

# TraLIS

Traffic Light Information System

ITS 1 – Final Report



Enschede, October 27th 2009

Rolink, N. (Niek)	S0116351
Homan, T.C. (Thijs)	S0115495

## Contents

1. Introduction.....	3
2. Research Questions.....	4
3. Questionnaire results .....	5
3.1 Design .....	5
3.2 Functions .....	6
3.3 Costs .....	7
3.4 System acceptance .....	8
3.5 Conclusion .....	9
4. Description TraLIS.....	10
5. ICT elements and communication.....	11
5.1 Communication .....	11
5.2 ICT Elements.....	11
6. Traffic Impact.....	12
6.1 Simulation description.....	12
6.2 Statistical calculation for lower penetration rates.....	12
6.3 Effects on Acceleration.....	13
6.3.1 Effects of 100% penetration.....	13
6.3.2 Effects of lower penetration rates .....	14
6.4 Delay time.....	15
6.4.1 Effects of 100% penetration.....	15
6.4.2 Effects of lower penetration rates .....	16
6.5 Number of stops.....	16
6.5.1 Effects of 100% penetration.....	16
6.5.2 Effects of lower penetration rates .....	17
6.6 Conclusion .....	17
7. Risk analysis.....	18
8. Overall conclusion .....	20
9. Recommendations.....	19
References.....	21
Appendix A: Questionnaire .....	22
Appendix B: Communication Scheme Von Arnim, Arief & Fusée (2008).....	28

## 1. Introduction

Because of the growing traffic density on the secondary roads there is much stop-and-go traffic at traffic lights. The deceleration and acceleration of cars at traffic lights has a negative influence on the traffic flow and the environment. Cars that have to stop and then have to accelerate will contribute more to the bad air quality than cars that can drive constantly. The stopping and going of cars also causes a shockwave and this will influence the traffic flow negatively; more cars have to decelerate and accelerate.

To get more constantly driving and passing cars at traffic lights we developed an Intelligent Transport System (ITS) which is called TraLIS (TRAffic Light Information System). The system TraLIS gives information about how to make it at green at a traffic light. This system is an in-car device which get information from the traffic light about the time till green and the system knows what the distance to the traffic light is. The system provides information about the speed that the driver has to drive or about the remaining time till green, so that the driver do not have to stop and a few seconds later has to accelerate again. The goal of this system is to make the traffic flow before the controlled intersections more smooth and because of this, the situation has to be better for the traffic flow, the environment and the safety.

## 2. Research Questions

The research question of this project is:

“Is the TraLIS an improvement for the situation on the network?”

There are several sub questions, which together has to give an answer at the research question. The sub questions are very wide of category. The sub questions have to make clear what the driver wants, what necessary is to make it work and what the influences of the system are.

- What does the general driver think of such a system?
- What is the best way to introduce this system?
  - Does this system have to be a stand alone, or in the navigation or dashboard?
  - Does the system have to give speed or time till green?
- What elements are necessary to make this system work?
- What are the impacts of this system on the traffic situation?

### 3. Questionnaire results

In the questionnaire (see appendix A) there were 186 respondents. The gender of the respondents is almost 50/50. The respondents that filled in the questionnaire were mostly young people, 76% was between 18 and 25 years old. And also most of the respondents don't drive many kilometers a year. It is not a perfect sample of the population, but it is good enough for the research.

#### 3.1 Design

The respondents like the system that is integrated in the dashboard the most (figure 1). This one is chosen by most of the people (58%) and is also rated mostly positive and very positive. They also think positive about the system that is integrated in a navigation system. The other two systems were not popular and are also negatively rated by the respondents.

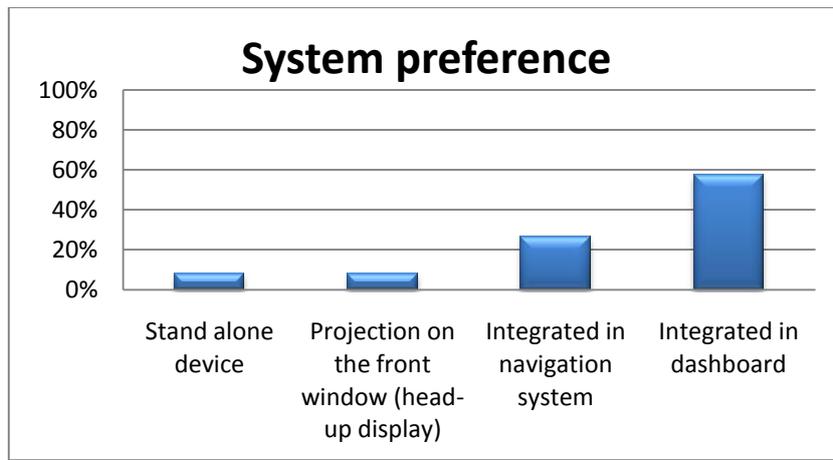


Figure 1

There were also 2 questions about the provision of the information. The first was about if respondents prefer a suggested time or the time that is left before the traffic light turns red again. The second was about if they want the information to be displayed constantly or just 1 time. In figures 2 and 3 is shown what the respondents prefer.

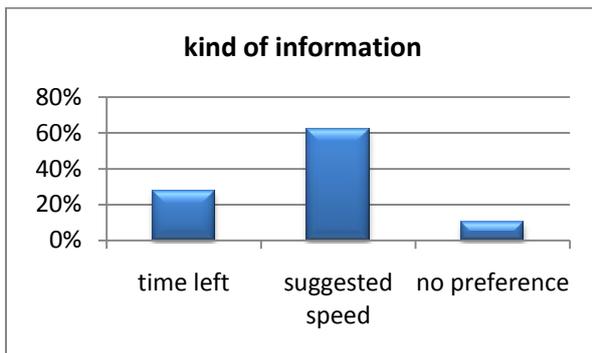


Figure 2

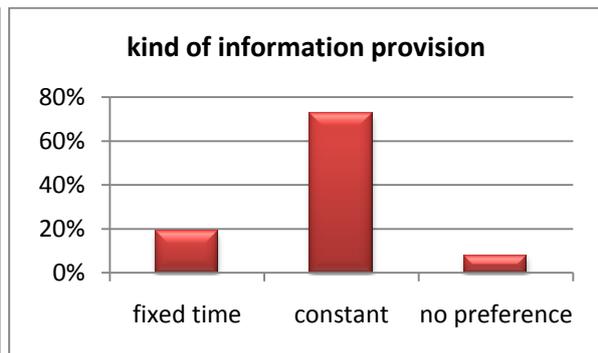


Figure 3

The respondents do want information about the speed they have to drive (62%) and they want it to be displayed constantly (73%). The respondents also rated the type of systems separately: the information of time left is rated positive, but a suggested speed is rated very positive. The respondents do not like the one time only provision of information, this is rated negative. The information that is constantly displayed is rated very positive.

The conclusion of the design questions is that the respondents like a system that is integrated in the dashboard. Also a system that is integrated in the navigation system is positively rated. When developing the TraLIS system those both systems should be considered. Integration in the dashboard is mostly liked, but is only possible in new cars. Integration in navigation systems will ensure a higher penetration rate on the market.

The information that should be displayed is a suggested speed at which the person will pass the traffic light at green. This information should be displayed constantly. That is what the respondents of this questionnaire want.

### 3.2 Functions

In figure 4 is shown in what kind of information about the directions people want. Almost all the respondents (72%) like the option of information about the direction in which they are going only. In order to provide this information TraLIS should be linked to their navigation system. There is also asked about how the respondents rate the both types of direction information. The respondents really like the information of their route only; this is rated mostly positive or very positive. The type of information about all routes is not liked and not disliked either.

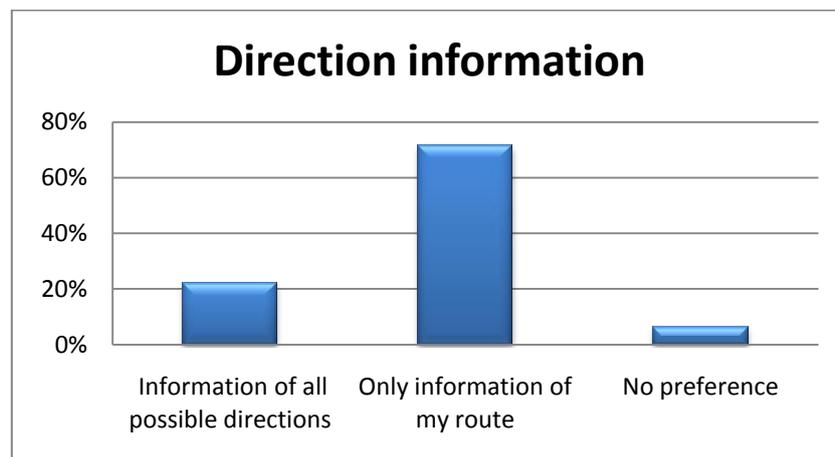


Figure 4

Another possible function of TraLIS was about rerouting when there is no possibility for getting a green light at the upcoming traffic light. The results of this question are shown in figure 5. In this figure is shown that most people like a rerouting function (72%), but only if it is quicker. There were also a couple of respondents that don't want such a function. The reasons of this group of respondents are:

- More emissions because of a detour/ bad for environment
- It will probably not save time
- More stress for drivers / more dangerous

The biggest part of the respondents did like the reroute function, so this function should also be included in TraLIS (probably as an optional one).

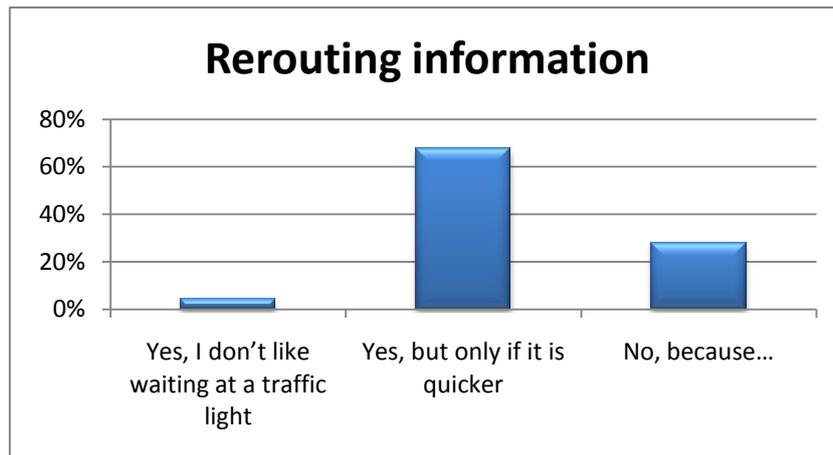


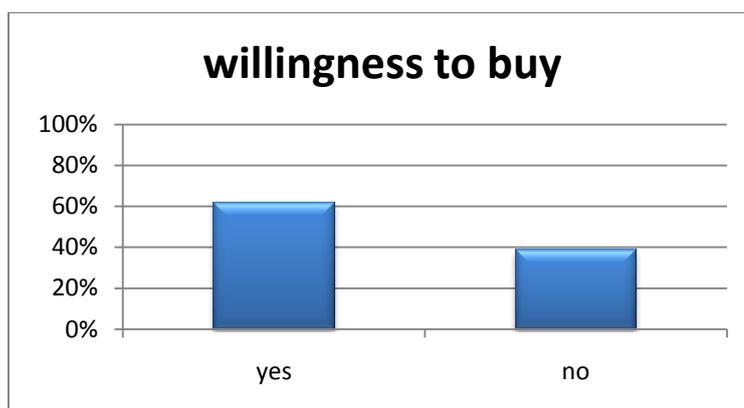
Figure 5

### 3.3 Costs

The first question was if people are willing to buy this system. Almost 40% said that they do not want to buy this system. This is shown in figure 6.

In the other question about the costs is asked how much people want to pay with different steps of improvement in waiting time. This is shown in figure 7. How brighter the lines, how more improvement in waiting time. It is clear to see that the top of the distribution move to the right, when the improvement is higher. This means that more people want to pay more, if their advantage is bigger.

In the previous question, 40% of the people said that they do not want to buy TraLIS. But in the question about willingness to pay, there are only 4 persons, who do not want to pay for every step of improvement. So this is contradictory. The conclusion can be made that people do not want to buy TraLIS, but filled in a price with the next question, which they think is reasonable for that improvement.



3.4

Figure 6

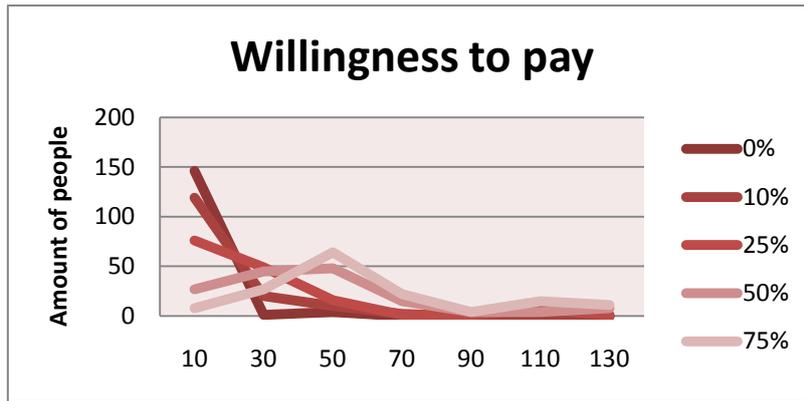


Figure 7

In the previous question, 40% of the people said that they do not want to buy TraLIS. But in the question about willingness to pay, there are only 4 persons, who do not want to pay for every step of improvement. So this is contradictory. The conclusion can be made that people do not want to buy TraLIS, but filled in a price with the next question, which they think is reasonable for that improvement.

We also asked the respondents to choose between different alternatives. In this question there were three options and also three attributes, namely the amount of stops, the travel time and the fee. The results of this question were not what we expected, because the results were not logical and contradictory to normal conditions. That is the reason why we disregarded these results.

### 3.5 System acceptance

The system acceptance is tested with the Van der Laan scale. This scale exist out of 9 questions, where you have to rate it on a Likert scale, for example at the one side useful and at the other side useless. These answer get a score of -2 to +2, where +2 is the most positive answer. The 9 questions can be divided into two groups, the questions related to satisfaction and the one related to usefulness. In figure 8 the average of the answers are shown, where blue represents the usefulness and red represents the satisfaction.

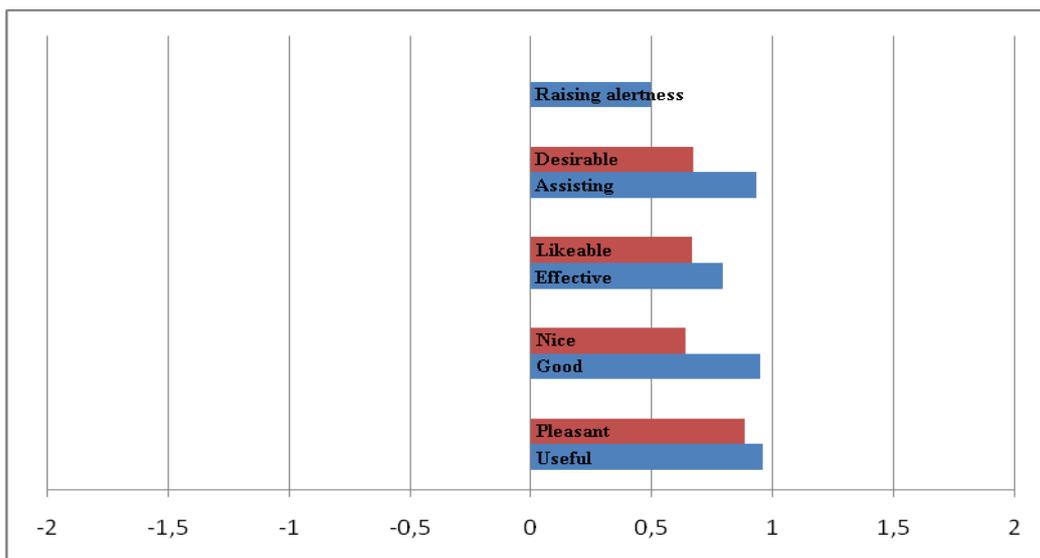


Figure 8

### **3.6 Conclusion**

The people who filled in the questionnaire are mostly young people who do not drive very much. But because there were a lot respondents, we can use the answers of the questionnaire. The people are like the system most when it is integrated in the dashboard, but to get a higher penetration rate, it has to be considered to provide it also in the navigation system. The people like constant information about their own direction. The function to reroute the people has to be optional, because most people like it when it is quicker, but not everyone, so it has to be their own choice.

The people rate the system positive at the van der Laan scale, and they think it is useful as well as satisfying. More than half the people want to buy this system, but the amount of money they want to pay depends on the advantages they get. The optimal price can be determined when the effects are estimated.

## 4. Description TraLIS

The TraLIS will be integrated in the new cars, in the dashboard or in an integrated navigation system. Because the implementation process will be slow, it has to be combined with a system which can be integrated in a navigation system. The system has to be linked with the navigation in the car, because the system has to know in which direction the car is going, so it can provide the car of his personal information. This information will be the advisory speed and it is dynamic information.

The advisory speed can be split up into three parts.

- If the car can reach the traffic light at green with the maximum speed, it will show the maximum speed
- If the car has to slow down to reach the traffic light at green, this advisory speed will be shown, unless it is lower than the minimum speed
- If the car cannot make it at green within the constraints, the system gives information about the fact that it cannot reach it. For the traffic situation it is better to slow down the vehicle, even if it cannot make it through green, but we think it is not acceptable to slow down the vehicle if it not can pass the traffic light at that speed.

## 5. ICT elements and communication

The elements which are needed depend on the communication which will be used. So the communication is described first and then the necessary elements are described.

### 5.1 Communication

The communication system which will be used is the KAR (Korte Afstand Radio, which is Dutch for short distance radio). This is based on ultrahigh frequency modems, which has a reach up to 1000 meters. This system has to be combined with global positioning system (GPS). If the GPS notices that the vehicle is close to a traffic light, it activates KAR. KAR will send a message to the traffic light that he is driving towards the traffic light. The traffic light sends a signal back to the vehicle with the information about the remaining time till green. So the position is determined with GPS and the information about the traffic light is send with KAR from the roadside unit of the traffic light towards the vehicle. More research is needed about the accuracy of GPS. If it is not precise enough it has to be combined with another system, like the system described in a report of Von Arnim, Arief and Fusée (2008). This system will work with infrared and the Zigbee smartdust sensor, which is based on radio communication to determine the location and speed of a vehicle. See also appendix B for a picture for the communication scheme of this system.

### 5.2 ICT Elements

The elements which are needed for this system are first of all a traffic light and a roadside unit which can communicate with each other. This roadside unit has a wireless connection with the vehicle via KAR, so the vehicle and the roadside unit both must can send and receive information. Therefore a modem and a antenna is necessary. The vehicle also has to have a GPS connection. Therefore needed is a satellite and a GPS device in the car. At last an in board unit with TraLIS is needed, to calculate and provide the advisory speed. In figure 9 a basic scheme of the communication between the elements is shown.

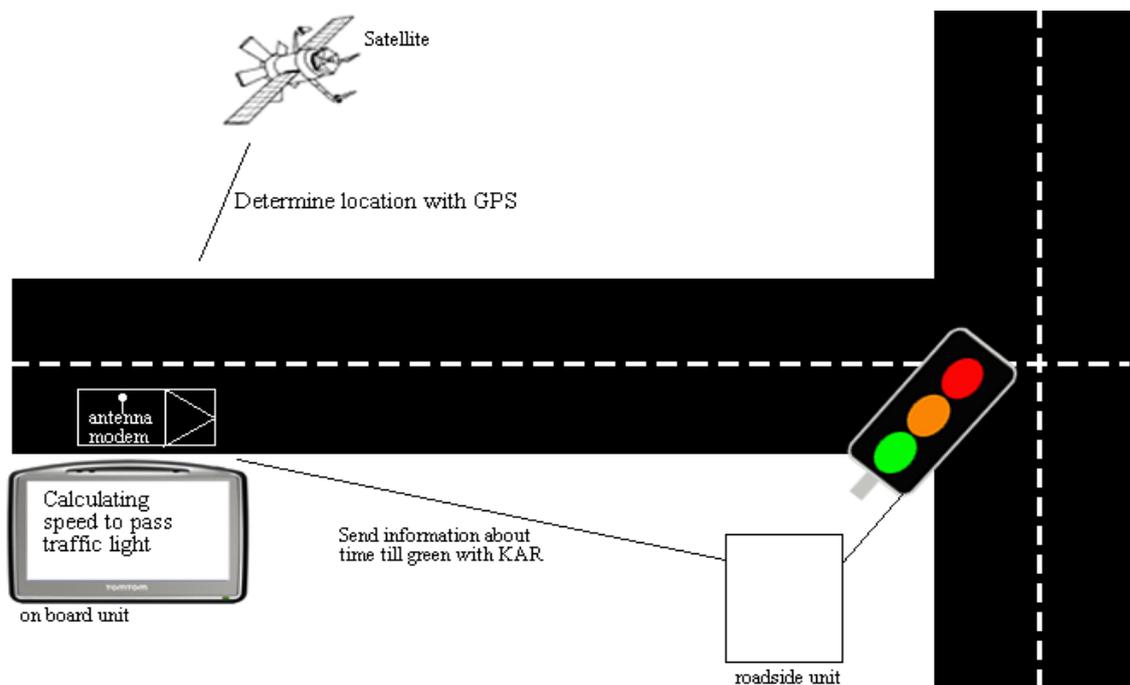


Figure 9

## 6. Traffic Impact

In this chapter the impact of TraLIS in the traffic situation is given. This is simulated with Vissim first and extend with a statistical analysis.

### 6.1 Simulation description

In order to simulate the traffic impact of TraLIS in Vissim, we had to make a network that approaches the effects of the system the best. To do this, we made a single lane road of 2 kilometer (so overtaking is not possible) with a traffic light at 1500 meters, this is shown in figure 10. The traffic light has a cycle time of 120 seconds with a green time of 60 seconds and a red time of 60 seconds. The density is 500 vehicles an hour and the maximum speed is 50 km/h. There were 2 types of simulations: one without the implementing of TraLIS, which was the reference case and one with the implementing of TraLIS with a penetration rate of 100%.

For the simulation without the TraLIS system implemented, we did not change the simulation as described above. For the simulation where the system is implemented (penetration rate of 100%) we set speed limits with which we could control the speed of every single vehicle. This speed limit can be set per second, so we could control all the vehicles individually. This is the same as giving information of a suggested speed to the vehicle and accordingly the vehicle follows this advice.

In this way we could simulate the traffic effects for the TraLIS system with a penetration rate of 100%. Using the measurements of this simulation and the measurements of the simulation without TraLIS we estimated the traffic effects of the system. Furthermore, we also used some analytical approaches for estimating the traffic effects of lower penetration rates (50%, 25% and 12,5%), because a penetration rate of 100% only exists in a ideal situation and will never happen in real life.

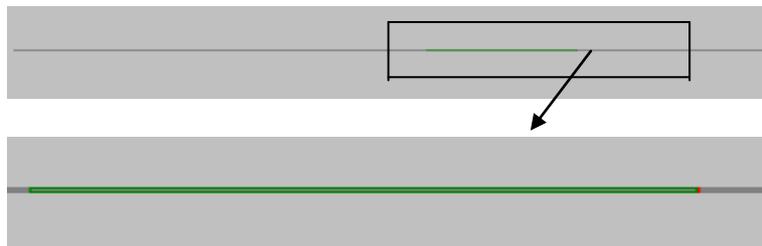


Figure 10: Reduced speed area towards traffic light in Vissim

### 6.2 Statistical calculation for lower penetration rates

The effects in Vissim are with a penetration rate of 100%. To estimate the effects with a lower penetration rate, some statistics is done first.

If a string of cars drive with the maximum speed to the traffic light, the car with the TraLIS system is able to drive the speed which is advised, because this will never be higher than the maximum speed, so he can slow down if necessary. The cars behind this car, also have to slow down and they benefit from the car in their front. The conclusion is made that in an urban area, every car behind the car with a TraLIS system, benefits from the car in the front

In a rural area this will be not the case, because the headways are larger. The assumption is made that one car behind a car with the TraLIS system benefits from the system.

The statistic is done by calculating all the possible sequences. For example if the penetration rate is 50%, 4 of the 8 cars will have TraLIS. This means that there are  $8 \text{ nCr } 4 = 70$  possible sequences. Then is calculated how many cars will have benefit from the system. If it is known how many cars have benefit from the system, it can be made relative by dividing it by the total amount of cars and then the relative effect, with respect to a 100% penetration rate, is known.

A small part of the statistic is given below, for a rural area with a penetration rate of 50%. The one is a car with TraLIS and the green cars have benefit of the system. In the parenthesis is shown (cars with benefit/ total amount of cars):

00001111 (4/8)  
 10101010 (8/8)  
 11110000 (5/8)

The results for these statistics are:

	12,5%	25%	50%
Rural	23,44%	43,75%	75%
Urban	56,25%	75%	90%

Table 1: Effects with respect to 100% penetration rate

The result of this analysis is that there are a lot more cars which benefits from the system than the amount of cars which actually have the system. Especially in the urban areas the effects are really high, even with a low penetration rate.

In the next chapters, the effect of a 100% penetration rate is determined with the simulation model Vissim. When those effects are known, the effects for a lower penetration rate can be determined with the results of this statistics.

### 6.3 Effects on Acceleration

For this situation we only looked at the vehicles (which drive the maximum speed) that approach the traffic light at red time just before a green light and those who will approach on the traffic light at green time. In the simulation there are exactly 10 vehicles that are covered by these conditions. These are the 10 vehicles of which the acceleration and deceleration is described. First the effects are described of the simulation with TraLIS implemented with a penetration rate of 100%. After that, the effects of lower penetration rates are described.

#### 6.3.1 Effects of 100% penetration

In this paragraph the traffic effects are described of a situation where the TraLIS system is implemented at a penetration rate of 100%, this is compared with the situation without TraLIS. The data is from the Vissim simulation as described above.

In figure 11 is the acceleration of the vehicles shown in the simulation without TraLIS. Here you can see that there is much acceleration and deceleration. There are lots of peaks, this is because many cars have to decelerate when approaching the traffic light at red and accelerate when the light turns green. Also some cars have to decelerate because of the queue before of the traffic light. The peaks for decelerating are between  $-2 \text{ m/s}^2$  and  $-5 \text{ m/s}^2$ , the peaks for accelerating are between  $1 \text{ m/s}^2$  and  $3,5 \text{ m/s}^2$ .

In figure 12 is the acceleration of the vehicles shown when TraLIS is implemented for 100% of the cars. In this figure you can see that there are less peaks then in the situation without TraLIS and the peaks have a smaller value. The peaks are also more distributed, the deceleration of some cars will begin earlier. The values of the deceleration peaks are between  $-1 \text{ m/s}^2$  and  $-3 \text{ m/s}^2$ , for acceleration these are between  $1 \text{ m/s}^2$  and  $3 \text{ m/s}^2$ .

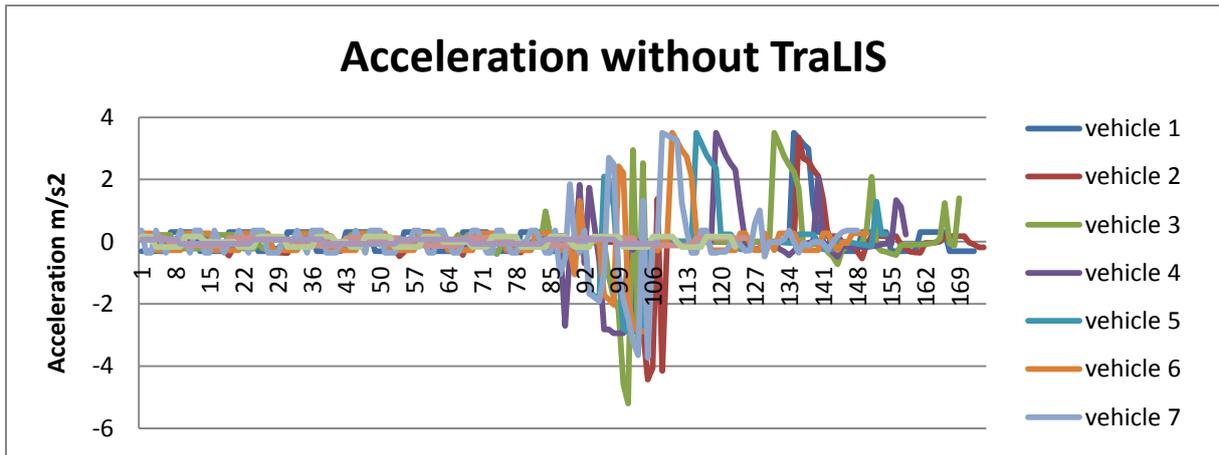


Figure11: Acceleration without TraLIS

So when TraLIS is implemented with a penetration rate of 100%, cars have to decelerate and accelerate a lot less than in the simulation without TraLIS. Not only the number of accelerations and decelerations is less, but also the value is lower, this is particularly the case for deceleration. Although, the amount of the environmental benefits can't be derived from the simulation, it is known that there are fewer emissions because of less acceleration and deceleration.

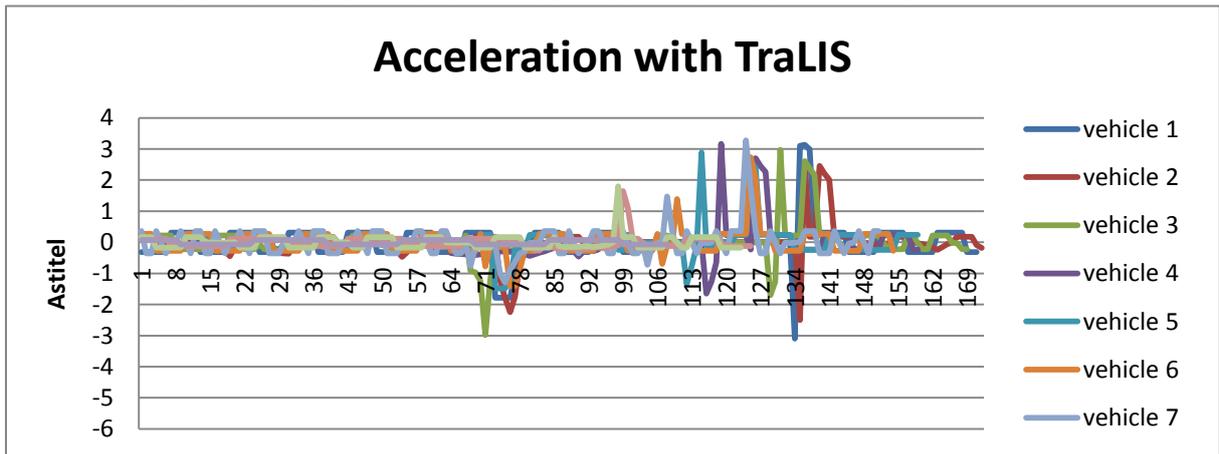


Figure 12: Acceleration with TraLIS

### 6.3.2 Effects of lower penetration rates

If the penetration rate is lower than 100% the effect on the acceleration and deceleration is also lower. As described in chapter 2, with a lower penetration rate, fewer cars will have the advantage of the TraLIS system. For acceleration this is of course the same. The effects of acceleration will be lower accordingly to the percentages described in chapter 2.

	12,5%	25%	50%
Rural	23,44%	43,75%	75%
Urban	56,25%	75%	90%

Table 2: Effects of lower penetration rates on acceleration

How the distribution of the acceleration and deceleration peaks would be in situations with lower penetration rates could not be simulated, but we assume that overall that the effects for acceleration and deceleration and of course the environmental benefits will be a bit lower (see the percentages above), but still good.

## 6.4 Delay time

First of all there is looked to the total travel time. But as expected, there is no significant improvement. This was expected, because people only can slow down, since the system will not give a speed higher than the maximum speed and the signal state of the traffic light will not change because of our system. So the only small improvement in travel time is the fact that you are not losing time with accelerating from 0 to 50 km/h, but from, for example, 30 to 50 km/h.

Then there is looked at delay time. The delay time is defined in Vissim as the time which you have to wait for a traffic light, or the delay you get by driving behind a slower vehicle. The time which you "lose" by driving a lower speed towards the traffic light is not taken into account with the delay time. But since a minute driving is more accepted than a minute waiting, drive slower is an improvement if the car does not have to wait. So in this chapter the difference can be seen between the waiting time with and without a system.

### 6.4.1 Effects of 100% penetration

For every car the delay time is measured. This is shown in figure 13, where the delay time with and without a system is shown.

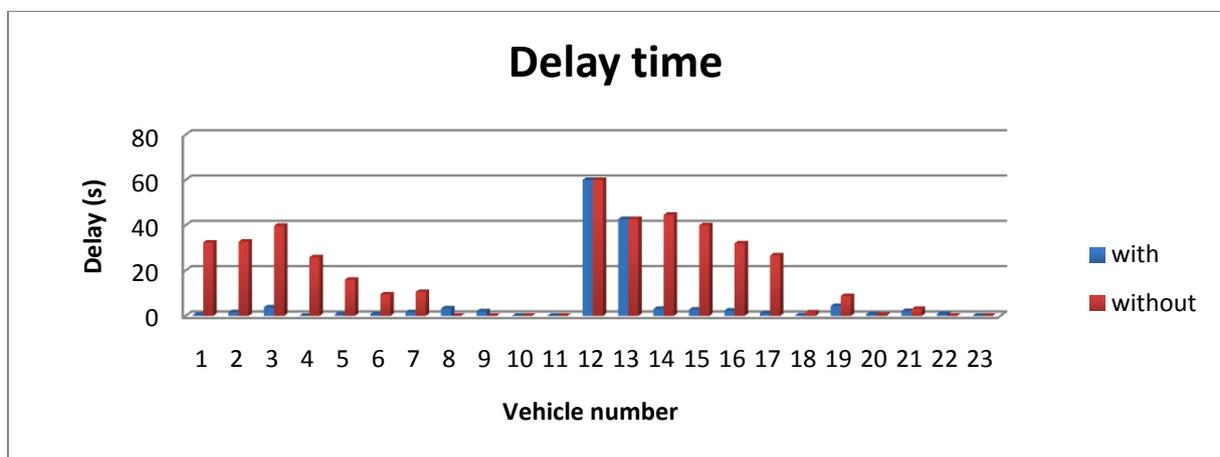


Figure 13: Delay time with and without TraLIS

It is obvious that the delay time without TraLIS is higher than with TraLIS. The red bars are very high compared to the blue ones. In the figure the red and the green time can be recognized by looking at the red bars. The first 7 cars have to wait for the traffic light, then 3 vehicles can drive without delay through the intersection. The cars 12 till 17 have to wait again and the other cars can drive with no, or a small delay ahead

The blue figure is very different. The first eleven cars can drive over the intersection without any significant delay. They drive slower, but they do not have to wait. The 12<sup>th</sup> and 13<sup>th</sup> car have no possibility, within the constraints of the speed, to reach it at green, so they have to wait as long as the cars without a system. Of course this delay time can be decreased by a lower advisory speed, but people would not accept to drive slower and also have to wait (even if the waiting time is shorter).

So the delay time of the people is decreased very much, except for the people who cannot make it within the constraints, and the delay time is also not decreased for the people who do not have to wait at all. Of the 23 cars in this simulation, 12 of them have almost the same delay time (10 of them has no or a slight delay in both cases), while eleven have a decrease in delay time.

The average delay time of these 11 vehicles is decreased from 28 to 1.5 second. So this is a decrease in delay of 95% for the vehicles which have an improvement. The improvement for all the traffic is from 18.6 seconds delay to 5.8 seconds delay. This is an improvement of 68.8%

### 6.4.2 Effects of lower penetration rates

With a 100% penetration rate, it is seen that the average delay is decreased with 68.8%. When the penetration rate is lower, the effect of TraLIS will also be lower. So the delay time will be higher with a lower penetration rate.

In chapter 3 the is calculated how many vehicles notices an effect of TraLIS with a certain penetration rate. In this case the effects will be proportional to the calculated effects. With 100% penetration rate the improvement in the delay is 68,8%. So if the urban area with 50% penetration rate has an effect of 90%, it will have an improvement of  $0,90 * 68.8\% = 61.9\%$ . The total table is given below.

	12,5%	25%	50%
Rural	16.1%	30.1%	51.6%
Urban	38.7%	51.6%	61.9%

Table 3: Vehicles which notices an improvement in delay time

In the table can be seen that in the urban situation the traffic notices a real improvement of the situation whatever the penetration rate is. A comment has to be made by this, when it is really busy and there is a long queue, the effect will be less, because the 400 meters will be not sufficient, so the cars which can have an improvement will be lower.

In the rural traffic network, a minimal penetration rate of 25% is necessary to make a real improvement in the traffic situation. This is the case, because even with a 100% penetration rate not every vehicle can make it at green, so if it is an rural situation it needs a higher penetration rate.

## 6.5 Number of stops

In this chapter the effect of TraLIS on number of stops is described. In this situation we run the simulation is such a way that the time of the simulation was three times the cycle time of the traffic light. In this way we could derive the number of stops of cars that approach the traffic light at all stages of the cycle time. In this chapter we first describe the effect of TraLIS on the number of stops of cars when TraLIS is implemented with a penetration rate of 100% and after that the effect of TraLIS is described when the penetration rate is lower.

### 6.5.1 Effects of 100% penetration

In figure 14 the difference between the situation with TraLIS and the situation without TraLIS is shown. Here you can see that without TraLIS 57% of the cars have to stop. In the situation were TraLIS is implemented only 9% of the cars have to stop. This, of course, means that the number of stops is decreased with 48%, which is a relative improvement of  $(1-9/57) 85\%$ . The effect of TraLIS with a penetration rate of 100% on the number of stops is really huge.

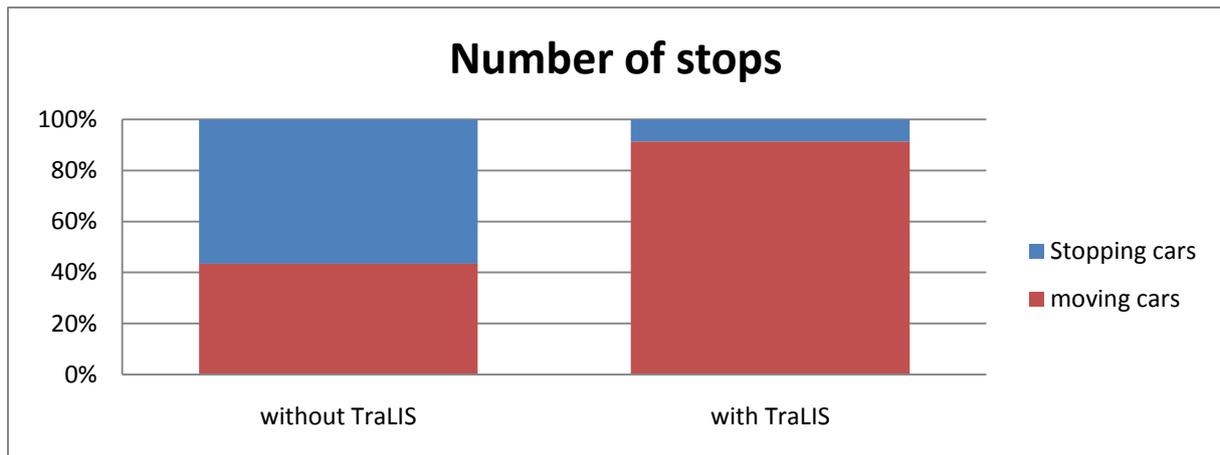


Figure 14: Number of stops with and without TraLIS

### 6.5.2 Effects of lower penetration rates

With a penetration rate of 100%, the amount of stops decreases with 85%. The effects for a lower penetration will also in this case be lower. The effects can be determined in the same way as the delay time, because the people who have benefit from the system will notices effects. In the table below the effects are determined. For example the urban situation with a penetration rate of 50% has  $0.90 * 85 = 76.5\%$  improvement.

	12,5%	25%	50%
Rural	19,9%	37,2%	63,8%
Urban	47,8%	63,8%	76,5%

Table 4: Vehicles which notices an improvement in delay time

For the amount of stops the conclusion is the same as for the delay time. This is not so surprising, because the delay time and the amount of stops are close related. The urban situation is good for all accounted penetration rates. In the rural situation a minimal penetration rate of 25% is required to have a noticeable effect.

## 6.6 Conclusion

TraLIS will have a positive effect on the traffic situation. It will decrease the number of stops and delay time and it will also decrease the acceleration and deceleration. It will not improve the travel time of the cars and also the capacity of the intersection will not increase because of TraLIS. So the conclusion is that TraLIS will not cause a higher throughput at the intersection but the flow before it will be smoother. It has a positive influence on the environment, because the acceleration will be less and this also might cause a safer traffic situation, because braking can cause collisions. TraLIS will influence the traffic situation positive, but the influence depends on the penetration rate of the system.

## 7. Risk analysis

In this chapter the risks of the project will be mentioned shortly. In such a project it is important to make a risk analysis because then the awareness is higher and it is easier to avoid or control the risk.

The first risk is a low penetration rate of the system. When the penetration rate is low, the traffic situation will not be effected that much. But for the user of the system, it still would have the same effect for his individual, because this system only gives a lower speed than the maximum speed and it is always possible to break. The likelihood of this risk is quite high, especially in the beginning, but the impact for the individual is low. The impact for the overall situation is not negative, but less positive. So this risk has to be controlled as much as possible, but is not critical.

The other risk has also to do with penetration rate, but with the penetration rate of the cooperative traffic lights. When a low share of traffic lights can connect with a roadside unit, the vehicles get information about just a few traffic lights. This impact is quite high, because if the system will work at a few intersections, nobody will use the system. The likelihood of this risk is low, because implementing a roadside unit is not that difficult.

Two risks which has to deal with the system itself are the fact of overreliance by a wrong advisory speed and distraction. Both are medium likely to happen, because people will be distracted with the system if it is not clear enough and if the advisory speed is wrong, it is likely that they pay no attention to the red light, or that they notice it to late. The impact of these two risks are high, because an accident might occur.

The first two risks have to be controlled and the penetration rate of the traffic lights and of the system has to be as high as possible, where the penetration rate of the traffic lights is way more important, because it has less impact. The last two risks have to be avoided, because an accident must be avoided at any time. This can be done by warning the people that it is still important to look at the traffic light and by creating a reliable system. There is more research necessary to know which way the speed has to be shown, in such a way that the distraction is as less as possible.

## 8. Recommendations

In the relative short time period, not everything can be researched. In this chapter, some recommendations are given to improve the quality of the report and to get a more complete view of TraLIS.

The first part which need some extra research is the traffic impact. A simulation is done with Vissim and for lower penetration rates a statistical method is used. First of all this is not a precise method to get the traffic impacts. It is a good indication to see if it improves some attributes, but the outcomes are not precise enough. With the external driver model in Vissim, the outcome will be more as in reality. Also different traffic situations have to be taken into account. More variation is needed in the cycle time and in the intensity. Also the single lane road is not realistic enough, because cars cannot overtake.

Another part of the project which need more research is the choice modeling part and the price study. In this report nothing can be said about the price of the system, because there was only one question about choice modeling in the questionnaire. So a better price study has to be done to determine the optimal price of the system.

The last important part which need extra research is the communication system which will be used. We are not sure if GPS is precise enough for TraLIS. In a navigation system GPS is precise enough, but in some literature it is said that the deviation of GPS can be up to 50 meters. If GPS is not sufficient to determine the location another method has to be taken into account, like the system that is described by Von Arnim, Arief & Fusée (2008), which consists infrared and the Zigbee smartdust sensor, which is based on radio communication.

## 9. Overall conclusion

In this research to a traffic light information system many things were investigated. These things are shortly mentioned in this overall conclusion.

The TraLIS system will be integrated in the new cars, in the dashboard or in an integrated navigation system. Because the implementation process will be slow, it has to be combined with a system which can be integrated in a navigation system. The information will be the advisory speed and it is dynamic information. The people rate the system positive at the van der Laan scale, and they think it is useful as well as satisfying.

TraLIS will also have a positive effect on the traffic situation. It has a positive influence on the environment, because the acceleration will be less and this also might cause a safer traffic situation, because braking can cause collisions. TraLIS will influence the traffic situation positive, but the influence depends on the penetration rate of the system.

We can say that this research gave much information about the TraLIS system. We think that this system definitely can be brought on the market. The technology is for this system is sufficient, people like the system and the traffic effects are also positive. Therefore we think after a bit more research, (like pilot projects etc. where the real traffic effects, users needs and satisfactory can be estimated) this system can be brought on the market many costumers will buy TraLIS.

## **10. References**

Von Arnim, Arief & Fusée (2008) *Cooperative road sign and traffic light using near infrared identification and zigbee smartdust technologies.*

## 11. Appendix A: Questionnaire

This questionnaire is about a new system called TraLIS (TRAffic Light Information System). This system will provide information in the car about the green time of a traffic light. When you are coming up to a traffic light, this system will tell you how many seconds it will take before it turns green or it will give a suggested speed at which you will pass the traffic light at a green light. The goal of this system is to get a better traffic flow at the intersections with traffic light, which is good for the traffic situation and it will improve the air quality. Another goal of this system is to provide a better route for the drivers, because they can avoid red traffic lights.

### 11.1 General questions

First of all there are a few general questions. These questions give information about you and your background. At this way we can analyze the results of this questionnaire in a better way.

Age:

- < 18
- 18 - 25
- 25 - 45
- 45 - 65
- > 65

Gender:

- Man
- Woman

Kilometers driven / year:

- < 5000 km/year
- 5000-10000 km/year
- 10000-20000 km/year
- > 20000 km/year

## 11.2 Design

We can provide TraLIS to you in several designs. The following questions are used to make the best design and provide the information to you in the best way.

This system can be provided in various ways (see figures beneath).



Stand alone device



projection on front window



Integrated in navigation system



integrated in dashboard

Please choose the option you prefer:

- Stand alone device
- Projection on the front window (head-up display)
- Integrated in navigation system
- Integrated in dashboard

The system can provide the information about the time that is left till the traffic light turns green, or the system can give information about the speed you have to drive to make it through green. Which type of information do you prefer?

- Time left
- Required speed
- No preference

The time the information is provided can also be done at fixed time/distance before the traffic light, or the information can be given constantly, which one do you prefer?

- Fixed information
- Dynamic constant information
- No preference

Please give your general opinion of the following subjects. Where 1 is very negative and 5 is very positive.

Subject	Very Negative 1	Negative 2	Undecided 3	Positive 4	Very Positive 5
<b>TraLIS as:</b>					
<i>Stand alone device</i>					
<i>Projection on the front window</i>					
<i>Integrated in a navigation system</i>					
<i>Integrated in the dashboard</i>					
<b>Information given by:</b>					
<i>Time left</i>					
<i>Suggested speed</i>					
<b>Provision of information:</b>					
<i>Dynamic (all the time)</i>					
<i>Fixed (one time only)</i>					

### 11.3 Functions

The next couple of questions are about the functions of TraLIS.

The information that you need from the traffic light depends on your direction at the signalized intersection. This can be done in two ways; you will get information of all the possible directions (left turn, straight ahead and right turn) or TraLIS can be linked to your navigation system and you will only get the information of the direction of your route.

Which type do you prefer?

- Information of all possible directions (independent of navigation system).
- Only information of my route (linked to navigation system).
- No preference

There is also a possible function related to rerouting. When TraLIS notices there is no possibility to make it on time at the traffic light, it can reroute you to avoid the traffic light. Would you use this function?

- Yes, I don't like waiting at a traffic light
- Yes, but only if it is quicker
- No, because...

Please give your general opinion of the following subjects. Where 1 is very negative and 5 is very positive:

Subject	Very Negative 1	Negative 2	Undecided 3	Positive 4	Very Positive 5
<b>Type of information:</b>					
<i>Information of all possible directions (independent of navigation system)</i>					
<i>Only information of my route (linked to navigation system)</i>					

### 11.4

## 11.5 Choice modeling

In the situations below there are given three possible options where you have to choose the one you prefer the most. The possible options are:

- The first option is that you do not have the system at all.
- The second option is the basic TraLIS, this can give you information about your speed/time to make it through the traffic light.
- The third option is the advanced TraLIS, this is the above system with the extension which can give you personal information about your direction and can give information about a small, but quicker, detour to avoid red traffic lights.

	No TraLIS	Basic TraLIS	Advanced TraLIS
Amount of stops	No improvement	-50%	-75%
Travel time	No improvement	-5%	-6%
Fee	0	€40	€50

## 11.6

### 11.7 Costs

These questions will be about the economical aspect of TraLIS.

Are you willing to buy TraLIS?

- Yes
- No

TraLIS is better for the general traffic flow and it is also good for the environment, because there is less pollution. What are you willing to pay for the system if it decreases your waiting time with the following percentages?

Percentage	Amount
0 %	€
10 %	€
25 %	€
50 %	€
75 %	€

Because there is an improvement of the traffic as well as the environmental situation, what do you think of subsidizing this system by the government?

## 11.8 System acceptance

The last questions are about the acceptance of the system, so please rate the aspects below at a scale of 5. So at the first one you have to choose if you find the system: very useful – useful – undecided – useless – very useless.

- 1 Useful           |\_|\_|\_|\_|\_| Useless
- 2 Pleasant       |\_|\_|\_|\_|\_| Unpleasant
- 3 Bad             |\_|\_|\_|\_|\_| Good
- 4 Nice            |\_|\_|\_|\_|\_| Annoying
- 5 Effective       |\_|\_|\_|\_|\_| Superfluous
- 6 Irritating      |\_|\_|\_|\_|\_| Likeable
- 7 Assisting      |\_|\_|\_|\_|\_| Worthless
- 8 Undesirable   |\_|\_|\_|\_|\_| Desirable
- 9 Raising Alertness |\_|\_|\_|\_|\_| Sleep-inducing

-

12. Appendix B: Communication Scheme Von Arnim, Arief & Fusée (2008)

