# Intrinsic versus Extrinsic:

## Motivational Research into the use of Bicycle Lights

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# Abstract

Currently, around 65 percent of all bicyclists use light. For teenagers and young adults this is much lower. The present thesis investigates what policy adjustments should be carried through to accomplish an increase in compliance. Based on a literature study and a survey among bicyclists, it argues first that the level of the fine should be increased. Secondly, policy makers should take notice off the 'Parkstad approach'. This is a comprehensive regional initiative targeting students in secondary education and can easily be applied elsewhere. Among other things, it comprises the distribution of free bicycle lights at schools and stringent police inspections. Such measures are needed because of the significant positive effect that bicycle lights have on traffic safety. A one percentage point increase in the use of bicycle lights is estimated to diminish the number of deceased and hospitalized bicyclists by ten to twenty per year. The survey results show that traffic safety is the most prominent reason for lit bicyclists to use light. They are predominantly intrinsically motivated and use bicycle lights to enhance their sense of security. On the other hand, bicyclists who are unlit do not use bicycle lights because they feel relatively safe and because they are insufficiently extrinsically motivated. The majority requires a higher fine than today's fine before they start using bicycle lights. Findings from the theory of planned behavior provide further support: the presence of a practical problem, which are mostly monetary in nature, has a negative impact on the probability to use bicycle lights. Unlit bicyclists are prone however, to an increase in expected legal costs. Hence, an increase in the costs of cycling without light should motivate unlit bicyclists to change their behavior.

*Key words: intrinsic and extrinsic motivation, theory of planned behavior, bicycle lights.*

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# Preface

Two questions commonly pop up when I tell unsuspecting bystanders at birthday parties about my master's thesis on bicycle lights: "How did you come up with this subject?" and "Did you not study economics?" Although I am not a mind reader, I am sure the answers to these questions will interest you.

While cycling from somewhere to home in the late autumn of 2009 I realized that I did not bring my bicycle lights. This bothered me; why did I risk a forty euro fine? At the time I was reading Levitt and Dubner's *Freakonomics*, which treats a variety of subjects such as the effect of abortion on crime as well as cheating teachers. Essentially, these subjects are all related to incentives. In their turn, incentives are at root of the economic science.

I remembered one discussion in *Freakonomics* on the effect of fines on compliance in particular. It was derived from *A Fine is a Price*, by Gneezy and Rustichini, who studied the introduction of a fine for late-coming parents in day-care facilities. Their conclusion: the fine stimulated late arrivals. Among other explanations, the authors pointed at the incomplete contract between day-care facilities and parents. Although it is commonly known that uncompensated late arrivals are undesirable, parents do not know exactly how much it costs. Now however, the fine labeled a late arrival with a price tag. So instead of responding to a moral incentive, parents were now facing an economic incentive and consequently changed their decision. So did I risk the fine for cycling without light because I thought using them was unlikely to have a great impact on traffic safety after all, the *expected* penalty was not that high? Or was the moral obligation to do whatever I can to improve traffic safety crowded out by the presence of the fine? These incentive-related questions motivated me to write my thesis on bicycle lights.

Last but not least, special thanks go to my supervisor Eline van der Heijden for giving me confidence in myself as well as advice on the contents of my thesis. I am grateful to all of my friends for being, well, my friend[1]. In particular, I would like to thank Gijs Peeters and Bas Bussink, who have helped me a lot during my studies and with my thesis. But above all, I would like to thank my parents for all their love and support throughout my entire educational career. They will receive a big hug after my graduation.

[1] Make no mistake; I regularly give them a hard time when I make them listen to all of my darts tales over and over again.

# Chapter 1

## *Introduction: Research objectives*

Roughly twenty percent of accidents involving bicyclists occur during dusk and dark. Possibly, this number is enlarged due to inadequate use of bicycle lights during these periods of the day. Recent research (Boxum, Broeks and Stemerding, 2009) has shown that about 35 percent of all bicyclists do not comply with the requirements on bicycle lights.

As a means to enhance the use of appropriate bicycle lights, the Dutch government maintains a fixed fine of 35 euro. According to standard neo-classical theory, a fine is an economic incentive which ought to steer actual behavior towards desired behavior. But as social scientists we know that there is more to it than money. For instance, bicyclists may be inclined to use bicycle lights due to their moral conviction that improving traffic safety is a good thing. This implies that the tools available to regulators are not limited to fines and stringent police enforcement.

The Dutch Ministry of Transport, Public Works and Water Management [VenW] started the campaign '*Licht aan. Daar kun je mee thuiskomen'* in 2003. Goals of the campaign were, among other things, to create a positive attitude towards using bicycle lights and to convince the public of the necessity of using them. If bicyclists are convinced that lights are needed to ensure traffic safety, their moral judgment can make them start using them.

But does this policy of triggering both economic as well as moral incentives actually work? Or do people mutually exclude these incentives and comply with just one? Is it plausible to think that fines might actually deter the use of bicycle lights? The present thesis focuses on fines as a means to enhance the use of bicycle lights. But to put things in a broader perspective, its aim is to answer the following research question:

*Can the number of bicyclists that use bicycle lights be increased through policy changes and hence improve traffic safety?*

This research question demands clarification. First, a bicyclist who has one light at the front and one light at the rear of his bicycle is defined as a 'lit bicyclist'. This is in accordance with the definition of incomplete conformity, which will be treated in section 2.4 in greater detail.

More important is the definition of policy. Not only is legislation part of it, national and regional campaigning efforts are included as well. Thus, if a municipality in Limburg decides to hand out free bicycle lights to high school freshmen (see Box 1 in chapter 2) that is considered to be part of policy. Not included are technical requirements for bicycles. For instance, if the law would be eased by requiring only one light instead of two then of course more people would comply without making traffic any safer. To find out what policy changes should be carried through, the following sub-question has to be answered:

*To which incentives do bicyclists respond when considering the use of bicycle lights?*

The thesis aims to find the decisive factor that motivates bicyclists to use light, since it is a necessity for giving grounded policy advice. A distinction will be made between intrinsic and extrinsic motivators. A moral norm that prescribes bicyclists to use light is an example of intrinsic motivation whereas the current fine is an extrinsic motivator. To formulate an answer to this sub-question the relevant literature on intrinsic and extrinsic motivation as well as the theory of planned behavior is discussed in chapter 3. The latter stems from psychology and is designed to explain and predict behavior. Here it is presented as an alternative to the intrinsic versus extrinsic approach. Furthermore, chapters 4 and 5 are dedicated to the design and results of a field study. Bicyclists in the municipality of Tilburg were interviewed to find the decisive factor for using bicycle lights.

The third and final part of the research question considers the presumed positive effect of bicycle lights on traffic safety. This is measured as the number of accidents that happen during the dusk and dark. Bicycle lights have been proved to enhance visual conspicuity (see section 2.5) but it is unclear whether they directly affect the probability of having an accident. In order to find out if they do, the following sub-question has to be answered:

*Will an increase in a bicyclist's visual conspicuity reduce the likelihood that this bicyclist gets involved in an accident?*

Or as in an alternative formulation: if more people use bicycle lights, will this lead to fewer accidents? The present attempt to answer this question is based on an extensive analysis of the SWOV's database.

The Institute for Road Safety Research [SWOV[2]] is a specialized institution in doing research on traffic safety and for that purpose it collects and analyzes data on for instance traffic accidents. These data are used here to estimate the effects of bicycle lights and visibility. The following chapter will provide the reader with an answer to this sub-question as well as an extensive outline of current Dutch legislation regarding bicycle lights.

[2] SWOV is an abbreviation for "Stichting Wetenschappelijk Onderzoek Verkeersveiligheid".

# Chapter 2

*Illumination: facts and effects of bicycle lights*

This chapter studies the effects of bicycle lights on traffic safety. It does so by means of two regression models that estimate the number of deceased and hospitalized bicyclists per billion seat kilometer. But before we come to that, the chapter aims to familiarize the reader with the subject *bicycle lights*. The first section briefly describes the history of cycling, from the invention of bicycles to the introduction of legislation. Section 2.2 extends this with a description of the law at present day. Law enforcement is discussed section 2.3. This is followed up by a discussion on the actual use of bicycle lights and the difference between complete and incomplete conformity. The final section before the conclusion discusses and analyzes figures on traffic accidents. These are then applied as dependent variables in two models that are used to estimate the effects of bicycle lights as well as visual conspicuity on traffic safety.

## 2.1 Cycling in the Netherlands

The German Karl von Drais is said to be the founding father of today's bicycles. His wooden *draisine* was considered revolutionary when he introduced this 'hobbyhorse on wheels' in 1817. Men could now cover longer distances and carry more weight than on foot. Throughout the 19$^{th}$ century, inventors in mainly Great-Britain and France continued to modify Drais' design. For instance pedals as well as bicycle chains were attached. Finally, in 1888 the Scottish veterinarian John Boyd Dunlop invented rubber wheels filled with air, which replaced the wooden wheels and made driving a bicycle much more comfortable ("De geschiedenis van fietsen", n.d.).

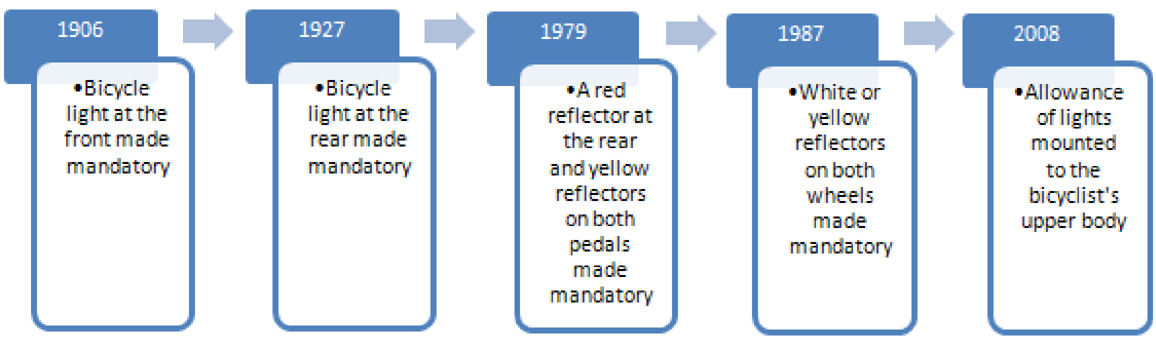
As new actors on Dutch street scenery, bicyclists did not go unnoticed. In fact, pedestrians, farmers, coachmen and many others were strongly opposed to bicyclists. According to them, bicyclists caused horses to go wild, cow milk to dry up and infertility amongst chickens. Bicyclists were turned into *persona non grata*. Consequently, local governments had to respond. In August 1869 the municipality of Gorinchem was one of the first to enact a law that required bicyclists to hold still in the neighborhood of horses. In the same year, the Amsterdam city council demanded bicyclists to carry a lantern during evening hours (Lesisz, 2004, p. 32-36).

To clear up the maze of municipal regulations, the Dutch government passed the *Motor- en rijwielwet* in 1906. This law was dedicated to all motor vehicles and bicycles. The law required that any bicycle should be equipped with a well functioning steering wheel, a bell, at least one brake and a bicycle light at the front. These lamps usually ran on paraffin oil, as electric lights were too expensive after their introduction in 1888. Finally, in 1927 a red light at the rear was made mandatory (Lesisz, 2004, p. 40-41).

**2.2 Current legislation**

The *Motor- en rijwielwet* has long been replaced. Figure 2.1 shows the development of Dutch legislation regarding bicycle lights and visibility. All of the current requirements to bicycle lights are established in the articles 35 and 35a of the *Reglement Verkeersregels en Verkeerstekens 1990* [RVV 1990] (Eurlings, 2008). This is in its turn part of the *Wegenverkeerswet 1994*, which contains the base rules for all road traffic.

**Figure 2.1: Legislative changes in recent history**




*Source: Boxum et al. (2009), Lesisz (2004); SWOV Institute for Road Safety Research [SWOV] (2009)*

Article 35 of the RVV 1990 states that during the dusk and dark[3] or during periods of the day when visibility is low (due to fog, for instance), a bicycle must be equipped with one white or yellow light at the front unless the bicyclist wears such a light on his chest. Similarly, one red light should be mounted on the rear of the bicycle, unless the bicyclist (or his passenger) wears such a light on his back. These

[3] During the dark luminous intensity, or "lichtgesteldheid" in Dutch, is less than 3 lux, while during the dusk this is less than 26 lux by definition (Boxum, Broeks, & Stemerding, 2009). Appendix A shows how luminous intensity changes in the morning and evening.

lights have to burn constantly which means they cannot alternate or flicker. Finally, they must constantly be visible but not dazzle other drivers. If Article 35 is violated, the bicyclist will receive a fine of 35 euro's[4] (*Tekstenbundel voor Misdrijven*, 2010). That is if he gets caught, of course.

**2.3 Law enforcement**

Table 2.1 gives an overview of the number of fines for lack or inappropriate use of bicycle lights in the Netherlands. Between 2002 and 2004 it almost quadrupled, whereas in 2008 the number of fines plummeted. From these figures alone one cannot conclude that more bicyclists used bicycle lights in 2008 and that the opposite happened in 2002-2004. The number of fines closely relates to the intensity of law enforcement, but statistics such as *the number of hours spent on enforcement* are not recorded.

TABLE 2.1

Number of fines for lack or inappropriate use of bicycle lights

| Year | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|
| No. of fines | 45843 | 99995 | 171603 | 178731 | 196059 | 191767 | 120091 | 178958 |

*Source: Dienst Verkeer en Scheepvaart [DVS](2008, p. 98) and T. Zuidema, CJIB, personal communication, April 16, 2010*

A plausible explanation for the 2008 outlier is the police strike in January that year, which continued for weeks ("Stakingen politie gaan door", January 16, 2008; T. Zuidema, Centraal Justitieel Incasso Bureau [CJIB], personal communication, April 16, 2010). This obviously meant a fall in the number of hours of enforcement. Another contributor to the low number of fines may have been the ease in legislation. Although that would not help to explain the rise in the following year, the number of fines in 2009 is still lower than it was in 2007.

In 2002 and 2003 no strikes took place. What did happen was the introduction of a performance contract between the national government and police representatives in February 2003 (Ministry of the Interior and Kingdom Relations, 2003). This was a binding contract for police departments nationwide and included an agreement on a significant rise in written out fines. Consequently, this number grew rapidly in 2003. It is reasonable to assume that police officers particularly targeted bicyclists more than before, which would enable them to fulfill the performance contract.

When progress was evaluated in 2006 it turned out that the actual increase exceeded the desired increase tremendously (Van Zanten, 2006). Moreover, public opinion on this matter had worsened. The need for a national minimum was relaxed and police departments were allowed to make contracts

[4] This does not depend on the number of lights that does not work. Adolescents under 16 pay half the fine.

regionally. According to R. van Heeswijk, Traffic Coordinator of the police region Midden- en West-Brabant, police in the municipality of Tilburg are strictly monitoring the use of bicycle lights in week 50 and week 2 only (personal communication, January 20, 2010). During these two weeks the police set up check points on heavily used bicycle paths and fine everyone that does not use appropriate bicycle lights. Usually, the locations of these check points are announced in local media. Despite these announcements, about 1680 bicyclists were given a fine at these occasions in Tilburg in December 2009 and January 2010. Similar approaches as in Tilburg are used nationally.

**2.4 Actual use of bicycle lights**

As was mentioned in section 2.3, changes in the number of fines alone are not enough to draw conclusions about the use of bicycle lights. To this end we need data on actual usage. Figure 2.2 provides findings from yearly returning research into the use of bicycle lights in the Netherlands, by order of the Dutch Ministry of Transport, Public Works and Water Management [VenW] (Boxum et al., 2009). The most recent study for which results have been published took place in December 2008 and January 2009[5]. Visual measurements were taken at 17 locations during the dusk and dark in both the morning and the evening. Bicyclists were observed and characteristics such as gender, (approximate) age and use of bicycle lights were registered[6]. In total 17027 bicyclists were included in the sample.

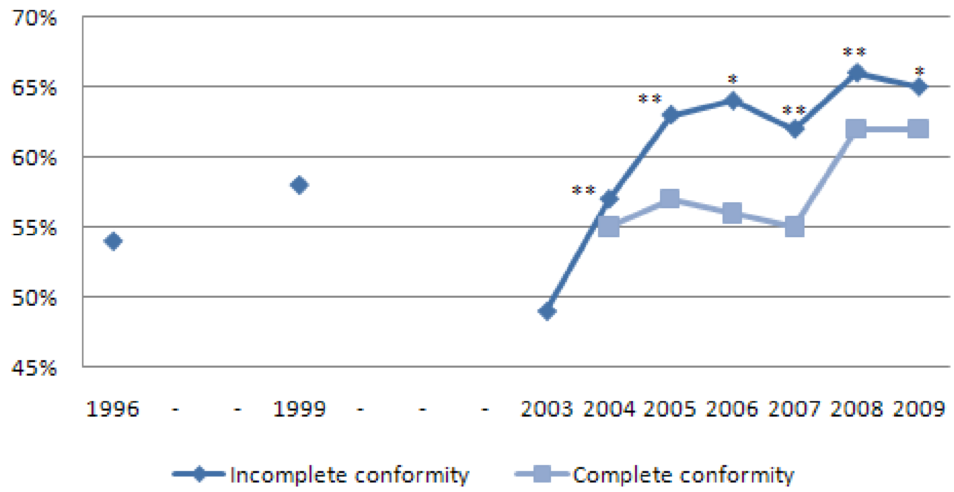
Figure 2.2 shows the share of bicyclists that use lights. The difference between the graphs is that between complete and incomplete conformity with the law. Incomplete conformity means that a bicyclist does have a front and rear light, but at least one of them is flickering (1,4%), not properly mounted (0,4%) or of the wrong color (0,6%) (Boxum et al., 2009, p. 14). The percentages in between brackets make up the gap between complete and incomplete conformity in 2009. As was explained in section 2.2, bicyclists can receive a fine for any of these anomalies.

The most common cause of incomplete conformity in 2009 was flickering lights. This is particularly due to a lack of knowledge about the rules: two thirds of all bicyclists are unaware of the prohibition of flickering lights (Dienst Verkeer en Scheepvaart [DVS][7], 2008, p. 101). Previous studies showed that the

[5] This is referred to as “2009” later on.
[6] The findings for 2003-2009 are based on comparable research plans, except that in 2003 measurements took place in February on 13 locations. Consequently, the sample size of 2782 was smaller than in later years. In 1996 (10 locations) and 1999 (32 locations) only evening measures were held (Goldenbeld & Schaap, 1999) which makes them less comparable.
[7] The Dienst Verkeer en Scheepvaart is part of Rijkswaterstaat, a governmental institution linked to the Ministry of Transport, Public Works and Water Management.

percentage of bicyclists that did not properly mount their bicycle lights was slightly larger than the group that had flickering lights. Before November 2008 it was not allowed to mount bicycle lights to the upper body or for instance a rucksack. As with flickering lights, knowledge about this rule was not common: just half the bicyclists were aware of this prohibition. After the law became less rigid (see Figure 2.1), a sharp decline in the number of bicyclists that did not properly mount their lights occurred automatically.

**Figure 2.2: Actual use of both bicycle lights**




* Significant at the 5%-level; ** Significant at the 1%-level

*Source: Boxum et al., 2008, 2009; Brink, 2005, 2006; S. van Halderen, DVS, personal communication, April 1, 2010*

Since the gap between complete and incomplete conformity is closing over time and exists mainly due to lack of knowledge, the focus will be on incomplete conformity. Examination of this graph shows a significant increase between February 2003 and January 2005[8]. Hereafter it seems to stabilize around 64 percent, despite significant alternating movements between years.

Simultaneous with these measurements, national and regional information campaigns were being held. National campaigning focused on an increase in the use of bicycle lights conform the law. It relied mainly on radio- and TV-commercials. Regional campaigning comprises many different initiatives like discount on repairs and a bicycle check by police officers. Box 1 illustrates a regional initiative in Parkstad Limburg. According to the DVS (2008) the combination of law enforcement and both types of campaigning is the most prominent reason to explain the rise in bicycle light usage. Unfortunately, the DVS does not put

[8] A z-test for proportions was used to test the difference between two point estimates within the incomplete conformity group. The difference between 1996 and 1999 as well as that between 1999 and 2003 was not tested, because the data come from less comparable research plans, see previous footnote.

forth other suggestions and it remains unclear which was most effective: law enforcement, national campaigning or regional campaigning.

**BOX 1 Regional action: the Parkstad approach.**

In imitation of a successful trial in 2004-2005, the conglomerate *Parkstad Limburg* started a campaign to promote the use of bicycle lights among students in secondary education in 2005-2006. Its main effort was the distribution of Light Emitting Diodes [LEDs] to all 12850 students in Parkstad. Their initiative received a great deal of (national) media attention.

After the festive kickoff of the campaign, schools began to hand out LEDs to all students. Just two days later police started monitoring at the school gates. Offending students immediately received a fine and their parents were informed by mail. 564 Fines were written, using up 256 man-hours. Schools were under surveillance 4,3 times on average, always before the beginning of class. Afterwards, the use of bicycle lights among students had risen from 60 percent to 77 percent on average. The maximum was found at 84 percent. Whether this was due to the fear of punishment or a change in attitude towards the use of bicycle lights was not investigated. However, rigorous police action was said to be very important in stimulating bicycle light usage: those schools that were better monitored showed greater improvement.

Because of the increase in the use of bicycle lights the campaign was marked successful by Parkstad Limburg. From a cost-benefit perspective this conclusion is supported. The purchase of the LEDs was sponsored by a private party while revenues from fines cancelled out police expenses. Promotional costs were about 23000 Euro, so less than 2 Euro per student. Parkstad Limburg therefore continued to hand-out LEDs to first graders in consecutive years.

*Source: Gemeentes Parkstad Limburg, 2005*

An alternative explanation for the rise between 2003 and 2005 may be that the share in 2003 was particularly low. Visual measurements were conducted in February, while they were held in December and January in the years after 2003. Keep in mind that especially in these two months the police are setting up (publicly announced) check points and consequently, most fines are given then. Therefore, the subjective probability to get caught is likely to increase and reduce the number of offending bicyclists in December and January. The comparison between 2003 and 2005 is not ceteris paribus.

This section concludes with a short summary of other findings from Boxum et al. (2009). These show for instance a positive relation between age and bicycle light usage. Amongst teenagers (< 18 years) 52 percent used bicycle lights in 2009, whereas 78 percent of all bicyclists over 50 years of age complied. Notice that this is 50 percent more. Age groups that are in between comply more than teenagers but less than those who are over 50. For all groups it goes that compliance has increased since 2003. Finally, it has been shown that women use bicycle lights significantly more often than men do, compliance is larger in the morning than the evening and larger during the dark than the dusk.

### 2.5 Effect of bicycle lights on traffic safety

96 Percent of the general public believes that cycling without appropriate lighting is dangerous. This figure is much lower for adolescents: 82 percent (DVS, 2008, p. 102).

Until recently little was known about the differences in effectiveness between certain types of bicycle lights. In response to social rumors[9], Minister Eurlings of VenW ordered an investigation into the effectiveness of LEDs versus conventional lights, flickering versus constant burning lights and alternative mountings in 2007. TNO, a prominent Dutch research center in applied sciences, was given this task. Toet, Beintema, De Vries, Van der Leden & Alferdinck (2008) concluded in their report that:

- constant burning lights are preferred to flickering lights
- lights mounted to the bicyclists' upper body do not reduce visual conspicuity as long as they remain visible
- there is no literature available that studies the direct effects of bicycle lights on traffic safety

The RVV 1990 was accommodated to the first and second conclusion. More important for the present thesis is however, that although bicycle lights enhance visual conspicuity, no literature that studies the direct relation between bicycle lights and traffic safety is available.

Such a study had been done in 1979 when red reflectors were made mandatory (see Figure 2.1). The conclusion was that the use of a reflector decreased the probability of having an accident by four percent. It is reasonable to assume that active lighting has a greater effect than passive lighting[10], especially in case of unilateral accidents. The SWOV has assumed that this effect is twice as large. Their

[9] The 2006-2007 national campaign '*Val op. Daar kun je mee thuiskomen'* promoted the use of LEDs while it did not mention its legal limitations. Therefore bicyclists felt indignant after receiving a fine for any of the anomalies discussed in section 2.4.
[10] A red reflector is an example of passive lighting, whereas a red rear light is active lighting.

estimate of the effect of (active) bicycle lights is therefore a reduction of the probability of having an accident by eight percent (C. Schoon, SWOV, personal communication, April 7, 2010). The DVS applied this estimate to the actual data on bicycle light usage. It found that about two to three deaths and 30 hospitalizations were prevented as a result of the increase in bicycle light usage between 2003 and 2007 (DVS, 2008, p. 107).

About one fifth of all accidents involving bicyclists take place during either dusk or dark. Table 2.2 shows the number of hospitalized and deceased bicyclists during the dusk and dark. Hospitalization means that a bicyclist who got involved in an accident was in-patient for at least 24 hours. Registered deaths and hospitalizations are based on police registrations. However, the police are not warned in all cases. And if they are, they do not always completely fill out registration forms[11]. The registration rate is therefore smaller than one. To fill the blanks, the SWOV (n.d.) estimates this registration rate by comparing four other databases (including National Medical Registration). They find that bicycle accidents are the least registered compared to other modes of transport. In general, accidents involving motor vehicles are better registered than accidents involving non-motor vehicles. The same can be said about fatal and non-fatal accidents.

The estimate of the true number of deceased and hospitalized bicyclists[12] during the dusk and dark (see Table 2.2) is calculated under the assumption that the registration rate is the same throughout the day. These numbers show heavy fluctuations; taking the three-year moving averages smoothes the data. For deceased bicyclists it shows a downward sloping trend, whereas for hospitalizations it shows an upward sloping trend. Both are approximately linear.

To test whether the trend is significant equation ⟨1⟩ is estimated with ordinary least squares [OLS], where $y_t$ is the estimated true number of deceased (or hospitalized) bicyclists and $t$ is the corresponding year. Results are presented in Table 2.4, columns (1)-(2). For both cases the trend line turns out not to be significant.

$$\langle 1 \rangle\ \mathrm{y_t} = \alpha_0 + \alpha_1 \mathrm{t} + \mathrm{e_t}, \qquad \mathrm{t} = 1996, 1997, \dots$$

[11] The number of hospitalized and deceased bicyclists that used light is not reported due to incomplete registration as well: this is only known in about five percent of the cases and this is not informative (own calculations based on the SWOV Database – Accidents).

[12] The reason behind the decision to report only accidents that led to hospitalization or even death of the bicyclist is that the data contain fewer unilateral accidents.

TABLE 2.2

Number of hospitalized and deceased bicyclists during the dusk and dark[a]

| | Year | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| Registered deaths | 47 | 65 | 37 | 50 | 43 | 37 | 48 | 43 | 37 | 40 | 31 | 38 | 39 | 28 |
| Registration rate (%) | 97 | 91 | 92 | 85 | 85 | 86 | 86 | 85 | 87 | 83 | 83 | 78 | 80 | 75 |
| Estimated true value | 48 | 71 | 40 | 59 | 51 | 43 | 56 | 51 | 43 | 48 | 37 | 49 | 49 | 37 |
| 3-Year moving average | | 53 | 57 | 50 | 51 | 50 | 50 | 50 | 47 | 43 | 45 | 45 | 45 | |
| | | | | | | | | | | | | | | |
| Registered hospitalizations | 513 | 505 | 499 | 562 | 509 | 482 | 447 | 477 | 444 | 448 | 454 | 498 | 507 | 378 |
| Registration rate (%) | 36 | 34 | 34 | 33 | 33 | 31 | 31 | 30 | 26 | 29 | 30 | 30 | n.a. | n.a. |
| Estimated true value | 1425 | 1485 | 1468 | 1703 | 1542 | 1555 | 1442 | 1590 | 1708 | 1545 | 1513 | 1660 | n.a. | n.a. |
| 3-Year moving average | | 1459 | 1552 | 1571 | 1600 | 1513 | 1529 | 1580 | 1614 | 1589 | 1573 | n.a. | n.a. | |

a: The numbers include both drivers and passengers and are irrespective of the difference between victim and inflictor.

*Source: SWOV Database - Accidents & Mode of transport*

TABLE 2.3

Number of hospitalized and deceased bicyclists per billion seat kilometers [a]

| | Year | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
| Estimated bsk | 1,218 | 1,320 | 1,279 | 1,449 | 1,395 | 1,393 | 1,331 | 1,497 | 1,531 | 1,619 | 1,603 | 1,617 | 1,579 |
| Deceased (per bsk) | 40 | 54 | 31 | 41 | 36 | 31 | 42 | 34 | 28 | 30 | 23 | 30 | 31 |
| Hospitalized (per bsk) | 1170 | 1125 | 1148 | 1176 | 1105 | 1116 | 1084 | 1062 | 1116 | 954 | 944 | 1027 | n.a. |

a: It concerns the estimated true values from Table 2.2.

*Source: SWOV Database - National Travel Survey [NTS](executed by: Central Bureau of Statistics)*

It may be that more people get involved in an accident because more people ride their bicycle and/or cover greater distances. Table 2.3 shows estimates for the number of seat kilometers during the dusk and dark[13]. These too increase over time and therefore directly affect trending in the number of accidents: once we look at either the number of deceased or hospitalized bicyclists, we see a downward sloping trend. A new estimation of equation ⟨1⟩, where $y_t$ is now the estimated true number of deceased (or hospitalized) bicyclists per billion seat kilometer[14] [BSK], confirms this pattern. Both coefficients are negative and statistically significant (see columns (3)-(4) in Table 2.4). Although based on rough estimates, this is an indication that traffic during dusk and dark has become safer for bicyclists over the last decade.

TABLE 2.4
Results of trend analyses

| | (1)[a] | (2) | (3) | (4) |
|---|---|---|---|---|
| Time $\alpha_1$ | -1,069 | 12 | -1,385* | -17,556** |
| | (-0,547)[b] | (7,531) | (0,455) | (3,764) |
| Intercept $\alpha_0$ | 55,7** | 1487** | 43** | 1182,1** |
| | (4,2) | (48,9) | (3,2) | (24,4) |
| Adjusted $R^2$ | 0,178 | 0,123 | 0,408 | 0,654 |
| n | 14 | 12 | 13 | 12 |

a: Dependent variables: (1) estimated true number of deceased bicyclists
(2) estimated true number of hospitalized bicyclists
(3) estimated true number of deceased bicyclists per bsk
(4) estimated true number of hospitalized bicyclists per bsk
b: standard errors in parentheses
* Significant at the 5%-level; ** Significant at the 1%-level; based on two-sided tests

Did bicycle lights contribute to these improved conditions? To analyze the effect of bicycle lights on traffic safety we turn to the estimation of equation ⟨2⟩. Here, the dependent variable *dec_hos_bsk* is the number of accidents per month from January 1996 to December 2008[15] in between sunset and midnight, divided by BSK. No distinction between deceased and hospitalized bicyclists is made, as the former contains little variation on a monthly basis. Midnight is taken as a cutoff point because the number of accidents per BSK is almost constant between 5.00 p.m. and midnight, whereas it triples during the night[16]. A possible weakness of this model is that there may be unobserved variables that shift by the hour, like human behavior and traffic composition. But, since these unobservable variables do not

[13] Appendix B gives more details about the realization of this estimate.
[14] In Dutch "seat kilometer" means "reizigerskilometer".
[15] The registration rate for hospitalizations in 2008 was estimated at 30 percent.
[16] See Appendix C for the exact course of the number of accidents per BSK throughout the day.

appear to affect the number of accidents per BSK, the choice for the current independent variable is valid.

$$\langle 2 \rangle \text{ dec\_hos\_bsk} = \beta_0 + \beta_1 * \text{bsk\_c\_ph} + \beta_2 * \text{share75} + \beta_3 * \text{work\_days} + \beta_4 * \text{red\_light\_ph} + \beta_5 * \text{bicycle\_lights} + u$$

Each independent variable is now briefly discussed:

bsk_c_ph: 58 Percent of all bicycle accidents concern collusion with a car (SWOV, 2009). Therefore, the number of kilometers driven by cars may influence the number of accidents. Because some months contain more hours in between sunset and midnight than others, the average per hour was used[17]. The coefficient should be interpreted as a ceteris paribus effect due to an increase of one BSK for cars. *Source: SWOV Database – NTS.*

share75: Bicyclists aged 75 or more are by far the most vulnerable group in traffic (SWOV, 2009). Per BSK they are about three times more often involved in an accident than younger bicyclists. This variable is the share that this age group has within bicyclists' total BSK. The data are positively skewed and it may have been better to use the natural logarithm instead. However, since that would imply elimination of certain data points it is left unchanged. The coefficient should be interpreted as a ceteris paribus effect due to an increase of one percentage point of this variable. *Source: SWOV Database – NTS*.

work_days: More accidents happen on work days than on weekend days (Van Kampen, 2008, p.32). The variable represents the number of work days per month. The coefficient should be interpreted as a ceteris paribus effect due to an additional work day per month. *Source: www.kalender-365.nl*.

red_light_ph: About 62 percent of all bicycle accidents takes place at a crossing (SWOV, 2009). This variable represents the average number of fines for driving through a red traffic light. It is an indication for traffic safety on crossings. The coefficient should be interpreted as a ceteris paribus effect due to an increase in the number of fines for crossing a red light. *Source: T. Zuidema, CJIB, personal communication, May 7, 2010*[18] *and SWOV Database – Traffic offenses*.

[17] Notice that this computation is not required for the dependent variable, as it is divided by BSK.
[18] The data were only available for 2004-2009. Combining monthly and hourly averages with the yearly figures available in the SWOV Database – Traffic Offenses, resulted in estimates for 1996-2003. A similar procedure was used for the estimation of equation ⟨3⟩, which is presented later.

bicycle_lights: Taken from Figure 2.2 are the estimates of bicycle light usage. Although measurements were done during the winter only, in the current analysis it is assumed that these findings are constant throughout the year. This is a strong assumption as subjective probabilities to get caught may vary. The coefficient should be interpreted as a ceteris paribus effect due to an increase of one percentage point of this variable. *Source: see Figure 2.2*.

The coefficient of interest is $\beta_5$. Its estimate can be used to test the null hypothesis: "Bicycle lights do not influence traffic safety, measured as the number of accidents" against its two-sided alternative: "Bicycle lights do influence traffic safety". Although the discussion so far only treated the positive effect of bicycle lights (visibility leads to fewer accidents), it may be that bicyclists without lights compensate for increased risks. Possibly, they pay more attention in traffic while bicyclists that do use lights become careless as they think they are spotted anyway. Therefore we need a two-sided test. Results are presented in Table 2.5.

The results for equation ⟨2⟩ show that bicycle lights indeed negatively affect the number of accidents: $\hat{\beta}_5 = -13{,}36$ and statistically significant at the 1%-level. A little more than thirteen accidents per BSK can be prevented if the use of bicycle lights would increase by one percentage point. This translates to about 21 accidents per year. This figure is probably larger than the estimate by the DVS, which was discussed at the beginning of this section, although they are hard to compare. A possible explanation for this difference is that the DVS base themselves on registered deaths and hospitalizations, neglecting the registration rate, but this does not become clear from their report. Alternatively, the present estimate may be too high, as we will see shortly.

For reasons such as a lower probability of being caught, the data on bicycle light usage may be overestimated outside the winter period. Therefore, several other regressions containing adjustments to this variable were run. These are useful in telling how robust the findings in Table 2.5 are against changes in *bicycle_lights*.

The first variant was a fixed decline in *bicycle_lights* depending on how far the concerned month was away from December and January. This meant a minimum in June and July. The second was a linear decline until October, followed by a linear rise towards the actual level in December. The final variant was a dramatic drop from January to February followed by a linear decline until June; hereafter it remained constant until October. The overall picture was that the coefficient rose; the magnitude depended on the forcefulness of the adjustment. Significance levels dropped but not more than the 5%-

level. This is now illustrated with a numerical example of the third variant. The following adjustments to *bicycle_lights* were made [month= decline in percentage points]: January= base level, F= -10, M= -12, A= -14, M= -16, J= -18, J= -18, A= -18, S= -18, O= -18, N= -9, D= 0. Regression results were: $\hat{\beta}_5$ = -7,30 with p-value = 0,0407, which implies a reduction of about eleven to twelve accidents per year. So despite declines of up to eighteen percentage points, the coefficient of *bicycle_lights* remained negative and statistically significant. Furthermore, neither exclusion of the outlier 2003 nor the inclusion of a monthly dummy affected any of the results. These findings contribute to the overall robustness of the model. However, they also indicate that the true reduction of the yearly number of accidents, due to a one percentage point increase in *bicycle_lights*, is likely to be smaller than 21.

TABLE 2.5

OLS regression results of number of accidents per BSK

| | Equation 2 | | Equation 3 | |
|---|---|---|---|---|
| | Coefficient | Standard error[a] | Coefficient | Standard error[a] |
| constant | 2.040,61 ** | 525,25 | 831,96 | 581,36 |
| bsk_c_ph | 476,74 | 460,81 | -406,04 | 410,22 |
| share75 | 33,16 | 23,30 | -26,56 * | 10,43 |
| work_days | -8,69 | 22,86 | 0,06 | 0,15 |
| red_light_ph | -0,46 * | 0,19 | 14,96 | 28,75 |
| bicycle_lights | -13,36 ** | 4,99 | - | - |
| daylight | - | - | -229,54 ** | 77,57 |
| Adjusted $R^2$ | 0,11 | | 0,09 | |
| N | 96 | | 156 | |

a: White heteroskedasticity-consistent standard errors.

* Significant at the 5%-level; ** Significant at the 1%-level; based on two-sided tests

Another significant coefficient in equation ⟨2⟩ is $\hat{\beta}_4$, which measures the effect of the number of fines for crossing a red light on *dec_hos_bsk*. Surprisingly, it is negative which implies that an increase in the number of fines for crossing a red light causes a decrease in the number of accidents. It makes intuitive sense that a crossing where everyone politely waits for a red traffic light is safer than a crossing where no-one waits for their turn. A possible explanation for this finding is that bicyclists are more alert when they are aware of their fellow road users' ignorant behavior. They think and look twice before crossing, rather than to rely solely on green traffic lights.

The conclusion so far is that bicycle lights presumably contribute to traffic safety. Earlier discussed is the report by TNO which concluded that bicycle lights increase visual conspicuity and not traffic safety per se. To find out whether visibility affects traffic safety, measured as the number of accidents, the following equation ⟨3⟩ was estimated with OLS:

$$\langle 3 \rangle\ \text{dec\_hos\_bsk} = \beta_0 + \beta_1 * \text{bsk\_c} + \beta_2 * \text{share75} + \beta_3 * \text{work\_days} + \beta_4 * \text{red\_light} + \beta_5 * \text{daylight} + \text{u}$$

Conversely to the previous model, the data that are used to estimate equation ⟨3⟩ comprise just one hour namely 19.00-20.00h. This particular hour has one interesting feature: in some months luminous intensity is lower than 25 lux while in other months it exceeds 25 lux[19]. Or in other words: it is either light or dark between 19.00-20.00h, depending on the time of year. Moreover, the choice for using only one hour implies automatic control for many unobserved variables like traffic composition. A downside is that fewer data is available which increases the variance.

The dependent as well as the independent variables are almost the same as in the previous model, except for inclusion of *daylight* and the exclusion of *bicycle_lights*. *Daylight* is a dummy variable for luminous intensity: d=0 means darkness whereas d=1 means daylight. The exclusion of *bicycle_lights* is important as it makes *daylight* an endogenous explanatory variable. Two requirements are needed for an omitted variable to cause a biased estimate. The omitted variable "*z*" must be 1) a determinant of the independent variable "*y*" and 2) correlate with the included explanatory variable "*x*" (i.e. Corr(z,x)≠0) (Stock & Watson, 2007, p. 187). For instance, separate bicycle paths may well enhance traffic safety but the exclusion of such a variable does not lead to a biased estimate as it is unlikely to correlate with *bicycle_lights*. As we have seen before, *bicycle_lights* is a determinant of *dec_hos_bsk* and obviously it (negatively) correlates with *daylight*. When the coefficient of an omitted variable is negative and the correlation between the included and omitted variable is negative as well, the bias in the coefficient of the included variable is positive (Wooldridge, 2006, p. 91). Therefore extra care should be taken when using *daylight* to test the null hypothesis: "Luminous intensity has no effect on traffic safety, measured as the number of accidents" against its two-sided alternative: "Luminous intensity does influence traffic safety".

The results are shown in Table 2.5. In contrast to equation ⟨2⟩ and according to expectations, the coefficient of *share75* is now negative and statistically significant at the 5%-level. More important is that the coefficient of *daylight* is negative and statistically significant at the 1%-level. Deletion of July and August [20] changed this result but it remained statistically significant at the 5%-level

[19] Recall that when luminous intensity is below 25 lux it is officially dark and mandatory to use bicycle lights.
[20] Summer holidays alter unobserved variables such as traffic composition.

($\hat{\beta}_5$=-174.86, p-value=0.033). Given its positive bias and statistical significance, these results show that an increase in luminous intensity decreases the number of accidents. Or in other words: visibility is good for traffic safety. The magnitude of the coefficient is not very helpful. Swapping the dummy, so that d=1 means *darkness*, obviously swaps the sign of the coefficient and the bias. Interpretation then is as follows: despite precautions such as bicycle lights and risk compensation, the decline in visual conspicuity causes more accidents. In the absence of these precautions even more bicyclists would get hurt or killed in these accidents.

**2.6 Conclusion**

In this chapter we have seen that cycling has a long tradition in The Netherlands. Legislators adapted their policy to developments in traffic composition and technical possibilities, in order to secure traffic safety. Recent campaigning efforts seem to pay off as the use of bicycle lights has increased to about 65 percent of the population. The government does this for a reason: bicycle lights are useful in preventing accidents with severe consequences such as hospitalization or even death. Regression analyses showed that if the use of bicycle light would increase by one percentage point, the number of severe accidents would decline with (at most) 21 each year. The growing number of bicyclists that uses light has obviously contributed to the downward sloping trend in the number of accidents per billion seat kilometers. Whether the benefits of promoting the use of bicycle lights outweigh its costs remains to be seen. Relevant questions such as: “How much does one day in hospital cost” and: “How many days do bicyclists stay in-patient?” were not investigated. However, the ‘Parkstad approach’, which combines education with enforcement (see BOX 1), suggests that with relative low costs the use of bicycle lights can increase significantly. To come to a comprehensive and grounded policy advice we must know how bicyclists would react to such new policies. The following chapter gives a theoretical answer to that question.

# Chapter 3

*Theory: why not everyone uses bicycle lights*

The previous chapter concluded that bicycle lights enhance traffic safety as they cause a reduction in the number of accidents that happen. Still, one third of all bicyclists do not use them. So the question is: to what incentives do bicyclists respond to when they decide to use bicycle lights or not? In this chapter three possibilities will be given. The first stems from the deterrence hypothesis which says that when a penalty is introduced, the occurrence of the behavior that is subject to this penalty will decline. This is a form of extrinsic motivation. But instead of avoiding the fine, a bicyclist may well use bicycle lights because he thinks it is what he ought to do. Moral norms that are intrinsic to bicyclists are therefore treated second. The theory of planned behavior is presented as an alternative to the intrinsic versus extrinsic motivational approach. Bottom line of this theory is that the intention to perform the behavior has a direct and causal effect on actual performance of that behavior. A justification for governmental interference in the individual decision to use bicycle lights is what this chapter will begin with.

## 3.1 Negative externalities and government intervention

Traffic accidents cause all kinds of problems. Imagine a case where an unlit bicyclist causes collusion with a car, hits the windshield, breaks an arm and suffers from concussion. What happens next? The emergency services show up. The police make their report, an ambulance brings the injured bicyclist to a hospital, the damaged car is towed away and a taxi brings the motorist home. Who has to pay the bill?

Of course this depends on the situation but generally speaking bicyclists are legally protected because of their vulnerability in traffic. Examination of verdicts by the Supreme Court shows that motorists[21] are for 100 percent liable for the damage done to bicyclists younger than fourteen years of age and at least 50 percent liable when the bicyclist is older than fourteen (Spier, Hartlief, Van Maanen, Vriesendorp, 2006, p. 151-164). The remaining 50 percent is up for debate: who is to blame for the accident? In the Netherlands it is mandatory to have liability insurance and often the insurers agree to a settlement over

[21] Legislation distinguishes between ‘owner’ and ‘driver’ of the motor vehicle, where the ‘owner’ is made primarily responsible. For simplicity this distinction is not made here.

the costs. When they do go to court it turns out to be very hard to prove that the bicyclist in question drove recklessly and no blame can be put upon the motorist. Furthermore, when the damage is done to the motorist rather than the bicyclist, each case is individually examined. Like before it turns out to be very hard to prove that the bicyclist drove unlawfully and that the motorist is not to be blamed. From this one can conclude that the motorist is very often held liable for the damage. He is likely to lose his deductible and obliged to pay a higher insurance premium in the future.

Given that this accident could have been prevented if the bicycle was lit, the bicyclist's irresponsible behavior imposes costs to society. Not only is the motorist held liable for a large share of the (medical) costs for the bicyclist, tax money is needed to pay for police and medical personnel. Internalization of these costs by bicyclists is not self-evident and the externality described above therefore calls for government intervention. The legal requirement to use bicycle lights seems to shield society from inviolable bicyclists.

### 3.2 The deterrence hypothesis

The deterrence hypothesis originates from the economic theory of crime and punishment. The goal of punishment is to deter intentional crime. Gneezy and Rustichini (2000) define the deterrence hypothesis as follows: "(…) the introduction of a penalty that leaves everything else unchanged will reduce the occurrence of the behavior subject to the fine". Under the assumption that criminals act rational, deterrence will work if the expected net benefit to the criminal becomes negative. Therefore, both the severity and certainty of punishment should be taken into account. A trade-off between these two has to be made by policy makers. Because of the costs of enforcement it may be argued that the probability to catch a criminal (certainty) should be as low as possible and the magnitude of the fine (severity) be set equal to the criminal's wealth. Polinsky and Shavel (1979) show that this is optimal in case of risk neutrality. However, since such a fine is likely to exceed the external costs imposed on society, it may be thought of as unfair. Furthermore, catching only a small fraction of criminals may be seen as arbitrary. A rigorous system such as that is therefore unlikely to receive broad public support[22]. Moreover, Polinsky and Shavel (1979) show that it is not necessary either when criminals are risk averse. They propose that when criminals are risk averse and the costs of catching them are low, the optimal probability should equal one and the fine should equal the private gain of the criminal. The choice between severity and certainty is thus influenced by the costs of enforcement.

[22] Note that if there is a limit to how much an individual can be fined there must also be a threshold probability below which deterrence is impossible.

Another option is to let this trade-off depend on the criminal's discount rate. If we drop the perfect rationality assumption and instead assume bounded rationality, we allow the criminal's discount rate to fluctuate. A higher discount rate diminishes the present value of future punishment. For instance, impulsive behavior may lead to regret in the future. Insofar impulsivity (associated with unreasonable high discount rates) causes crime, severity is ineffective as a means for deterrence. Certainty may well work much better. When crime is deliberate however, emphasis should be on severity (Cooter & Ulen, 2008).

Does the literature confirm the deterrence hypothesis? Lee and McCrary (2005) measure the effect of incarceration length on criminal behavior. They find that juveniles in the US who turn 18, which means they are now legally treated as adults and face longer incarceration, do not change their behavior and are undeterred by severity. Other research suggests that especially young people are prone to use unreasonable high discount rates (Cooter & Ulen, 2008, p. 505). In line with these findings, Lee and McCrary (2005) argue that offenders have hyperbolic time preferences. Hyperbolic discounting (or time-inconsistent preferences) is characterized by declining discount rates over a certain time span. When this is such a common feature, the marginal deterrence effect of one dollar spent on catching a criminal is likely to be larger than the effect of spending it on longer incarceration.

There are many other studies that found a significant deterrence effect. As cited in Cooter and Ulen (2008, pp. 529-530) these are amongst others Ehrlich (1973), who found that a higher probability of conviction for robbery decreased the robbery rate in the US in 1940, 1950 and 1960; Blumstein and Nagel (1977), who found that a higher probability of conviction and a higher penalty lead to less draft evasion in the US in the 1960s and 1970s; and Wolpin (1978), who found that the crime rate in the UK negatively depended on the probability and severity of punishment over the period 1894-1967.

Gneezy and Rustichini (2000) on the other hand, argue that the deterrence hypothesis had lost its predictive power in their experiment among Israeli day-care facilities[23]. The experimenters introduced a fine for late coming parents. Surprisingly, they found that the introduction of the fine caused an increase in the number of parents that arrived late. Moreover, this behavior did not disappear after the abandonment of the fine. Gneezy and Rustichini's explanation for the failure of the deterrence hypothesis is that the introduction of the penalty did not leave everything else unchanged. They argue that the parents' perception regarding the strategic situation they were facing was modified by the fine.

[23] Possibly, the reader finds it inappropriate to label late-coming parents (and later on bicyclists) as criminals. Even though this may be true, the economic theory of crime is still applicable.

This may have been due to the acquisition of new information (i.e. they learned that the fine is the worst that can happen to them when they arrive late) or a more severe change in social norms. Rather than viewing the fine as punishment for a late pick-up, parents now perceive it as a price for some additional time to themselves. Arguably however, the experimenters introduced the 'wrong' fine. So far we have seen that when the costs of catching an offender are low, the fine should equal the private gain to the offender. A high degree of certainty should also correspond to a low level of severity, especially when the offender behaved impulsively. Whereas an incidental late pick-up can be seen as impulsive, a series of late pick-ups by parents is likely to be deliberate. Moreover, frequent late pick-ups indicate that the private gains to the parents are much larger than the fine. In that case a larger fine is not only justified to accomplish deterrence, it is a necessity.

Alternative to the neoclassical approach, crime is said to result from a set of socioeconomic factors or possibly even biological factors. In the US during the 1990s, property crimes dropped by 30 percent and the number of homicides declined by 40 percent. Rather than attributing this remarkable downturn to the deterrence effect of punishment, the decline in crack cocaine consumption, the economic boom of the nineties, victim precautions or innovative policing strategies, Donohue and Levitt (2001) offer the legalization of abortion in 1973 as an explanation. The number of abortions rose rapidly hereafter which caused a decline in cohort-size. Therefore fewer 18-year-old males who are vulnerable to start a criminal career were present in the 1990s. Equally important, according to Donohue and Levitt (2001), is the fact that most women who have an abortion (e.g. teenagers, unmarried and/or economically disadvantaged mothers), are most likely to give birth to a child who would engage in criminal activity. Conclusion: fewer potential criminals were born in the 1970s and this lead to a downfall in crime in the 1990s.

The decision to use bicycle lights or not is of primary interest in this thesis. If we assume that bicyclists are rational, selfish and well-informed, they will constitute a cost-benefit analysis before making this decision. Costs such as the purchase of LEDs and batteries, maintenance to the bike and increasing effort to spin the pedals around are being weighted against benefits such as a smaller probability of dying in an accident and avoidance of the fine. The costs that result from an accident and imposed on society may also be internalized as benefits by the bicyclist. This of course depends on the specification of each utility function, but a rational and selfish individual will neglect this. By making bicycle lights mandatory and violation punishable by law, the government tries to deter such undesirable behavior. In this section we have seen that there is evidence that the deterrence approach worked in some, but not all, other cases. The study by Gneezy and Rustichini (2000) showed that we should not eliminate the possibility that an individual's perception of the situation he acts in may change as a consequence of the presence of a fine. The next section on intrinsic and extrinsic motivation deals with changes in perception in greater detail.

### 3.3 Intrinsic and extrinsic motivation

Intrinsic motivation is a desire within an individual to perform well for its own sake. Rewards are inherent in the activity. It originates from the organic needs to be competent and self-determining (Deci & Ryan, 1985). An example of intrinsically motivated behavior is the amateur athlete who trains for a triathlon. With no chance of winning, the foresight of completing the event is what intrinsically motivates her. In contrast, rewards are extrinsic motivators when they are imposed upon the individual. A fine for driving without bicycle lights is a clear example of extrinsic motivation.

Extrinsic motivation may undermine intrinsic motivation. This is due to a change in the perceived locus of causality, a construct suggested by Heider in 1958. The locus of causality reflects the perception of an individual about its motivational dynamics: what drives the individual to do what he does? This can either be for internal or external rewards. Deci and Ryan (1985) suggest that intrinsic motivation is unlikely to function when the activity is externally controlled or reinforced. An activity may become a means to an end, rather than an end in itself.

Bénabou and Tirole (2003) show that rewards are weak positive stimuli in the short run and negative stimuli in the long run. The tension between the short- and long run exists because the reward is required and expected every time the activity has to be performed again. Frey and Oberholzer-Gee (1997) model and test the effect of a monetary reward on the willingness to accept a NIMBY[24] project in the neighborhood. They find that in Swiss cantons the willingness to accept a nuclear waste repository declines when the local population is offered monetary compensation. Accepting such a facility is part of one's intrinsic sense of civic duty. Frey and Oberholzer-Gee argue that in general, when intrinsic motivation can empirically be shown to be important, the use of economic incentives should be reconsidered. In cases where intrinsic motivation is already undermined, economic incentives should prevail.

Motivation to comply with norms can be either intrinsic or extrinsic. The intention with which an individual complies with the norm determines this difference (J. Graafland, Tilburg University, personal

[24] NIMBY is an abbreviation for "not in my backyard". It refers to facilities that receive widespread support but put a heavy burden on the local community. Think of prisons and garbage dumps.

communication, July 9, 2010). Although there is still a debate in the philosophical and psychological literature about what sorts of norms exist (Dubreuil and Grégoire, 2010), the assumption here is that moral norms can be identified. Moral norms are on what is right and what is wrong. Elster (as cited in Dubreuil and Grégoire, 2010) believes that the content of the norm does not determine its typology. Instead, the emotional mechanisms underlying compliance with the norm make it either a social, moral or quasi-moral norm. The emotion sustaining a moral norm is guilt. It leads people to prevent harm doing and to apologize, for instance. The intention to comply with a moral norm arises internally and independently from other individuals or institutions. Moral norms are therefore intrinsically supported.

Suppose that road-users believe they have a positive right[25] to safely move about in traffic. This requires them to enable others to freely pursue this right as well by driving safely too. So far we have seen that the majority of bicyclists believe that bicycle lights enhance traffic safety. If bicyclists indeed perceive it as their duty to promote traffic safety for other road-users, they will use bicycle lights even in the absence of regulation and penalties. Their decision is based on a sense of duty. According to Kant this is based on a good will which makes the action morally right (Graafland, 2007). When a regulator steps in because it wants to gain control over the action, the perceived locus of causality may shift from internal to external. The intrinsic motivation to do what is morally right may then be lost.

### 3.4 The theory of planned behavior

Rather than looking at intrinsic and extrinsic motivation to perform a certain action, this section deals with an alternative approach from social psychology. The theory of planned behavior has been proposed by Ajzen and stems from the theory of reasoned action which was developed by Fishbein and Ajzen (Ajzen, 1985).

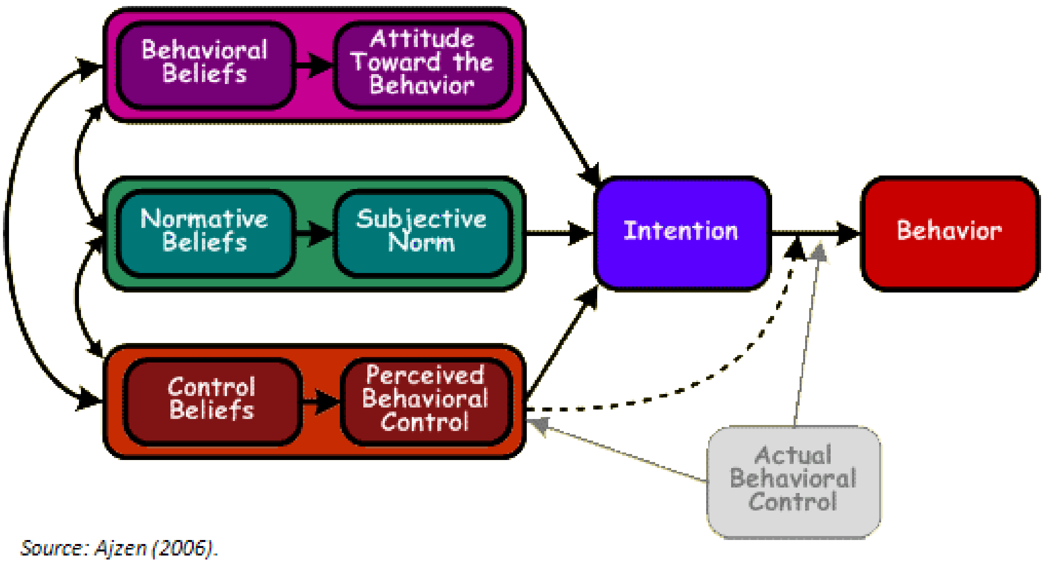
The goal of the theory of reasoned action is to explain and predict behavior that is under complete volitional control, which means that no internal or external factors hamper performance of the behavior. A person's intention to perform (or not to perform) a certain behavior is the causal determinant of the actual performance of the behavior. Intentions can change over time and depend on both the individual's attitude towards the behavior and on subjective norms, which stem from the individual's perception of social pressure to perform the behavior. In general, people intend to perform a behavior

[25] A positive right imposes a duty on others to enable the holder of the right to freely pursue his interests, whereas a negative right requires others not to interfere in activities employed by the holder of the right (Graafland, 2007, p.182).

when they have a positive attitude towards it and when they believe that others think they should perform the behavior.

Underneath these two determinants of intentions are behavioral and normative beliefs. When an individual beliefs that a given behavior will yield positive outcomes for him, the attitude towards the behavior will be favorable. Normative beliefs affect the subjective norm. If an individual beliefs that others who are important to him and to whom he is motivated to comply with favor performance of the behavior, the subjective norm will also be favorable towards performing the behavior. Because beliefs are built on the information set available to individuals, it follows that behavior stems from this information.

**Figure 3.1: The theory of planned behavior**




*Source: Ajzen (2006).*

The intention-behavior relation can be disturbed by factors that are outside the individual's control. For instance, the (internal) lack of will power may turn a behavior such as 'losing weight' into a flop whereas 'going to the movies' may be (externally) hampered when tickets are sold out. Rather than actual behavior, intentions only predict an individual's *attempt* to perform a certain behavior. Ajzen therefore included non-volitional factors into the model. Perceived behavioral control is just like the attitude towards the behavior and the subjective norm a determinant of behavioral intentions. It represents an individual's perception regarding the difficulty of performing the behavior and includes for instance past experience, a plan of action and general self-knowledge. Like behavioral and normative beliefs, control beliefs determine perceived behavioral control. Control beliefs are individual beliefs about the presence of factors that may hamper or ease performance of the behavior. The conceptual model in figure 3.1 shows the relations between each of the constructs of the theory of planned behavior. Finally, an individual will be successful in performing the behavior when he correctly perceives sufficient internal and external control over it (Ajzen, 1985).

The theory of planned behavior is applicable to the individual decision to use bicycle lights or not. The attitude towards the behavior is determined by the individual's belief about the effects of bicycle lights on traffic safety. For instance, if it is the conviction of the bicyclist that it helps to make traffic safer, then this contributes to the intention to attempt using bicycle lights. If the bicyclist believes that others, with whom he is motivated to comply with, also think it is needed to use bicycle lights, the perceived subjective norm also contributes to his intention. Finally, perceived behavioral control also has this effect when the bicyclist is convinced that his capabilities will enable him to use light. The intention to perform the behavior 'using bicycle lights' then predicts that the bicyclist will in fact perform this behavior, unless he is hampered by factors beyond his control. One might think of rainfall which makes the dynamo slippery and ineffective.

### 3.5 Conclusion

Some people use bicycle lights while others do not. This imposes costs on society and requires government intervention. The present chapter gave several possibilities that might explain noncompliance among bicyclists. First of all the deterrence hypothesis has been discussed. The fine as well as the probability of being caught ought to trigger a bicyclist to use bicycle lights. However, we have seen that the actual effect of penalties, as well as rewards, does not always correspond to the theoretical prediction. This may be due to a change in the perceived locus of causality; instead of intrinsic it becomes extrinsic. An example of intrinsic motivation that may be applicable to the decision to use light is the moral norm that demands bicyclists to contribute to traffic safety. When the monetary punishment is low, actual use of bicycle lights may decline due to the crowding out of this moral incentive.

The theory of planned behavior partially overlaps this incentive based trade-off: the attitude towards the behavior captures the moral norm to promote traffic safety if it is the bicyclist's belief that bicycle lights actually have this property. But it does not stop there. A bicyclist's perception of a subjective (social) norm can still motivate him to comply with the law even when the moral norm to use bicycle lights is crowded out. Finally, his perceived and actual behavioral control may hamper the effect of either type of incentive. When it is practically impossible to use bicycle lights, the government does not seem to have powerful tools.

Certain effects that are predicted in this chapter are unknown. In order to test these relationships a survey among bicyclists was conducted. The next chapter describes this survey in detail.

# Chapter 4

*Research method: representation and measurement of the population*

The theoretical answer to the question of why not everyone uses bicycle lights is largely hypothetical. It *may be* that the fine crowds out moral obligations and it *may be* that bicyclists face practical issues that withhold them from using light. Street interviews during the dusk and dark were conducted to find out what motivates bicyclists when they decide to use bicycle lights or not. This chapter describes the research method that was used. It tries to point out possible errors and discusses why this method in fact minimizes these errors so that the outcome is of greater validity and reliability. The first section of this chapter treats the target population, the sampling procedure and the actual sample, whereas the second section focuses on the questionnaire. The third and final section concludes.

## 4.1 Representation

### *4.1.1 Target population and sampling procedure*

The target population consists of all bicyclists in the Netherlands who cycle during the darker times of the day. A clear sampling frame[26] is missing however, since owners of bicycles are not registered. Arguably, a random list of inhabitants such as a phone book would be a good sampling frame as bicycle ownership and phonebook registration are unlikely to correlate. Convenient too is the fact that many people own a bicycle which makes calling or writing them not a lost cause on forehand. Despite these advantages this survey mode was dropped, due to the fact that people lie. From section 2.4 we know that in 2008 66 percent of the bicyclists used light. In contrast, in the same year 88 percent of the general public reported to use bicycle lights all the time (DVS, 2009). This gap of 22 percentage points is not negligible. A face-to-face interview overcomes this issue since it is easy to verify that the respondent indeed uses bicycle lights. An additional advantage is that respondents are likely to be more aware of the pros and cons of their behavior at the time of the interview. For instance, bicyclists will think of practical issues much sooner when they are sitting on a bike rather than a couch.

[26] A sampling frame is a physical representation of the target population, for instance a phone book.

Street interviews are an example of convenience sampling which is a form of non-probability sampling. This means that the probability of selection is unknown for each unit in the sample. An implication of this procedure is that instead of the target population inference is only possible on the sample itself (Pieters, 2010a). Time and place of realization of the survey are chosen at the researcher's convenience and are therefore non-random. Possibly, covered units systematically differ from non-covered units; this decreases the survey's reliability. Thus, generalization of the results is difficult as a result of coverage error. On the other hand, this procedure is cheap and flexible for instance, it does not require envelopes and stamps. Finally, the required sample size was not calculated on forehand but evaluated ex post instead.

### *4.1.2 The actual sample*

The municipality of Tilburg was chosen to conduct the survey for the practical reason of proximity. The municipal ground is made-up of the city Tilburg and the surrounding villages Berkel-Enschot and Udenhout. Its total population slightly exceeds 200.000 inhabitants, which makes it one of the larger municipalities in The Netherlands. The survey was held from Monday February 22nd to Friday February 26th 2010 between 06.00-07.30 a.m. and 18.30-21.00 p.m. on five different locations throughout the municipality.

Locations were chosen carefully. The first requirement was of course the presence of bicyclists. The next one was that the locations should reflect the municipality as it is: a conglomerate of a city and surrounding villages. Thirdly, a distinction was made between residential and non-residential areas. As a final requirement, roads were distinct from one another based on their function. Any road either has a traffic function or a residential function. The latter two requirements stem from the NPR 13201-1. This is a national guideline for public lighting based on European directives. The NPR distinguishes roads based on, among other things, their location (inside versus outside residential areas) and their function (traffic versus residential function)[27]. Each location was characterized in consultation with J. van Groenewoud and A. Mans from the department Public Lighting of the municipality of Tilburg (personal communication, February 11, 2010). Table 4.1 shows the relevant details of each location and may give the reader an idea about the setting. Appendix D contains a map of Tilburg on which each location is marked.

[27] NPR is an abbreviation for "Nederlandse Praktijk Richtlijn". The complete set of determinants includes the following items: number of lanes, traffic composition, traffic intensity, road complexity, social safety and degree of public lighting in surrounding areas.

TABLE 4.1
Details of each location

| Tag | Day | Road | Place | Area | Function |
|---|---|---|---|---|---|
| (1) | Monday | Bosscheweg | Berkel-Enschot | non-residential | traffic |
| (2) | Tuesday | Smidspad | Tilburg | residential | residential |
| (3) | Wednesday | Kreitenmolenstraat | Udenhout | residential | traffic |
| (4) | Thursday | Tuinstraat | Tilburg | residential | traffic |
| (5) | Friday | Reeshofdijk | Tilburg | residential | traffic |

At each location bicyclists were summoned to pull over and if they did so they were asked to cooperate with the survey. No distinctions between bicyclists were made except that groups were ignored for practical reasons. To increase response rates every respondent was rewarded with one free LED after completion of the questionnaire. At the same time, all bicyclists who were eligible to participate in the survey were counted and their use of bicycle lights was registered[28]. Eligibility in this case means that bicyclists were either given a halt sign but ignored it or, refused to cooperate after pulling over or, could have been given a halt sign if the interviewer wasn't already occupied or, were not given a halt sign because it was impossible or impractical to do so. No attention was being paid to visibility and mounting of the lights which is in line with the definition of incomplete conformity from chapter 2. Duplication may distort these findings. However, the duration of each session is quite short which makes it less likely that someone passes by multiple times. Moreover, at (2) and (3) only one direction was recorded. Finally, if it was obvious that someone who was already interviewed or registered came by a second time, no repetitive registration was made.

This type of registration enables an analysis of non-response. Non-respondents are eligible candidates that are not interviewed. If for instance unlit bicyclists refuse to cooperate more often, they are relatively underreported which may cause non-response bias. Fortunately, results do not indicate a non-response bias of this type. The difference between the share of unlit bicyclists amongst respondents and non-respondents is insignificant[29]. Exclusion of the evening session at (4) does not affect this result. Possibly respondents and non-respondents differ in another way such as age or gender but no data are available to test this.

[28] Rainfall made registration impossible during the evening session at location (4).
[29] This is based on a chi-square test for contingency tables; the p-value is 0,942. Section 5.1 provides more details.

## 4.2 Measurement

### *4.2.1 Definition of the constructs*

In the previous chapter the two main constructs were discussed: intrinsic and extrinsic motivation. The deterrence hypothesis formed the basis of extrinsic motivation. It is applied to bicycle lights because the fine and the probability of being caught for not using them are considered to be part of a bicyclist's cost-benefit analysis. Their expected value is a benefit to the bicyclist when he decides to use light. This benefit is then being weighted against the costs: using bicycle lights requires maintenance to the bike, pedaling becomes heavier or new batteries have to be purchased in case of LEDs.

Moral norms constitute intrinsic motivation. If a bicyclist decides to use light because it his belief that it is the right thing to do, then the benefits are inherent in the activity. In that case he is said to be intrinsically motivated. To define and directly measure a moral norm is a difficult thing to do. Therefore the focus is on the attitude towards traffic safety. If a respondent believes that improving traffic safety is important and if that is a key motive for him to use bicycle lights, this is an indication of the presence of a moral norm.

The theory of planned behavior, which is build on many constructs discussed in section 3.4, was put forth as an alternative for explaining behavior from intrinsic or extrinsic motivation. However, we have seen some common ground with both types of motives. The attitude towards the behavior may be of moral kind and the presence of practical problems such as maintenance is part of actual behavioral control.

### *4.2.2 Measurement of the constructs*

Successful performance of street interviews requires more than patience and a nice introductory talk. The length of the questionnaire is important as well: if it is too long no-one will be willing to participate[30]. For that reason the length of the questionnaire was limited to two pages. Because of this restriction, quite a few constructs have been measured by one question only. This imposes a possible validity problem on the conclusions. Constructs of greater importance however, have been measured by multiple questions. The final version, which can be found in appendix E[31], consisted of 21 questions and took about five minutes to complete.

[30] This is based on common sense as well as personal experiences on similar field projects conducted at a side job.
[31] The questionnaire was in Dutch, appendix E contains a translation.

Ten questions are dedicated to the theory of planned behavior. All of them are based on example questions by Staats (2003, p.189). The questions on the subjective norm and normative belief are transformed into a single question. As can be seen in the appendix[32], that particular question (no. 7) is formulated as follows: "Do you think that your friends and family feel that you should use bicycle lights?" This is a double-barreled question since friends and family are not necessarily the same. However, under the assumption that respondents would first think of people that are close to them and of whom they know to have an opinion on the use of bicycle lights, this conjunction saved the need for two additional questions. This assumption may indeed be true since none of the respondents asked for clarification or made a remark about it. In section 5.3, which is on data analysis with respect to the theory of planned behavior, this variable is included as regressor in two different models that predict intention. So intention is not only measured directly by question no. 2, it is estimated by two different models that yield consistent estimates as well.

The questions that are used to measure intrinsic and extrinsic motivation are based on intuition and common sense. These include for extrinsic motivation questions on the respondent's belief of the level of the fine and the probability of being caught, a 'required' fine that would force the respondent to use light all the time and a question on practical problems that trouble the use of bicycle lights. A moral norm that lies underneath intrinsic motivation is not measured directly. Its presence may be derived from a positive attitude towards using bicycle lights and traffic safety being a key motive to actually use them. For this purpose lit bicyclists were asked to rank several possible motives from most important to least important. Further support stems from hypothetical questions on behavioral responses to tightened police enforcement and the abolishment of the legal obligation to use bicycle lights.

Other issues that need to be addressed are measurement error and data processing error. The former occurs when respondents misunderstand the question. For instance, consider saying question no. 10: "What should the level of the fine be in order to make you use your bicycle lights all the time?" Many of the respondents answered this question halfway: they said what the level of the fine should be. Data processing errors occur when answers to open ended question are misinterpreted. For instance, question no. 16: "Do you have any practical problems that trouble the use of bicycle lights?" was answered ones with "Sometimes my shopping bag blocks the light". An advantage of having a face-to-face interview is that when in doubt, both the respondent and the interviewer can ask for clarification. Measurement errors as well as data processing errors can thereby become smaller and enhance validity

[32] Each question that is used for the theory of planned behavior is labeled in appendix E by "TPB + construct name".

of the survey. In this case the respondent was asked how often his shopping bag had actually blocked his light. This number was negligible and the respondent then said to have no practical problems.

This last example shows more than just the highlighted advantage of having face-to-face interviews. It also shows that the presence of an interviewer can change the respondent's answer. Some response tendencies such as social desirable responding and acquiescence are being promoted by the mere fact of presence of an interviewer (Pieters, 2010b). In particular, the first six questions (except question no. 5) are vulnerable to socially desirable answers. The next chapter will confirm this hypothesis from the data.

**4.3 Conclusion**

Face-to-face street interviews are a form of non-probability sampling. Time, location and eligible candidates were non-randomly chosen. This imposes a possible reliability problem on the data. Several measures were taken to enhance reliability: a series of requirements was imposed on locations, the use of bicycle lights for non-respondents was registered and except for groups, no bicyclists were selected. One should ask oneself the question: is there a good reason to believe that this particular sample responds differently from a random sample? If one feels that there is none, the results of this study can be applied to the target population. Otherwise it is needed to take a random sample such as suggested in section 4.1.1. Validity too may be of little strength, since some of the constructs were measured by a single question. It will become clear in the next chapter on data analysis which questions and constructs this concerned. However, multiple questions were devoted to the more important constructs such as intrinsic and extrinsic motivation, intention and behavior.

# Chapter 5

*Survey findings: intrinsic versus extrinsic motivation*

This chapter presents the results from the survey. Its main goal is to determine what drives bicyclists to use light: are these motives predominately intrinsic or extrinsic? Sample statistics such as the response rate, gender ratio and of course figures on the use of bicycle lights comprise the first section. Section 5.2 tries to formulate answers to questions on the deterrence effect of the fine and the presence of a moral norm. It is an attempt to elicit intrinsic and extrinsic motives from the relevant survey questions. The theory of planned behavior is analyzed in section 5.3. Two alternative regressions that estimate behavioral intentions will be compared. The intention-behavior relation is estimated by means of a probit model. The reader is advised to take note of the questionnaire in appendix E before proceeding.

**5.1 Sample statistics**

The survey was conducted on five different locations in the morning (from 06.00-07.30 a.m.) and the evening (from 18.30-21.00 p.m.). In total ninety bicyclists were willing to cooperate; two of them left halfway[33]. This is slightly below what was hoped for, which was one hundred interviews, but still enough to continue doing research with. The number of respondents did not depend on the time of the day, since the average of 4,5 interviews per hour was the same for both the morning and evening. Looking at the number of registered bicyclists, which was 459, we see that the average per hour is larger in the morning than the evening: 29 versus 21. The overall response rate, defined as the number of interviews divided by the sum of registered and interviewed bicyclists, was 13,7 percent[34].

Looking at the gender distribution we see a large gap between the number of men (which is 58 or 64,4%) and women (which is 32 or 35,6%). In Boxum et al. (2009) men comprehend 52,7 percent of the sample. If this share is the 'true value', then the overrepresentation of men in the present sample is statistically significant[35]. Table 5.1 shows how many of the men and women used bicycle lights, or in other words: how many of them were 'lit'. Whereas Boxum et al. (2009) find that women use bicycle lights

[33] Ten questionnaires were not completely filled out due to accidental skipping of questions, but of course none of them was left out of the statistical analysis on forehand.
[34] Due to weather conditions registration was impossible during the evening session at location (4). For that reason the number of interviews during that session was left out in calculating the response rate.
[35] This is based on a one-sided binominal test. The probability of finding at least 58 men in this sample is 0,019.

significantly more often than men, the observed difference here is not significant[36]. Since this difference is insignificant and the theory of planned behavior does not predict a direct effect of gender on behavior, there is no need to weigh the data. Apart from that, only one of the respondents thought to comply with the law while in fact she did not. Because of this negligible number she is treated as being lit, in line with the incomplete conformity definition. Finally, there is no significant difference between the shares of lit bicyclists in the sample compared to the registered group. Out of the 459 registered bicyclists 285 were lit, which is close to 62 percent. This finding was already discussed in section 4.1.2 and shows that there is no non-response bias between lit and unlit bicyclists in the sample.

TABLE 5.1
Bicycle light usage for men and women

| | Lit | Unlit | Sum |
|---|---|---|---|
| Men | 33 (59%) | 23 (41%) | 56 (100%) |
| Women | 22 (69%) | 10 (31%) | 32 (100%) |
| Sum | 55 (63%) | 33 (37%) | 88 (100%) |

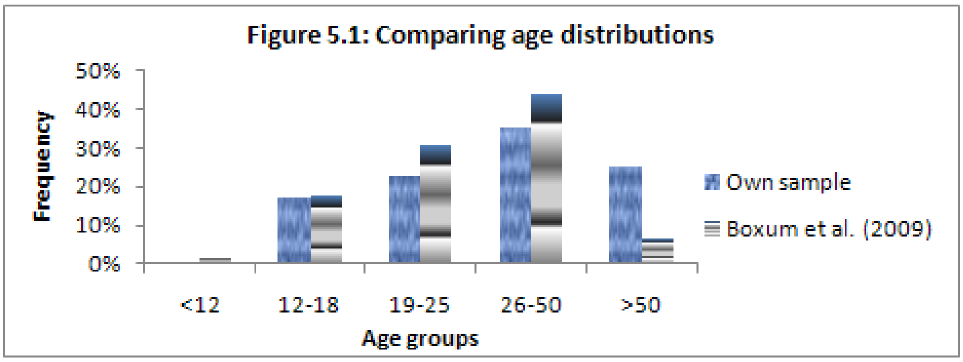
*Note:* shares are in between brackets.

TABLE 5.2
Bicycle light usage for bicyclists in possession of a driver's license

| | Lit | Unlit | Sum |
|---|---|---|---|
| Driver's license | 36 (69%) | 16 (31%) | 52 (100%) |
| No driver's license | 18 (51%) | 17 (49%) | 35 (100%) |
| Sum | 54 (62%) | 33 (38%) | 87 (100%) |

*Note:* shares are in between brackets.

The age distribution is given in Figure 5.1. Comparing this distribution to the one found by Boxum et al. (2009) shows that the highest age group is larger, whereas the other groups are (slightly) smaller. The mean age is 36,1 and the median 35. Among lit bicyclists the mean and median are larger: 38,2 and 38,5 respectively. For unlit bicyclists these are 32,0 and 25. This difference is insignificant.[37]




52 Out of 87 respondents were in possession of a driver's license. Looking at Table 5.2 to see how many of them used bicycle lights we find that 69 percent of them did so. This is 18 percentage points more

[36] This is based on a chi-square test for contingency tables. All expected values in the contingency table (not shown) exceed ten. The p-value is 0,360.
[37] This is based on a two-sided Mann-Whitney U-test, the p-value is 0,127.

than the group without a driver's license, which is significant at the 10%-level[38]. This difference is neutralized however, when all respondents younger than 18 are excluded.

Section 4.2 stated the possibility of social desirable responding and acquiescence (to agree with everything) due to the presence of an interviewer. It may be of course that the survey findings represent the 'true value' of the sample, but there is at least a theoretical argument to doubt this. Moreover, such response tendencies seem to be present in the first six questions (except no. 5). The results are characterized by a high mean and median, as well as a low standard deviation. In particular, questions no. 4 and no. 6 have a mean of 6,6 and their standard deviation is smaller than one. Another way of looking at response tendencies is to calculate the share of respondents that answered '7' to question no. $i$ after having answered question no. $i$ - $1$ with '7' as well. It turns out that these shares are all above eighty percent for the first six questions, with the exception of no. 5. Only 21 percent of the respondents that answered '7' to question four answered '7' to question five as well. Although it remains hard to prove that respondents gave social desirable answers and easily agreed to some of the statements, these findings should be kept in mind.

**5.2 Intrinsic versus extrinsic motivation**

The deterrence hypothesis says that the introduction of a fine, ceteris paribus, will reduce the occurrence of the behavior subject to the fine. The severity and certainty of the fine determine its expected legal costs and a rational, money maximizing individual will use this in a trade-off with the expected benefits of violation. Here, the benefit of violation converts into not having any costs to use or maintain bicycle lights. Table 5.3 yields an insight into what respondents thought to be the level of the fine and the probability of being caught.

Question no. 9 asked respondents for their belief[39] regarding the level of the fine whereas question no. 12 asked this with regard to the probability of being caught. The latter question was formulated as if the bicyclist was cycling through the municipality of Tilburg for one hour during the dark, without using bicycle lights. The table shows that both lit and unlit bicyclists are well aware of the level of the fine and their beliefs do not significantly differ. The same is true for the probability of being caught: both median values are 15 percent and the observed beliefs do not significantly differ. Note that this probability implies that the median bicyclist expects to get caught once every 6-7 hours. Multiplying both beliefs

[38] This is based on a chi-square test for contingency tables. All expected values in the contingency table (not shown) exceed ten. The p-value is 0,093.
[39] The beliefs that are being treated in this section are unrelated to the beliefs from the theory of planned behavior.

yields the expected legal costs for cycling without bicycle lights. Again, there is no difference between the two groups. This is a surprising result since lit and unlit bicyclists have the same beliefs but come to a different decision. Possibly, lit bicyclists are better informed when it comes to the costs of being lit. For instance, prices for a new set of LEDs vary from about € 2,50 to € 20,-.

TABLE 5.3

Beliefs regarding severity and certainty of punishment

| | Median | | Average rank[a] | | P-value[b] |
|---|---|---|---|---|---|
| | Lit | Unlit | Lit | Unlit | |
| Belief about the level of the fine (no. 9) | € 35,00 | € 35,00 | 45,6 | 41,4 | 0,457 |
| Belief about the probability of being caught (no. 12) | 15% | 15% | 42,9 | 44,5 | 0,769 |
| Expected legal costs of being unlit (no. 9 x no. 12) | € 5,50 | € 4,50 | 43,5 | 43,4 | 0,206 |
| Required level of the fine (no. 10) | € 30,00 | € 50,00 | 37,8 | 55,7 | 0,001 |
| Required legal costs of being unlit (no. 10 x no. 12) | € 3,50 | € 5,00 | 40,4 | 50,0 | 0,691 |

a: All observations were ranked from smallest to largest. A smaller average rank indicates that observations for that group were smaller than for the other.
b: The p-values belong to two-sided Mann-Whitney U-tests. If observations for both groups are similar, then this should reflect itself in similar ranks and an insignificant p-value.

An alternative explanation would be that lit bicyclists are partially intrinsically motivated and that unlit bicyclists are not sufficient extrinsically motivated. Question no. 10 asked respondents to indicate the level of the fine at which they would always use bicycle lights. The results show that lit bicyclists require a smaller fine than unlit bicyclists; this difference is significant at the 1%-level. Looking at the required legal costs however, no such difference seems to exist. Still, the finding that lit bicyclists require a smaller fine supports the hypothesis that intrinsic motivation does play a role for them.

Instead of comparing lit and unlit bicyclists we can also look at differences within each group. In general one could say that lit bicyclists who do not require a fine, or require a fine that is larger than (their belief of) the actual fine, are intrinsically motivated. On the other hand, a bicyclist whose belief is larger than or equal to his required fine is sufficiently extrinsically motivated. The data show that thirteen respondents indicated to require a fine of one or nil euro. To them the fine is of negligible importance and that means they are entirely intrinsically motivated. They are accompanied by sixteen bicyclists who require a larger fine than their belief of the actual fine. Intrinsic motivation is what drives them to use bicycle lights. Thus, a slight majority of lit bicyclists (29/54) is intrinsically motivated.  The remaining lit bicyclists are sufficiently extrinsically motivated: six of them require a fine that is smaller than the actual fine and nineteen require a fine similar to the actual fine.

For unlit bicyclists this is a different story. Twenty-three of them require a fine that is larger than their belief of the actual fine. Thus, the vast majority (23/33) is insufficiently extrinsically motivated. Two bicyclists indicated not to require a fine to make them use light. If they were lit, they would be classified as intrinsically motivated. Now it is not clear how to interpret this finding. Likewise, eight others required a fine that is smaller than or equal to their belief of the actual fine. Already in section 4.2 the possibility of measurement error was discussed for this particular question. Now it turns out that 10/33 respondents gave an answer that is 'ruled out' by the question. Two of them were unfortunate to be interviewed in the rain which caused their light to malfunction, but the other eight are likely to have misunderstood the question. On the whole, the required fine for unlit bicyclists is significantly larger than their belief of the actual fine[40]. Similarly, the required legal costs significantly exceed expected legal costs[41]. This result supports the hypothesis that unlit bicyclists are not yet enough extrinsically motivated.

TABLE 5.4

Ranking of motives to use bicycle lights

| | Traffic safety | Social pressure | Legal obligation | Level of the fine | Probability of being caught |
|---|---|---|---|---|---|
| # Ranked 1st** | 44 | 1 | 5 | 3 | 2 |
| # Ranked 2nd* | 6 | 11 | 21 | 11 | 9 |
| # Ranked 3rd | 5 | 10 | 13 | 17 | 9 |
| # Ranked 4th** | 0 | 11 | 11 | 18 | 14 |
| # Ranked 5th** | 0 | 22 | 5 | 6 | 21 |
| Total score | 71 | 207 | 155 | 178 | 208 |

*Note:* One respondent ranked all but traffic safety (1st) on 2nd place.
* Significant at the 5%-level; ** Significant at the 1%-level; based on chi-square goodness-of-fit tests. The null hypothesis states that the proportions are the same.

Question no. 14 was designed to find out what the decisive factor was for bicyclists to use light. It asked respondents to rank five possible motives to use bicycle lights, from most important ('1') to least important ('5'). Results are presented in Table 5.4, which shows the number of occurrences that each motive was ranked $1^{st}$, $2^{nd}$ et cetera, as well as the total score. This is a summation of all ranks. A low total score means that it was rated as relatively important.

The table provides overwhelming evidence for traffic safety being the most important reason to use bicycle lights. Eighty percent of all lit bicyclists ranked it number one. The fact that bicycle lights are

[40] This is based on a two-sided Wilcoxon matched-pairs signed-ranks test: n=27; T=58; p-value = 0,002.
[41] This is based on a two-sided Wilcoxon matched-pairs signed-ranks test: n=26; T=71; p-value = 0,008.

mandatory by law also is a good reason to use them. At third place we find the level of the fine. The distribution of the number of occurrences that each motive was ranked third however, does not differ from the null hypothesis that these are equally distributed (p-value = 0,113). This means that the level of the fine is not more important than the probability of being caught and social pressure to use bicycle lights, which both do not seem to play a role.

We already knew from section 5.1 that bicyclists find improving traffic safety very important (question no. 6) and bicycle lights an effective means to do this (no. 4)[42]. Now we know that traffic safety is the strongest motive for lit bicyclists to use light. The question now is do they use bicycle lights for themselves or for others? A moral norm such as proposed in section 3.3 requires the presence of a positive right to safely move about in traffic. This implies that bicycle lights are being used to enhance traffic safety for others; perhaps bicyclists keep in mind that car drivers are usually held liable for the damage. Question no. 5 asked respondents to indicate how unsafe they feel in traffic when they are not using /would not use bicycle lights. It turns out that lit bicyclists would feel significantly more unsafe[43]. The mean answer for unlit bicyclists is 3,5 whereas for lit bicyclists it is 4,8. Although the feeling of insecurity is an intrinsic motivator, this finding does not support the presence of a moral norm. It suggests that lit bicyclists are more risk averse and use bicycle lights as a means to reduce the risk they feel exposed to.

The conclusion so far is that unlit bicyclists are not sufficiently extrinsically motivated. This hypothesis gains more support from the following results. Question no. 15 asked unlit bicyclists explicitly why they were not using light. All of them gave at least one reason, seven respondents gave two reasons. Over half the answers refer to either the malfunctioning or absence of bicycle lights. LED related reasons and weather conditions both make up one-eighth of replies. Six people (or 15%) said that using bicycle lights was not necessary or they simply forgot it. In the present discussion, reasons such as maintenance or the purchase of LEDs are part of a cost-benefit analysis and fall under the extrinsic (financial) motivator. Moreover, question no. 20 asked for behavioral responses when one would notice the police to be inspecting bicycle lights more often. 76 Percent of the unlit bicyclists said they would start using light. Also supportive are the findings from question no. 21, which asked for behavioral responses when the legal obligation to use bicycle lights would be abandoned. The vast majority of unlit bicyclists (82 percent) would persist in their behavior. So if intrinsic motivation has been crowded out by the presence

[42] No significant differences between lit and unlit bicyclists exist. This is based on two-sided Mann-Whitney U-tests.
[43] This is based on a two-sided Mann-Whitney U-test, the p-value is 0,004.

of a fine, it for sure will not crowd back in. It requires larger expected legal costs to make the unlit bicyclists from this sample use light.

**5.3 The theory of planned behavior**

Before proceeding to the survey findings related to the theory of planned behavior, the constructs that comprise this theory will be reiterated. The bottom line is that actual behavior stems from the intention to perform this behavior. This relationship may be disturbed by actual behavioral control. Intentions are being formed by: attitude towards the behavior [AT], subjective norm [SN] and perceived behavioral control [PBC]. These constructs are proportional to the multiplication of their corresponding beliefs[44] and outcome evaluation ([E], with regard to AT), motivation to comply ([M], with regard to SN) and perceived power ([P], with regard to PBC)[45]. The remainder of this section employs the respondents' answers to estimate the intention to use bicycle lights. Subsequently, these results are used to estimate the intention-behavior relation and the effect of practical problems on bicycle light usage.

From Ajzen (1985) it is not clear whether a user of the theory of planned behavior should use the direct or indirect determinants of intentions [IN]. Therefore, both are used initially. By means of OLS the following equations ⟨4⟩ and ⟨5⟩ were estimated and the results are presented in Table 5.5.

$$\langle 4 \rangle\ \mathrm{IN} = \beta_0 + \beta_1 * \mathrm{AT} + \beta_2 * \mathrm{SN} + \beta_3 * \mathrm{PBC} + \mathrm{u}$$

$$\langle 5 \rangle\ \mathrm{IN} = \beta_0 + \beta_1 * (\mathrm{B} * \mathrm{E}) + \beta_2 * (\mathrm{N} * \mathrm{M}) + \beta_3 * (\mathrm{C} * \mathrm{P}) + \mathrm{u}$$

The only significant coefficient in ⟨4⟩ besides the intercept is $\hat{\beta}_1$. Its positive sign confirms the theoretical prediction that a favorable attitude towards the behavior enhances the intention to perform the behavior. Although this finding is not supported by the results of ⟨5⟩, the p-value of *BE* is 0,177, it is not opposed either.

Now the estimates from ⟨4⟩ and ⟨5⟩ can be used to construct new independent variables: *intention_4* and *intention_5*. Or in other words, the estimated coefficients are applied to the individual data on *AT*, *SN* and *PBC* (and likewise to the indirect determinants of *IN*) and constitute a predicted value of the intention *IN*. According to expectations, both of the newly developed variables positively correlate to *IN*:

[44] These were behavioral beliefs [B], normative beliefs [N] and control beliefs [C].
[45] These will be referred to as the *indirect* determinants of intentions. Conversely, AT, SN and PBC are *direct* determinants.

$\text{Corr}\ (\text{IN}, \text{intention\_4}\ ) = 0{,}548$ and $\text{Corr}\ (\text{IN}, \text{intention\_5}\ ) = 0{,}273$. Equation ⟨4⟩ again seems to offer more support for the theory of planned behavior.

TABLE 5.5

OLS estimation results of the intention to use bicycle lights

| Equation 4 | | | | Equation 5 | | | |
|---|---|---|---|---|---|---|---|
| | Coefficient | Std. error[a] | P-value | | Coefficient | Std. error[a] | P-value |
| CONSTANT | 3,036 * | 1,169 | 0,011 | CONSTANT | 4,813 ** | 1,074 | 0,000 |
| AT | 0,710 ** | 0,147 | 0,000 | BE | 0,030 | 0,022 | 0,177 |
| SN | -0,131 | 0,086 | 0,131 | NM | 0,005 | 0,004 | 0,170 |
| PBC | -0,090 | 0,115 | 0,438 | CP | -0,019 | 0,015 | 0,221 |
| Adjusted R^2 | 0,282 | | | Adjusted R^2 | 0,040 | | |
| F-statistic | 12,415 | | 0,000 | F-statistic | 2,125 | | 0,104 |
| n | 88 | | | n | 83 | | |

a: White heteroskedasticity-consistent standard errors.

* Significant at the 5%-level; ** Significant at the 1%-level; based on two-sided tests

Together with actual behavioral control [ABC], these new independent variables are used to estimate the intention-behavior relation. In this case, *ABC* is a dummy variable: d=0 means the respondent did not report any practical problems that might trouble the use of bicycle lights whereas d=1 means that the respondent did at least report one practical problem. Looking at the results from question no. 16 we see that 41 respondents did not report any problem, whereas 47 respondents reported at least one. Approximately one third of them indicated that bicycle lights require too much maintenance, which makes it the most common complaint. LED related problems as well as bad weather conditions each make up about one quarter of the problems. The remainder of complaints was on heavier pedaling.

The dependent variable *light* is binary too: d=0 means that the respondent did not use bicycle lights at the time of the interview whereas d=1 means that the respondent did use them. Such a dependent variable requires the use of a binary response model in which interest lies in the response probability: how will a change in intention or actual behavioral control affect the probability that an individual uses bicycle lights? The probit model (based on Wooldridge, 2006, ch.17) is used here. The response probability for *light* is given by[46].

$$\langle 6 \rangle\ P(light = 1 \mid intention\_4,\ ABC) = P(light^* > 0 | intention\_4,\ ABC),$$

where

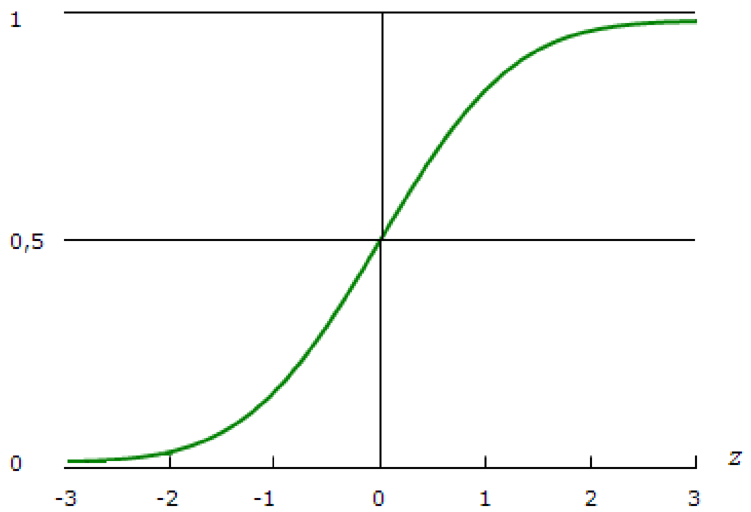
[46] *Intention_4* can of course be substituted by *intention_5*.

$$\langle 7 \rangle \; light^* = \beta_0 + \beta_1 * intention\_4 + \beta_2 * ABC + u$$

In $\langle 7 \rangle$, $u$ is normally distributed. The value generated by $\langle 7 \rangle$ is plugged in $G(z)$ as z-value to guarantee an outcome that is strictly between 0 and 1. In the probit model, $G(z)$ is the standard normal cumulative distribution function which is shown Figure 5.2. The graph shows that when $\langle 7 \rangle$ is positive the probability of success, meaning that a bicyclists uses bicycle lights, is larger than 0,5.

**Figure 5.2: The standard normal cumulative distribution function**

$$G(z) = \int_{-\infty}^{z} (2\pi)^{-0.5} exp(-z^2/2)\, dz$$




The results are presented in Table 5.6. Again, the model based on the direct determinants of intentions is the better of the two and therefore the remainder of the text will focus on that one. This conclusion is based on the percent correctly predicted [PCP] as well as other measures of goodness of fit[47]. The PCP compares the forecasted probabilities, which are based on the regression coefficients and the values of all $x_j$, to the actual value of the independent variable. Using as threshold probabilities 0,2 (lower boundary) and 0,8 (upper boundary), this model correctly predicts about one fifth of all observations.

Although the magnitude of the coefficients cannot be interpreted, we can conclude from their signs that intention has a positive partial effect on actual behavior while the presence of a practical problem has a

[47] These are the Akaike and Schwarz criteria: a lower value is favorable.

TABLE 5.6

Maximum likelihood estimation results of the latent response probability to use bicycle lights

| | Equation 7, $x_1 = intention\_4$ | | | | Equation 7, $x_1 = intention\_5$ | | |
|---|---|---|---|---|---|---|---|
| | Coefficient | Std. error[a] | P-value | | Coefficient | Std. error[a] | P-value |
| CONSTANT | -3,480 * | 1,380 | 0,012 | CONSTANT | -6,137 * | 2,646 | 0,020 |
| INTENTION_4 | 0,669 ** | 0,217 | 0,002 | INTENTION_5 | 1,089 ** | 0,420 | 0,010 |
| ABC | -0,585 * | 0,293 | 0,046 | ABC | -0,408 | 0,320 | 0,203 |
| Percent correctly predicted | | 19,32 | | Percent correctly predicted | | 16,87 | |
| Akaike info criterion | | 1,21 | | Akaike info criterion | | 1,26 | |
| Schwarz criterion | | 1,29 | | Schwarz criterion | | 1,34 | |
| n | | 88 | | n | | 83 | |

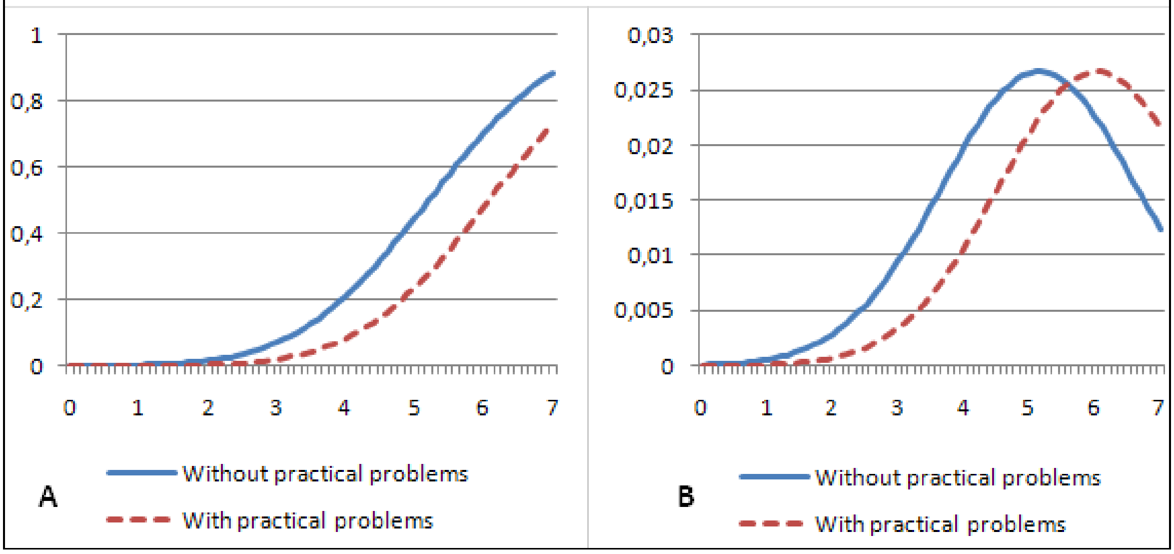
a: Huber-White robust standard errors.

* Significant at the 5%-level; ** Significant at the 1%-level; based on two-sided tests

negative partial effect. Both are significant at convenient levels. Figure 5.3A shows response probabilities depending on intentions. At low intention levels practical problems hardly play a role. But at for instance the average of $intention\_4$ (which is 6,17), a bicyclist who moves from no practical problems to at least one practical problem experiences a decline in response probability from 0,742 to 0,525. Conversely, a bicyclist with no practical problems whose intention to use bicycle lights increases from five to six, for instance due to a more favorable attitude towards the behavior, experiences an increase in response probability from 0,447 to 0,704. In case of practical problems this increase is

**Figure 5.3 A: Response probabilitiy curves for given levels of intentions**

**Figure 5.3 B: Marginal response probability effects for decimal changes in intention**



slightly smaller: from 0,236 to 0,480. Figure 5.3B shows that changes in response probability strongly depend on the level of intention. If there are no practical problems, the strongest movements occur around intention level five, whereas this is around level six in case of practical problem. The graphs intercept at about intention level 5,6. The figure tells us that when intentions are below this intercept, the occurrence of practical problems has a smaller effect compared to intentions being larger than 5,6.

This motivational analysis based on the theory of planned behavior has shown that an individual's attitude towards using bicycle lights is critical for actual usage. This attitude significantly influences the intention of using them and in its turn, intentions significantly enhance the probability of actual performance of the behavior. However, practical problems significantly reduce this probability[48]. We have seen that most practical problems are related to maintenance. Whether it is a malfunctioning dynamo or a pair of low batteries, in the present discussion these are related to extrinsic motivation.

These conclusions are robust. First, they do not depend on the (arbitrary) choice for a probit model; logit estimation did not yield different results. And secondly, the substitution of $intention\_4$ by *IN* has no large effect either. With the exception that response probabilities reacted slightly more to changes in intentions and the introduction of practical problems, the main conclusions remained unaffected.

**5.4 Conclusion**

The present chapter analyzed the survey results. Its sample size of 90 interviews was convenient enough to do research with. Several sample characteristics such as gender and the use of bicycle lights were compared to the literature and registered non-respondents. These comparisons enhanced the belief that the present sample represents the population well.

The focus of the chapter was on the distinction between intrinsic and extrinsic motivation. It turns out that more than half the lit bicyclists are at least partially intrinsically motivated; thirteen respondents do not require a fine and are entirely intrinsically motivated. Strong evidence was found that traffic safety is the most prominent reason to use light. Presumably, a higher degree of insecurity when moving about through traffic unlit is of decisive importance. Lit bicyclists do not seem to morally oblige themselves to use light for the benefit of others. Admittedly, a direct question on for instance guilt, which arises when someone acts in contrast to his own moral norm, was not asked.

[48] A separate probit estimation for a model with a dummy for each of the practical problems yielded negative coefficients for all $x_j$ except *intention_04*, but only one of them (heavier pedaling) was significant at the 5%-level. Not surprisingly, the PCP went up to almost forty percent.

On the contrary, unlit bicyclists do not use bicycle lights because they are not yet enough extrinsically motivated to comply and feel relatively safe in traffic. Their so called ‘required fine’ is larger than what they belief to be the actual fine. Moreover, the most prominent reasons not to use bicycle lights are cost-related: maintenance, batteries et cetera are part of a financial trade-off. This group is sensitive however, to an increase in legal costs. This becomes apparent from the fact that most of them will start to use bicycle lights when they notice the police are inspecting more frequently.

The theory of planned behavior supports this conclusion as well. It was shown that the presence of practical problems decreased the probability of using bicycle lights, despite good intentions. These practical issues are monetary in nature: the absence or malfunctioning of bicycle lights can easily be overcome by having it repaired. Weather conditions should not pose a problem either, since it does not bother the functioning of LEDs. Even a dynamo works fine when it is equipped with an anti-rain cap. The possibility of validity problems due to the fact that some constructs were being measured by a single question does not seem to be at hand. Outcomes hardly change as a consequence of implementation of alternative variables.

# Chapter 6

*Conclusions and recommendations*

### 6.1: Conclusions

Over 1500 bicyclists end up in hospital each year due to involved in a traffic accident during the dusk or dark. A small fraction of them consequently dies. Bicycle lights may decrease the probability of having an accident. The objective of this thesis therefore was to find an answer to the following research question:

*Can the number of bicyclists that use bicycle lights be increased through policy changes and hence improve traffic safety?*

Two more sub-questions were needed: “To which incentives do bicyclists respond when considering the use of bicycle lights?” and “Will an increase in a bicyclist’s visual conspicuity reduce the likelihood that this bicyclist gets involved in an accident?” Relevant literature was studied and a field study conducted to come to grounded policy advice, which is given in section 6.2.

Chapter 2 was dedicated to the second sub-question. A downward sloping linear trend in both the number of deceased and hospitalized bicyclists per billion seat kilometers was found. This obviously is good news. Did it have to do with the concurrent increase in the use of bicycle lights which went up from 57 percent in 2004 to 65 percent in 2009? Yes it did. Bicycle lights were shown to contribute significantly to a decrease in the number of accidents. The magnitude of this positive effect is debatable. Under the assumption that compliance does not differ between months, the number of accidents declines by approximately 21 with each percentage point increase in the use of bicycle lights per year. Measurements to determine bicycle light usage were normally taken in December and January. However, in 2003 this was done in February and it turned out that bicycle lights were used significantly less than in any other year. Except for unforeseen events, a plausible explanation for the decline is that police are inspecting less in February. It may be that bicyclists (immediately) respond to such relaxation in enforcement and hence make little use of bicycle lights during the rest of the year. For this reason, several adjustments to the variable *bicycle_lights* were made: steady declines were combined with steady recovery, sharp declines with sharp recovery et cetera. The general picture that came about was that bicycle lights contribute to a reduction in accidents, but the percentage point effect is more likely to lie somewhere between ten and twenty.

The relevance of the first sub-question becomes clear from the above answer to the second sub-question: it *may be* that bicyclists respond to changes in police enforcement. A theoretical framework distinguishing intrinsic and extrinsic motivation, as well as the theory of planned behavior formed the fundament for the survey. 90 Bicyclists were willing to cooperate; statistical analyses do not indicate that this sample does not represent the population well.

The main conclusions from the survey are that lit bicyclists are predominantly intrinsically motivated and unlit bicyclists insufficiently extrinsically motivated. About one quarter of lit bicyclists do not require a fine at all and are entirely intrinsically motivated. A slightly larger group is partially intrinsically motivated. Furthermore, the most prominent motive to use bicycle lights is traffic safety. This too proves the presence of intrinsic motivation. However, the existence of a moral norm could not be shown. Rather than improving safety for other, lit bicyclists use light to enhance their own feelings of security. In contrast, unlit bicyclists feel relatively safe. They seem to make a financial trade-off between the expected value of noncompliance and the costs of using bicycle lights. They face practical problems that are monetary in nature and require a larger fine than at present before they start using bicycle lights. Moreover, they indicated to comply when they would notice the police to be inspecting more stringent.

Finally, application of the theory of planned behavior has shown that the attitude towards using bicycle lights is of significant importance in predicting actual usage. Whereas the subjective (social) norm and perceived behavioral control do not seem to influence intention, the attitude towards the behavior clearly does. Intention in its turn is a good predictor of behavior, and so is the presence of practical problems. We have seen that these do not have a strong negative impact at low intention levels. Once intentions become stronger, the presence of practical problems increasingly hampers the use of bicycle lights.

**6.2: Recommendations**

The first question a policy maker who is interested in using this thesis' results should ask himself: "Do I belief that the sample represents the population well enough?" An earlier discussion of the survey pointed out that street interviews are a form of non-probability sampling and that results are hard to generalize because of coverage error. One might think of uncovered weekend days for instance. If a policy maker finds the results interesting but reliability doubtful, he may want to consider a second survey on a larger scale.

Given that this is not the case; the first recommendation is to increase the level of the fine. The survey results show that unlit bicyclists are sensitive to an increase in legal costs: they require a larger fine and indicate to use bicycle lights more often if they experience an increase in the probability of being caught. The trade-off between certainty and severity was discussed in chapter 3. Polinsky and Shavel (1979) have shown that when criminals are risk averse and the costs of catching them are low, the probability should be one and the fine should equal the private gain of the criminal. Presumably, in order to establish the latter, the fine has to be enlarged for repetitive violation. The fact that police are only inspecting on a coordinative basis during week 50 and week 2 indicates that the costs of catching bicyclists are not that low. This is not a plea though to shrink police inspections, since otherwise the expected legal costs will not increase and no behavioral changes take effect. For this to happen, more emphasis should be put on severity rather than certainty.

On the other hand, we have seen that a (large) fine might work counterproductive. It may be thought of as unfair to the few bicyclists that are caught (Polinsky and Shavel, 1979) and thus negatively affect the attitude towards using bicycle lights. Moreover, Gneezy & Rustichini (2000) found that the introduction of a fine may crowd out other incentives and Deci & Ryan (1985) suggested that it may undermine intrinsic motivation through a change in the perceived locus of causality. If this is generally true, then it has already affected today's use of bicycle lights. From the survey results we know that intrinsic motivation has not been crowded out entirely and there is no evidence that intrinsic motivation will crowd back in once the fine is lowered or abolished. Moreover, the fine works as an extrinsic motivator. Finally, bicyclists generally have a positive attitude towards using bicycle lights. This was found by the DVS (2009) and confirmed by the data from the current sample.

A second recommendation is to take a closer look at the 'Parkstad approach', which has been described in Box 1. The survey findings provide good arguments to copy such policy. Parkstad aims to enhance the use of bicycle lights within the age group that is most commonly unlit: teenagers. Students in secondary education were given one pair of LEDs as well as information on the usefulness of bicycle lights. Regular police presence at the school gates was used as a complementary tool. A comprehensive package such as this is indeed necessary[49].

First, students that did not use bicycle lights because they were insufficiently extrinsically motivated will not continue to use light once the batteries of their LEDs run out. This statement is justified by the results from the theory of planned behavior: the presence of practical problems such as empty batteries significantly decreases the probability of actual use. Additionally, bicycles may be inspected and repairs offered at discount. Still, an extrinsic motivator is needed. Secondly, the presence of police on a regular basis may be seen as arbitrary: other bicyclists are being targeted less. The distribution of free LEDs is needed to compensate for this. It shows that the government is committed to increase traffic safety and strengthens the information campaign. On the other hand, Bénabou and Tirole (2003) have shown that rewards are only weak positive stimuli in the short run and negative reinforcers in the long run. However, when LEDs are distributed as compensation for stringent police enforcement instead of reward for good behavior, it will not have a long run detrimental effect per se. When in doubt, a policy maker can request an investigation of the long run effects of the distribution of free LEDs in Parkstad. Schools keep a close record of students who receive a pair of LEDs and it should be possible to verify bicycle light usage at later ages. Thirdly, this approach will only work if local governments receive more funds. Any additional income from fines should be used to cover the costs. Additionally, funds that are used for national campaigning can be redistributed to regional campaigning. Section 2.4 showed that the use of bicycle lights seems to stabilize at 65 percent. This is what national campaigning primarily focuses on. A similar trend is observed in the attitude towards bicycle lights. Though this thesis gave no information on the costs of national campaigning, one may conclude that the marginal benefits are becoming too small.

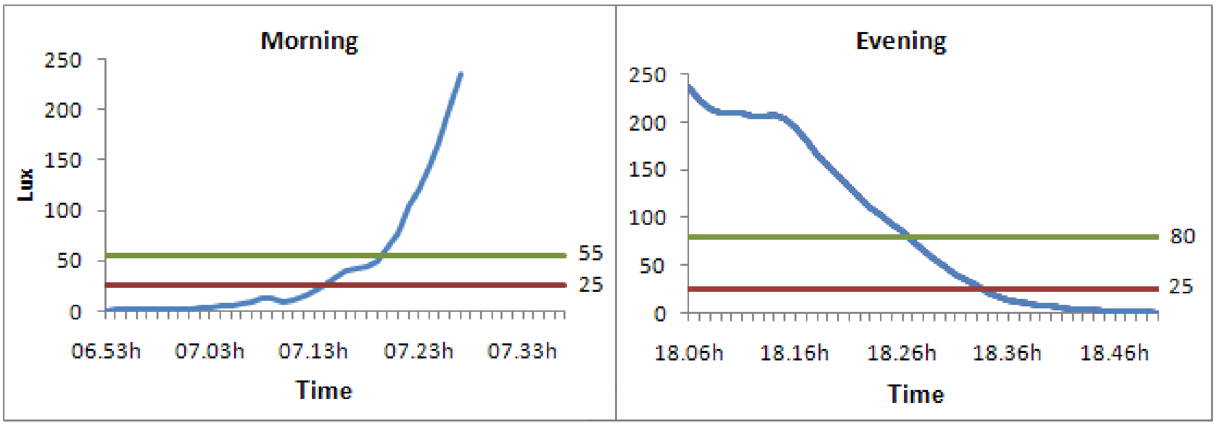
Finally, the answer to the main research question of this thesis is “yes”. Bicycle lights improve traffic safety because they enhance a bicyclist’s visibility. Intrinsic motivation is still present and unlikely to get crowded out by new policy. Unlit bicyclists are sensitive to extrinsic motivators such as a fine and the probability of being caught. Policy changes that would include a larger fine for all and a comprehensive package for students in secondary education are proposed to improve traffic safety even further.

[49] Equity considerations may provide a good argument to expand the law that allows adolescents less than sixteen years of age to pay half the fine. For instance, by shifting the age limit upwards.

# Appendices

*Appendix A: The development of luminous intensity over time*

These graphs give an impression of the speed at which luminous intensity (measured in lux) changes. Evening measures were taken on Saturday 27th of February and morning measures on Monday 1st of March. A public park with no nearby lampposts or trees that may disturb the measurement formed a suitable location. Both days were heavily clouded. Public lights switched off at 55 lux (07.19h) and switched on at 80 lux (18.26h). 25 Lux is the threshold between 'light' and 'dusk'. From the graphs it becomes clear that luminous intensity rises quicker than it declines beyond this threshold. The time in between 0 and 25 lux is about similar though. Irregularities, such as the flat pattern between 18.09h and 18.15h in the evening, may be due to (an opening in) the clouds.




*Appendix B: Estimation of billion seat kilometers*

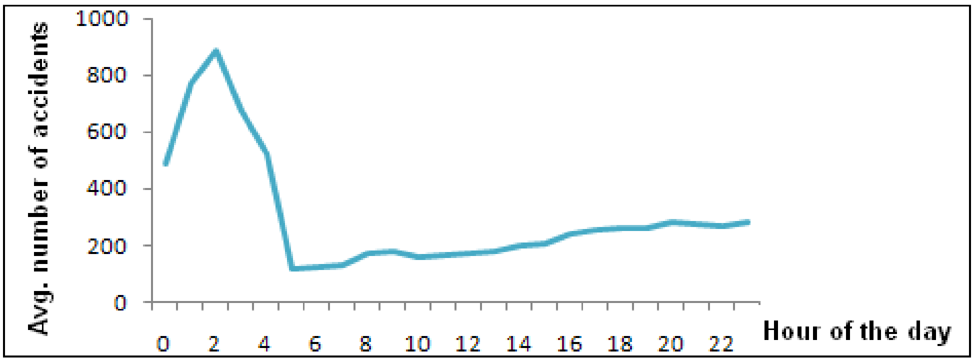
The SWOV Database – National Travel Survey[50] [NTS] contains estimates of BSK's by the Central Bureau of Statistics on all kinds of means of transport. From this database the time of departure was used for hourly data. A table from the Royal Netherlands Meteorological Institute[51] that contains the schedule for sunrises and sunsets per day and per month was exploited to find the dark hours per month. Applying these hours to the NTS data lead to the estimated BSK's presented in Table 2.3. The following hours are included in the calculation:

[50] In Dutch this is "Onderzoek VerplaatsingsGedrag".
[51] Retrieved from: http://www.knmi.nl/klimatologie/achtergrondinformatie/zonop2010.pdf.

| | | | | | |
|---|---|---|---|---|---|
| January | 18.00-08.00h | May | 22.00-05.00h | September | 21.00-07.00h |
| February | 19.00-07.00h | June | 22.00-05.00h | October | 20.00-08.00h |
| March | 19.00-06.00h | July | 22.00-05.00h | November | 18.00-08.00h |
| April | 21.00-06.00h | August | 22.00-06.00h | December | 17.00-08.00h |

*Appendix C: Number of accidents per BSK throughout the day*

The following graph bears on January 1996 to December 2008 and shows the average number of accidents per hour of the day (source: SWOV Database – Accidents & NTS).




*Appendix D: A map of Tilburg displaying each location*

(1) Bosscheweg (2) Smidspad (3) Kreitenmolenstraat (4) Tuinstraat (5) Reeshofdijk

*Appendix E: A translation of the questionnaire*

| Respondent no.:<br><br>Date: | Location:<br><br>Time: Lux: |
|---|---|
| # Lit: | # Unlit: |

**1. Theory of planned behavior [TPB] – Behavior** Previous research showed that about 36% of all bicyclists do not use a front and/or rear light. When you cycle during the dusk and dark, how frequently do you use bicycle lights?

*Never* *1* *2* *3* *4* *5* *6* *7* *Always* ☐

**2. TPB – Intention** To what extent do you agree to the following statement: "When it's dark I always try to use bicycle lights".

*Strongly disagree* *1* *2* *3* *4* *5* *6* *7* *Strongly agree* ☐

**3. TPB – Attitude** Cycling with bicycle lights during the dark I find …

*Very unimportant* *1* *2* *3* *4* *5* *6* *7* *Very important* ☐

**4. TPB – Behavioral belief** Do you think that traffic becomes safer when you use bicycle lights?

*Most unlikely* *1* *2* *3* *4* *5* *6* *7* *Most likely* ☐

**5.** Do you feel unsafe in traffic when you cycle without lights (by accident)?

*Never* *1* *2* *3* *4* *5* *6* *7* *Always* ☐

**6. TPB – Outcome evaluation** Improving traffic safety is …

*Very unimportant* *1* *2* *3* *4* *5* *6* *7* *Very important* ☐

**7. TPB – Subjective norm & Normative belief** Do you think that your friends and family feel that you should use bicycle lights?

*Most unlikely* *1* *2* *3* *4* *5* *6* *7* *Most likely* ☐

**8. TPB – Motivation to comply** To what extent do you agree to the following statement: “Normally speaking I behave according to how my friends and family think I should behave”.

*Strongly disagree* 1 2 3 4 5 6 7 *Strongly agree* ▢

**9.** What do you think is the level of the fine for not using bicycle lights?

______ *Euro* ▢

**10.** What should the level of the fine be in order to make you use your bicycle lights all the time?

______ *Euro* *Interviewer: tell the respondent what the level of the fine is.*

**11.** What do you think of the level of the fine?

*Low* 1 2 3 4 5 6 7 *High* ▢

**12.** Imagine yourself cycling through the municipality of Tilburg for one hour during the dark. You don’t use bicycle lights. With what probability do you think the police will catch you?

______ *Percent* ▢

**13.** Do you think that you at this moment live up to the legal norms with regard to bicycle lights? Interviewer: does the bicyclist live up to the law? Yes / Incomplete conform/ No

*Yes (go to 14) / No (go to 15)* ▢

**14.** I will give you five possible reasons for using bicycle lights. Can you indicate which one is the most important to you? And which reason hereafter? A “1” is the most important reason. *(Go to 16)*

| | |
|---|---|
| Traffic safety | |
| Social pressure | |
| The legal obligation | |
| The level of the fine | |
| The probability of being caught | |

**15.** Can you indicate why you do not use bicycle lights?

______________________________________________ ▢

**16.** Do you have any practical problems that trouble the use of bicycle lights? Which are they?

________________________________________________________________ ☐

**17. TPB – Control belief** To what extent do these practical problems trouble you when using bicycle lights?

*Don't trouble me at all 1 2 3 4 5 6 7 Trouble me a lot* ☐

**18. TPB – Perceived power** To what extent do you agree to the following statement: "The practical problems make the use of bicycle lights for me a lot more difficult". ☐

*Strongly disagree 1 2 3 4 5 6 7 Strongly agree*

**19. TPB – Perceived behavioral control** To what extent do you agree to the following statement: "I'm capable of using bicycle lights". ☐

*Strongly disagree 1 2 3 4 5 6 7 Strongly agree*

**20.** Do you think that you will use bicycle lights more often when you notice the police are inspecting more?

☐ *Yes* ☐ *No* ☐ *No, I'm always using my bicycle lights* ☐

**21.** Image that, in contrast to the previous question, cycling without bicycle lights is no longer being punished. Do you think that you will use bicycle lights more often?

☐ *Yes* ☐ *No* ☐ *No, I'm always using my bicycle lights* ☐

| Age: | Gender: | Driver's license: |
|---|---|---|

| Remarks: | ☒ No opinion |
|---|---|

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