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MECHANICAL PAVING IN THE NETHERLANDS

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Summary

This paper deals with a number of aspects related to mechanical paving in the Netherlands. Equipment for mechanical paving of new elements is available since decades, and recently some promising machines for repaving already used elements were developed. However, the share of mechanical paving is not more than 3%, in other words 97% of the huge amount of paving is still done manually.

The strongly divided paving market is considered one of the reasons for the low share of mechanical paving. This market consists of thousands of commissioners, a very large number of different paving elements (produced by tens of manufacturers) that are handled by many thousands of paviors that are employed at some thousands of, mostly (very) small contractors.

Furthermore, the pavior's branch is a shrinking and aging branch that is less and less attractive for youth, leading to an ongoing loss of expertise. Besides, the legislation on the working conditions is continuously getting more rigorous to reduce the workload and physical complaints of the paviors.

Since January 1 2007, a new rule of action of the Labor Inspection Department is valid which enforces mechanical paving in many cases: if a single area of more than 1 500 m² is paved with new elements, this has to be done mechanically regardless the weight of the element. If it is uphold, this rule of action will be an important stimulus for the growth of mechanical paving.

Under certain conditions (such as straightforward paving work, a works site of sufficient size and width, and the paving machine is in operation most of the working hours) mechanical paving is preferable compared to manual paving because:

- Less paviors and assistants drop out because of physical overloading;
- The surroundings experience less hindrance due to larger daily productions;
- The investment costs per m^2 are lower.

1. INTRODUCTION

In the Netherlands small element pavements are applied on a very large scale during centuries. Even today, the great majority of paving is done manually by paviors. The share of mechanical paving is limited to 3%. For various reasons, such as more rigorous legislation with respect to the pavior's working conditions and an increasing shortage of paviors, the share of mechanical paving will have to increase in future. Therefore in 2007 a study was done by a Working Group of the National Information and Technology Platform for Transport, Infrastructure and Public Space (CROW) into available knowledge with respect to manual and mechanical paving and (subjective) objections against and possibilities for mechanical paving. This paper is a summary of the Working Group's report (CROW, 2007).

Section 2 contains short descriptions of the various paving methods. First manual paving and manual laying are discussed together with some mechanical auxiliaries. Then some machines for mechanical laying of new paving elements are described. Finally, some promising, recently developed machines for mechanical laying of already used paving elements are discussed.

In Section 3 a brief overview of the paving market is given. In general terms data on the application of small element pavements, the available paving elements, the extent of paving, and developments with respect to both the number and size of contractors and the number of paviors are presented.

Section 4 concerns the pavior's working conditions. Subsequently the workload and physical health complaints of paviors and the legislation in this respect are discussed.

Section 5 presents a comparison, from an economical point of view, of the various paving methods.

Finally, section 6 contains the conclusions.

2. PAVING METHODS

The placement of paving elements is done in the Netherlands in two (2) ways, namely 'paving' and 'laying'. The traditional paving is always done manually; laying can be done both manually and mechanically.

2.1 Paving

The traditional paving of paving elements according to the typically Dutch craft method is done by a paviors team that nearly always is composed of a skilled pavior and an assistant.

Mostly the pavior is kneeling in the sand sub-base that is roughly levelled. In the case a base is applied the pavior is kneeling in the loose bedding sand layer. The pavior paves backwards and knocks every individual paving element down into the sub-base or the bedding layer with a hammer (see Figure 1-left). When concrete blocks, burnt clay bricks or natural stone sets are applied this is a steel hammer, and in the case of concrete tiles or natural stone tiles, this is a rubber hammer.

The assistant places the paving elements in the sub-base or bedding layer, in such a way that the pavior always has sufficient stock. Furthermore the assistant does all kind of other jobs, such as supplying missing sand for the sub-base or the bedding layer, cutting paving elements when necessary, sweeping the jointing sand into the joints of the top-layer and the vibratory compaction of the pavement.

The manual repaving of already used paving elements is done in exactly the same way as the manual paving of new paving elements.



Figure 1. Manual paving according to the traditional Dutch craft method (left) and manual laying (right).

2.2 Laying

In the case of laying of the paving elements the sand sub-base or the sand bedding layer (when a base layer is applied) is accurately leveled. After that, the paving elements are laid down on the sub-base or the bedding layer, which can be done manually by the pavior or mechanically by a machine.

Compared to manual paving, the paviors team is larger in case of manual laying. Now the team consists of three (3) or four (4) persons, because of the extra tasks to be done (such as accurate leveling) and the higher production rate. After leveling the sub-base or the bedding layer should not be damaged in any way.

When applying manual laying the assistants place the paving elements on the pavement that is completed just before. The pavior(s) then simply lay(s) down the elements in a high production rate on the leveled sub-base or bedding layer (see Figure 1 right). The pavior is standing or kneeling.

The manual relaying of already used paving elements is again done in exactly the same way as the manual laying of new paving elements.

In case of mechanical laying the production rate is higher than for manual laying, however that higher production is done by a larger paviors team that consists of four (4) persons at least. The machine handles 0.5 m^2 to 1 m^2 paving elements in one time. The elements have to be supplied in the desired pattern in special, more expensive layers. The machine picks up a layer by means of a mechanical or hydraulic clamp or by means of a vacuum system. Machines for mechanical laying of new paving elements are readily available. Some machines will be briefly discussed in section 2.4.

Recently some promising machines for mechanical relaying have been developed. The paving elements taken out of the road are first cleaned with a shovel or rotor-bucket and then dumped into the machine. The machine composes a layer of elements in the correct pattern and lays it down, or the machine lays down the elements one by one in the correct pattern. These machines are discussed in section 2.5.

2.3 Mechanical auxiliaries

A great variety of mechanical auxiliaries is available to improve the working conditions of the pavior and his assistant during manual paving or laying and during other activities, such as the placement and positioning of heavy kerbs. Examples of some intensively used auxiliaries are shortly discussed.

A mechanical assistant is a small, self-driven machine. Various types of auxiliaries can be attached to it (see Figure 2, top left). The machine is able to move smaller quantities of soil, to move paving

elements, to position kerbs, to lay down big size concrete tiles, to mechanically level the sand sub-base or the bedding layer with a laser-guided levelling beam, to sweep in the jointing sand and to clean the pavement. Thus, it really is a multi-task machine.

Figure 2, top right, shows a mechanical leveling beam for accurate levelling of the sand sub-base or the bedding layer. This specific machine is laser-guided.

A tile lifter (see Figure 2, bottom left) consists of a horizontal rod, with two (2) handles, and a vertical rod with a vacuum unit. A weight of maximum 20 kg can be lifted with this simple device.

Figure 2, bottom right, shows a kerb-positioning device. An auxiliary provided with a vacuum unit that allows picking up, displacing and exact positioning of kerbs is connected to a mini-shovel.



Figure 2. Some examples of mechanical auxiliaries.

2.4 Existing equipment for mechanical laying

Since the sixties attempts have been made in the Netherlands to mechanise paving of elements. The reasons were:

- Economic considerations.
- The strongly decreasing number of paviors.
- The legislation on working conditions to improve safety, physical health, and welfare of employees.

Only in the beginning of the eighties equipment became available that appeared to be successful. The break-through came in 1983 when the 800 000 m2 ECT container terminal was constructed in

the Rotterdam harbour area. The 120 mm thick concrete blocks were laid down with the Delta-S machine, that is supplied with a four-sided hydraulic clamp system (see Figure 3, top left). Because of its size this machine is less suitable for paving roads within built-up areas as maneuvering in a limited space is time consuming, resulting in a reduced production and increased construction costs.

Also in the eighties the Schaeff was developed which is a rather big machine supplied with a vacuum system (see Figure 3, top right). In first instance, the machine was only able to handle concrete blocks but later auxiliaries were developed that enable the machine to lift and position concrete tiles and kerbs.

Furthermore, nowadays a great number of rather small machines are available. These machines are supplied with either a mechanical or a hydraulic clamp or a vacuum unit. These self-driven and very manoeuvrable machines have a length of around 4 m, a width of around 1.4 m and a height of about 2 m. Their weight amounts 1 000 to 1 200 kg. The manufacturers claim a production of 600 to 1 000 m2 per day. Some examples are shown in Figure 3, bottom left, and Figure 3, bottom right.

All the mentioned machines have in common that:

- They are only able to handle new paving elements, repaving of already used elements is impossible.
- Every time a layer of 0.5 m2 to 1.0 m2 of concrete blocks or burnt clay bricks (with small dimensional tolerances) or concrete tiles is laid down.



Figure 3. Some examples of machines for mechanical laying of paving elements.

2.5 Equipment for mechanical relaying

In the Netherlands, an ever increasing share of the paving work is repaving. Currently the share of repaving is 70% to 80%. Already during a long period of time it is tried to develop machines that are able to perform (nearly) all the subsequent activities related to repaving, which are breaking up the existing small element pavement, cleaning the elements, if required composing a layer of elements in the desired pattern, and laying down the elements. Recently some machines for mechanical relaying are developed. Below two (2) promising machines are shortly described.

The 'Paving Stone Layer' is a user-friendly machine suitable for handling both new and already used paving elements, also on smaller works sites. The machine consists of a bunker, two (2) conveyor belts and an arm with a vacuum unit. The self-driven machine is placed on the frame of a trailer (see Figure 4, left).

In case of relaying the earlier cleaned elements are dumped into the bunker by a small shovel and then moved by a conveyor belt to the two (2) paviors. They move the elements into the right pattern. Next one of the paviors lays the 0.5 m2 layer of elements into the road. A third pavior fills the bunker if necessary, lays the so-called bishop-hats, and performs all other small activities. The reach of the machine is nearly 4 m at either side. The production of the machine plus three (3) paviors is 200 m2 to 250 m2 per day.

The big advantage of this machine is the improvement of the pavior's working conditions, the production rate in itself is not very impressive.

The 'Streetwise 1200' is a computerized vehicle on wheels with a robot arm for laying and relaying of pavement elements (Figure 4, centre and right). The whole system including Diesel aggregate, electronics and cameras is embedded in a four (4) wheel driven shelter with over-pressure to prevent dust from entering. With a rather simple device data such as width of the carriageway, paving block format, pattern and tolerances can be input with an accuracy of 0.1 mm. The machine bypasses all the obstacles due to the GPS system, the three (3) cameras and the four (4) wheels. The machine stops as soon as it hits a subject or a person. The robot arm moves with a speed of maximum 3 km/h. The machine automatically gives a signal when the stock of paving blocks is nearly empty.

The Streetwise 1200 is able to completely automatically lay down the paving blocks one by one in any desired pattern. The pavior only operates a keyboard and a joystick. The machine takes over the job of three (3) paviors and is able to operate 24 hours per day at any weather condition. The production rate of the Streetwise 1200 is 1 200 blocks per hour (200 m2 to 250 m² per day).

The 'Brickclean 201' for automatic cleaning and stocking of used paving blocks is under development. A small shovel drops the blocks into the machine where they are cleaned and automatically laid straight on their correct side. On pallets, the layers of blocks can then be fed into the Streetwise 1200.

Furthermore the 'Sidewalk 101' is under development which is a machine for picking up and positioning tiles and kerbs.



Figure 4. 'Paving Stone Layer' (left) and 'Streetwise 1200' (centre and right) paving machines.

3. THE PAVING MARKET

3.1 Introduction

In the Dutch paving market a variety of actors is present. Small element pavements have their specific applications and are constructed in commission of authorities (municipalities), private companies or private persons. The pavement is constructed manually or mechanically by paviors that are employed at one of the (very) small contractors. For the pavement a great variety of elements can be chosen that differ with respect to material (concrete, burnt clay, stone), shape, dimensions, colour and price and that can be laid in different patterns. In this chapter a very short overview of the Dutch paving market is given, when possible in quantitative terms.

3.2 Application of small element pavements

In the Netherlands, about one-third of the paved area has a small element pavement, i.e. a pavement with a top-layer of concrete blocks, burnt clay bricks, concrete tiles or natural stone sets. Within built-up areas, especially in the west and north of the country where the subsoil is very weak and compressible, the share of small element pavements is often (much) higher (see Figure 5). Also relevant is that in the Netherlands the underground infrastructure (cables and piping) is often located within the pavement structure. Compared to asphalt and concrete pavements, settlements can be repaired much easier and much cheaper in small element pavements and the underground infrastructure is much easier accessible for repair or extension.



Figure 5. Division (%) of the paved area in the Netherlands in 2007; left: total paved area (estimate), right: municipal paved area (data Oranjewoud Consultants).

Within built-up areas, small element pavements are especially applied on:

- Roads (mainly residential streets) and parking lots, that are not too heavily loaded by (truck) traffic; nearly always the rather small concrete blocks and burnt clay bricks are used, with horizontal dimensions of about 200 mm x 100 mm; the elements are usually laid in herringbone bond, and sometimes in stretcher bond, diagonal bond or (especially for temporary pavements) basket weave.
- Bicycle tracks and footways, where mostly the standard concrete tile (300 mm x 300 mm) in stretcher bond is applied.
- Shopping-streets, squares, and historical city centers where the appearance (aesthetics) of the pavement plays an important role; on these pavements mostly burnt clay bricks, (big size) concrete tiles, or natural stone sets are applied.
- (Very) heavily loaded industrial yards such as container terminals are another important application of small element pavements, with a strong base layer. Concrete blocks are able to withstand the large contact stresses due to the off-the road vehicles and stacked containers.

The total amount of paving in the Netherlands is about 35.5 million m^2 per year. The amount of new paving is two (2) to three (3) times smaller than the amount of repaving existing pavements (which is required because of settlements, cables and piping or structural damage). Nearly 100% of repaving and around 92% of new paving is done manually. This means that only 3% of all paving is done mechanically.

3.3 Paving companies and paviors

The number of paving companies has strongly increased in the period 1997 to 2006. The increase is mainly caused by the erection of so-called one-person companies.

Figure 6, left, gives an overview of the number of officially registered paving companies in the period 2000 to 2006. The number of one-person paving companies has increased from 684 to 1 638 and the number of paving companies with one (1) to nine (9) employees has increased from 778 to 937. On the other hand, the number of big paving companies, with 10 or more employees, has decreased from 200 to 142.

The number of paviors has strongly decreased during the last decades (Figure 6, right). The number of people leaving the paving branch is considerably larger than the number of young people starting a career in this branch. People that stop paving find a physically less demanding (management) job in the paving branch, find a job in another economic branch, become unemployed, or are physically disabled.

In September 2004, 21% of the paviors was younger than 25 years of age, 61% had an age between 25 and 44 years and 18% was 45 years or older. Similar to other (construction) branches, the percentage of elder paviors constantly increases, especially since 1997; in 2003 the percentage of paviors elder than 55 years had increased to 6.5%.

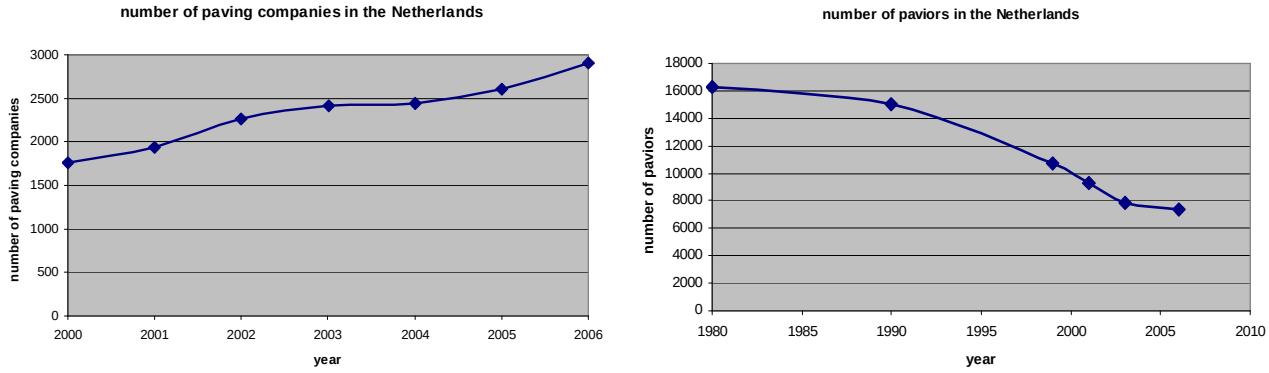

Figure 6. Number of paving companies in the period 2000 – 2006 (left) and number of paviors in the period 1980 – 2006 (right) in the Netherlands.

3.4 Overview

It appears that the paving market in the Netherlands is a divided market in many respects:

- There are many thousands of commissioners: not only all the municipalities (around 430) but also many private companies and private persons.
- The number of different paving elements is very large, where the differences concern the material (concrete, burnt clay, natural stone), format (shape and dimensions), colour and price.
- Manufacturers produce elements of the same format sometimes with slightly different horizontal dimensions; elements of different manufacturers can therefore not be (re)used together.
- The elements are produced by dozens of manufacturers and are handled (for the major part manually) by many thousands of paviors that are employed at a few thousand, mostly (very) small and financially weak paving companies.
- The paving branch is a shrinking branch, in which the employees are getting older and that is decreasingly attractive to youth; on balance the expertise in the paving branch decreases.

4. PAVIOR'S WORKING CONDITIONS

From a physical point of view, a pavior has a demanding profession. Since the eighties, various investigations into the pavior's working conditions and health complaints have been done. Both industry and authorities have a lot of attention for improvement of the pavior's working conditions. Legislation in this field becomes more and more rigorous and is intensively controlled on works sites.

A considerable part of the paviors has physical complaints. Complaints related to the back are most frequent, but also complaints with respect to the upper body members (shoulders, elbows, wrists, hands), the lower body members (knees) and the neck are often heard (see Table 1). Over 30% of the paviors has physical complaints because of their job.

The percentage of paviors on sick-leave has strongly decreased during the last decades. Since 2000 this percentage is around 6% which is about equal to the average percentage of sick-leave of all the labourers on construction sites.

Table 1. Division of physical complaints of paviors in 2006.

PHYSICAL COMPLAINT	PERCENTAGE (%)
Pain or stiffness on upper body members	42
Pain or stiffness on lower body members	40
Pain or stiffness in the neck	21
Pain or stiffness at the back	50
Complaints because of the job	32

In the Netherlands, a number of legislations and guidelines with respect to the pavior's working conditions are valid. In this paper only the most relevant rules of action, and the rules of enforcement, of the Labour Inspection Department of the Dutch Ministry of Social Affairs are explained.

The most relevant articles of the current rules of action of the Labour Inspection Department with respect to the pavior's physical working conditions are:

- Manual lifting should be avoided or limited as reasonably is possible.
- The maximum weight lifted by 1 person with his hands is 25 kg.
- The maximum weight lifted by two (2) persons together with their hands is 50 kg, provided that there is sufficient space to move.
- Concrete blocks and burnt clay bricks with a weight of more than 4 kg are not manually handled.
- Concrete tiles with a weight of more than 9.5 kg are not manually handled.

Since January 1, 2007 a new rule of action of the Labour Inspection Department is valid which enforces mechanical paving in many cases: if a single area of more than 1 500 m² is paved with new elements, this has to be done through mechanical paving regardless the weight of the element.

Also since January 1 2007, a new law on working conditions is in force. Good working conditions are the joint responsibility of both commissioners and contractors. The authorities do stimulate the development of working condition catalogues for the construction sectors and for the construction sites. The Labour Inspection Department especially takes action against commissioners and contractors that do not reduce the working related risks. The height of the maximum penalty is doubled compared to the earlier law.

5. ECONOMIC COMPARISON BETWEEN MECHANICAL AND MANUAL PAVING

Mechanical and manual paving can be compared with each other from different points of view, for instance aesthetics, functional behaviour, structural behaviour and economic appraisal. In this paper only a comparison from an economical point of view is made, where it should be realized that in the Netherlands the labour costs are quite high and thus the costs of materials and equipment are relatively low.

In 2003 a study was performed into the effects of using devices which contribute to better working conditions for paviors. Compared to manual laying, the costs and benefits of a hydraulic clamp system and a vacuum system for mechanical laying of paving elements were determined. The starting points for the calculation of the costs and benefits were:

- New paving work is done with 80 mm thick, cobble format concrete blocks; in case of mechanical handling the layers of blocks supplied by the manufacturer are somewhat more expensive than layers for manual handling.

- A distinction is made between narrow (width maximum 5 m) and wide streets because in practice the daily paving production depends on the width of the road, i.e. The available working space.
- The used average daily productions are based on measurements at a number of works sites;
- With respect to labour costs, a distinction is made between paviors, assistants and drivers (only for the vacuum system).
- Size of the paviors team:
- Maanual laying: 1 pavior and 1 assistant
- Mechanical laying, hydraulic clamp: 1 pavior and 2 assistants
- Mmechanical laying, vacuum system: 1 pavior, 2 assistants and 1 driver
- Machines are in operation 100 days per year.

The result of the cost calculation is presented in Table 2.

Table 2. Costs and benefits of manual and mechanical laying in 2003.

	MANUAL LAYING		**MECHANICAL LAYING WITH HYDRAULIC CLAMP**		**MECHANICAL LAYING WITH VACUUM SYSTEM**	
	NARROW STREET	**WIDE STREET**	**NARROW STREET**	**WIDE STREET**	**NARROW STREET**	**WIDE STREET**
Production (m^2/day)	80	100	195	270	260	360
Material costs (€$/$m^2$)						
Concrete blocks	8.30	8.30	8.80	8.80	8.80	8.80
Labour costs (€$/$m^2$)	210	210	210	210	210	210
Pavior	183	183	366	366	366	366
Assistant(s)	-	-	-	-	237	237
Machine driver	3	3	4	4	5	5
Industrial clothing etc.	13	13	13	13	13	13
Mobile canteen etc.	35	35	35	35	35	35
Transport						
Machine costs (€$/$m^2$)						
Hydraulic clamp	-	-	124	124	-	-
Vacuum system	-	-	-	-	287	287
Total costs (€$/$m^2$)	13.85	12.74	12.66	11.59	13.23	12.01
Material	8.30	8.30	8.80	8.80	8.80	8.80
Personal	5.55	4.44	3.22	2.33	3.33	2.41
Machine	-	-	0.64	0.46	1.10	0.80
Relative total costs (%):	109	100	99	91	104	94
Material	65	65	69	69	69	69
Personal	44	35	25	18	26	19
Machine	-	-	5	4	9	6

A number of conclusions can be drawn from Table 2:

- Paving narrow streets is about 10% more expensive than paving wide streets.
- Mechanical laying is cheaper than manual laying: laying with a vacuum system is about 5% cheaper than manual laying and laying with a hydraulic clamp is about 10% cheaper than manual laying.
- The material costs constitute the greatest share (60% to 76%) in the total costs; the wider the street, the larger the share of the material costs.

- The share of the labour costs is 20% to 40%; the wider the street, the smaller the share of the labour costs.
- The share of the machine costs is 4% to 8%; the wider the street, the smaller the share of the machine costs.

It appears that mechanical laying is somewhat cheaper than manual laying and manual paving. Pre-conditions for this are a quite high daily production, the machine is in operation during at least 50% of the time, and only new paving work is done.

Notwithstanding all this, mechanical paving was not done on a large scale during the past years, apparently because most of the contractors had the idea that mechanical paving is more expensive than manual paving. However, this opinion does not hold when considering the integral costs (labour costs, machine costs, material costs, costs of diseases) of paving work.

6. CONCLUSIONS

In the Netherlands the great majority of the extensive amount of paving works consists of repaving. Only a very small part (around 3%) of the paving is done mechanically. However, a new rule of action of the Labour Inspection Department is valid since January 1, 2007: if a single area of more than 1 500 m² is paved with new elements, this has to be done through mechanical paving regardless the weight of the element. This rule will possibly be an important stimulus for increasing the share of mechanical paving which is especially suited, also from an economical point of view, for larger scale and rather simple paving works. The large production rate leads to less hindrance for neighbouring inhabitants, shops and companies.

On the other hand, mechanical paving requires a much better organisation and logistics on the works site compared to manual paving. A complication, at least in the Netherlands, is that the great majority of the contractors are of a (very) small size and do not have much possibilities for investments in paving machines.

Increasing the share of mechanical paving is also desirable because of the further improvement of the pavior's working conditions and because of the increasing lack of sufficient skilled paviors.

Equipment for mechanical paving of new elements is readily available during decades. Recently some promising equipment for mechanical repaving of already used elements became into operation and given the situation in the Netherlands, this is a very relevant development.

Notwithstanding all developments with respect to mechanical paving, manual paving will always hold a considerable share of the paving work. Small scale and/or complex (different types of elements, different patterns) paving work can only be made through manual paving by skilled paviors.

7. REFERENCE

CROW, 2007. Mechanical Paving (in Dutch). Publication 255, National Information and Technology Platform for Transport, Infrastructure and Public Space (CROW), Ede, the Netherlands.