U.S. Department of Transportation

Federal Highway Administration

The Dutch Approach to Bicycle Mobility:

RETROFITTING STREET DESIGN FOR CYCLING

Technical Report Documentation Page

<table>
<tr><td>1. Report No.

PL-18-004</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalogue No.</td></tr>
<tr><td colspan="2">4. Title and Subtitle

The Dutch Approach to Bicycle Mobility: Retrofitting Street Design for Cycling</td><td colspan="2">5. Report Date

09-10-2017</td></tr>
<tr><td colspan="2">7. Author(s)
Kees van Ommeren, Paolo Ruffino, Sara de Boer, Jeroen Buis</td><td colspan="2">6. Performing Organization Code</td></tr>
<tr><td colspan="2">9. Performing Organization Name and Address

Rijkswaterstaat
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The Netherlands</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="2">12. Sponsoring Agency Name and Address

Federal highway Administration
Office of International Programs
1200 New Jersey Avenue, SE 20590</td><td colspan="2">10. Work Unit No. (TRAIS)</td></tr>
<tr><td colspan="2" rowspan="3">15. Supplementary Notes

Reviewed by the Federal Highway Administration, Office of Public Affairs</td><td colspan="2">11. Contract or Grant No.</td></tr>
<tr><td colspan="2">13. Type of Report and Period Covered</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">16. Abstract
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network, improve transportation system efficiency, leverage investments, and
meet local public demand.</td></tr>
<tr><td colspan="2">17. Key Words

Dutch, Bicycle, Bicycling, Cycling, Pedestrian, Mobility, Retrofitting, Design</td><td colspan="2">18. Distribution statement</td></tr>
<tr><td>19. Security Classif. (of this report)

Unclassified</td><td>20. Security Classif. (of this page)

Unclassified</td><td>21. No. of Pages

76</td><td>22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Note:

This material is based upon work supported by the Federal Highway Administration under contract number DTFH6116I00039.

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Preface

This report highlights techniques and strategies for retrofitting existing road infrastructures in order to improve safety, fix gaps and barriers in the pedestrian and bicycle network, improve transportation system efficiency, leverage investments, and meet local public demand. It draws from the experience and perspective of Dutch transportation practitioners, who have demonstrated success in developing a high-quality transportation system that meets the needs of all users.

This report was developed under the bilateral cooperation between the Federal Highway Administration (FHWA) and the Dutch Rijkswaterstaat, which is responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands. This effort builds off of work done by FHWA under a Global Benchmarking Program (GBP) effort to learn how international transportation experts, primarily the Dutch, have created safer and more comfortable bicycle transportation networks. The GPB effort produced two reports, including:

- Bicycle Network Planning & Facility Design Approaches in the Netherlands and the United States (2016)
- Delivering Safe, Comfortable, and Connected Pedestrian and Bicycle Networks: A Review of International Practices (2015)

Through the bilateral cooperation, the FHWA continues to work with Dutch officials on bicycle transportation issues. The aim of the cooperation agreement is for the Dutch and United States practitioners to learn from each other and increase knowledge related to planning, designing, monitoring, and improving the performance of bicycle transportation networks. As noted above, this report provides examples of how the Dutch have retrofitted their infrastructure to better serve all road users.

Executive Summary

Over the last two decades, cycling is becoming increasingly relevant as daily transport mode around the world. On the one hand, policy-makers have acknowledged the growing demand for more and flexible mobility. On the other hand, the benefits of cycling on public health, the environment and the local economy are becoming widely evident. Hence, many local and national governments want to increase the share of trips made by this mode of transport, thereby contributing to more livable and sustainable urban areas.

Within this context, The Netherlands is regarded as an inspiring example when it comes to cycling for utilitarian purposes. The extensive, safe and high-quality bicycle network crisscrossing the Netherlands provides one of the safest cycling experiences in the world. As a result, more than a quarter of all trips are made by bicycle. This transport mode is embraced for any kind of purpose and by all social groups, including children. Given the safe conditions, more than two-thirds of (secondary) high school students commute to school by bicycle, while only 5% are taken by car. The high bicycle use not only reduces carbon emissions and prolongs the average life expectancy of six months, it also saves 19 billion euros (20 billion dollars) every year in healthcare costs[1]. In addition, by providing an inexpensive alternative to both public transport and the car, the bicycle promotes social inclusion and access to jobs, services, and leisure in an efficient way. Investments on cycling do not come at the expenses of other road users. Evidence shows that policies to encourage bicycle users also benefit car drivers and the public transport network in terms of lower travel times, better accessibility and increased safety. For these reasons, cycling is included in multiple policy domains and the Netherlands keeps promoting bicycle use by investing in cycling projects, socio-technical innovations and behavioral campaigns.

Despite its long tradition in the field of cycling, it may come as a surprise to discover that the Netherlands has not always been the bicycle friendly country known today. Decades ago, Dutch cities struggled with the same problems that many European and American cities are facing today. Namely, alarming growth of traffic congestion, pollution, inefficient use of public space and safety issues. In the Netherlands, cycling declined dramatically between the 1950s and 1970s. Well-timed social movements, coupled with exogenous events such as the energy crisis and key political events, triggered a transport policy change. Policy-makers shifted their focus from promoting car use by expanding the supply of roads to prioritizing human safety, health, environmental quality and vibrant street life. This policy change reverted the declining bicycle use which is now growing again.

[1] Fishman et al. (2016) Dutch Cycling: Quantifying the Health and Related Economic Benefits

The report illustrates effective strategies and techniques that have contributed to this success. It unfolds with a historical perspective on the development of Dutch cycling policy and infrastructure, it describes the contemporary approach and it illustrates four U.S. relevant cases of retrofitting in both urban and sub-urban areas in the Netherlands that initially have been designed mainly for car use.

From both the analyzed cases and the general overview of the historical and contemporary bicycle policy perspective, several key findings emerge:

- Planning bicycle-friendly environments requires a broader understanding of the interaction between physical and psychological factors that influence travel behavior and mode choice.
    - Implementing an extensive, cohesive, safe, attractive, comfortable and direct network of bicycle infrastructure is an important factor to encourage bicycle use. Working towards a complete network is important, but this has to be accomplished one step at a time by following a coherent and logical method.
    - Planners must not only focus on the (quantitative) generalized costs of transport (namely travel time, travel costs, etc.) but also include (qualitative) aspects of the travel experience (comfort, perception of safety, attractive street design, level of noise, occasion of social interaction, presence of social activities, etc.).
- Retrofitting the road network should start with experimenting. For example, by testing intelligent traffic systems (i.e. green wave for cyclists).
- Promoting a cycling culture goes beyond the implementation of bicycle paths. It also requires integration with public transport. Integrating cycling with public transport by means of dedicated facilities (such as bicycle parking) at transport hubs to increase accessibility to distant locations[2].
- Influencing the demand side of other modes of transport by means of physical interventions (narrowing streets to reduce speed, raised intersections or changes in the geometry of intersections), monetary incentives (such as road pricing) and behavioral campaigns (such as traffic education and communication campaigns, see paragraph 3.2).

The Netherlands has a holistic and comprehensive approach to cycling:

- Streets are designed on the basis of a systematic safety approach, as expressed by the Sustainable Safety policy (paragraph 3.4.1). Unlike the reactive approach (which focuses on identifying and fixing black spots in the road network), the Dutch system attempts to minimize all potential conflicts at their root by:
    - Unravelling (or unbundling) bicycle networks from car networks.

[2] Evidence shows that bicycles do not compete with public transport, but they represent its feeder system.

    - Employing specific road layouts and designs according to the function of the street, the volume and, the speed of traffic.
    - Diverting traffic from city centers and employing traffic calming measures systematically.
- Cycling is included in long-term policy plans and integrated into other policy domains: most important in spatial plans, but also in health and environmental policies.
- Dedicated budget allocations and clear competences between government agencies are also needed. At the regional level funds are used to enhance the homogeneity and continuity of (cycling) infrastructure across municipal boundaries. Municipalities are responsible to set their vision and implement cycling facilities at local level.
- Given the complexity and interconnectedness of mobility challenges, planning for cycling is a holistic discipline (which requires input and expertise from all domains including social science, economics, anthropology, geography, engineering, architecture, history, etc.) and the use of a wide variety of tools and techniques: from the direct observation of the phenomenon to the use of big data.
- Strong political will and commitment to long-term goals is a common denominator to any transformation.

1 Introduction

1.1 Framing the challenge

Contemporary cities face fundamental sustainability challenges. In particular, the transport system sustains the economic development of cities, social cohesion, and environmental quality. However, rapid urbanization coupled with globalization, climate change and changing preferences of a young urban population, require a fundamental shift in the way we plan and develop our cities at all levels. Starting with strategic planning through implementation. In particular, there is an increasing need to decouple the growing demand for more (and flexible) mobility and the externalities that a car-based system produces.

Figure 1 Modern freeway with heavy traffic (picture: Interstate 80 in Berkeley, California)

Source: Wikimedia Foundation, Inc.

Attention is therefore shifting towards non-motorized and carbon neutral transport solutions as efficient, healthy and equitable alternatives to our current mainstream transport system. Cycling, in particular, represents a fast, efficient and cost-effective means to travel through cities for any purpose. It requires a limited amount of space and the energy to be propelled is produced directly by the user, contributing to several health and environmental benefits which translate to substantial economic savings[3].

[3] See a literature review of socio, economic and environmental benefits of cycling here: de Hartog et al., 2010; Oja et al., 2011; Pucher & Buehler, 2012; Martens, 2013 and the EU-funded Evidence Projects (2015) www.evidence-project.eu, that brings together a systematic peer reviewed body of high quality research on sustainable transport, including cycling.

Municipal governments around the world are therefore becoming interested in promoting cycling in their own cities. However, the transition from a car-oriented to a bicycle and pedestrian-oriented mobility system represents a great challenge. These challenges are often coupled with and aggravated by strong path-dependencies and lock-ins that are difficult to overcome since established social norms, institutional practices and cultures reinforce the existing system. Achieving a systemic transition requires a long-term approach as it does not only involve technological change, but also material, organization, institutional and socio-cultural change. However, the urgent need to make our cities more resilient require an acceleration and facilitation of such transition. How do we deal with it?

1.2 Cycling in the Netherlands

Figure 2 Haarlemmerstraat, Amsterdam (1930s – 1950s – 2017)

Source: Beeldbank Amsterdam; Paolo Ruffino

An increasing number of scholars, practitioners, and policy-makers are regarding the Netherlands as an inspiring example to follow in their implementation of bicycle policies. The Netherlands is considered by many to be the *"bicycle capital of the world"* for its high level of bicycle use and its extensive and high quality network of bicycle paths. The Dutch cycle almost every day, covering an average of 630 miles per year and own over 1,2 bicycles per person. This means that there are more bicycles, over 22 million, than inhabitants, just 17 million[4]. Cycling is embraced by all social groups, ranging from children to adults and it is equally distributed between genders[5]. According to the last national mobility survey[6], the bicycle is used for any kind of purpose. Over 50% of all

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[4] RAI (2016)
[5] Pucher & Buehler (2012)
[6] KiM (2016) http://web.minienm.nl/mob2016/

education trips, 28% of shopping trips and 11% of business trips are made on the *"two wheels"*. However, The Netherlands has not always been the bicycle-friendly country known today. After the Second World War, car use exploded and new roads were planned and designed to accommodate the growing motorized traffic at the expenses of cyclists and pedestrians. Only from the late 70s and 80s, the national and local governments started to revert this development. This involved the retrofitting of infrastructure designed for car traffic back to bicycle- and pedestrian-friendly infrastructure. A process that is still ongoing today and represents an opportunity to make cities more livable, resilient and create space to experiment and study new innovative socio-technical innovations. The socio-political transition that happened in the Netherlands is of great relevance for policy-makers and practitioners as it testifies that mobility cultures can change and sustainable modes of transport such as the bicycle can upscale and become a mainstream mode of urban travel. In addition, when combined with public transport, cycling can also extend the catchment area of trains and buses, thereby increasing accessibility and promoting social inclusion.

1.3 What is this report about

This study aims to shed light on the transition from a car-oriented to a human-oriented approach to infrastructure planning in the Netherlands. This is done by providing insights and examples of practices of bicycle planning in both urban and sub-urban areas in the Netherlands that have initially been designed for car use. The Netherlands is a relatively compact and dense country with old historical cities. With the selection of cases, attention was paid to comparability and relevance for the American context. In particular, the study focuses on urban streets with a wide profile (such as arterial roads) and intersections, low-dense sub-urban areas and countryside paths. These had previously either no or bad quality cycling infrastructure, which has been lately upgraded following specific design standards.

Before diving into the cases, this report begins by framing cycling policies from an historical standpoint in order to provide the reader with relevant background information. This is done extensively as many regulations, design principles and policies currently in place are the direct product of historical decisions and contextual developments that should be considered. After the historical introduction, this report addresses the contemporary bicycle planning practice, highlighting some examples of both physical and soft measures, and it informs about innovations and challenges in the field. The objective is to yield policy-relevant information that can be used as guiding example in planning choices, provide practice-informed arguments and offer a useful tool to compare and learn from different perspectives. Some recommended readings and references are reported at the end of the document (p. 68).

2 Historical perspective on Dutch cycling

2.1 Background

Several scholars have categorized the historical transport policy transition in the Netherlands (and in other European countries) in four main phases[7]. An early era between the 1860s and the 1920s in which the bicycle was introduced, followed by the explosion of cycling between the 1920s and the early 1950s. The decline of cycling as result of mass mobilization between the late 1950s and mid-1970s. Finally, the contemporary era, from 1975 until today when cycling started rising again and became a symbol of urban sustainability. These periods have been characterized by several institutional, social, economic and political transformations at different levels that have shaped the trajectory of development of cycling culture in the Dutch context. In this chapter, these are briefly outlined and the approach and the role of different actors are highlighted.

2.1.1 The early bicycle introduction 1860s – 1920s

In the late nineteenth century, cycling was not an everyday transportation practice but rather one of the many leisure activities of the Dutch élites. By the beginning of the twentieth century, the bicycle started to become the mode of transport of a wider group of individuals, including professionals, public officials, and specialized workers.

Figure 3 Old towpath in Kop Weespertrekvaart & school director on his bicycle (1893)

Source: Beeldbank Amsterdam

Bicycle associations and clubs, such as RAI (*Rijwiel- en Automobiel Industrie*) and ANWB (*Algemene Nederlandsche Wielrijders-Bond*), were formed and began to lobby for more open streets and towpaths in which cyclists could also ride. The main technical problem at the time was the pavement. It was not a coincidence that during this period, Dunlop

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[7] The topic has been treated by de la Bruhèze & Veraart (1999); Oldenziel & de la Bruhèze (2011); Jordan (2013); Oldenziel et al. (2016) more extensively.

developed in this period the first pneumatic tires for bicycles. Cycle tracks (also known as Separated Bike Lanes and Protected Bike Lanes in the U.S.) often were the result of private initiatives and they were designed to improve the cyclists' comfort[8].

The first intervention by the Dutch government on cycling was in 1899 when a luxury tax was introduced. Although this was highly contested, the revenue represented the first financial contribution to improve local roads and construct dedicated bicycle facilities. This tax was finally removed in 1919 when the retail price of bicycles dropped dramatically and it could not be claimed that the bicycle was a luxury good anymore. By 1920, the bicycle became a model accessible to everyone and it was used as a *"workhorse"* rather than a *"fancy"* object.

Government	Planners	Bicycle organizations
Top-down taxation to finance early cycling infrastructure	Town and road infrastructure planning performed jointly by government officials and cycling organizations	Advocated for better road surface in cities and towpaths in the country side. Provided expertise to planning and government institutions

2.1.2 The bicycle as mass transport: 1920s – 1950s

During the post-Great War era, bicycle use began to boom becoming a real mass-scale urban phenomenon. By mid-1934, the Netherlands had over three million bicycles, every second citizen owned one.

Figure 4 Leidsestraat (Amsterdam) during peakhour (1934)

Source: Beeldbank Amsterdam

[8] CROW (2007)

The network of bicycle paths reached 870 miles and funds were made available for future expansion and improvement[9]. An American journalist of the time described the bicycle in the Netherlands as *“almost a part of the body”* and joked that in the future, Dutch babies would come *“into this world on tiny bicycles”*[10].

Figure 5 Rokin (Amsterdam) during peakhour (late 1930s)

Source: Beeldbank Amsterdam

One of the reasons for this boom was the hyperinflation in Germany after World War 1, which made bicycle more affordable for a larger group of people[11]. However, this period also saw the appearance of the automobile on Dutch roads and, for the first time, local government authorities had to deal with unprecedented challenges such as bottlenecks, crashes, and early traffic congestion. City councils and traffic departments began an early road expansion and regulating traffic speeds. In the urban context, segregated cycle tracks were introduced, mostly to push cyclists aside. The upper-middle class culturally shifted from cycling to promoting car use. Local governments, including bicycle-friendly Amsterdam, began to frame bicycle traffic as a threat rather than a solution to be embraced. In a public report of the 1930s, the City Department of Public Works argued that the Netherlands was “lagging behind” the U.S. in terms of car ownership[12]. Despite the image shift, cycling was the most popular transport mode in the country. In

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9 Ploeger (1990)

10 As cited by Oldenziel & de la Bruhèze (2011)

11 Jordan (2013)

12 Gemeente Amsterdam, Het Verkeer te Amsterdam volgens de uitkomsten van de openbare verkeerstelling 1930 (Amsterdam: Dienst Publieke Werken, 1934)

Amsterdam, the modal share of cyclists was about 70% to 80% of total traffic. This continued to be so until after the Second World War. Bicycle clubs and advocacies, initially, strongly opposed segregated bicycle tracks and bicycle lanes as they perceived them as a threat to their rightful access to public space. However, their position and expertise was soon challenged and marginalized by new emerging professional figures such as civil and traffic engineers whose main role was to plan future cities following the functionalist principles of segregation of space. These new figures also had a proactive role in paving the way for the later car growth. This mass-motorization did not happen until the 50s as World War II and German occupation delayed this development. This late motorization must be considered of great importance as the bicycle continued to be very present in Dutch society untill the 60s.

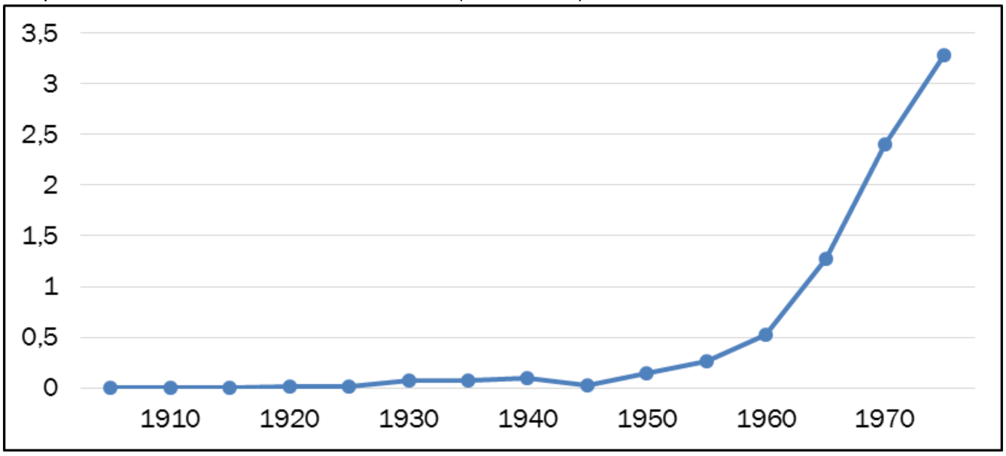
Government	Planners	Bicycle organizations
Cycling started to be considered a mode of the past, but government officials had to deal with it as cyclists outnumbered cars by far.	Traffic and civil engineers emerged as the new professional figure able to solve the puzzle of mobility by focusing on separating modes and on how to maximize car speed, reduce travel time and achieve better flows.	Cycling clubs begin to lose importance in planning. They strongly contested segregated infrastructure as a threat to freedom of movement and saw bike lanes as a violation of people’s right to access public space.

2.1.3 Mass-motorization: 1950s – 1970s

The need to rebuild the country offered Dutch planners and policy-makers an opportunity to realize the blueprints of a modern car-based transport system. Political parties of all ideologies supported and promoted car use. On the one hand, mass motorization was seen as the expression of modernism, self-determination and industrial power, on the other hand, the automobile was also framed as the symbol of social redemption and freedom for the working classes. In addition, the (perceived) feeling of flexibility and independence promulgated by commercial advertisement and abundant cheap oil, reinforced the image of the car as the icon of progress. The (initial) comparative advantage over other modes and the benefits of fast travel, long-distance accessibility, and the capability to carry heavy weights, became solid arguments to increase funding to accommodate the “inevitable growth” of cars. This prompted roadway expansion, filling up canals, pulling down houses and building sub-surface roads. This, coupled with a flourishing economy and increasing domestic income, contributed to a car boom.

The number of private cars increased from 139,000 in 1950 to 3.4 million in 1975 (Graph 1). The average number of miles traveled followed an exponential increase from 2 billion miles in 1950 to 55 billion in 1975.

Graph 1 Private cars in the Netherlands (in millions)



Source: SWOV (2010)

At the same time, plans were made to allow direct access by car to city-centers at the expenses of some historical buildings and neighborhoods. Squares were turned into parking lots and the cycling infrastructure was partly eliminated as it was assumed that bicycles would eventually disappear. However, the rapid growth in car use and the sudden transformation of streets, from shared spaces to functionalist and segregated public utilities, led to growing problems in terms of road congestion, road fatalities and quality of life.

Figure 6 – 7 Amsteldijk 61 & Elandsgracht (Amsterdam) late 1960s beginning 1970s

Source: Beeldbank Amsterdam, University of Amsterdam

Case: The White Bicycle Plan

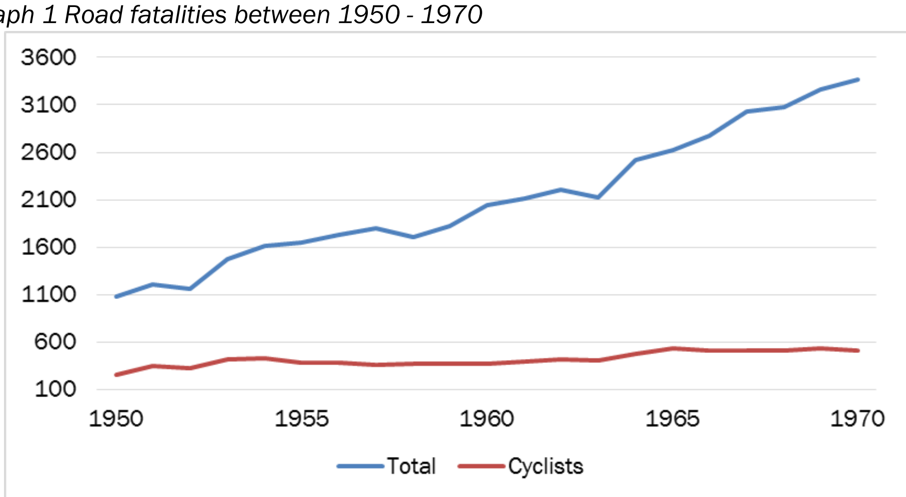
Figure 8 – 9 Provos and the Witte Fietsen (White Bicycles)

In July 1965, the Provo's – an anarchistic political organization involved with social and environmental issues and with strong views against mass motorization – released the "White Bicycle Plan" in Amsterdam. Fifty white painted bicycles were left permanently unlocked, and placed throughout the inner city for the public to be used freely. Although this utopist measure did not last more than a few days as either the people would steal or the police seize them, the idea had great resonance all over the world and it is considered the first example of bicycle share system.

Source: Beeldbank Amsterdam; Shaheen et al. (2012)

What caught attention particularly was the so-called *"slaughter of kids"*. Over 400 children were killed in traffic crashes in 1971 alone. As a result, parents took to the streets and campaigned to *"Stop de Kindermoord"* (or to stop the child murder) and asked for safer, quieter streets for children to play in.

Graph 1 Road fatalities between 1950 - 1970



Source: SWOV (2010); CBS Historical database; Rijksoverheid (2010) reworked by Decisio

These were later joined by other grass-roots movements, who strongly and violently opposed the development path undertaken by the Netherlands, such as the Provos and the Dutch Cyclists Union (Fietsersbond) - established in 1975.

Figure 10 - 11 Protests in 1970s

Source: Beeldbank Amsterdam

The Second Report on Spatial Planning ("*Tweede Nota over de Ruimtelijke Ordening"),* published in 1966, included a finely meshed highway network with a total length of 3300 miles for the year 2000 based on an extrapolation of the rapidly growing car mobility at a time when only 370 miles of highways were available. This plan was a symbol of the belief in pro-car policies.

Then, in 1972 a report by the Dutch Economic Research Institute (NEI) calculated that meeting the needs of such car ownership growth would have had required an investment of a total between 15 to 22 billion guilders (8 to 15 billion US dollars[13]) in roadway expansion till 2000. The outcome of the report had a huge political impact. The financial implications required to pursue such development, combined with protests, was politically unacceptable and it was evident that the trend towards car-oriented infrastructure had to be broken. The Ministry of Transport and Water management concluded that priorities had to change and quality of life and a safe environment had to be prioritized over traffic flows. However, the turning point that led to a shift was the oil crisis in 1974 that halted the country. This, reinforced by the 1980 economic recession, created an important window of opportunity for cycling advocates to promote cycling as the tool for sustainable, healthy and livable cities for everyone. Cycling could not be ignored anymore and policy makers needed to include cycling infrastructure in their plans and visions.

[13] Dollars are calculated to the value of the year the money was spend. So in this case 8 to 15 billion dollars between 1972 and 2000.

Case: “The Battle for Nieuwmarkt (Amsterdam)”

An iconic event that profoundly changed Amsterdam’s policy approach to transport was the 1975 plan to tear down the Nieuwmarkt area (An historical neighborhood right at the center of Amsterdam, see Figure 12 and 13) to make room for a metro line, an “urban highway” and a brand new central business district (CBD) with offices, university buildings and luxury shops (Figure 14 and 15). This *“modernist”* vision clashed with the needs of local residents who stood up to protect the historic and iconic value of the neighborhood (Figure 17). The fierce resistance forced the municipality to change their approach favoring a human-scaled development: dense and diverse neighborhoods, small scale buildings, low traffic speeds and priority for pedestrians and cyclists (Figure 18 and 19). Figure 16 reveals what’s left from the construction of the metro line. Of the vision proposed in the 70s, the metro remains the only project that was accomplished. Today, the neighborhood is a lively and commercially busy area that attracts international and domestic tourism.

Figure 12 – 13 Nieuwmarkt in 1930 and 1950

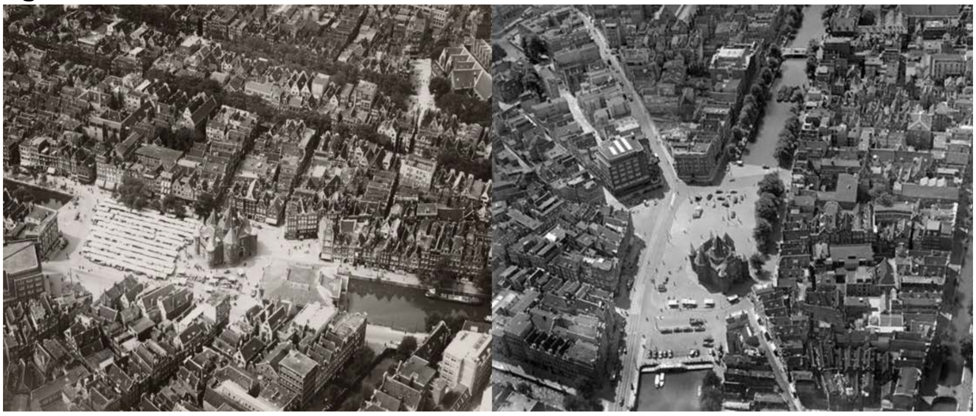


Figure 14 – 15 A model of the 70s representing the new vision for Nieuwmarkt

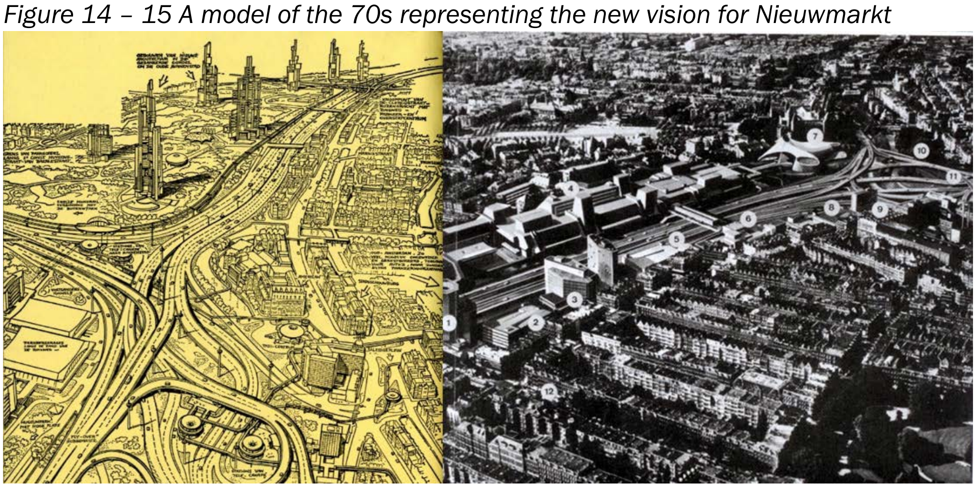


Figure 16 – 17 Nieuwmarkt 1975 for the construction of the metro line and protests to preserve the historic buildings.

Figure 18 – 19 Nieuwmarkt in 2010 and 2015 after the policy change and the reconstruction

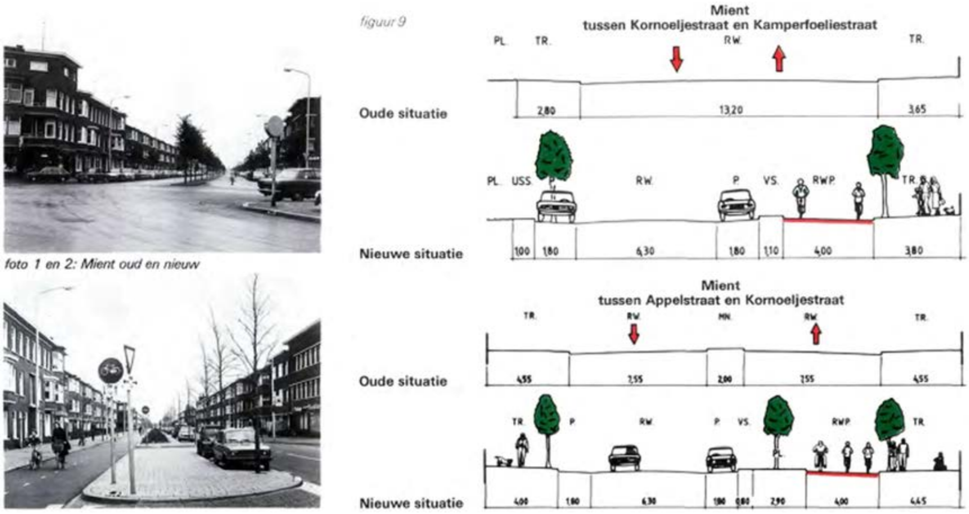
Source: ANP Historisch Archief; Beeldbank Amsterdam; Bicycle Academics; University of Amsterdam; Paolo Ruffino.

Government	Planners	Bicycle organizations
Acknowledge that cycling was part of Dutch culture and an efficient mode of transport.	Planning shift to preserve functional mix, constrain car use and promote bicycle and public transport use.	Regain advisory role, use the window of opportunity to insert cycling in the political agenda.

2.1.4 Return of cycling on the political agenda: 1975 – 2000s

From the late 1970, municipalities kick-started the implementation of cycling infrastructure. In 1976, the Ministry of Transport, Public Works, and Water Management, issued the *Multiyear Plan for Passenger Transport 1976-1980*, which, for the first time, had significant attention for cycling. This plan included so-called *"demonstration bicycle routes"* in the cities of Tilburg and The Hague and meant to encourage cycling and inspire other municipalities to develop similar projects (see figure 20).

Figure 20 An example of redesign in The Hague



Source: Dienst der Gemeentewerken 's-Gravenhage (1978)

These successful experiments encouraged the Ministry of Transport to adopt two schemes for the implementation of cycling infrastructure at the city level. Municipalities were subsidized up to 80% of the construction costs to implement urban cycling infrastructure. Provinces and other municipalities were able to get 50% subsidy on the costs to upgrade and expand bicycle paths along secondary and tertiary roads. This financial injection rose from 25 million guilders (9.5 million dollar) in 1976 to 53 million (20 million dollar) in 1982. The goal of the *Multiyear Plan for Passenger Transport* was to get 90% of secondary roads and approximately 70% of tertiary roads covered by bicycle infrastructure (inside as well as outside urban areas). The value of such contribution is reflected by the length of cycling infrastructure, which grew from 5.780 miles in 1978 to 6.200 miles in 1988. Of great relevance is the case of Delft. In 1979, the city of Delft was the first city to draft a cycle plan which included a proposal for a whole city-wide cycle network as well as a five-year investment program. Between 1982 and 1986, the city received a total of 29 million guilders (12 million dollar) of funds from the Dutch Ministry of Transport to upgrade its bicycle infrastructure, including tunnels and bridges. A condition for the national funding was to study the effects of the plan. This was done extensively with before and after studies in no less than 21 reports[14]. Bicycle use increased by 6% in those years and car growth reduced by 3% in the intervention area, while the number of crashes decreased. The main findings of the studies were that cycling infrastructure expansion is a key factor. In particular, cycling becomes attractive when attention is paid to directness, comfort and safety of the network[15]. However, adding bicycle lanes is not enough. Simultaneous implementation and execution of policies to improve road safety and comfort for cyclists and at the same time change policies for car use (for example by means of paid parking and partially car-free city centers) might help to stimulate bicycle use. Finally, integration between public transport and cycling, as well as continuous information to the public is fundamental.

Figure 21 The new temporary bicycle lane on the Berlagebrug which made use of an existing car lane (Amsterdam) 1982

Source: Beeldbank Amsterdam

This contribution was halted in 1985 and the budget decentralized to the municipalities through general taxation, partially as the result of the general effort to decentralize government tasks. This great financial injection was thus greatly reduced. However, the government continued, where possible, to subsidize important high quality tracks to encourage a shift from cars to cycling.

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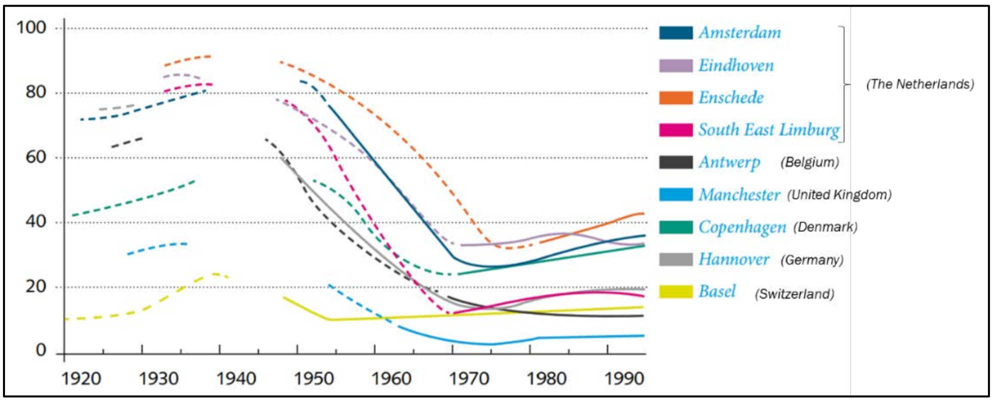
14 Topics studied included changes in mode choice, route choice and the use of the cycle network. As well as origin- and destination patterns, road safety and specific studies on effect of expensive infrastructure measures such as bridges.

15 CROW (2007)

Figure 22 Historical trend of the bicycles' share in total traffic



Source: Oldenziel & de la Bruhèze (1999)

In November 1988, the *"Second Structure Scheme for Traffic and Transport, Part A: Policy Plan"* reported that unnecessary car travel had to be tackled to improve the road accessibility for *"economically essential mobility"* and freight while simultaneously improving the quality of life. This resulted in a specific task force to develop comprehensive bicycle policy, which resulted in the formulation of the *Bicycle Master Plan (BMP*)[16]. The overall objective of the BMP was to promote the attractiveness and safety of cycling in an integrated logic with transport, while simultaneously discouraging car use[17]. The strategy was to stimulate local authorities, companies and organizations, and public transport operators to incorporate bicycle policy in their regular policies and activity programs, so that the BMP goals could be achieved in the long-run. The plan encompassed 112 innovative and pilot projects and included substantial financial incentives from the national road fund to subsidize regional authorities in their construction of bicycle paths between villages and towns and the implementation of larger projects such as bicycle tunnels, bridges and parking facilities. Moreover, the BMP intended to provide authorities with relevant knowledge and assist them with arguments, instruments and measurable targets. Communication and behavioral campaigns were also adopted and marketing campaigns launched in various mainstream media. The BMP was supposed to be a three-year project, but then it was extended to a 7-year plan until 1997. The effects of the Bicycle Master Plan have been evaluated as highly effective (Fietsberaad).

During the same period, the policy *"Sustainable Road Safety"* ("Duurzaam veilig" in Dutch) has been implemented as an approach to achieve better road safety. The term *"sustainable"* was based on the Brundtland report as a *"development that answers to the needs of the present generation without harming future generations' possibilities to answer to their own needs".* The main objective of *Duurzaam Veilig* is to prevent severe

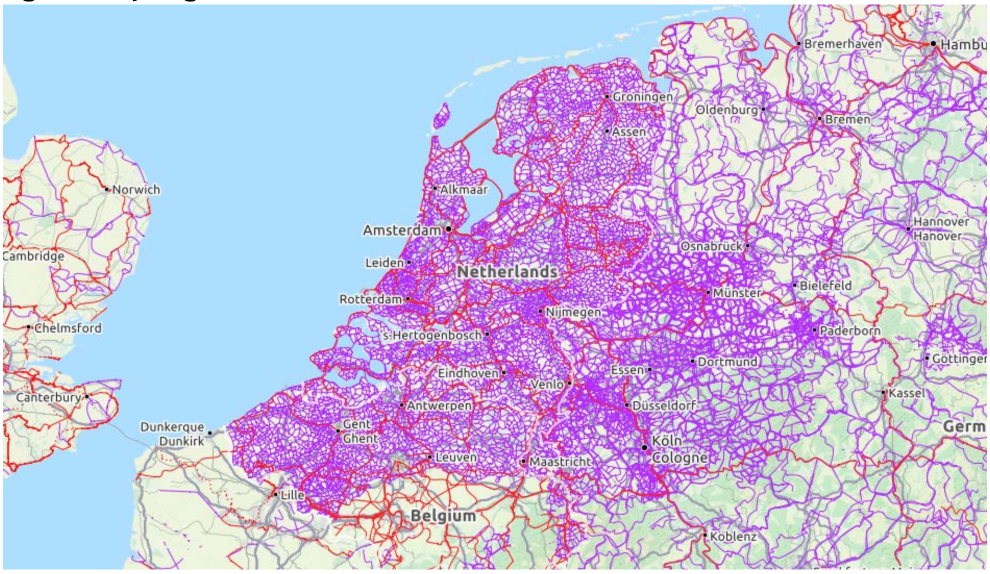
[16] Martens (2007)
[17] Ministry of Transport and Water management (1999), p.50 - 51.

crashes and injuries. It was introduced and adopted by all road managers in 1992 and revised and extended in 2005. The policy included principles of infrastructure design with the behavior of all road users in mind (this is discussed in details in Chapter 3). Special attention was payed to vulnerable road users such as children, pedestrians and cyclists. Innovative is the incorporation of the unpredictability of human behavior. Roads and vehicles, according to the policy, had to be adapted to incorporate these principles, leading to a fundamental revision, which in turn seriously reduced traffic crashes. Still today, roads are being redesigned according to the Sustainable Road Safety principles.

2.2 Present Situation

Currently, over a quarter of the total trips are made by bicycle, the highest modal share in the industrialized world, and a network of over 24.200 miles of bicycle paths crisscrosses the entire country.

Figure 23 Cycling network in the Netherlands



Source: OpenCycleMap.org

The combination between high quality cycling infrastructure and the establishment of a road hierarchy with large traffic-calmed areas where through traffic is diverted outside city centers to the freeway network, has resulted in an 80% reduction in the number of both car crashes and bicycle fatalities (predominantly bicycle-motor vehicle crashes) per 600 million bicycle-miles travelled over a thirty years period[18]. This, in spite of increasing car ownership and use[19].

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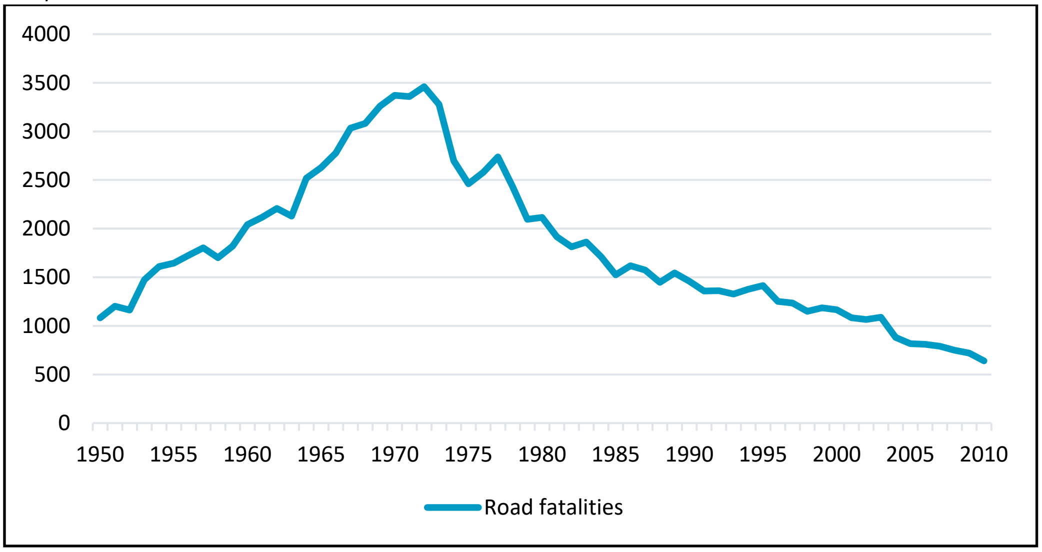
18 CROW (2009); Pucher& Buehler (2012); CROW (2015); Schepers et al. (2017).

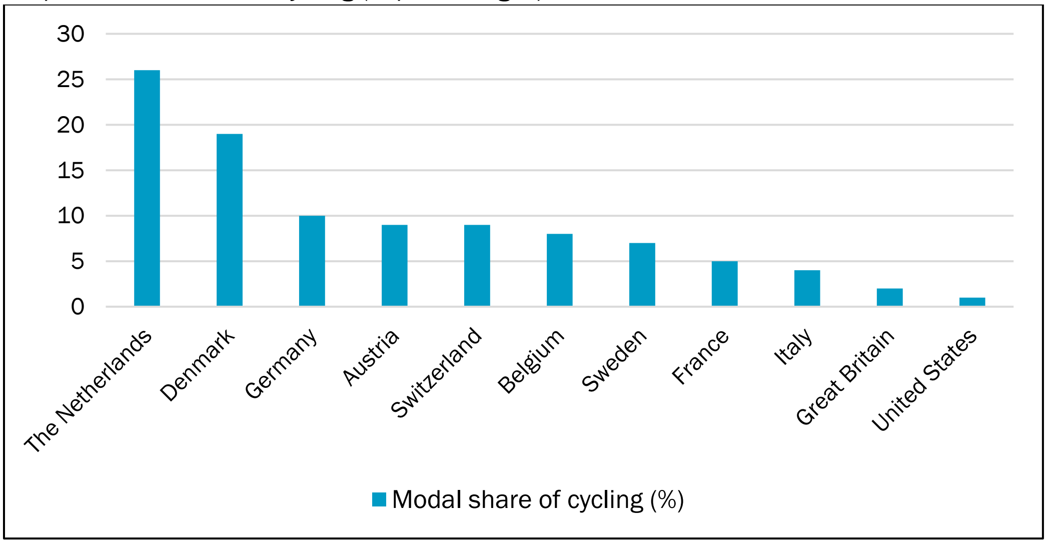
19 SWOV (2017)

Graph 3 Road fatalities in the Netherlands between 1950 – 2010



Source: SWOV (2010)

Graph 4 Modal share of cycling (in percentages)



Source: CBS (2016); OViN (2016); CROW (2009), ECF (2015) and Istat (2015); NCBI (2009)

As a result, cycling has reverted its decline and it is now booming again. Since 2005, both the number of users (+11%) and the distance travelled by bicycle has increased (+10%)[20]. On average, the ordinary Dutch person cycles 600 miles per year, which is 40% more than in 1975. Part of the increase has been favored by the diffusion of e-

20 OViN (2015); CBS (2015)

bikes, which enable longer distance accessibility to a broader range of target groups including elderly and young adults[21].

Figure 25 Morning rush hour on Weesperzijde (Amsterdam)

Source: Paolo Ruffino (2016)

Such high bicycle use positively contributes to Dutch society in terms of health, livability and accessibility which translates into considerable economic benefits for individuals, companies and the government[22]. At the national level, the direct economic benefits, in terms of employment, bicycle production, and turnover have been estimated to be about € 1,3 billion yearly (USD 1,5 billion per year). A figure that is conservative as it does not include jobs and revenues that are indirectly produced or induced[23]. If the social benefits are accounted, this figure grows exponentially. For example, a study performed by Utrecht University shows that cycling saves 19 billion euro (USD 20 billion) yearly in healthcare costs and prolongs the average life expectancy by six months[24]. At the local level, the benefits are also substantial. The cycling *"gross domestic product"* of Utrecht has a direct economic value of € 38 million (USD 44.6 million) per year and the increasing number of kilometers cycled instead of driving avoids over € 250 million (USD 295 million) annually of social costs (pollution, congestion, productivity loss, etc.). In turn, car drivers and the public transport system benefit from cycling in terms of lower travel times, better accessibility and, increased safety. This is evidenced by a study performed by Waze which ranks the *"Driving Experience"* of The Netherlands to be the best in the World[25]. Hence, the investments to promote cycling while discouraging private motor vehicles have proved to be beneficial for all road users.

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21 KiM (2016)

22 Decisio (2012). Social costs and benefits of investing in cycling.

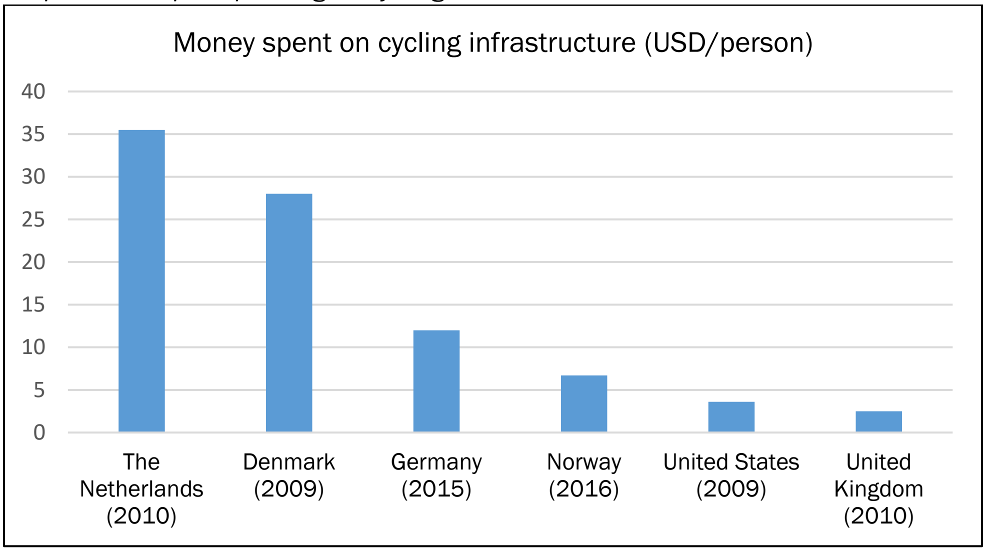
23 Decisio (2016). Bruto Utrechts Fietsproduct (Gross cycling domestic product of Utrecht).

24 Utrecht University (2015): http://www.uu.nl/en/news/dutch-bikers-live-six-months-longer

25 Waze Driver Satisfaction Index: https://www.waze.com/driverindex

The impact of cycling goes beyond *"financial"* effects. It also contributes to social cohesion, community building, social capital, livability, freedom and inclusion for a broader range of target groups. Thanks to the safe cycling infrastructure, more than two-thirds of secondary high school students commute to school by bicycle, while 5% only are taken by car[26]. For these reasons, cycling is included in multiple policy domains and the Netherlands keeps promoting bicycle use by investing in cycling projects, socio-technical innovations and behavioral campaigns. At the present time, the Netherlands is the country that the most invests in cycling projects per person, circa USD 35/inhabitant per year.

Graph 5 Per capita spending on cycling infrastructure[27]



Source: ECF, 2016a; Pucher & Buehler, 2012; DCE, 2009; German Federal Ministry of the Environment; 2015; Decisio, 2016

[26] Van Goeverden & de Boers (2008)

[27] This data is not converted to dollars, because it is just meant to show a comparison between countries.

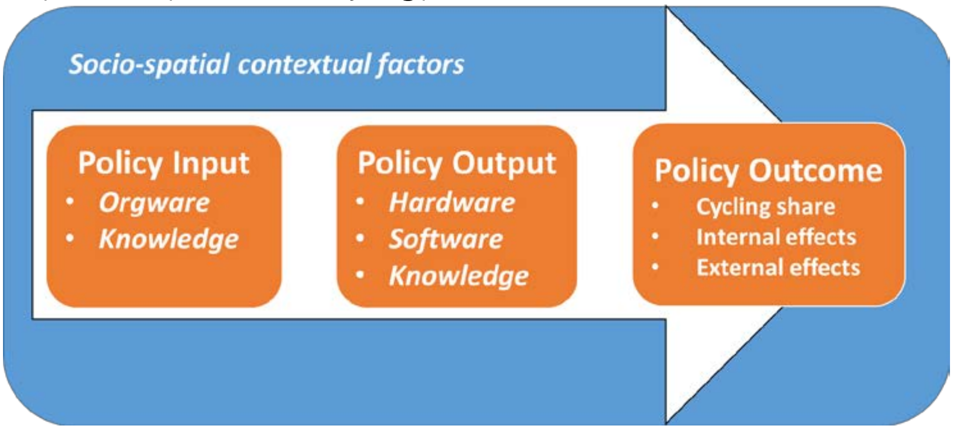
3 Cycling Policies in the Netherlands

Figure 26 De Uithof, Utrecht

Source: Paolo Ruffino (2015)

A conceptual definition of cycling policies is *"a set of actions, rules or guidelines adopted or issued by an organization (public or private) with the intention to achieve an outcome on bicycle use"*[28]. These can be broadly classified between, hardware, software, orgware and knowledge[29].

Graph 6 conceptual model of cycling policies



Source: Harms et al. (2015) adapted by Decisio

[28] Ruffino (2016)

[29] This is a Dutch classification used by the knowledge centre CROW Fietsberaad. In the US context, a similar classification is used called 4 E's (Engineering, Education, Enforcement, Ecouragement).

3.1 Hardware

Hardware are physical measures including different types of infrastructure including cycle tracks, bike lanes, bicycle bridges, tunnels and bicycle parking facilities. The implementation of an extensive and comprehensive network of cycling infrastructure is a key prerequisite, because it provides the basic safety level needed to encourage people to shift to cycling. Moreover, ensuring a high-quality cycling experience by means of comfortable, direct and attractive routes is fundamental to strengthen the position of cyclists on the streets. The five main requirements for a high-quality bicycle-friendly infrastructure are expressed in the *Design Manual for Bicycle Traffic* by CROW[30] (for further explanation and technical details see Appendix 2)[31]:

- **Cohesion**
- **Directness**
- **Attractiveness**
- **Safety**
- **Comfort**

These requirements are based on the Sustainable Safety policy which underpins the Netherlands' approach to road safety and road design. This policy is further explained in the paragraph below.

3.4.1 Sustainable Safety

Adopted in 1997 and revised in 2005, Sustainable Safety policy can be classified as a "*systematic approach*" (or Vision Zero) to road safety. Unlike the *"reactive*" approach which focuses on identifying and fixing black spots where an unusual number of crashes occurs, the Dutch system systematically eliminates all potential sources of risks at their root by incorporating two important human properties[32]*:*

- *Vulnerability* (of the body and the mind) and,
- the *uncertainty of human behavior* (we make intended or unintended mistakes).

Examples of these properties are functionality of roads, homogeneity, predictability and forgivingness. Although they are not compulsory or required by law, the Sustainable Safety principles are widely applied to re-design roads as several ex-post studies have

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[30] National knowledge center on transportation (described in paragraph 3.3.1).

[31] CROW (2007)

[32] Mark Wagenbuur (2017) in his blog bicycledutch.wordpress.com takes an in-depth look at Sustainable Safety and its implications on road design. See references.

proved to increase safety (for a more technical explanation see Appendix 2). Table 1 below lists and describes the principles, while Table 2 shows some concrete examples:

Table 1 Sustainable safety principles

Principles	Description
Functionality *(of roads)*	Mono-functionality of roads (roads with single purpose) as either through roads, distributor roads, or Access roads in a hierarchically structured road network.
Homogeneity *(of mass, speed, and direction of the user)*	Similar speeds, direction, and mass at moderate and high speeds. This means that large differences in speed and mass must be eliminated as much as possible by means of road design such as segregated space or traffic calming measures.
Predictability *(of road course and road user behavior by a recognizable road design)*	Road environment and road user behavior that support road user expectations through consistency and continuity of road design. The infrastructure design and purpose must be easily recognizable by the user.
Forgivingness *(or Error Recovery road users)*	Injury limitation through a forgiving road environment and anticipation of road user behavior. Humans make errors and willingly or unwillingly break rules. This is a given that cannot be changed. Hence, roads and streets should be designed in such a way that this natural human behavior does not lead to crashes and injuries.
State of awareness *(by the road user)*	Ability to assess one's capability to handle the driving task. This has to do with understanding vehicle operation and knowing how speed changes the behavior of the vehicle.

Source: SWOV (2005)

Table 2 Examples of different degree of separation in different contexts

Pelikaanstraat (Utrecht)

Residential and quiet street with shared use closed to the railway line. The street design prevents car from driving too fast in this area which is meant also as recreational space for children and living function.

Nieuwe Spiegelstraat (Amsterdam).
Local street characterized by a great mix of functions with high density of commercial activities and touristic attractions. Given the high flow of people and goods in a narrow space, the route is designed to give priority to pedestrians and cyclists (also contraflow allowed to increase the capacity of the street). Cars are allowed at a low speed (max 18 mph).

Prins Hendriklaan (Utrecht)
With more than 14,000 cyclists using the bike street every day and only less than 3,000 cars per day (4,6:1 ratio), it is considered a successful example of shared space that gives priority to cyclists. The main target group using the route are students as it represents an important link between Utrecht city center and the university campus. Cars allowed at low speed and act as "guests" (max 18 mph).

F29 Fast cycle route ('s-Hertogenbosch)
Segregated and priority cycle track that connects 's-Hertogenbosch to Oss. The illustrated section runs parallel to a trafficked road and thus it is physically separated. Distributor Road 2x2 with a 30-mph speed limit.

Source: Paolo Ruffino (2015; 2016)

3.4.2 Unbundling bicycle and car networks

In the last decade, the concept of unbundling of car network from the bicycle network and public transport network has become prominent. In a nutshell, the term *"unbundling"* is used to describe a strategy to disaggregate different road networks (car, public transport, pedestrian and cycle) as much as possible to minimize potential conflicts[33]. This means that the main bicycle network follows its own alignment as much as possible and intersects with other networks – especially main motorized arterial networks – as little as possible. For the bicycle networks, this form of separation can be achieved by using access roads in traffic-calmed areas, green and residential areas, and using bicycle tunnels and bridges (or other forms of segregated solutions) to cross distributor roads. This contrasts with the *"complete streets"* design policy in place in the United States which requires that streets need to be planned in order to give access to all users regardless of their mode of transportation Bicycle-only routes of high quality (within or between cities) are often used for longer-distance cycling for both commuting and recreation. These routes (usually longer than 10 miles) are either called *snelfietsroutes* (fast cycle routes) or *fietsnelwegen* (bicycle highways). These are usually bi-directional (circa 4 meters wide), follow a very straight stretch (with few ups and downs, curves or turns), traffic lights are absent, they are built with superior pavement quality (smooth red asphalt, ideal also for racing bicycles) and avoid crossings as much as possible.

Figure 27 unbundling of networks. A physical segregation of the road network and the cycle network in the Dutch city of Zwolle.

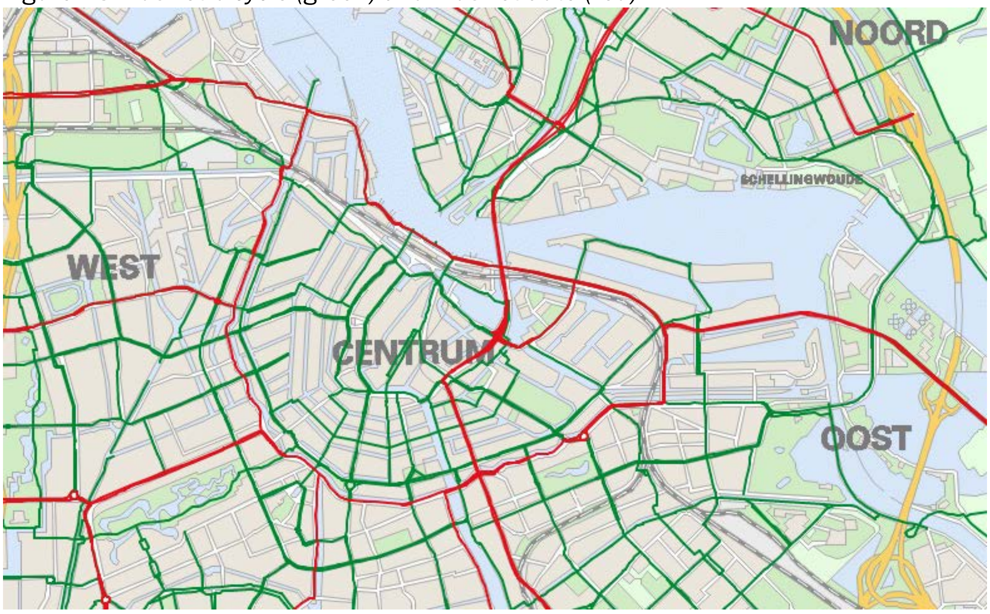
Source: Jeroen Buis

To ensure that this network-level separation does not impact the directness and convenience of the cycling network, measures to unbundle cyclist and vehicular are often combined with the creation of short-cuts. These can be contraflow cycling one-way streets and the creation of links accessible to non-motorized traffic only.

33 As defined by Schepers et al. (2013)

Unbundling offers multiple advantages compared to complete streets[34]. In the first place, it reduces the number of intersections and crossings with busy roads. This decreases the likelihood of bicycle-motor vehicle crashes. Secondly, bicyclists cycle through more pleasant areas with cleaner air. Thirdly, a higher modal share of cycling in traffic-calmed area mixed with motorized vehicles corresponds to a lower share of driving and greater awareness among drivers. This increases safety for all road users. The high incidence of cycling and behavioral adaptation of motorists in the presence of cyclists has the important effect of providing the so called *"Safety in Numbers"*[35]. Finally, unbundling prevents a high number of cyclists and motorists on the same intersections. This reduces complexity and increases the capacity of intersection, which again improves road safety

Figure 28 PlusNet bicycle (green) and PlusNet auto (red)



Source: City of Amsterdam (2016)

A practical example of network-level separation is the *PlusNet* of Amsterdam[36] (see Figure 28 above). The main bicycle network (green) and the main car network (red) are kept separated as much as possible. Although streets are generally accessible by any mode, different road design solutions are used to encourage different users to use specific roads. For example, the PlusNet for cars is characterized by multiple lanes and it allows higher volume of traffic and faster circulation. The PlusNet for cycling privileges

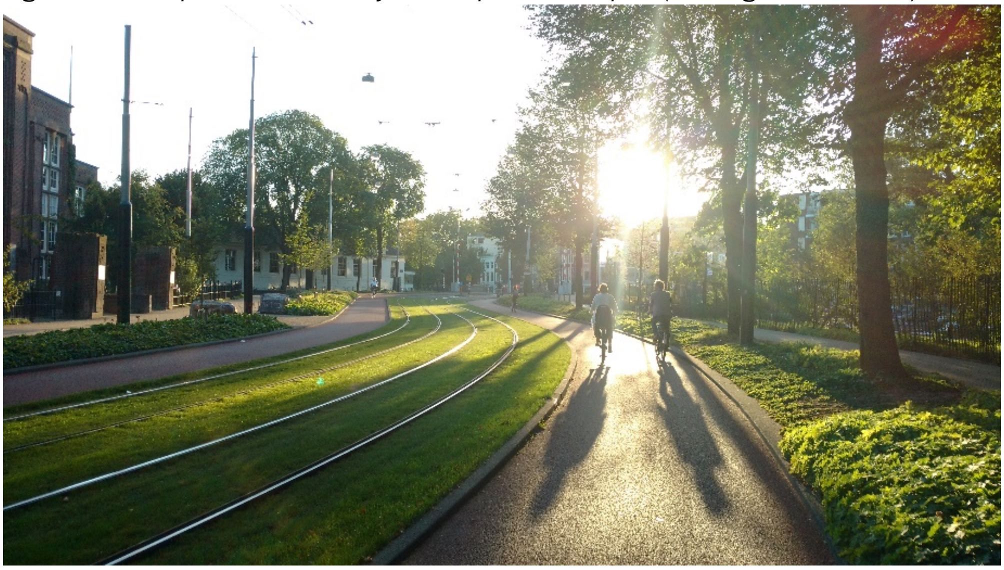
[34] See Schepers (2013). Road safety and bicycle usage impacts of unbundling vehicular and cycle traffic in Dutch urban networks

[35] In the presence of high bicycle traffic, car drivers tend to adjust their behaviour (lowering their speed and driving more carefully) to avoid collision and thus increasing safety.

[36] An interactive map can be found here: http://maps.amsterdam.nl/plusnetten_inspraak/?LANG=nl

green areas (such as the Vondelpark), traffic-calmed streets and also scenic streets (with historical buildings, canals and areas dense with activities). In most streets, no more than two PlusNets exist, for instance, public transport and bicycles, cars and bicycles or public transport and cars.

Figure 29 Example of PlusNet bicycle and public transport (Plantage Middenlaan)



Source: Paolo Ruffino (2016)

3.4.3 Junction design

Another important element of road safety stemming from Sustainable Safety is safe intersection design. In many cities around the world, cycle tracks and lanes end where most needed, at junctions. These represent the location in which most conflicts take place due to limited visibility and differences in direction and speeds. In general, the most desirable situation is to unravel these different modes and thus simplify interaction between road users. In the Netherlands, for instance, traffic flows tend to be kept separated as much as possible both at junction and roundabouts. For segregated cycle tracks, the CROW cycling design manual recommends applying a segregated design at intersections. This means that cyclists turning right remain physically segregated from motorized traffic (see figure 30).

Figure 30 Example of an intersection in Utrecht

Source: Wagenbuur (2013)

Dutch designed roundabouts lead to a significant reduction of traffic speeds and have led to a significant reduction of traffic crashes, making traffic much safer for cyclists and other road users when replacing un-signalized or signalized intersections. As at road sections, at roundabouts, there are three options: segregated cycle tracks, cycle lanes or shared use of the roundabout.

Figure 31 Example of a roundabout with cycle lanes in Den Bosch

Source: Wagenbuur (2013)

Every junction presents different designs and applications of these concepts in order to meet the needs of traffic in the specific location. An interesting example is at the Valkenboslaan in The Hague where a complicated intersection with high traffic speeds has been replaced by an oval roundabout and a shortcut for cyclists (see pictures in Appendix 3).

3.2 Software

Along with physical measures, the Netherlands has introduced a number of soft measures that are designed to change perceptions, beliefs, and attitudes thereby motivating voluntary change in transportation choices[37]. These include education campaigns, information, and communication to the public. For instance, early school education programs such as bicycle traffic examinations (*VVN Verkeersexamen*) are employed in the Netherlands to raise awareness among children about traffic safety and rules. In contrast with the Walk and Bike to School Day in the US, the VVN exams are an example of measures that structurally focuses on raising knowledge and awareness of traffic and the role of cyclists in it. It includes a theory component as a written test and a practical component which consists of a cycling trip.

Figure 32 Traffic exam in Deventer

Source: Deventer extra (2011)

Students are assessed for their behavior and confidence in using road facilities. Several studies argue that early education is a necessary condition for establishing cycling skills and habits that pupils are likely to retain as adults[38]. In addition, bicycle use does not only provide freedom and accessibility to a young population, but it also has a positive

[37] Harms et al. (2015)

[38] Stauton, Hubsmith & Kallins (2003)

impact on mental and physical health. Furthermore, learning to interact with traffic at an early stage appears to make children more aware of traffic regulations and to learn to share public space with other road users[39]. Other important instruments include marketing programs and incentives. An example in the Netherlands is the *"Fiets Kilometervreter"* (Kilometers eaters), a form of monetary incentive for cycling that gives access to discounts on selected shops. Currently, this form of incentives is not country wide but experimented at specific locations and with different initiatives.

3.3 Knowledge

Knowledge relates broadly to produce, gather, mobilize and use (scientific) knowledge and data. For instance, different professions exist around cycling and universities, both scientific and technical. These professions address the topic of bicycle planning and design from multiple perspectives: civil engineering, human geography, urban and regional planning, anthropology and transport economics. Hence, traffic experts and planners possess a broad knowledge and expertise in this field.

3.3.1 CROW Fietsberaad

In 2001, the *"CROW Fietsberaad",* a knowledge center for cycling policy of the Dutch government, was founded on the initiative of the Ministry of Transport (now Ministry of Infrastructure and Environment). CROW is funded by the government and plays an important role in carrying out development, dissemination and exchange of practical knowledge for cycling policy. The main activities are:

- Research;
- Participate in studies from other organizations;
- Improving the accessibility of existing knowledge;
- Organize meetings for the exchange of knowledge and experiences;
- Actively disseminating knowledge and experiences via the website, publications, a magazine and communication channels of others;
- Scheduling cycle related issues based on new knowledge and insights;
- Audiences.

In addition, and as part of the Bicycle Masterplan, the magazine *"Fietsverkeer"* was introduced and is still published every 3 months free of charge for professionals that plan and design for cycling at government organizations (municipalities etc.) and in the private sector. CROW also actively maintains relationships with the private sector and NGOs to find new solutions to pressing problems such as bicycle traffic and parking issues.

[39] Pucher & Buehler (2012)

3.3.2 Fietstelweek – Bicycle count week

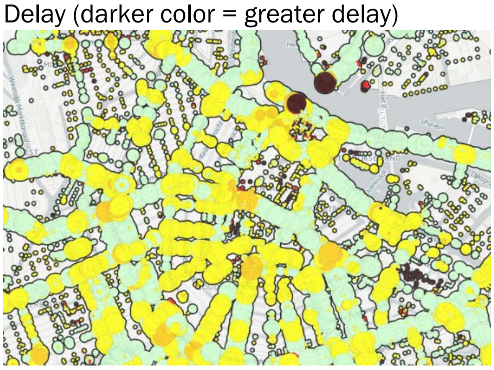
Another important building block for bicycle planning is the systematic data collection. On a national, regional and metropolitan level, aggregated data is constantly collected by CBS, the national bureau of statistics. At the operational level, data is usually collected directly by municipalities by means of traffic counting systems. More recently, innovations such as the *Fietstelweek* (or Bicycle Count Week) has been introduced. This is a national cycling survey that takes place once a year.

Table 3 Example of bicycle data using Fietstelweek

Intensity of use (red = preferred routes)

Average speed (blue faster, red slower)

Delay (darker color = greater delay)



Origin & Destination[40]

Source: BikePrint (2017)

Developed as a joint initiative of the Dutch Cyclists' Union (Fietsersbond), government authorities and several companies such as Keypoint, Beaumont Comunicatie, Mobidot and universities of applied sciences, it was first tested in 2015. The program works by downloading an application on the smartphone. The application counts and registers each participant's movements while active. The results are displayed in the form of heat maps that are able to support planners in identifying the most frequently used roads and the location in which prioritize interventions. In particular, it allows for insights into:

40 By selecting a route on the map, the heat map highlights the most common origins and destinations of cyclists in that specific map.

- Route choice
- Average cycling speed
- Bicycle densities
- Delays in traffic
- Origin and destinations

This data is publicly available and retrievable at http://www.bikeprint.nl/fietstelweek/. From the last survey, it appeared that more than four out of five Dutch inhabitants own a bicycle. On average, bicyclists cycle 1,5 miles a day at an average of 9,5 mph. An example of ways in which this data is used is shown in paragraph 3.2.1. where it has been employed to appraise the effects of a bicycle route improvement in the area of Hoofddorp.

3.4 Orgware

Although bicycle planning is mainly domain of Dutch municipalities, it is common practice to involve multiple stakeholders from different levels (government, provinces and city regions) and domains (both private and public) during all phases (from problem definition to implementation and evaluation). Effective governance arrangements (or what are here defined as *"orgware"*) are crucial to ensure homogeneity of interventions, identify common goals, share responsibilities, resources and risks, and provide adequate services to the end-user. This is especially the case when large (intercity) infrastructural projects are implemented. For example, public–private partnerships between municipalities, transport authorities and other stakeholders are formed when implementing and managing large bicycle parking facilities at stations. The table below briefly describes some of the main stakeholders in cycling projects as well as their role and responsibilities.

Table 3 Role and responsibilities of main stakeholders

Actor	Description
Municipality	Direct role in developing a cycling strategy and stimulating bicycle use by planning and implementing infrastructure (bicycle parking, bicycle network, constructing missing or weak links) but also combating bicycle theft, promote safety, and monitor progress. Direct funding of infrastructure and access to state subsidies. Together with Provinces, cities are responsible to ensure policy cohesion at the regional level.
Provinces, transport regions and water boards.	Leading role in determining and bridging regional / inter-local bicycle network. Focus on both utilitarian and recreational purposes. Coordination and co-funding of projects.

Central government	The government role is to promote decentralization and to provide a framework. Currently the main activities are four: 1) provide general guidelines 2) looking after intrinsic issues (legal aspects of traffic) which can only be arranged at the national level 3) funding of decentralized bicycle policy 4) support of decentralized bicycle policy with knowledge development and distribution.
Dutch Railways (NS), Pro-rail and local public transport companies.	Given the strong interaction between the bicycle and public transport, transportation companies are commonly involved in planning processes when it comes to co-finance and manage, for example, bicycle parking facilities at transportation hubs. Additionally, NS has also implemented a popular bike rental scheme, known as OV-Fiets, in over 300 locations (especially nearby stations) around the country.
Advisory bodies	Linked to knowledge development, several advisory bodies constantly support bicycle policy. Together with the already mentioned CROW/Fietsberaad, KpVV supports the decentralized authorities with practice knowledge on safety, mobility and infrastructure, the Fietsersbond (cycling association) is the interest group for cyclist which monitors activities and benchmark cities' performance. Stichting Landelijk Fietsplatform, or national cycling platform association, focuses on recreational cycling.

3.5 Challenges

The Netherlands may represent an inspiring model in many ways. However, the country still faces numerous challenges. First, bicycle parking issues are increasing in cities, particularly at railway stations, as bicycle use increases. Secondly, bicycle theft is also an unresolved phenomenon that requires increasing attention and innovative solutions. Thirdly, immigrants tend to cycle less than the locals. Statistics show that even second generation immigrants from these countries cycle much less than the Dutch. Fourth, one type of motorcycles with a legal maximum speed of 15 mph, are allowed on the bicycle paths, and represent a main source of complaints from Dutch cyclists.

Figure 33 Scooters on bicycle paths

Source: Fietsersbond (2014)

Currently new legislation is under development to enable road authorities to ban these motor cycles from the cycle tracks. Finally, the shift from car to cycling appears to have a negative effect in terms of single-bicycle crashes which are becoming increasingly frequent leading to substantial medical costs[41]. For instance, each year 46,000 injuries are registered by the Accident and Emergency departments. Of these, approximately 6,000 victims are admitted to hospital in the NL. Most of these, are often not reported and their number is hardly known with certainty[42][43]. The most vulnerable target group are people aged 65+ who have a greater risk of injury compared to the younger population. Hence, the benefits of shifting from car to cycling may result, in some cases, unequally distributed among ages.

41 Single-bicycle crashes refers to those accidents that involve only the cyclist him- or herself. For example, when the rider loses their lane position, collide with obstacles etc.

42 Ormel et al. (2008). Enkelvoudige fietsongevallen [Single-bicycle crashes]. Amsterdam: Stichting Consument en Veiligheid.

43 Schepers & den Brinker (2011). What do cyclists need to see to avoid single-bicycle crashes.

4 Case studies

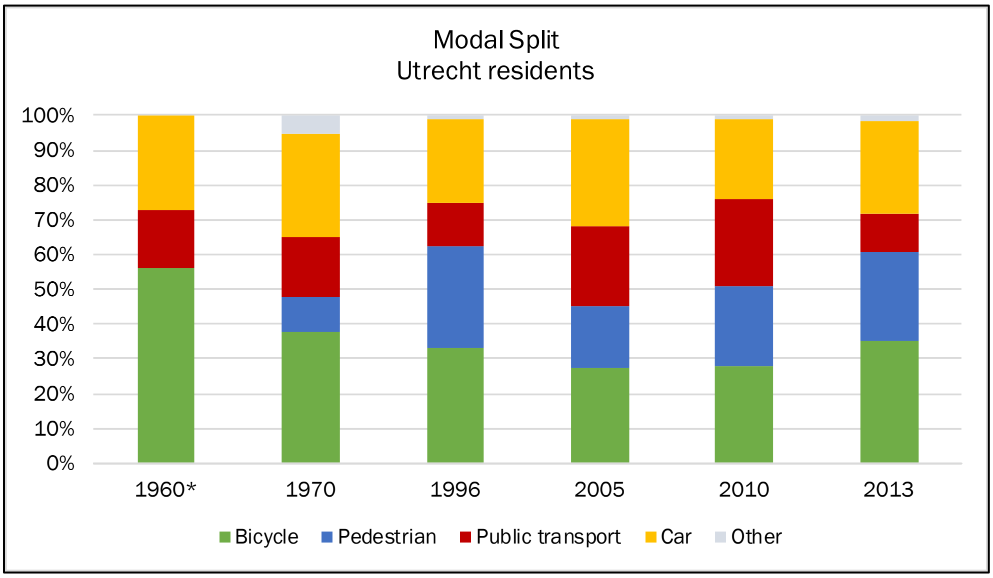
This chapter highlights four cases to demonstrate retrofitting examples in the Netherlands in practice. The cases are selected because they are comparable to situations in the U.S. The urban cases in Utrecht and Amsterdam show retrofitting at locations in wide streets or large junctions. Next, two sub-urban cases are selected to show the retrofitting in the sub-urban context[44].

4.1 Retrofitting in urban areas

4.1.1 Utrecht

In Utrecht, cycling policies changed in the early 1990s. Sustained lobbying by the Cyclists' Union moved parliament to provide subsidies. The city improved existing cycling routes by creating segregated cycle tracks, cycle lanes and bicycle parking facilities. After 1995, radical measures to limit on-street car parking created more space for cyclists. The authorities banned car parking at the central square and blocked through-traffic. This was successful: car use decreased with around 30 percent and cycling increased with around 30 percent.

Graph 2 Modal split in Utrecht



Source: Oldenziel, R. et al. (2016). Cycling cities[45]

[44] During this research, we discovered that it was hard to find documentation, images and policy documents to support the cases. We interviewed experts for additional information and took pictures ourselves. That is why not every not every case is build up in the same order and with the same type of information.

[45] Data collection for pedestrians started in the '70s. Before this, pedestrians were mainly included in the share of cyclists.

More and more people used bicycles for multimodal bicycle-train-bicycle trips. Cycling policy turned out to be an ongoing process of negotiation. The initiative of a dedicated ''bicycle street' and a cycle path through the park sparked heated debates. It was only after 2011 that a new coalition brought more changes and bigger innovations in cycling infrastructure. Today Utrecht boosts 150 miles of cycle paths, 55 miles of cycle lanes and numerous bicycle parking garages in the city center, especially around the central train station.

Utrecht before / after

Figure 34 – Neude 1964 and 2015 (Utrecht)

Figure 35 – Vredenburg 1964 and 2015 (Utrecht)

Figure 36– Catharijnesingel 2000 and 2018 (Utrecht)

Source: Archive Utrecht, Bicycle Dutch, CU2030

The two cases that are presented here for Utrecht show retrofitting in different situations. The first case illustrates changes made in a residential area that was mainly designed around cars in the 1960s and it has been recently 'retrofitted' to an area with improved road safety and livability. The second case shows a recently redesigned junction where an innovative street designed has been tested.

Case 1: Overvecht

The situation

Overvecht is a neighborhood developed in the 50s and the 60s as result of the expansion of the city. This was initially designed around car use: the streets present a wide layout, on street parking and easy access to the motorway. However, the area mainly had residential functions, so the focus on motor traffic did not suit the use of the area. The street grid in this neighborhood is recently updated to the 21st century Dutch standards to make the area safer, more attractive and more livable for its residents. This is mainly done by concentrating motorized traffic flows on Distributor roads and changing the remaining areas into 18 mph zones (Access roads).

Design

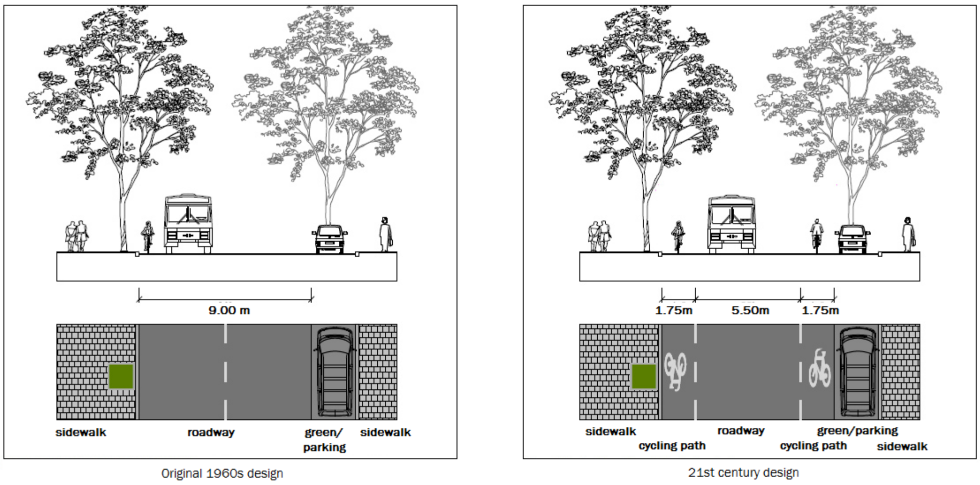
In the original 1960s grid design, motor traffic could use all streets to cross the neighborhood. Most streets were residential, but all streets had the same speed limit of 30 mph. To better channel traffic flow a 'neighborhood' ring was designated and the function of distributor road (*gebiedsontsluitingsweg)* was assigned. This ring is depicted with the green line in figure 17. The light blue streets in the figure changed from main streets to Access streets with a speed limit of 18 mph. At some places through car-traffic was blocked to force car traffic in a specific direction and allow only cyclists and pedestrians to pass. These principles are an application of the Sustainable Safety principles and policy as explained in the previous chapter.

Figure 37 Changes to the original 1960s grid

Source: Wagenbuur (2013)

Besides differentiation between the neighborhood ring and access/residential streets, the road design was also changed to improve safety. On the neighborhood ring the center line was removed and bicycle lanes were added (Figure 37)[46]. In this case, the municipality chose for cycle lanes instead of separated cycle tracks for the ring road. This was done because the ring is not for through traffic and the speed limit is 30 mph (see Appendix 2 for technical details).

Figure 38 Design neighbourhood ring



Source: Wagenbuur (2013)

46 This measurements are similare to the Advisory Shoulders. These lanes create usable shoulders for bicyclists on a roadway that is otherwise too narrow to accommodate one. Motorists may only enter the shoulder when no bicyclists are present and must overtake these users with caution due to potential oncoming traffic (FHWA, 2016. Small town and rural multimodal networks)

The process

At the time when the plans for retrofitting were presented not all residents were in favor. They feared that forcing car drivers to use the neighborhood ring would lead to longer routes and more emissions.

The effects

The new road design provides cyclists in the area with more safety and comfort. Follow up research conducted by the municipality showed that traffic diversion did not lead to increased congestion and environmental problems, rather traffic safety and livability has improved as traffic is pushed out of the residential neighborhood. Car drivers are now used to the new road design and lower their speed. One of the goals of the municipality was an increasing number of residents from the area to travel by bicycle, but this effect has not been measured yet. The bicycle facilities in the area are more often used by through traffic (by foot or bicycle) then before. These travelers do think the new road design has a positive effect on their bicycle "*experience*".

Retrofitting in Utrecht Overvecht

Figure 39 – 40 Before & after the intervention

1966 | 1994

2013 | 2016 (new design)

Source: Het Utrechtse Archief

Case 2: Adriaen van Ostadelaan

The situation

Recently, in Utrecht, a complicated five-arm junction has been reconstructed. The junction was originally designed to suit the needs of the car. Multiple car lanes and traffic lights were needed to organize traffic going in the five different directions. There are many shops, schools and a large hospital located around the junction, so the design did not suit the public use of the area. Therefore, this has now been reconstructed for 'people'. Cyclists and pedestrians have gotten more space and cars have to behave as 'guests' at the intersection. Meaning that the urban space is no longer designed for the car, but every location can still be reached with one[47].

Figure 41 Old profile Adriaen van Ostadelaan

Source: Wagenbuur (2016)

The design

Many elements have changed at the junction. The key change is that rather than having traffic from five different directions coming together in one single intersection, now the intersection is split in T-junction and one main road with two side roads. This is according to Sustainable Safety principles, it makes the intersection simpler and reduces complexity. Traffic signals have been removed, the maximum speed has been reduced

[47] Source: Wagenbuur (2016)

from 30 mph to 18 mph and the roads have been narrowed. Nevertheless, the width is still enough to allow a smooth traffic. It is now easier for pedestrians to cross the streets as sidewalks have been widened and bus stops can be reached easily and safely. Dedicated crossings have also been improved for cyclists.

The process

Implications were discussed in the planning phase. The changes at the intersection were designed by the city in close cooperation with residents and entrepreneurs in the area. In particular, two main concerns were raised by participants with regard to motor traffic volumes. First of all, they feared that by removing traffic lights, reducing speed limits and downsizing the intersections would have led to increased congestion. Secondly, it was believed that mixing traffic and eliminating physical separation between cyclists and motor traffic would lead to safety issues. The city simulated different scenario showing that the design was feasible. Requests by stakeholders for zebra crossings, speed humps and more traffic signs informing about the speed limit were mostly dismissed, because they would go against the nature of a 18 mph zone.

Figure 42 The design of the new junction at the Adriaen van Ostadelaan

Source: City of Utrecht (2016); Wagenbuur (2016)

An important stakeholder group in this reconstruction were the entrepreneurs. The owners of shops and restaurants in the area were in favor of the design and thought that it would contribute to the economic vitality of existing businesses.

The effects

Now that the junction has been recently reopened after reconstruction a totally new atmosphere can be experienced in the area. The design of the junction makes cyclists - and especially pedestrians - feel safe. Still, there were some challenges worth mentioning. The junction was always designed for motorists, so after the reopening of the junction motorists had to get used to the new situation and speed levels. Like the municipality and the designers expected users got used to the junction fast and the situation has improved to a more quiet, safe and welcome area[48]. Residents and entrepreneurs are satisfied with the changes made and pedestrians as well as cyclists feel more safe.

Retrofitting of Adrian van Ostadelaan – current profile (2016)

Figure 43 - 44 Intersection

Figure 45 Main street

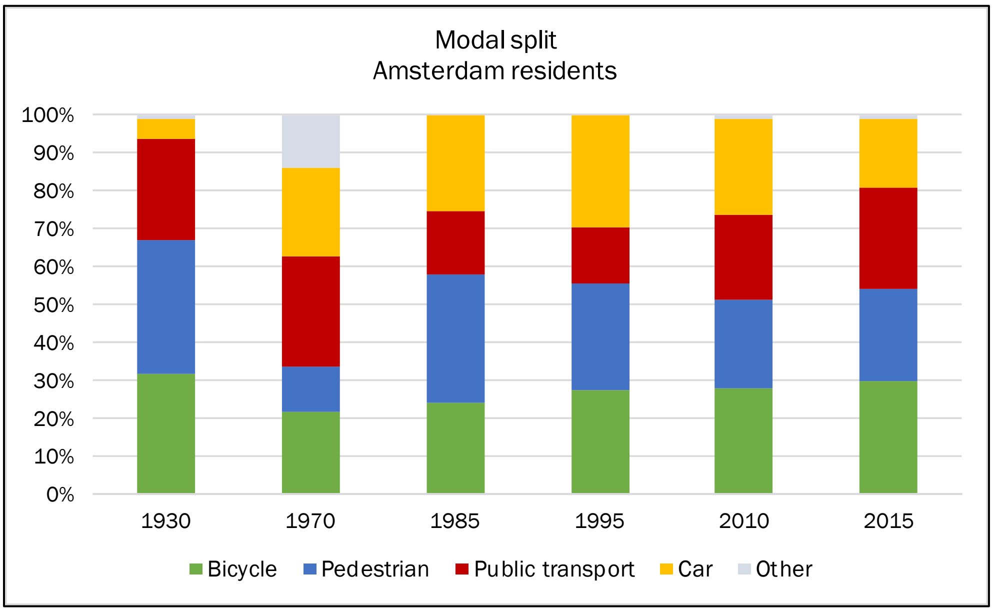
Source: Wagenbuur (2016); Paolo Ruffino (2016)

[48] This video shows the situation before and after retrofitting: https://www.youtube.com/watch?v=Ibcly3iLpS8

4.1.2 Amsterdam

It was only around the 1990s that cycling reversed its decline and began to expand at a startling pace. Reducing car use by cutting back on car parking was one of the tactics. In a fifteen-year period (1990 – 2006) traffic counts in the historic center showed a drop-in car trips (235.000 to 172.000) and a 40 percent increase in the number of cycling trips per day (340.000 to 490.000).

Graph 3 Modal split in Amsterdam from 1930 - 2015



Source: Oldenziel, R. (2016)

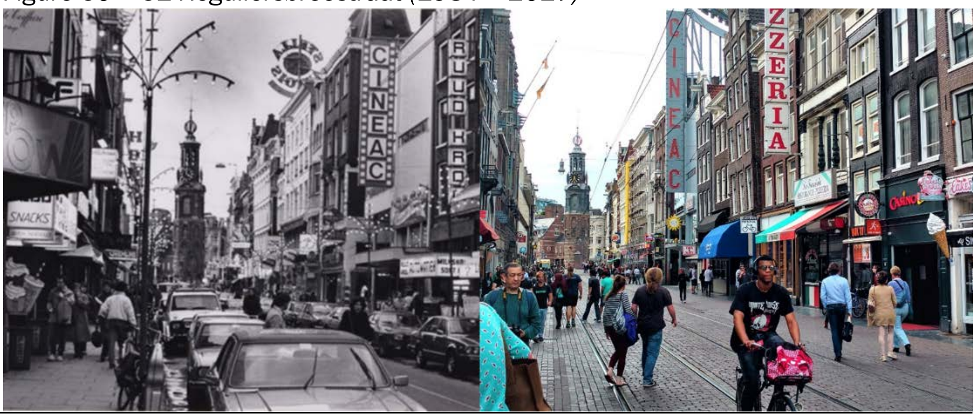
The share of cycling in the modal split in the metropolitan area of Amsterdam was 32 percent in 2014. However, in the city center the modal split was 87 percent (for trips shorter than 2 miles).

Retrofitting in Amsterdam

Figure 46 – 47 Eerste van der Heltstraat (1975 – 2017)

Figure 48 – 49 Gerard Douwstraat (1982 – 2017)

Figure 50 – 51 Reguliersbreestraat (1984 – 2017)



Source: Beeldbank Amsterdam; Paolo Ruffino (2017)

The cycling network that was created in 1978 (Hoofdnet Fiets) still counts as a guide for policymakers. Now the 'bicycle team' in the city is working on an improved network to make cycling in the city even more convenient and safe. The city appointed a bicycle coordinator to align neighborhoods' policies with the policy of the central city. In 2002 the budget for bicycle infrastructure was increased from 5 to 70 million Euros[49] (5 to 75

[49] Cycling cities (2016)

million USD) per year and the goal was set to achieve a cycling share of 37 percent in 2010. The new city council realized cycling could not grow in a safe manner by itself: measurements are needed. The graph shows that modal split between the different transport modes is well balanced in Amsterdam.

Case 3: Overtoom

The situation

The Overtoom is a busy street in the center of the city. This street had been retrofitted for cyclists many years ago. No specific documentation about this retrofitting can be found, but the pictures below show that the transformation fits the original cycling policy of the 90s. Issues that discouraged citizens from using their bicycles were safety, exhaust fumes, theft, the weather, and distances.

The design

The basic principles of the cycling policy in the 90s were:

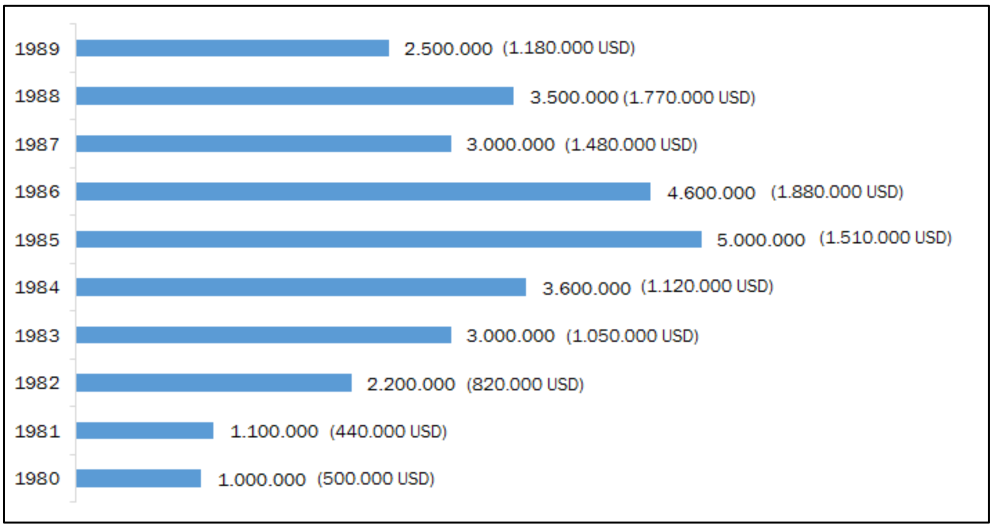
- Create short and fast routes.
- Pleasant routes. Cyclists appreciate pleasant routes with a lot of green and without too much traffic.
- The feeling of social safety. It is important for cyclists to feel safe during the day and at night. This can be achieved by enough lighting, routes along busy areas and sufficient overview.

The new cycling infrastructure was attached to the 'Duurzaam Veilig' principles (see Chapter 3.).

The process

When new councilors were appointed in 1978, serious attention was given to cycling policy. In this period, a cycling workgroup was set up to draft cycling policies and research the main bottlenecks in the city. The Cyclists' Union was also a member of this workgroup and operated as an advisory body. A specific budget was appointed for cycling infrastructure and other matters like parking facilities and the promotion of cycling. In ten years a total amount of 30 million Guilders (13,8 million dollars) was spend on bicycle policy. This separate 'bicycle budget' appeared to be an effective tool for cycling policy. Other funds for bicycle policy came from major maintenance projects in the municipality, the 'city renovation fund' and subsidies from the province or the central government.

Graph 4 Budget available for cycling policies and projects (in guilders and USD)



Source: Cycling cities (2016)

When improving and creating cycling routes, a distinction was made between the main and secondary network. Citizens as well as some councilors opposed this idea claiming that the entire cycling network should be optimal for cyclists. But this distinction made clear which routes were the most important ones and should get priority. This was also part of the so called 'bottleneck approach'. The worst and most dangerous bottlenecks were taken care of first. This ensured the transformations to be visible in the entire city. Often the changes in the cycling network were combined with general infrastructure maintenance works to lower the costs.

The effects

The Overtoom transformed from a car oriented street to a street that is safe for pedestrians and cyclists. Segregated cycle tracks for cyclists and additional traffic lights are exemplary implementations to ensure this effects.

Retrofitting of Overtoom in Amsterdam

Figure 52 – 53 Overtoom in the 1940s

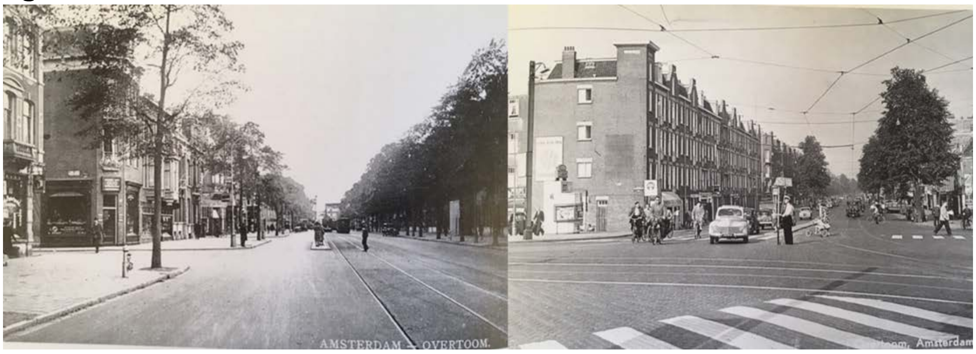


Figure 54 – 55 Overtoom in 1982 and 1971

Figure 56 – 57 Overtoom in 2016

Soure: Beeldbank Amsterdam: Wagenbuur (2012): Decisio (2016)

Case 4: Wibautstraat

The situation

The Wibautstraat is an important thoroughfare which connects two main 'entrances' to the city. Over the last couple of years the street has transformed from a mono-functional road to a multifunctional area. Several organizations and companies are now established on the street, from profit to non-profit, cultural institutions, colleges, restaurants, shops, a hospital and a lawyer's office. At the same time, little has changed to the spatial layout and the quality of the area. This does not fit the new functions and diversity anymore.

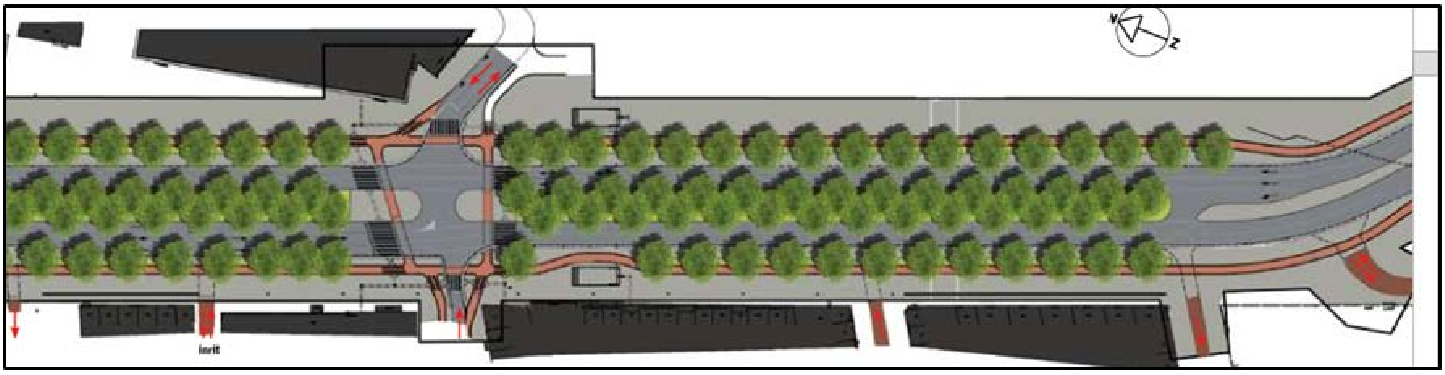
The design

The new design aimed/aims to make Wibautstraat a lively, pleasant and safe open space for residents and other users. Measures will be implemented in a way that the street can still serve as a thoroughfare for cars and public transport. The most important changes are:

- The current roadways will be separated by two rows of trees. Another row of trees will be placed between the cycle tracks and the carriageway.
- There will be wide sidewalks and bicycle tracks to ensure comfort, safety and the possibility to cycle with speed.
- The bottom part of buildings will get an 'active function' like shops, restaurants and companies.
- Materials used for paving and street furniture will be uniform in the entire street
- Attractive and suitable street lighting will be placed.

When making all these changes 106 car parking places will be removed, but they will be compensated in a new parking facility.

Figure 58 Planning map



Source: City of Amsterdam (2009)

Figure 59 New street profile

Source: City of Amsterdam (2009)

Figure 60 An impression of the Wibautstraat

Source: City of Amsterdam (2009)

The process

From 1998 until 2001 a new design was created for the street in close cooperation with residents and other users of the area. The Wibautstraat project is divided into several subprojects. Besides redesigning the street and its layout, other buildings and functions along the street are improved. For example a big metro station and squares along the street. The project group '*Wibaut aan de Amstel'* was set up to coordinate the different components of the project for coherence and alignment. The project group made sure that change in public transport schedules did not cause for too much nuisance for example. The project group is also in close contact with the planners in the central city to make sure the plans at the Wibautstraat connect to infrastructure planning in the rest of the city.

The effects

Since the first changes were made in 2010, much of the original design elements have changed in the Wibautstraat (see Figures 57 to 62). Besides the existing functions, new restaurants, coffee bars, two hotels and other young companies settled in the street. The transformation is not yet completed, but this will be done in the coming years.

Retrofitting of Wibautstraat

Figure 61 - 62 Wibautstraat in 1960 and 1966


Figure 63 – 64 Wibautstraat in 1983 and 1985


Figure 65 – 66 Wibautstraat in 2016


Source: Beeldbank Amsterdam, Paolo Ruffino (2016) and Decisio (2016)

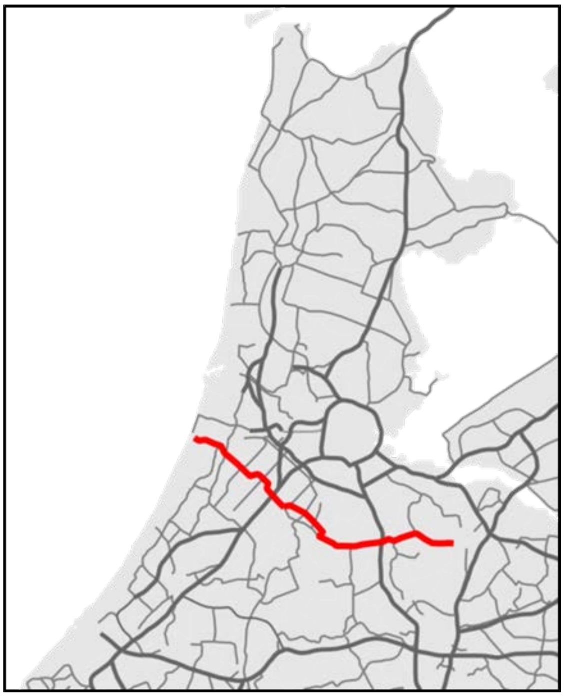
4.2 Retrofitting in sub-urban areas

4.2.1 Hoofddorp

Hoofddorp is the main town of the Haarlemmermeer municipality in the province of North Holland in the Netherlands. In 2009, the population was just over 73,000. The town was founded in 1853, immediately after the Haarlemmermeer had been drained. Located in the south of Amsterdam, the city mainly has a sub-urban residential function with low density. The cycle track addressed is located in the metropolitan area of Amsterdam between the cities of Hoofddorp and Aalsmeer. Although the fast cycle route is still in realization it illustrates what reasons may motivate such intervention.

Case: Kruisweg fast cycle route

Figure 67 Depiction of the route



Source: GIS Wegen (2016)

The situation

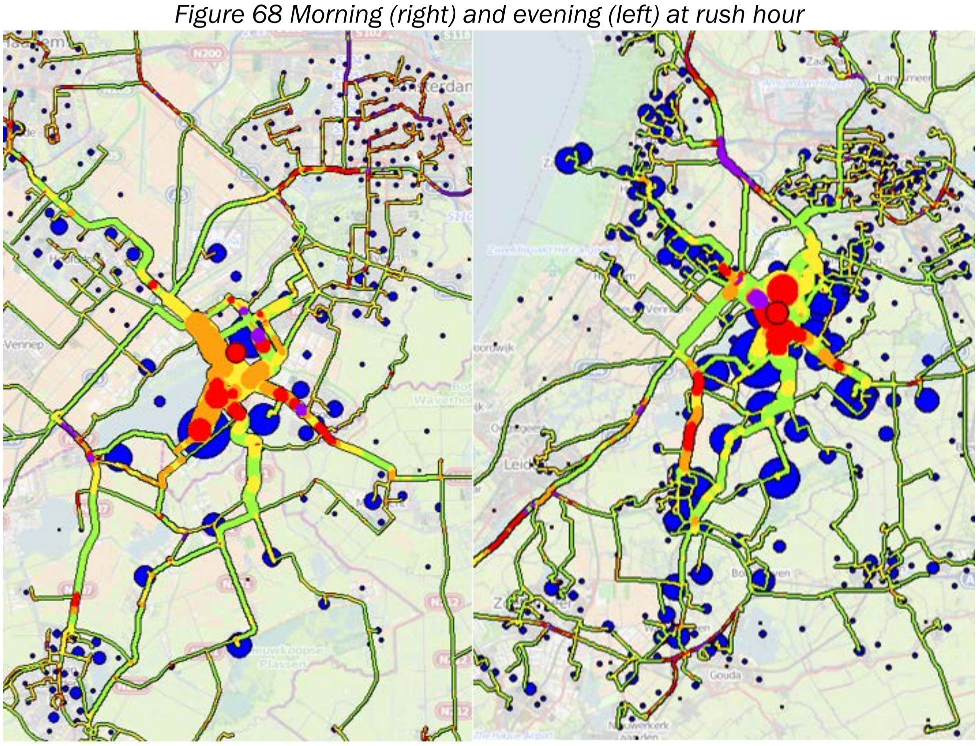
The N201 Kruisweg is an important provincial road that connects Zandvoort to Hilversum and intersects with the A4 between Hoofddorp, Aalsmeer and the Schiphol Airport. Although this is not specifically listed in the "congestion top 50"[50], annual travel time and traffic measurements indicate it has one of the busiest road sections of the country (ibid.).

Between Hoofddorp, Schiphol and Aalsmeer, important economic activities are located which attract traffic from the surrounding municipalities causing bottlenecks during morning and evening rush hour. Part of this congestion is caused by short trips taking place during morning and evening rush hour due to traffic arriving to and/or departing from Schiphol Airport and its surrounding area (ibid.). In addition, the motorized traffic currently cuts through a number of residential and commercial areas, impacting the quality of life, traffic safety and determining slow traffic on other provincial and regional roads[51]. According to a local and regional problem analysis, the level of

[50] List of busy roads and intersections in the country
[51] Stadsregio Amsterdam, 2010

bicycle use in the area is low due to the poor quality of the infrastructure that may bring substantial “disutility” to cycling and encourage car travel instead[52]. Traffic counts show low levels of bicycle use in relation to the number of people living and working in the area[53]. An early qualitative analysis and a large-scale mobility survey among Schiphol Airport employees, underlined these unattractive conditions as a factor for not cycling[54]. In particular, the comfort, the number of intersections and safety concerns were specifically mentioned. Moreover, between 2010 and 2013, the number of workers commuting to the Schiphol Area by bicycle declined from 3,2% to about 2,6%[55]. Meanwhile, car use has steadily increased to almost 60% of the totality of the trips (ibid.). This is also the case for those workers living in the neighboring municipalities where bicycle use has declined in favor of car use.

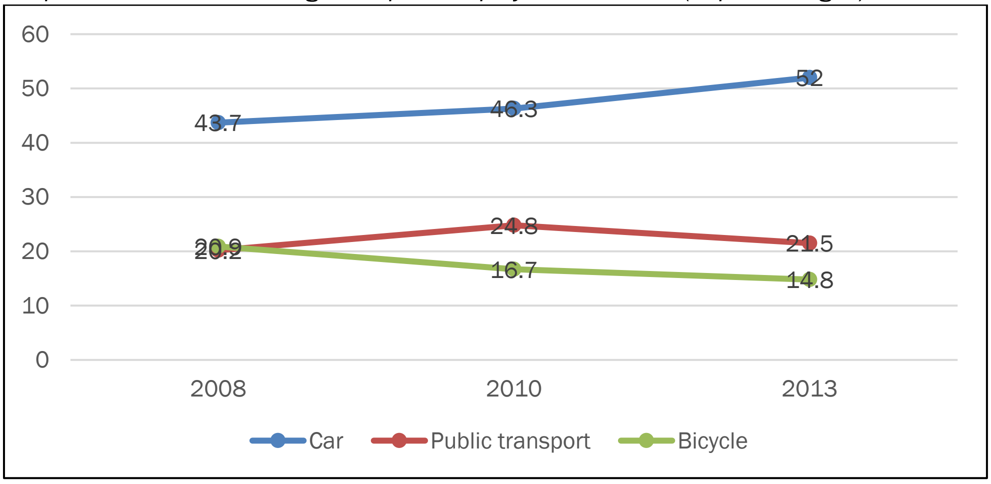
Figure 68 Morning (right) and evening (left) at rush hour



Source: Stadsregio Amsterdam (2015)

[52] Stadsregio Amsterdam, 2010; Gemeente Haarlemmermeer, 2015.
[53] De Meerlanden, 2008; Gemeente Haarlemmermeer, 2015a).
[54] Stadsregio Amsterdam, 2010; SOAB, 2013
[55] SOAB 2010; SOAB 2013

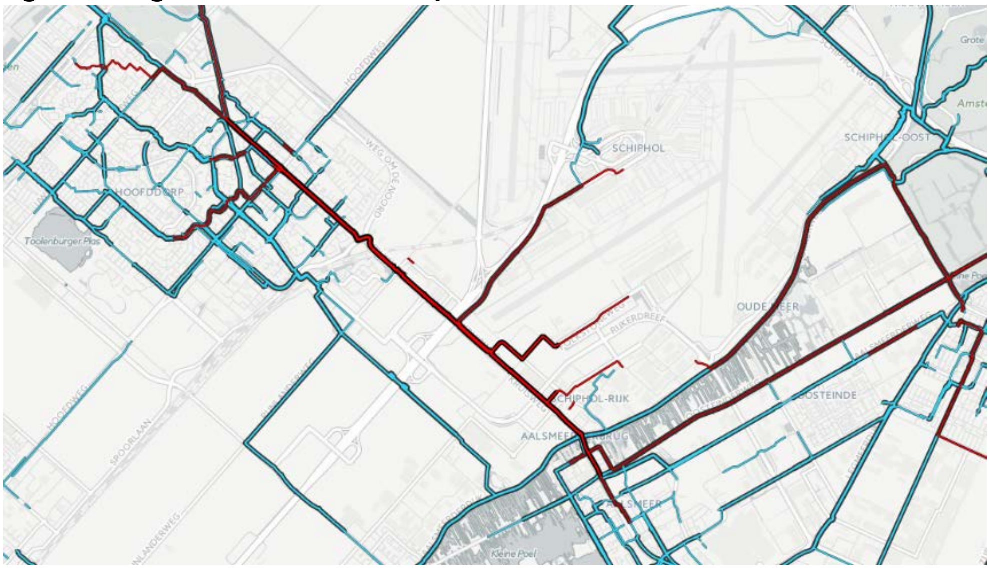
Graph 5 Modal share change Schiphol employees < 6 miles (in percentages)



Source: SOAB (2013)

Hence, by improving the cycling conditions, it is believed that there is the potential to substantially increase bicycle use in the area[56]. In addition, by encouraging a modal shift to cycling it is also believed to be beneficial to tackle traffic congestion in the area (ibid.).

Figure 69 Origin and destination of bicycle traffic based on 'fietstelweek' data



Source: Bike Print (2016)

The proposed intervention aims at encouraging a modal shift to cycling by improving the current cycling conditions. In particular, the construction of a high-quality fast cycle route

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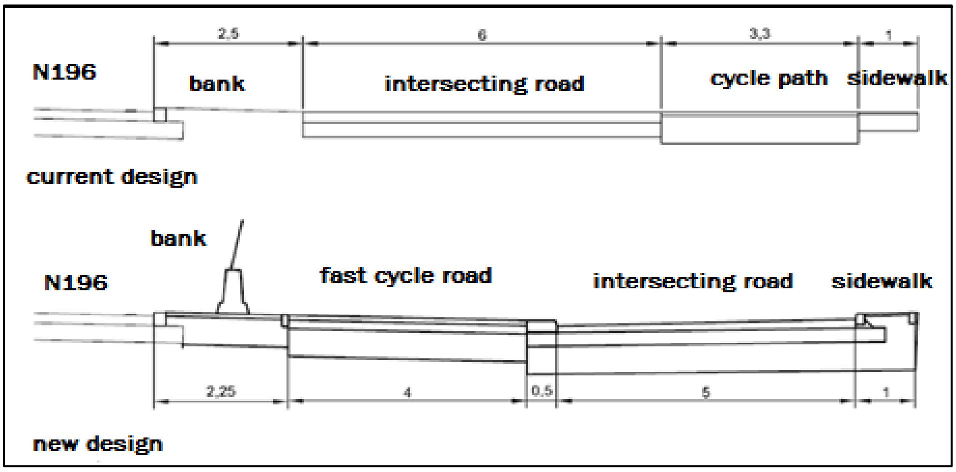
[56] Stadsregio Amsterdam, 2010; Gemeente Haarlemmermeer, 2015; Gemeente Haarlemmermeer, 2015b

to connect Hoofddorp, Aalsmeer and Uithoorn (circa 4 miles) in order to improve local and regional accessibility to the Schiphol Airport and to other local economic areas by bicycle.

The design

The Kruisweg was an old towpath upgraded to main arterial road for cars, cutting through the city center. After the policy shift in the late 70s, the traffic was rerouted outside of the city center to a ring road *(Weg om de Noord*) and a bicycle track added to the Kruisweg. However, until now the part connecting Hoofddorp till Aalsmer has hardly been upgraded, except for a few intersections and stretches. The fast cycle route will reuse the old infrastructure, whenever possible, and partially rebuild on the south flank of the Kruisweg to avoid potential conflicts with motorized traffic. The total number of intersections will be reduced from five to two. In addition, the material used will be upgraded to ensure a higher level of comfort. Together with the physical intervention, a behavioral campaign (demand management approach) will be completed in order to encourage people working and living within 9,5 miles to commute to work by bicycle. A special target group of this intervention are the Schiphol employees, which together represent 65000 people. The majority of which commute by car. The total realization cost for the project is €18 million, while the stretch addressed between Hoofddorp and Aalsmeer is of €6 million.

Figure 70 The old and the new profile



Source: City of Haarlemmermeer (2015)

Redesign of the Kruisweg

Figure 71 Kruisweg in 1960

Figure 72 Current profile (from 1980s-2016)

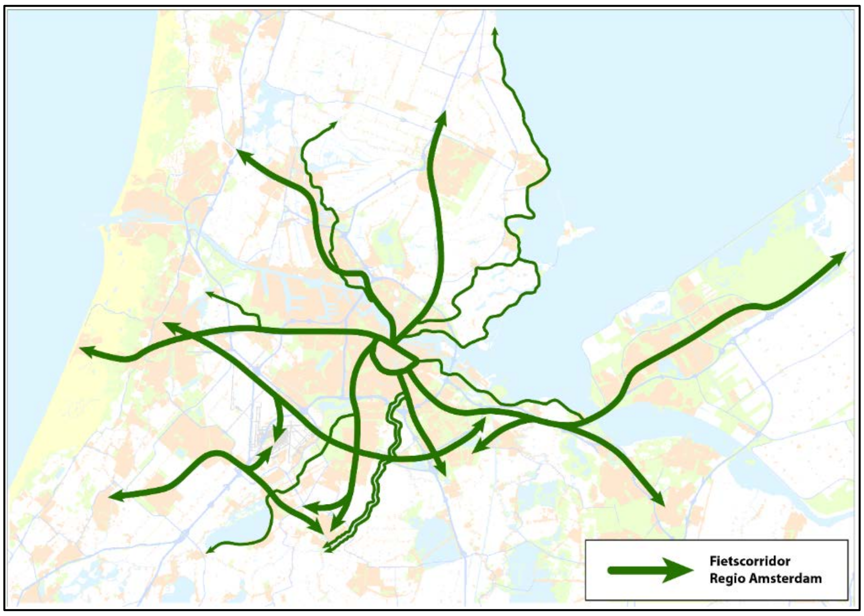
Figure 73 New profile (from 2018)

Source: Paolo Ruffino (2016); Stadsregio Amsterdam (2015); Beeldbank Provincie Noord-Holland

The process

This intervention is embedded within the "Fietscorridor" policy framework of the "Investeringsagenda Fiets" (Bicycle Investment agenda) of the Transport Region of Amsterdam. One of the main goals of the framework is to invest in a high-quality and long-distance regional network of fast cycle routes that connects the municipalities of the City Region and the major transport hubs.

Figure 74 Network of the Fietscorridor of the Amsterdam Region



Source: Stadsregio Amsterdam (2015)

The overall ambition is to structurally increase the use of sustainable modes of transport (bicycle combined with public transport) in all types of built environments: low, medium and highly urbanized[57]. To achieve the goal, the approach is to improve the weak links in the network by upgrading them to the latest design standards. To upgrade the bicycle connection to a fast cycle route, the involvement and cooperation of the various authorities (road authorities) are required.

1. Stadsregio Amsterdam
2. Provincie Noord-Holland
3. Municipality of Aalsmeer
4. Municipality of Haarlemmermeer
5. Schiphol Group
6. Local bicycle advocacy (Fietsersbond)

[57] Public Transport and cycling must pick the striker a market share of 70% together in dense urban areas, 50% in the large nuclei and 30% in small towns.

The above parties have established a working group coalition to ask for a grant from the Ministry of Infrastructure. The implementation of the measures is also accompanied by the working group. The Stadsregio Amsterdam acts as the content coordinator on the fast cycle route Hoofddorp-Aalsmeer Schiphol.

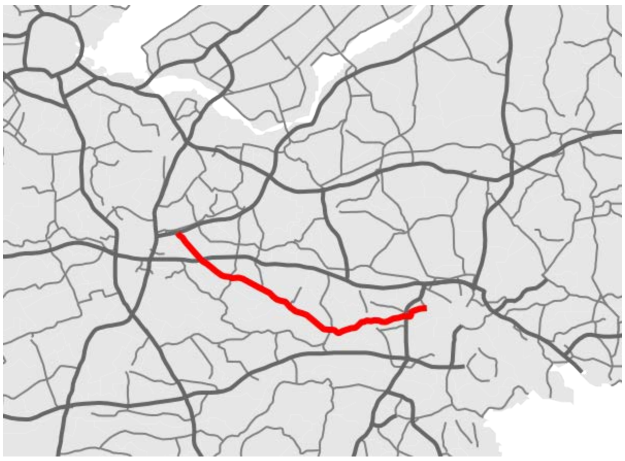
The effects

Although the project has not yet been implemented, an assessment was conducted to estimate what would be the economic impact of the project. In particular, it is assumed that the fast cycle route will reduce travel time and increase safety by reducing the number of intersections[58]. Moreover, the current paving slabs on the path will be replaced by smooth red asphalt to increase speed and perceived comfort (ibid). Other benefits identified were attractive roads that increase the propensity to cycle, easier access to jobs located at Schiphol Airport area, tourist attraction and increased physical activity. Finally, by reducing car use, it leads to lower air and noise pollution and the potential for traffic crashes. On the basis of the analysis, a social cost-benefit analysis was performed for this project showing a positive economic balance of about € 2,5 million on average (min -3,5 million, max 8.5 million) after 15 years.

4.2.2 Rhenen – Elst

The case addressed is a cycle track along the N225 provincial road between the cities of Rhenen and Elst. The N225 is a former motorway in the provinces of Utrecht and Gelderland. The road links Driebergen and Oosterbeek to Wageningen. The route runs almost parallel to the A12 motorway and the Lower Rhine.

Case: Provincial road N225



Source: GIS Wegen (2016)

This 29 miles long route was originally the national highway 25 and remained as such between 1932 and 1958. Then the A12 was completed and the N225 was downscaled to provincial road. This also because it crosses several urban centers and villages. In line with the Sustainable Safety policy, the N225 is a distributor road. The speed limit is 50 mph on rural

[58] Gemeente Haarlemmermeer, 2015

roads and 30 mph along the cities. In Elst (Province of Utrecht), the road was downscaled to an access road with a speed limit of 18 mph.

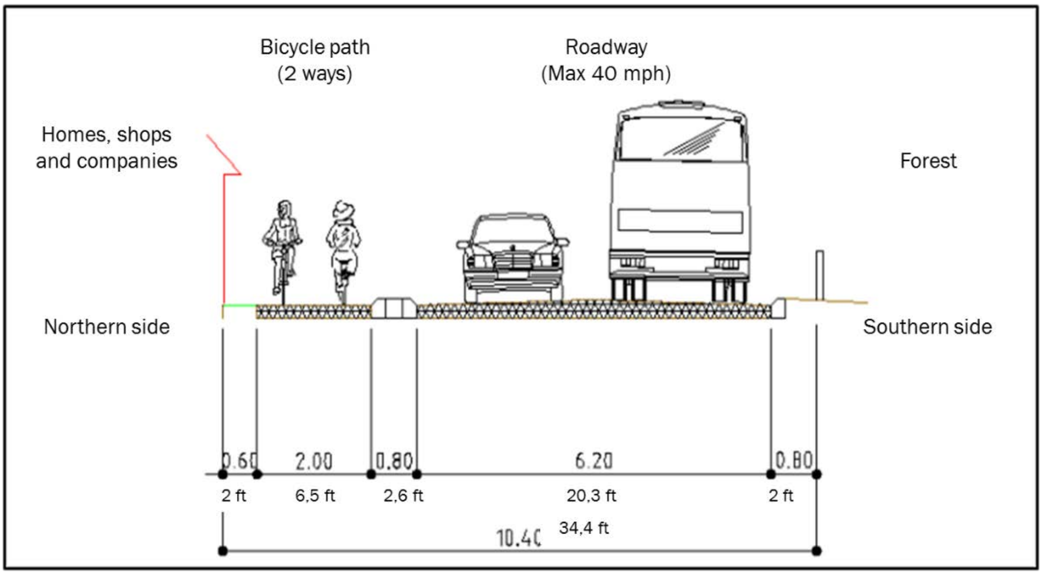
The situation

The motivation behind the intervention was the safety issues along the N225 between Rhenen and Elst. Between 2001 and 2003, over 30 crashes took place due to lack of visibility and lack of segregated cycling infrastructure. As a result, the province of Utrecht decided to allocate €3 million to reconstruct the road and dedicate a separated bicycle track to increase safety in the area. In addition, adding a bicycle track would have improved local access to Remmerden, an important industrial site in the area.

The design

A two-way segregated cycle path on the northern flank was constructed to ensure safety from fast and intense traffic (40 mph and over 17.000 pcu/day). Because on this road, the volume of cyclists is very low and space is limited at certain locations. A minimum width of only 2.00 m. for the two-way cycle track is applied here while 3.00 to 4.00 m. is used as a standard for busier urban cycle tracks and cycle tracks on fast cycle routes.

Figure 75 The new road design



Source: Province of Utrecht (2004) reworked by Decisio

In addition, elevated cycle crossings and a roundabout was added to reduce speeds at intersections and improve visibility.

Retrofitting of the N225

Figure 76 N225 in 2009 before the intervention

Figure 77 N225 in 2010 during the road works

Figure 78 N225 in 2015 after the reconstruction

Source: Google Street View

The process

The process started in 2004 and it was implemented in 2009. Several evenings were organized between the municipality, province, local residents and interest groups (cyclists' union and road safety organizations). The evening events registered a high participation as improving the local cycling conditions was considered by all parties a priority. The sketches of the plan were discussed with all stakeholders and the reactions recorded and assessed. Many attendees, including road safety organizations, raised some objections against the plan as a single path would have crossed several exits, not addressing safety concerns entirely. Two separated bicycle paths, with one way per direction, were preferred by some parties. However, this represented both a technical and financial problem. The higher costs were primarily due to substantial physical barriers (buildings and the Rhine Valley), especially on the southern flank. Hence, it was decided to keep the original plan with one-sided separated bicycle track but with a broader profile and higher separation.

The effects

Although no hard figures are present regarding traffic safety, fewer problems are now reported to the traffic departments of the two small municipalities and the overall impression is that traffic safety has been greatly increased. People cycling in the area declare to feel safer and much more motivated to use their bicycles for their daily commute[59].

59 Interview with local cyclists' union

5 Conclusion and lessons from the Netherlands

This report addressed the transport policy transition that happened in the Netherlands and materialized in the form of retrofitting from car-oriented streets into bicycle and pedestrian friendly streets. First the topic was introduced in an historical perspective to illustrate the different phases of this transition. Secondly, current approaches that are the basis for bicycle planning in the Netherlands were summarized and explained. Finally, several cases were analyzed where the process of retrofitting took place. Every transition in any country and any location is context specific, hence design principles and policies need to be adapted to the local situation and culture. However, it is possible to learn from the Dutch experiences and knowledge on cycling infrastructure. In the following chapter, some general lessons that can be learned from The Netherlands are presented.

The individual as unit of analysis

Planning for a people- and bicycle-friendly environment requires an understanding of individual needs and preferences. These differ when planning for cars or for people, because a broader set of physical and psychological factors must be considered. This means addressing both rational needs (travel time minimization, costs etc.) and emotional needs (safety and comfort). Thus, road design should reflect and accommodate different types of travel behavior, but also account for the unpredictable human behavior and incorporate potential (intended and not intended) mistakes. In this regard the Sustainable Safety principles represent a systematic approach to road safety. It can provide the fundamentals for innovation with practical implications for the design of physical spaces and lead to a decrease in road fatalities.

Coherent integrated strategic vision

Dutch towns and cities reversed the decline of bicycle use by developing integrated local and regional traffic and transport policies. At some stages supported by the national government. These policies led to a simultaneous change in the organization of car use, and the promotion of cycling. New concepts to plan and design for motorized traffic have been created with the bicycle in mind. It is this integrated approach - much more than just the construction of cycle tracks and lanes - that has made the Netherlands a successful cycling country.

Integration with other policy domains

Effective promotion of bicycle use requires its inclusion in multiple policy domains. For instance, the bicycle is not only a means of transport but also an important tool to achieve better health, livable cities, lower congestion, clean air, social inclusion and economic growth. This integrated vision hasn't always been the standard procedure in the Netherlands. It is only recently that cycling policy is more involved in other policy domains. With (an increase) in bicycle use goals can be reached on social, economic and environmental domains instead of solely mobility. Therefore, mobility plans are communicated, adjusted and (financially) supported by several policy domains.

Integration of cycling with public transport

The assumption that cycling and public transport are competitors proves wrong in the Netherlands. Cycling and public transport over longer distances, particularly by train, mutually reinforce each other[60]. About half of the trips to and from train stations are done by bicycle. Integrating cycling with trains allows to increase the catchment area of public transport and reduce car dependence for long distance commuting. Scholars and practitioners are therefore beginning to define the Dutch system as the "bike-train system" thanks to this close development.

Close cooperation with stakeholders

The Dutch are famous for the so-called 'polder model'[61]. For every new piece of cycling infrastructure and every new road design, significant public participation is possible. This often leads to good input and better plans and designs. The National Cyclists' Union, with its many local branches is also closely involved in many cycle plans, policies and projects developed by local authorities. Their knowledge and experience, as cyclists are often a valuable source of information for planners.

Political will

The most important factor that contributed to the mid-70s transport policy shift in the Netherlands was the realization that the car-oriented development was unsustainable for the long-term perspective. Road fatalities together with the oil crisis and social unrest, pushed a political transition that favored a paradigm shift in transport policy and planning. This reverted the declining bicycle trend which is now stabilized and growing again. Without political will to change, it is likely that projects such as the Delft bicycle network plan and the partial pedestrianization of city centers, such as in Groningen and Utrecht, would have been less ambitious and thus less successful.

Demonstration and pilot projects

The Netherlands is a country of demonstration and pilot projects. Many innovations in the field of traffic planning and planning for cycling started with experiments on a small scale. Examples of innovations that have developed the *'woonerf', 'shared space'* and

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[60] Local bus transport and cycling do prove to be competitors in the Netherlands as the introduction of a free public transport pass for students showed.

[61] This Dutch model is the idea of solving problems via consensus decision-making and dialogue, with every party having an equal say. Mostly parties with different interest like employers, (labor) unions and government.

roundabouts where cars cannot pass in all directions but cyclists can. Doing a pilot might be easier in the Netherlands than in most Anglo-Saxon countries because of the legal system. It is relatively uncommon and quite difficult to sue the local authority for a crash claimed to be caused by a newly developed design or concept.

6 Appendix

Appendix 1 References & Additional readings

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SWOV (2012). Background of the five sustainable safety principles.

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<u>*Video material*</u>

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Wagenbuur, M. (2011). How the Dutch got their cycle paths: https://www.youtube.com/watch?v=XuBdf9jYj7o

Wagenbuur, M. & Furth, G. (2017). Systematic Safety: https://www.youtube.com/watch?v=5aNtsWvNYKE

Appendix 2 technical details

Hardware

- **Cohesion.** The need for a complete, comprehensible bicycle infrastructure that is integrated with other means of transport. Elements of cohesion include: easy wayfinding, consistency of quality and freedom to choose a route.
- **Directness.** Cyclists are offered the most direct route as possible and therefore keeping detours to a minimum. In addition, the number of intersections and "stop & go" should be limited to cycling. Hence, the overall competitiveness of the bicycle (in terms of travel time) should be higher than for car driving.
- **Attractiveness.** Bicycle infrastructure is designed and fits into the surroundings in such a way that cycling becomes attractive and enjoyable. To be attractive, the infrastructure must guarantee "social safety". This implies, for example, that good illumination should be installed along bicycle routes or in tunnels.
- **Safety.** The infrastructure must guarantee an adequate level of traffic safety for cyclists and other road users. This is especially the case when the traffic is mixed.
- **Comfort**. This comprises factors concerning nuisance (smell, noise) and delay caused by bottlenecks and/or shortcomings of the bicycle infrastructure, which require additional physical effort on the part of the cyclist.

2.2 Sustainable safety road design

Sustainable Safety has important implications for road design. It divides all urban roads into two road categories: access roads[62] with a 18 mph speed limit and distributor roads[63] with a 30 mph (main roads) or 45 mph (through traffic roads) speed limit. Based on these principles and these road classification, the Netherlands implemented three main types of cycling infrastructure. Segregated cycle tracks are to be used for roads on distributor roads when the speed exceeds 30 mph and 2x2 lanes are present. At the other extreme, shared space, combined with speed bumps and other design measures to lower car traffic, is preferred on access roads with speeds below 18 mph. Moreover, depending on the volume of car traffic and bicycles, bicycle streets[64] or cycle lanes with right of way are implemented. On bicycle street CROW recommends that the ratio between cycling and motor traffic should be 1 car to 2 people cycling, or preferably 1 motor vehicle to 4 bicycles. Moreover, the cycle street should have priority over all side roads and should be placed in an area that is frequently used by cyclists. The asphalt used should be smooth to enhance comfort. At speeds between 18 mph and 30 mph and depending on the volume of cycling and motor vehicles, designers may opt for bicycle lanes (on 2x1 streets) or tracks. Outside urban areas, cycle lanes and shared

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[62] 'Erftoegangsweg' in Dutch.

[63] 'Gebiedsontsluitingsweg' in Dutch. On the urban scale 30 mph Gebiedsontsluitings roads are typical Collector or Distributor Roads and 45 mph Gebiedsontontsluitings roads can be considered urban Arterial roads.

[64] "Fietstraat" in Dutch.

space or cycle lanes on 40 mph roads are allowed only when the number of motor vehicles is lower than < 500/day. At higher speeds and higher volumes, segregated cycle tracks along the road are preferred. The table below summarises the main segregation principles.

Table 3 Option diagram for road sections inside the built-up areas (CROW, 2007)

				Bicycle network		
Function	**Max. speed of motorized traffic (mph)**		**Motorized traffic intensity (pcu[65]/day)**	**Basic network ($I_{bicycle}$ > 750/day)**	**Cycle route ($I_{bicycle}$ 500-2500/day)**	**Main cycle route ($I_{bicycle}$ >2000/day)**
	n/a		0	Solitary track		
Access roads	Walking pace or 18 mph		1 – 2.500	Shared use		Cycle street or cycle lane (with right of way)
			2.000 – 5.000			
			> 4.000	Cycle lane or cycle track		
Distributor roads	30 mph	2x1 lanes	Irrelevant	Cycle lane or cycle track	Cycle track or parallel to road	
		2x2 lanes		Cycle track or parallel to road		
	45 mph			Cycle track, moped/cycle track or parallel to road		

Table 4 Option diagram for road sections outside urban areas (CROW, 2007)

			Bicycle network	
Function	**Speed (mph)**	**Motorized traffic intensity (pcu/day)**	**Basic network**	**(main) cycle route (I_{cycle} > 2.000/day)**
Access roads	40 mph	1 – 2.500	Combined traffic	Cycle street (if I_{pcu}< 500/day)
		2.000 – 3.000	Cycle lane or cycle track	Cycle track or lanes
		2.000 – 5.000		
		> 4.000	Cycle track	
Distributor roads	50 mph	Irrelevant	Cycle / moped track parallel to roads	

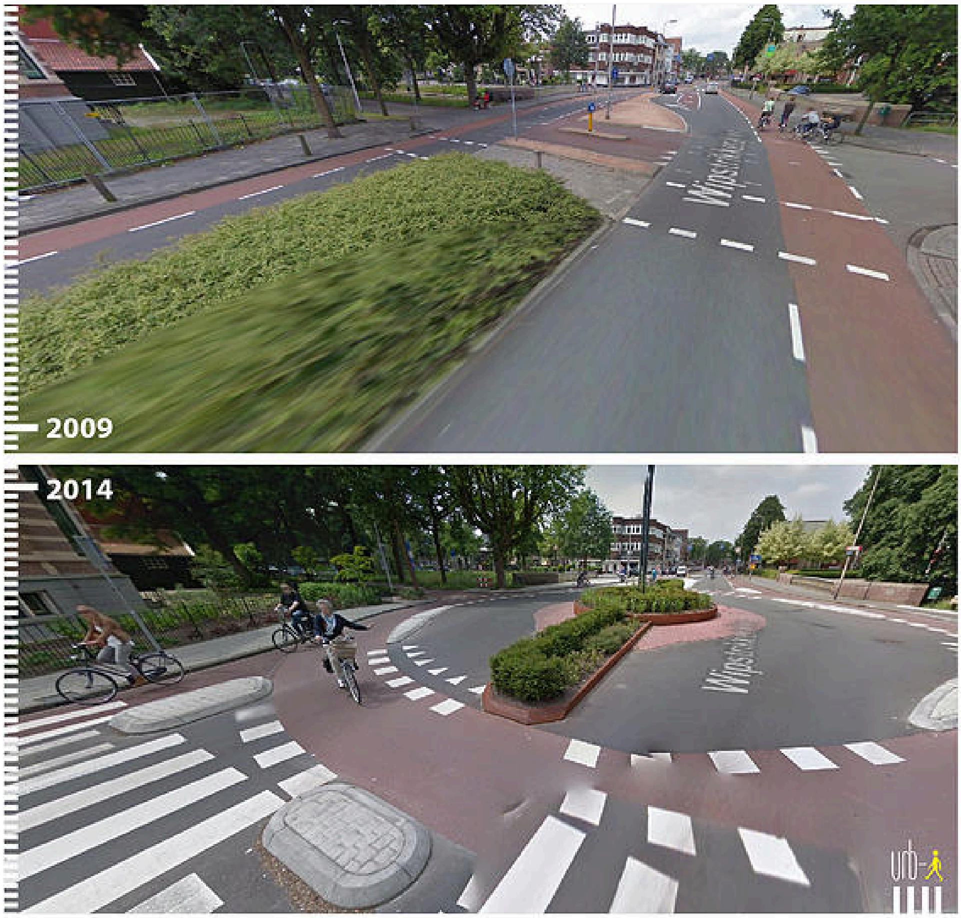
65 Passenger Car Units

Appendix 3 Further retrofitting examples

Figure Veenkade in The Hague. Before and after.

Source: http://www.urb-i.com/netherlands

Figure Wipstrikalle in Zwolle. Before and after



Source: http://www.urb-i.com/netherlands

Figure Kerkhoflaan, Emmen

Source: http://www.urb-i.com/netherlands

Figure The old situation: a signalled intersection

Source: Google street view

Figure the current situation: a long oval roundabout with a shortcut for cyclists

Source: Google street view

Figure Example of a shortcut for cyclists

Source: Jeroen Buis