,187
1996	1,130,577	446,531	94,464	119,562	84,357	78,714,957
1997	1,224,717	489,082	100,381	126,219	92,870	86,658,898
1998	1,309,614	528,961	105,172	131,297	100,965	94,212,539
1999	1,359,594	555,612	106,841	132,338	106,610	99,480,416
2000	1,317,826	545,073	101,189	124,261	105,146	98,114,148
2001	1,235,723	502,640	93,892	112,959	102,118	95,287,998
2002	1,269,751	507,093	95,377	112,126	108,832	101,552,958
2003	1,334,053	522,106	98,956	113,323	118,776	110,832,316
2004	1,485,459	568,477	108,677	120,772	137,611	128,407,697
2005	1,593,404	594,743	114,811	123,228	153,864	143,573,238
2006	1,582,664	574,406	112,123	115,539	18,074	148,937,654
2007	1,687,208	593,252	117,291	115,148	11,393	166,182,095
2008	1,604,200	544,052	109,175	101,076	2,612	165,767,130
2009	1,375,400	447,452	91,376	78,677	2,356	149,494,734
2010	1,489,249	461,390	96,037	75,414	1,076	170,657,706
2011	1,484,633	440,364	97,427	72,181	1,132	179,639,315
2012	1,349,896	378,392	90,615	62,329	1,149	182,277,386
2013	1,229,870	324,234	79,515	52,558	1,132	179,549,164
2014	1,223,198	307,983	77,073	49,701	1,202	190,615,208
2015	1,085,890	263,731	67,213	42,866	1,171	185,719,119

Table 9: Annual emissions and fuel use of MMCTs, (kg/y)

Year	N2O	NH3	PM2.5	EC2.5	Metals	Diesel (TJ)
1990	479	187	81,350	41,895	0.76	798
1991	492	192	81,321	41,880	0.79	820
1992	535	209	85,838	44,207	0.85	892
1993	538	210	83,822	43,168	0.86	897
1994	585	228	88,208	45,427	0.93	974
1995	614	239	89,683	46,187	0.98	1,023
1996	636	248	89,741	46,216	1.02	1,059
1997	700	273	95,362	49,112	1.12	1,166
1998	761	297	99,913	51,455	1.22	1,268
1999	803	313	101,499	52,272	1.28	1,339
2000	792	309	96,130	49,507	1.27	1,321
2001	769	300	89,197	45,937	1.23	1,282
2002	820	320	90,608	46,663	1.31	1,367
2003	895	349	94,009	48,414	1.43	1,492
2004	1,037	404	103,243	53,170	1.66	1,728
2005	1,159	452	109,070	56,171	1.85	1,932
2006	1,203	469	106,517	54,856	1.92	2,005
2007	1,342	523	111,426	57,385	2.14	2,237
2008	1,339	522	103,716	53,414	2.14	2,231
2009	1,207	471	86,807	44,706	1.93	2,012
2010	1,378	537	91,235	46,986	2.20	2,297
2011	1,451	566	92,555	47,666	2.32	2,418
2012	1,472	574	86,084	44,333	2.35	2,453
2013	1,450	565	75,540	38,903	2.32	2,417
2014	1,539	600	73,220	37,708	2.46	2,565
2015	1,500	585	63,852	32,884	2.40	2,500

Figure 3 shows the NOx, CO, PM and HC emissions from MMCTs over time.

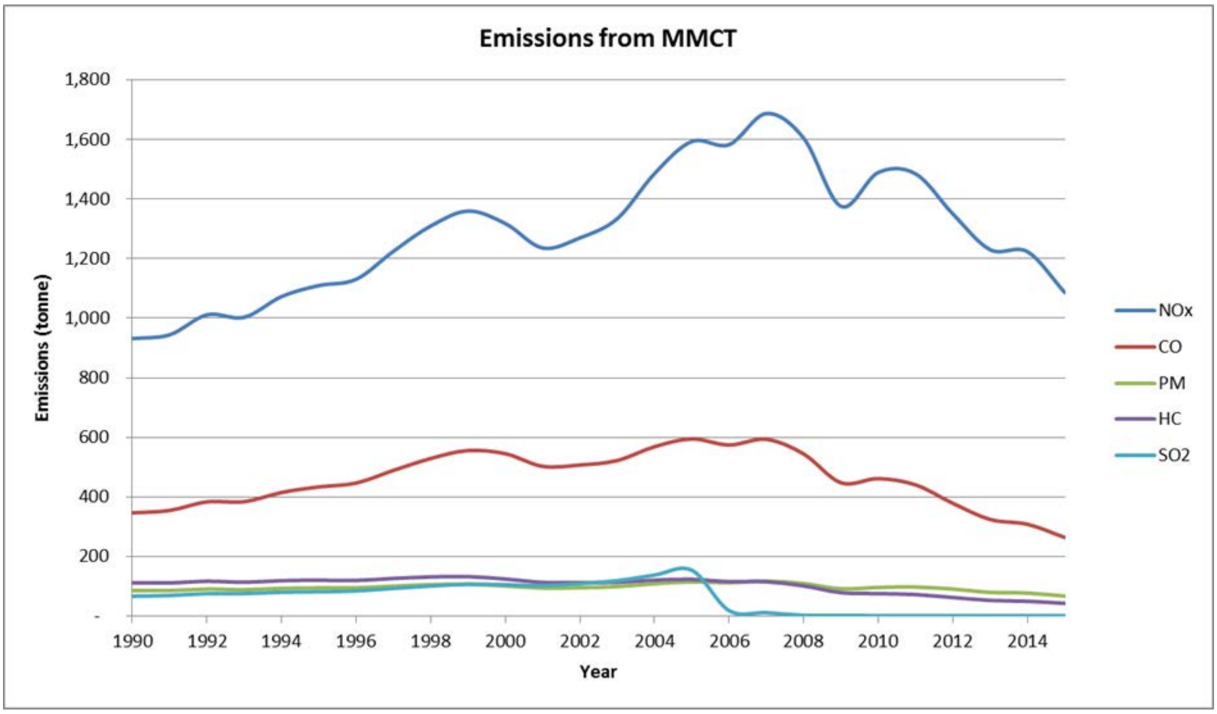

Figure 3: National emission from MMCTs, 1990–2015

Table 10 shows the total emissions of MMCTs in 2013 and the contribution to the national emissions of these substances.

Table 10: Contribution to national emissions by MMCTs in 2013, (kg/y)

Substance	National emissions	Emissions MMCTs	Share
NOx	336,600,000	1,229,870	0.37%
CO	665,864,000	324,234	0.05%
PM	31,126,900	79,515	0.26%
HC	113,530,000	52,558	0.05%
SO_2	54,544,300	1,132	0.00%
CO_2	184,226,000,000	179,549,164	0.10%
N_2O	29,099,100	1,450	0.00%
NH_3	133,816,000	565	0.00%
$PM_{2.5}$	16,924,000	75,540	0.45%
$EC_{2.5}$	4,428,430	38,903	0.88%

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Appendix

A: Future actualization of the results

Using the Excel documents delivered in this project, the emissions from MMCTs can be calculated from 1990–2014 and geographically distributed over Dutch container terminals. These documents are designed to be easily updated when more recent or accurate data become available, and to produce annual emission results (at least) up to 2020. In the text below, Doc. 1 refers to the “Mobiele werktuigen containers” Excel document, while Doc. 2 refers to the “Terminals distribution v2” Excel document.

Mobile machinery fleet
The mobile machinery fleet composition in 2010 has been extrapolated to 2020 so no action is required here. However, if accurate data on the machinery fleet become available in the future, these can be implemented in the model. This can either happen in the “Aantal verkochte machines” or “Machineoverzicht” part of the “Parkverloop cont.” tab (Doc. 1), but does require some knowledge of the model.

Energy requirement container handling
Since the energy requirement is expressed in delivered energy per TEU, improved fuel efficiency over time is already included through the standard fuel emission factors (fuel use/energy delivered). However, if container terminals start using more electrically powered mobile machinery in the future, fuel use per handled container may decrease irrespective of fuel efficiency. Accounting for such a development in the future requires some changes in the model. If electrification happens gradually over many terminals simultaneously, the new situation can be expressed in an updated diesel requirement per TEU container handled (in litre/TEU). This updated value can be used to replace the current value of 4.5 litre/TEU located on the “Liter per TEU – ton” tab in the Excel document (Doc. 1).

However, when large container terminals revert completely to electric machinery, a change in the average fuel requirement is not adequate since it will not impact the geographical distribution. It would be more appropriate to disregard the container handlings from the completely electrified terminals and remove these terminals from the geographical distribution model.

The litre/TEU values for modern container terminals that can be calculated from Oonk (2009) could give insight in future diesel requirements at container terminals. Furthermore, the port of Hamburg also publishes annual data on fuel use per container handled on their website (HHLA, 2015).

Emission factors
When updated standard emission factors or TAF profiles become available, these can be used to replace the current factors in the “Technologie & EF” tab (Doc. 1).

Container handlings in the Netherlands

Ideally, data on container handlings in the Netherland will become available in a similar format from CBS every year. If this is not the case, data from the port of Rotterdam will likely be available every year and, given its share of almost 90% within Dutch container handlings, can be used to estimate total container handlings in the Netherlands. New data can be added to the “Containeroverslag” tab in Doc. 1 to calculate total emissions, and added to the “Totaal overslag” tab in Doc. 2 to update the geographical distribution of the emissions.

Distribution of emissions over container terminals

To further update the geographical distribution of emissions of the Dutch container terminals, newer or more accurate data on the annual number of container handlings per terminal are required. These can possibly be found on the website of the port of Rotterdam for terminals in Rotterdam, and on the website of Inland Links for other container terminals. When the number of container handlings per terminal are updated in the individual sheets, the share of each terminal is automatically updated in the “Overzicht met aandelen” tabs (Doc. 2). New terminals at a specific location must be added manually to the respective locations’ tab and added to the “Overzicht met aandelen” tab.

Implementing or updating the results

The emission results for the years 1990 to 2014 have been included in the EMMA model (MS Access database). To incorporate later years into the model, the Excel document “Mobiele werktuigen containeroverslag” must be updated and saved as .xls document. In the EMMA database, the links to the Excel, named “Emissie_Havenmachines” and “EVV_Havenmachines” must be updated. Then, two append-queries, “app_ET_Havenmachines” and “app_EVV_Havenmachines” must be opened in design view. In the ‘der_emissiejaar’ criteria, make sure only the year is selected for which you want to add the emission results. When you are sure only the correct data is selected you can run both queries to add the relevant data to the “EMISSIE_TAAKGROEP” and “EVV_HOEVEELHEID” tables, which are used for the Dutch emission inventory.