A Design Research on Temporary Traffic Measures in the Urban Roadwork Environment Based on a Scenario-based Design Methodology

Author

Chen Mao

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Chairman

Mascha van der Voort

Supervisor

Anouk Geenen

Mentor from company

Frans Taselaar

Master Thesis of Industrial Design Engineering

UNIVERSITY OF TWENTE.

hompe en taselaar

Falculty of Engineering Technology (ET)


BUKO.

Abstract

As renovations develop in Amsterdam Zuidas, numerous roadworks have become a severe concern to a livable urban environment. Traffic measures have been essential subjects determining roadwork status. Even though many studies have learnt about related infrastructural issues, the impact of roadwork traffic measures on user experience—cycling, walking and driving is not clear. Filling the research gap is a touchpoint to understand stakeholders' dilemmas and demands for the design research. The research aims to understand the user experiences of target users, to provide design requirements for improving this experience during road construction.

The project applies a scenario-based design methodology to clarify how traffic measures affect the stakeholders' user experiences. This methodology decentralizes design powers and invites stakeholders to participate in design processes. Employing scenarios in nine expert-interviews helps gain in-depth knowledge and organize vibrant scenarios of their routines. A co-design session took place with five participants and two facilitators, in forms of keeping diaries and creating storyboards. Two storyboards, in consequence, contain present and future scenarios and produce valid requirements for design opportunities.

The design research identified vital stakeholders—cyclists, pedestrians, residents and civil engineers, who are of strong influence and interest for design success. In scenarios, users indicated that frequent problems result from losing orientation and collecting indicative information with difficulties in roadwork areas at night. Subsequently, stakeholders proposed design requirements of easy light, interactive map and traffic signpost, to provide clear guidance for traveling in detours. Also, the excessive use of traffic measures is one of the major issues, which necessitates the idea of less is more. As a result, a composite of requirements translated into a final concept—vegetated traffic guide.

The scenario-based design methodology is sufficient to make explicit road users' dilemmas and design implications of improving the traffic measures. The co-design, combined with scenarios, helped participants reflect experiences and create solutions. Still, tight schedules constrained the creation of high-quality scenarios. An evaluation with a stakeholder reveals that the design contributes to a safer and human-friendly atmosphere by illuminating guidance during relatively long-term roadworks. However, future works are required to verify the reliability of the concept.

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Introduction

1. Introduction

1.1. Background on traffic measures

The rapid growth of business concentration, educational institutions and residential areas in Amsterdam Zuidas reflects constant renovations in this new metropolitan district (Stok, Tempel & Huisman, 2019). Situating at between Amsterdam city center, Schiphol airport and Amstelveen, Zuidas has already shown ambition to be a major sustainable hub for financial business, research, education, and residence in the Netherlands. The place is changing rapidly, considering buildings popping up and public space maintenance (Amsterdam Zuidas Informatiecentrum, 2016). Recently, developers set a goal to realize 290,000 m² for office space, 585,000 m² for homes and 340,000 m² for amenities yet to be constructed until 2030 (Amsterdam Zuidas Informatiecentrum, 2019).

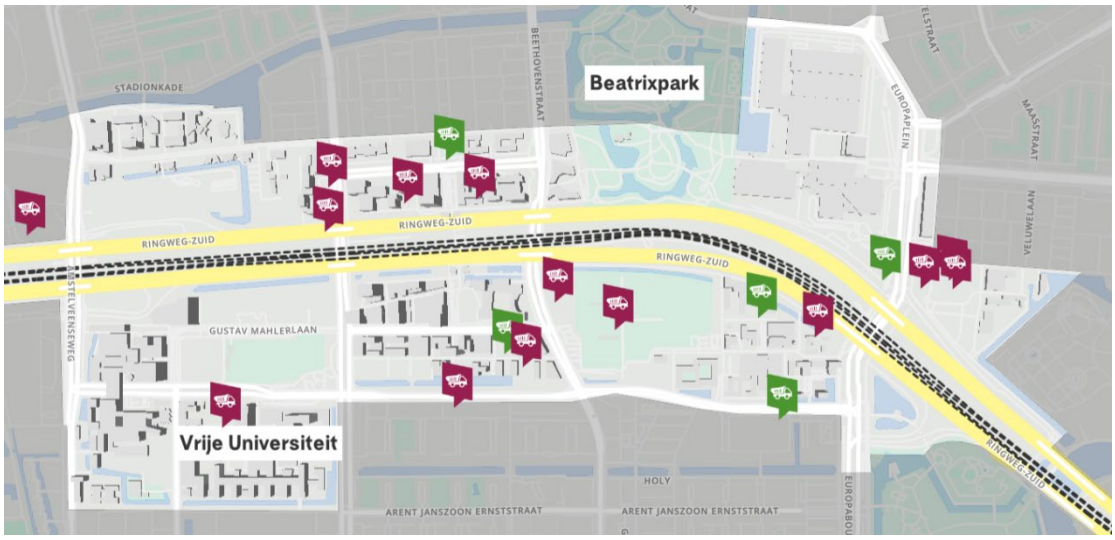


Figure 1. Construction projects in Amsterdam Zuidas in March, retrieved from Amsterdam Zuidas Informatiecentrum website (2020)

With numerous construction works in progress at the same time, figure 1 shows a large amount of urban space taken up by roadworks and traffic measures around (Amsterdam Zuidas Informatiecentrum, 2020). Traffic measures, understood in this project as traffic calming measures, use white and red striped boards and traffic cones in combination with other measures like concrete barriers. They are used to prevent traffic from going off the road into prohibited areas (Karim, H, 2012) and to contain speeding and unsafe conditions for road users and workers during district roadworks (Caves, 2005). Conceptually, the term “roadwork” refers not only to road repairing works, but also to inevitable construction works carried out in road space. Today, roadworks predominantly employ traffic measures to sustain the order and safety within work areas to cope with corresponding construction works.

Guidelines and requirements have been provided for civil engineers to manage traffic within roadwork area, typically known as 96, 96a and 96b published by CROW. These guidelines for work in progress contain indications of potential working risks to roadside safety and provide policies and requirements for temporary traffic measures to guarantee the safety with a proper design of roadworks (CROW, 2017). Additional requirements called BLVC (in Dutch) framework, standing for accessibility, safety, livability and communication, are given to prevent construction nuisance (Amsterdam Zuidas Informatiecentrum, n.d.). With these, contractors make use of temporary traffic measures to enclose the roadwork area and to arrange traffic flows, for carrying out the project as safely as possible, with minimal disruption and clarity for road users (Rijkswaterstaat [RWS], 2005).

1.2. Problem statement

Complying with the guidelines, contractors are capable of conducting roadwork with minimum disruption to the environment (Rijkswaterstaat [RWS], 2005). However, disruption in roadworks has been a major concern to engineers and road users. Numerous studies illustrate that safety in roadworks is more severe than in other periods (Pigman & Agent, 1990; Kraay & Dijkstra, 1989). Traffic measures, as shown in figure 2, couple with a variety of traffic control infrastructures in urban space; they cause traveling frustration and non-compliance with traffic regulations (Debnath et al., 2014). In particular, there has been an inconsistency between guidelines and practices; it poses potential hazards to the wellbeing of people and harms to human-centered environments, featured by narrowed space, limited movement (Conteh & Oktay, 2016), blocked sight, and social severance (Bradbury, 2014). In our context, the social severance demonstrates negative effects the traffic measure brings about, such as limiting people's social interaction and access to services. (Tate, F.N, 1997). Rather than creating a place for road consutrcution, the improper use of traffic measures may cause confusion, hesitation and risk of accidents, especially at night (Welsh Assembly Government, 2009).

The insight into the impact of roadwork traffic measures on the user experience of driving, cycling and walking is not clear. Even though numerous research has tried to improve temporary traffic measures, the majority of these researches employed traditional approaches based on traffic accident data, barrier containment experiments, numerically simulated comparisons. Of these trials, related stakeholders did not fully involve in decision-making processes, but classically through scattered interviews and video monitoring. Considering the needs of high quality of urban life during construction, the human-centered development must be considered to ensure the safety of an area and to make it functionally and visually effective for road-users.

Figure 2. Traffic measures in the day time. Captured by the author in Sept. 2019

1.3. Research scope

The scope of this design research is to define the impact of traffic measures on the user experience—driving, cycling and walking and traffic measures development. Provided that road users are the major stakeholders outside the engineering parties, they usually have to cope with roadwork planning rules. Although the roadworks are unavoidable during development, the street livability and roadwork quality can be improved. Given this, the research incorporates a scenario-based design methodology and co-design to understand stakeholders' dilemmas. In this, scenarios accumulate evidence for the balance between the utilization of traffic measures and the user's experience. Research results, in the end, will suggest a design of the temporary traffic measures to resolve identified issues and to achieve desired scenarios—temporary traffic measures are functionally and visually effective to road users.

For better understanding, visual effectiveness in this context concerns how easily the user can see, understand and find out information they want. It mirrors the effectiveness that users can use information for their goals (Carey et al. 2014, p. 421). The term "traffic" mainly refers to both motorized and non-motorized users, and the term "road-user" ultimately indicates the non-motorized users- cyclists, pedestrians and residents.

Following the previous sections, a main design research question arises:

"How can we ensure that temporary traffic measures can improve the work area as human-friendly public space that is safe, understandable and visually positive for road users and city image during the roadworks?"

To answer the research questions, several sub-questions are outlined:

1. What are the relevant stakeholders in the use of temporary traffic measures?

2. What participatory design method is appropriate to support the involvement of stakeholders in the design process?
3. What are the problems with traffic measures for roadworks?
4. What design strategy optimizes the traffic measures such that it meets the requirements of the design research?

1.4. Thesis structure

Chapter 2. A literature review is performed to acquire knowledge regarding traffic barriers regulations, road user's behaviors, roadwork studies, barrier material development and alternative design strategies. The understanding unfolds current situations of traffic measures under roadwork guidelines, indicating a research gap between current research scopes and traffic barriers in roadworks.

Chapter 3 introduces a scenario-based design methodology to fill the research gap. The method includes multiple design research techniques - expert interviews, explorative scenarios, personas and a co-design session. A complete co-design session consists of cumulative diary-keeping and a co-design event. An analysis method is used to reflect on research results.

Chapter 4 reveals the results produced by applying the methodology stated above. Scenario-based design approach provides rounded scenarios of using traffic measures. Two storyboards from the co-design, highlight several solutions in future settings. In consequence, the results indicate a requirements map.

Chapter 5 patterns four design ideas by prioritizing requirements in the requirement map. Through an analysis, four design ideas arise: temporary lights, interactive maps, traffic signposts, vegetated traffic guides. Each idea represents a distinct emphasis on problem-resolving solutions in response to the needs of stakeholders.

Chapter 6 selects the vegetated traffic guide as a final concept. The concept prototype incorporates the easy light and uses green elements to improve current traffic measures. A certain roadwork setting for the design concept reinforces the connection to the external green environment.

Chapter 7 evaluates the design research methodology and the final solution, based on criteria and a physical prototype with an engineering stakeholder. The evaluation provides critical perspectives towards research processes and the solution.

Chapter 8 A conclusion is made to reflect the extent to which the methodology supports defining design requirements, and the final concept can meet these requirements. The conclusion

recommends the potential application of research outcomes and suggests future works to support the concept realization.

Literature review

2. Literature review

2.1. Introduction

This chapter exhibits relevant research in the field of traffic measures and analyzes essential results. Being a useful knowledge basis for this project, the literature review classifies present research studies in four categories: traffic measures integration, road users' behaviors, application of traffic measures, and traffic measures innovation. Of these, a research gap is found when traffic measures are applied to a temporary roadwork context. There is not sufficient evidence to fill this gap, specifically considering the aspects of accessibility, safety, livability and communication.

2.2. Integrated traffic measures

Research into traffic measures uncovers urban infrastructural frameworks, which concern a variety of problems in different natures. Sas-Bojarska et al. (2016) analyzed public infrastructural objects like roads, railways, which are found to generate problems on their surroundings. The problems encompass the damage of a city's fabric and functionality and the threat to its environment and landscape. A regulatory analysis proposed a guideline to support the effectiveness of traffic control system, in ways of improving traffic recognizability and reducing the speed of vehicles at crossings and separating traffic flows to prevent collisions (Lu, Wevers & Bekiaris, 2006). To promote the traffic safety for road users, Dutch traffic professional developed a concept "Duutzaam Veilig", treating road safety as a basic quality for traffic environments, to avoid serious accidents (Weijermars & van Schagen, 2009). This concept emphasizes on building safe traffic conditions to provide support, in line with road users' capabilities. Another study in road construction safety identify an inconsistency between roadwork guidelines and actual practice, due to the cost of traffic measures in competitive tendering, lack of proof for the effectiveness of traffic measures and pressures to minimize disruption in public space (Debnath et al., 2014)..

Residential streets are not only a place for parking facilities and accessible destination for residents and visitors, but also a place with more functions for social interaction (Kraay & Dijkstra, 1989). Triggered by the situation, in which motorized traffic takes up plenty of space urban space, Kraay and Dijkstra (1989) acknowledged the connection between behavior-influencing techniques and road safety and amenities. Here amenities are considered safer traffic conditions, human-friendly facilities and less nuisance in a street. They verified that area-geared measures are more effective than incidental measures for traffic safety and amenities. Thereafter, Sas-Bojarska, A. and Rembeza, M. (2016) classify the influence of motorized traffic

on public spaces classified into four aspects: spatial and functional; environmental; visual and compositional; social.

2.3. Road users perceptional behaviors

Of all influential dimensions, user's perceptional behaviors are one of the dominant concerns in traffic infrastructure research. Results from an early analysis imply that road users are inclined to cross at a certain location where pedestrians facilities are properly designed (Sisiopiku & Akin, 2003). While they are unlikely to walk in a certain route and to undertake certain activities in unfavorable traffic conditions (Hine and Russel, 1993). It is because an increase in barriers safety would reduce the comfort of people in use (Carsten, Sherborne & Rothengatyter, 1998). Availability of the pedestrian's facilities, for example signals, crosswalks and midblock influence the crossing behaviors at a specific location with a high rate of 74%(Sisiopiku & Akin, 2003). Furthermore, the latest findings shed a light on the joint perceptions of traffic conditions and their influences on walking and health conditions. People with physical restrictions are unlikely to undertake activities and have opportunities to fulfill the need of their lives, referred to as mobility impairments (Strohmeier, 2016). There is another group of people who could not move freely within traffic barriers. It is referred by (Victoria Transport Policy Institute [VTPI], 2019) to barrier effects—a description of "delays discomfort and lack of access" that vehicle traffic brings for nonmotorized modes.

A surprising feature of an engineered situation is the incompatibility between transport engineer's planning and road users' behaviors, such as walking, cycling and driving (Strohmeier, 2016; Walker & Calvert 2015). The phenomenon existing in urbanization development encourages high pedestrian activity, referenced as a standard transportation mode in major urban roads (Hine& Russell, 1993). Constant and Lagarde (2010) contend that space-sharing helps to build effective and friendly urban landscape for pedestrians characterized by "vulnerable" social groups. Also, cyclist's behavior is firmly dependent on the design of cycling infrastructure planning. For example, abnormal behaviors, like disrespect to the traffic law, are liable to occur when traffic planning comes to complicated solutions of cycling infrastructure and in case of its discontinuity (Cieśla, et al., 2018). Walker & Calvert (2015) also found an incompatibility between transport engineers' roadwork planning and drivers behaviors.

However, an evaluation on numerous interviews (Strohmeier, 2016; Sammer et al., 2012; Bundesministerium für Verkehr, Bau und Stadtentwicklung, 2012; Hieber et al., 2006) describes that there are a significant number of problematic traffic infrastructures in active service, including pavement curbs, short green light phase, uneven walking path, fewer lights, narrow pavements, mix-used lane, broken signage, less barrier-free access to destinations and such

like. The utilization of these facilities may become a threat to people's wellbeing. For example, Anciaes Paulo Rui. et. al (2016) identified the seriousness of social severance. It illustrates that traffic volume and traffic speed negatively correlate to the people's health conditions and walkability (Mindell and Karlsen, 2012).

2.4. Application of current traffic measures

The road safety measures have become research concerns since insightful research revealed their unsafe applications. Butāns et al., (2015) have explored an approach to improve road safety by investigation of several types of road constraint systems, such as concrete barriers, W-beam steel guardrail, cable median barriers, composite material barriers, and portable water-filled barriers. With the help of the PC-Crash computer program, the research simulated the crash test to reflect a crash mechanism in case of a car-to-barrier collision. The evaluation of performance of road barriers in different types, enlightens the classification of barrier containment levels for optimal situations.

Road guardrails are common traffic barriers over the world. Hussin (2012) argues that the guardrail should function as a shape of roadside and a reminder in dangerous zones. The guardrail is shown to have higher injuries rate for its dangerous fixed objects in vehicle accidents. When comparing impact damage, collapsible guardrails are considered safer than rigid guardrails because rigid guardrails cannot disperse the impact forces on both vehicles and barriers. However, steel guardrails in several research unfold a high fatalities rate of involved motorcycles (Yumrutas & Yorur, 2017). Despite a high barrier containment level and recyclable features (Butāns et al., 2015), concrete barriers could increase transportation costs and negative psychological effect on drivers (Yumrutas & Yorur, 2017).

The usability of barriers on motorized roads has been extended to many concerns in urban environments around the world. One research of the Global Cultural Districts Network (GCDN, 2018) recognizes a significant role to protect public safety from unpredictable attacks. Traffic barriers, regarded as street furniture, can help prevent and reduce the impact of terrorist attacks and minimize the injury rates near a protected area. Besides, road barriers have become a kind of effective measure of noise abatement and public furniture across Europe (Bendtsen, 2009, p. 5). The study highlights the importance of which barriers need to be adapted to the surroundings. Taking other road users into account, the study has pointed out the need to ensure an acceptable barrier space for road users to look at. Another recent study incorporates the vegetation into barriers structure, showing that noise reduction is possible with vegetated noise barriers for their positive noise absorption at the surface(Van Renterghem et al., 2012).

The environmental effects of road barriers, in other words, the influence of solid barriers on near-road and on-road air quality are examined by Baldauf, et.al (2016). They used analytical methods of mobile and fixed-site monitoring in the analysis of pollutant concentration influenced by noise barriers. The research identified that noise barriers can reduce pollutants for residents downwind of a road, but possibly increase traffic-related pollutants for motorists.

2.5. Development by innovation

In traffic measures research, only a few studies suggest state-of-art based on practical problems. Hussin (2012) made an improvement for W-beam guardrail, shown to reduce the weight of existing products while retaining a displacement below optimum working width. The design makes installation and maintenance processes easier for operators. Essawy. et al. (2013) carried out an alternative solution for production industries-hot mix asphalt (HMA) which reuses 5-15% of waste polypropylene and polyester and this solution might be an alternative way to produce concrete traffic measures. Among alternative engineering solutions, Van Renterghem et al. (2012) developed vegetated low noise barriers to reduce noise pollution in urban streets. Moreover, Yumrutas and Yorur. (2017) proposed a hybrid road barrier design to attain a more pleasant driving experience, whilst promoting the qualities of energy absorption and light blockage.

As long as the people-related issues of traffic measures stay unchanged, researchers have been trying out different ways to offer better traffic conditions for road users. The municipality of Amsterdam carried out trails of bicycle detour pink signs that strive for improving way-finding and information display for cyclists. The experiment was based on the analysis of cyclists' behaviors and perceptions. The design of pink sings with black text and higher frequency have gained positive feedback so far. Zeile et al. (2016) unveiled a new method to study and evaluate urban emotions in cycling experience. Researchers utilized a combination of parameters, for example, electroencephalogram (ECG), skin conductance and temperature as well as heart rate variability. Using this method of bio-physiological sensing, it is feasible to detect emotional feelings of places where cyclists felt unsafe and uncomfortable.

2.6. Conclusion

The literature review provides fundamental knowledge about area-geared traffic infrastructures and prospective innovations. The influence of traffic infrastructure design is discovered as unpredictable manners tend to occur under multiple traffic conditions. Several studies profoundly illustrate a systematic overview of traffic measures that contribute to traffic safety and fatalities rate reduction (Lu et al., 2006; Kraay & Dijlstra, 1989; Sas-Bojarska et al, 2016), and research identifies the patterns of behaviors of pedestrians and motorists associating road

barriers strategies and their surroundings (Hine and Russel, 1993; Carsten et al., 1998; Strohmeier, 2016; VTPI, 2019; Cieśla et al., 2018; Anciaes Paulo Rui et al., 2016). The research into the application of traffic measures provides a conglomerate of findings in diverse fields and their resultant performance (Butāns et al., 2015; Hussin, 2012; Yumrutas & Yorur, 2017). In line with the applications, several studies on traffic measures development give prospective ways of improvements, concentrating on recyclable materials (Essawy et al., 2013), vehicle containment level (Prochowski, 2010), easy maintenance(Hussin, 2012), environment (van Renterghem et al., 2012; Bendtsen, 2009; Baldauf et al., 2016) as well as pleasant driving and cycling (Gemeente Amsterdam, 2019; Zeile et al., 2016; Yumrutas & Yorur, 2017). The relationship between social severance and traffic environment is more evident when it correlates to vulnerable groups like impaired people and older people. Particularly, the walkability and accessibility to desired destinations play the paramount part for the wellbeing of elderly and impaired people as road users (Hine & Russell, 1993; Sisiopiku & Akin, 2003; Strohmeier, 2016; Anciaes & Jones, 2016; Karim, Magnusson & Wiklund, 2012b; Zeile, Resch, Loidl, Petutschnig & Dörrzapf, 2016).

Going back to our research, Kraay & Dijkstra (1989) acknowledge that the occupation of traffic space brings dangers to road safety, especially for pedestrians, cyclists and scooter drivers. Besides this, the classification of motorized traffic effects on public space contributes to evaluating the impact of roadwork traffic measures from few perspectives: spatial, environmental, infrastructural, social and visual (Sas-Bojarska & Rembeza2016). The information facilitates design evaluation on whether traffic measures in roadworks are being used properly or improperly. These two research reveal the efficacy of priority given to a coherent urban tissue and pedestrian-friendly landscape. To answer our research question, the urban planning strategy theoretically features a common ground in roadwork contexts, as both aim to create a human-friendly and coherent urban fabric where safety and comfort are guaranteed.

Hine and Russel (1993) provide a conclusion to suggest unfavorable traffic conditions, in order to increase traffic safety. This principle makes clear the layout of a roadworks site, where traffic infrastructure is likely to be overused for the “safety”. This implication is of significance to frame a road construction and to formulate desirable future scenarios. Besides, two research findings demonstrate the importance of vegetation for livability and noise absorption in urban streets (Van Renterghem et al., 2012; Yu. H, n.d.). For this reasoning, the vegetation probably benefits human-friendly space and mitigates the unfavorable effects of neighborhood roadwork constructions. Regarding the vegetation as an opportunity would also be advantageous in design phases.

On the contrary, the research into traffic measures for roadworks is rather scarce. Even though the motorized traffic infrastructures are thoroughly explored, traffic measures in roadworks still lack evidence in terms of road users' solid experience and consequent engineering performance. One research into developing safety barriers with automatic detection to support heavy truck lateral control in roadworks mainly concerns driver's experience which does not directly correlate to vulnerable groups (Wimmer, Weiss, Flogel & Dietmayer, 2009). Traffic measures are developing well for classic situations. Nonetheless, there is not much research classifies the difference between traffic measures use in typical streets and streets under construction. Even though roadworks strength the incompatibility between engineers planning and drivers' behaviors, the effects have not been captured accurately (Walker & Calvert, 2015). To continue, further tests are required to fill the gap between the current research scope and traffic barriers in roadworks.

Methodology

3. Methodology

3.1. Methodology selection

This chapter describes a methodology used for this design research. Because temporary traffic measures contain many variables in application, defining the approach was quite a challenge at the beginning. Considering complex use situations and a vast user base of traffic measures, centering stakeholders in design processes benefits achieving desirable results. An approach actively engaging stakeholders in the central roles of development is unique to participatory design.

Unlike traditional design methods centralizing powers in product development based on explicit knowledge (de Bont et al., 2013), the participatory design decentralizes the powers in the design process. The participatory design is proficient in specifying tacit knowledge and gathering rich user insights. When designing for a professional product in complicated contexts, a designer can compensate for his practical expertise and problem insights by incorporating stakeholders in the design research (de Bont Bont et al., 2013).

Many uncertainties and biases to the road users may occur in design practice. A measure of this challenge here is to use scenarios-based design and co-design approach. Design scenarios are an effective means of communication in cross-disciplinary research activities; they make communication easier for people from different professions and backgrounds. An advantage of the method can reflect a coherent storyline depicting possible contexts of user-product interaction, demonstrating critical concerns and explorative ideas by stories. Another advantage is that the methodology explores the new use of a product in future (Anggreeni & van der Voort, 2007). Scenarios depicting future narratives can produce more realistic product features than imagination and lay a solid basis for design opportunities.

Regarding that the traffic measure involves a composite of social stakeholders, a gathering of stakeholders and conflicts remains crucial in design. Through the co-design, designers and other stakeholders are able to develop the awareness of core issues and corresponding resolutions. Figure 3 describes the project methodology, based on the study of scenario-based product design (Anggreeni & van der Voort, 2007) and advanced design methods for innovation (de Bont, den Ouden, Schifferstein, Smulders & Van Der Voort, 2013).

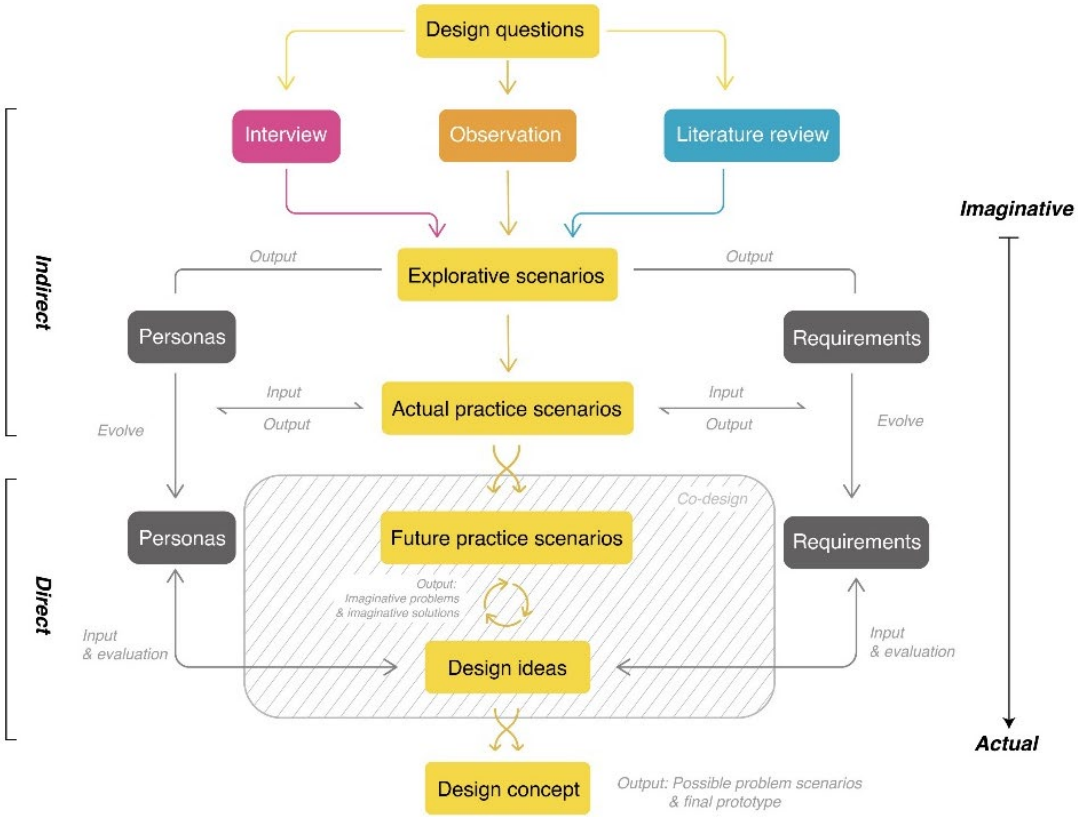


Figure 3. Roadmap of methodology, based on theories from Anggreeni and van der Voort (2007), de Bont, den Ouden, Schifferstein, Smulders and Van Der Voort (2013)

3.2. Scenario-based design approach

So far, this methodology has focused on the participatory design methodology. The following section will discuss the scenario-based design approach. As pragmatic methods to include interested stakeholders in processes, the road map roots in Scandinavian participatory design approaches in the nineteen seventies with the following characteristics: democratic design processes, explicit debates of product values and features, accept stakeholder's conflicts in design (Gregory, 2003). Our research uses multiple participatory design techniques—context-mapping, role-playing games, scenarios creation, persona building, etc.

In figure 3, several participatory design techniques are organized. In the early stages, ethnography research plays an essential role in collecting needed knowledge for producing general scenarios. Creating scenarios from early stages is necessary to facilitate a better understanding of different types of issues and user groups. A scenario is a descriptive design tool for both designers and stakeholders in research and design phases. The source of explorative scenarios comes from interviews, observations and literature review. Therefore, researchers can construct explorative scenarios to predict available hypothetical events pertaining to the use of traffic measures in a reasonable context.

As design study progresses, explorative scenarios, personas and requirements are available to develop actual practice scenarios. These scenarios reveal vibrant stories and requirements on a systematic level wherein surrounding settings, actors, traffic measures products perform in a vivid context. Actual practice scenarios capture elements relevant to commuting activities and problems based on contextual behaviors and reflections from participants (Anggreeni & van der Voort, 2007). In co-design, participants will enrich actual practice scenarios through co-design events. More importantly, actual practice scenarios are eligible to identify underlying dilemmas and requirements of users.

The scenarios creation, if successful, will contribute to feasible future scenarios and requirements, enabling design ideas, likely in forms of prototypes and possible problem scenarios in evaluation. To ensure the feasibility and affordability of design concepts, the researcher will apply requirements to design ideas production and final concept evaluation.

3.2.1. Stakeholder analysis

Based on the scenario-based design method, stakeholder analysis could contribute to defining and understanding the dilemmas of key stakeholders. In the beginning, it is hard to identify a precise sort of user groups owing to intricate stakeholder connections; an integrated method is in demand to specify interests, latent conflicts, and relations in between. Once the stakeholders are defined, the design team needs to analyze them based upon their interests and the importance of these stakeholders to the success of the design project (MacArthur & John, 1997).

The analysis follows four steps: identify stakeholders, create a stakeholder map, identify stakeholder allegiance, create a stakeholder management strategy (MacArthur & John, 1997). Stakeholders who influence the use of traffic measures can be roughly outlined. As for intricate user relations, a useful method called stakeholder classification matrix comes into use (B. Levitan, 2014). A spectrum grades the features of influence and interest in nine segments. Seven segments are of less importance, but two segments in the upper right are paramount to the project (figure 4). The position of each stakeholder will be reflected in the matrix diagram (B. Levitan, 2014). Results, in the end, would suggest a stakeholder matrix that allows designers to identify a stakeholder management strategy.

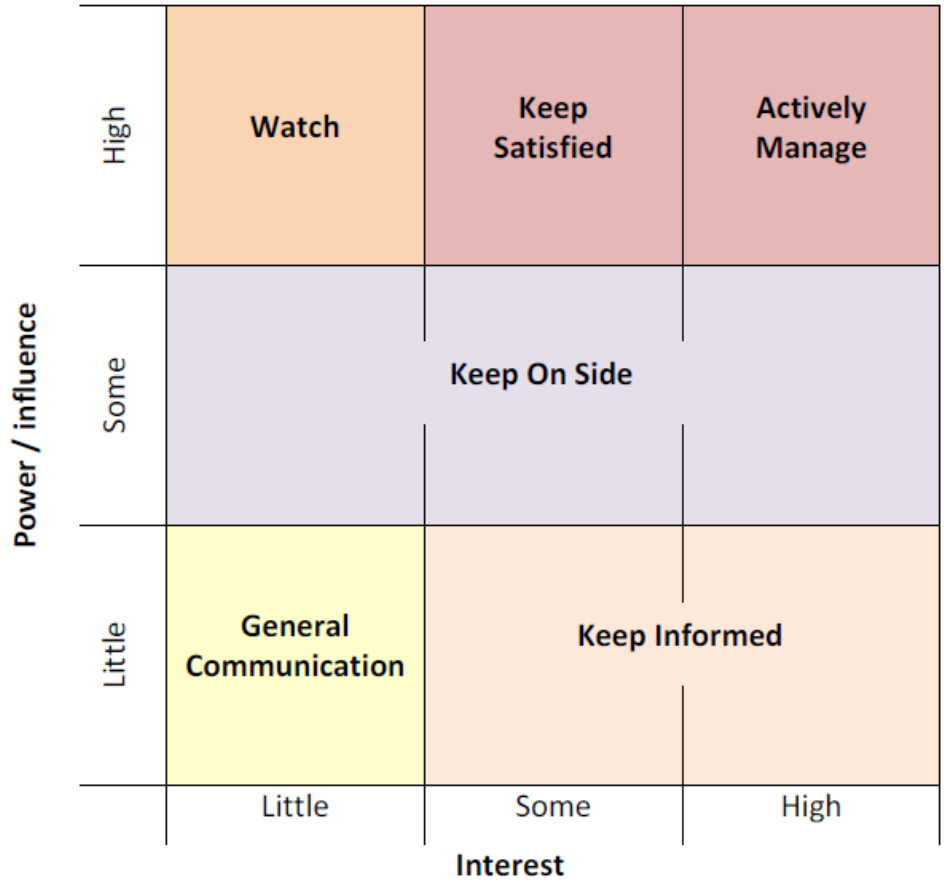


Figure 4. Blank stakeholder matrix classification regarding interest and influence, reprinted from B. Levitan (2014)

3.2.2. Expert interview

As far as stakeholders are concerned, a pragmatic way to understand the problems, networks and aspirations of stakeholders is to talk with them directly (IDEO, 2015). An interview is the crux of inspiration processes, in which a designer starts having connections with individuals and their specialized knowledge. Experts can always give you the information in-depth and latest breakthroughs on a systematic level—including organizational investments, technical parameters, new materials and guidelines made for traffic measures.

To successfully interview stakeholders, the designer has to do preparations, such as conversation starters, questions, data-recorders and even small gifts for interviewees. The researcher could start with technical stakeholders and road-users, as they directly associate with traffic measures. The designer needs to arrange step-by-step interview guidance. The questions for stakeholders are experience-oriented and are substantially broad and elementary. Second, questions would turn to their current activities and possible problems in their recent

memories. Third, interview questions should go from nonspecific to specific and from abstract to actual.

However, conventional techniques such as interviews, observations and literature review can limit people's perspectives on their past and current experience (Visser, Stappers, van der Lugt & Sanders, 2005). The conventional techniques are short on involving stakeholders in design processes (figure 5). The field of stakeholder's perspectives tends to be ill-defined in the beginning. To overcome these, collaging comes into use in interviews—collages capture participant's minds from surface to deep thinking. Once the collage is created, the participant becomes motivated to explain the meaning of chosen images related to their personal experience.

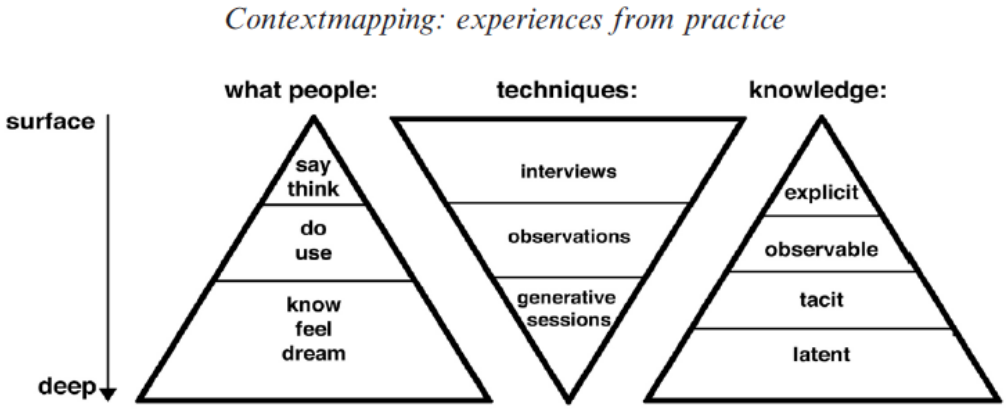


Figure 5. Different levels of knowledge about experience assessed by different techniques, reprinted from Visser, Stappers, van der Lugt and Sanders (2005)

3.2.3. Case study

In terms of heavy reliance on contextual use situations, a traffic measures case is imperative to the research. As a result of longer time-span and space availability of road construction, the case study is chosen in the major intersection of Hobbemakade, as illustrated in figure 6. The case area on the edge of Amsterdam Zuid connects three roads of van Hilligaertstraat, Stadionweg, and it is an important traffic route leading to the other Zuidas areas.

When we visited here, the road construction had been going on for a month, depicted in figure 7. Nearly all distributor roads were partly blocked, occupying space from functional roads. Crossing the area from Stadionweg, a visitor might see yellow signposts telling a time length and diversions. Furthermore, a large number of beacon barriers could be seen throughout the area. They separate one-way bike lanes into two lanes and prevent road users from entering work zones. Behind the entrance, steel barriers with beacon barriers closed pedestrian routes. Inside, traffic barriers appeared on sidewalks from time to time. They were made of stainless

steel and plastics. The intersection was enclosed by several kinds of traffic measures, leaving a small space for pedestrians, cyclists and vehicles. In this limited space, an accessible way crossed the motorized road and concrete barriers area. In contrast, a sidewalk was reopened beside the cycling path without any protective measures. When going out of the work zone, the visitor could see numerous beacon barriers at roadwork exits.

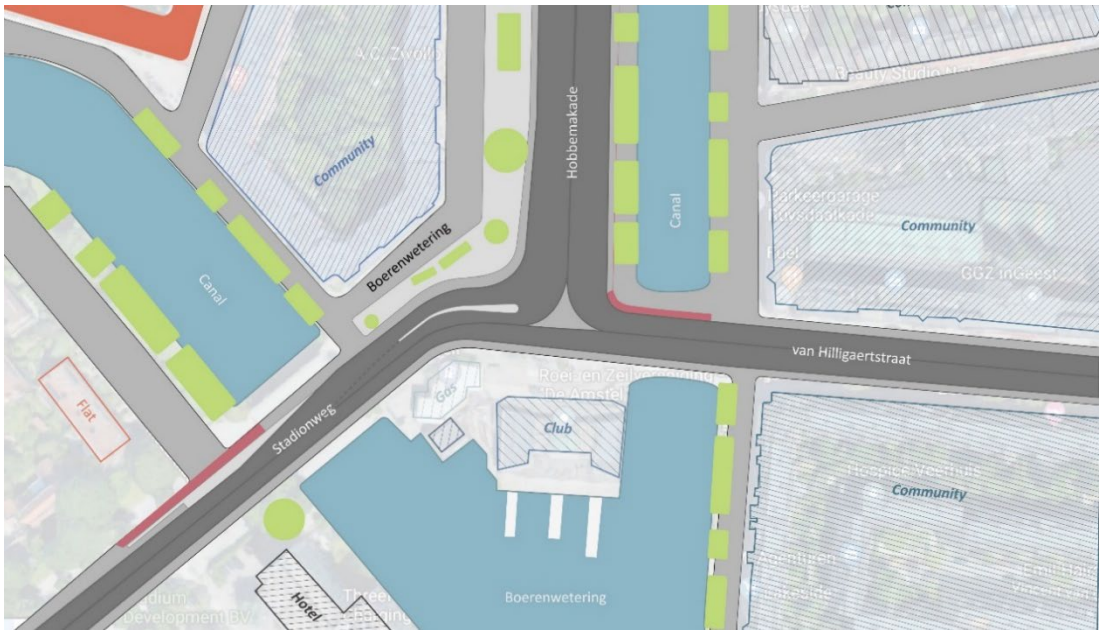


Figure 6. Studied site: Hobbemakade under normal conditions. Adapted from google map

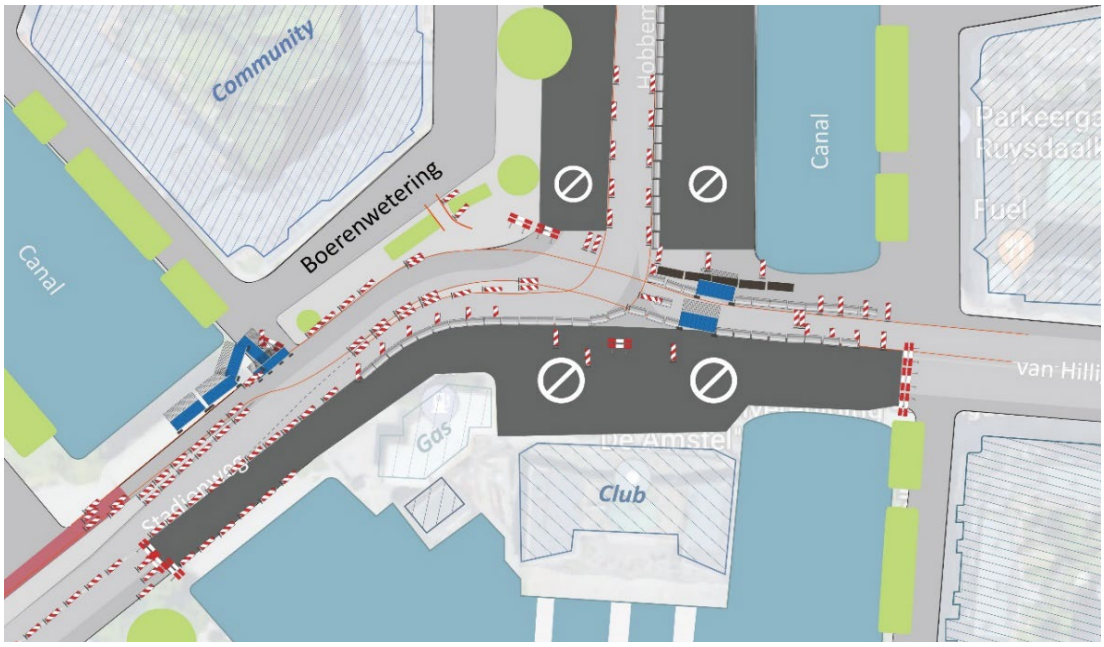


Figure 7. Studied site: Hobbemakade roadworks circumstances on 30, September 2019

3.2.4. Personas

Personas are fictitious, specific and concrete representations of target users (Pruitt & Adlin, 2006, p. 11). A persona is an aggregate of a group of users who share common behavioral characteristics and might live in similar atmospheres (Pruitt & Adlin, 2006). Generally, a persona is the abstraction of features of target users in a narrative form, which aims to make the 'person' like a real person and to provide a vivid story regarding the needs of the persons in a context (Miaskiewicz & Kozar, 2011).

Concerning the participatory design of traffic measures, it is vital to take stakeholders into account. The personas of critical stakeholders are created based on the data collected from the ethnography research. The first draft of personas was made during the beginning of ethnography research and developed in scenarios as the project progresses. When developed concretely, personas contribute reference to reflecting stakeholders' personality and design decisions.

In the evaluation phase, personas are practical to validate a design concept. It is a rather useful tool when individuals' presence is not available in the evaluation. Personas mirror normal persons who experience the holistic storyline of scenarios. Therefore, the designer can evaluate whether the design concept meets the potential requirements.

3.3. Co-design

Co-design is one of the most practical ways to provoke stakeholders in innovative activities actively. It is appropriate to the project context in which multiple societal parties are engaged and conflicting with each other. The co-design offers a platform for them to reach an agreement on concept generation in an early stage of design processes; it allows interferences of stakeholders to justify a design track. Combined with scenarios, the co-design contributes justified contexts to design ideas. Co-design session is going to specify the goals in:

1. Obtain the insights of user experiences of interacting with traffic measures
2. Explore the design of traffic measures in roadworks
3. The design will further the roadworks area to be people-friendly urban spaces where it is safe and visually positive for road users.

At present, ample evidence shows that design studies progressively use both techniques in the front-end of participatory design activities. In this iterative path of expression (Sanders & Stappers, 2012), figure 8 presents a revised framework of generative techniques (Sanders & Stappers, 2014). Probes in the fuzzy front end sensitize users to the traffic measures in environments, in the ways of recording, expressing and envisioning about their lives. Even if

designers cannot speak to them all the time, participants would acquire enough information to engage in the co-design.

In the co-design session, a design toolkit enables meaningful communication delving into deeper layers of issues. Following this, participants can co-create an artifact. In view of this, this research adopts both long-term diaries and storyboard, created in two stages (see Appendix C). The design diaries here intend to sensitize participants to lived experiences, facilitating understanding of current situations and recording ideas from ongoing roadworks (Visser et al., 2005). While creating storyboards visualizes scenarios for a design concept.

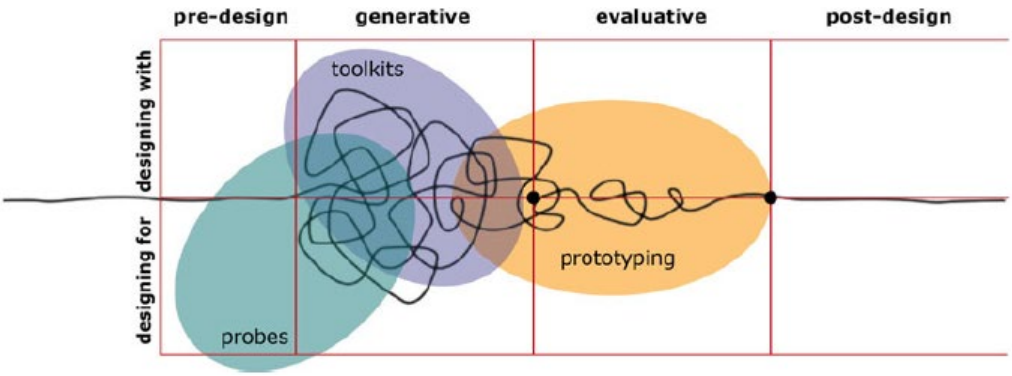


Figure 8. The positioning of generative techniques in the participatory design process, reprinted from Sanders and Stappers (2014)

3.4. Data analysis

In an example of a common approach, Visser et al. (2005) offer a means of data-orientated analysis by collecting, patterning and translating data. This method is useful to collect multi-layered scratches of data for analysis. In this project, we adopt this method improved by Corbin and Strauss(1990) who uncover underlying indicators and requirements.

The first step is to fixate on the data—fragmentary information in forms of notes, video clips, diaries and storyboards. The data gathering by audio recordings, video recordings and handwriting captures data fragments. Data documentation involves reviews of conversations and written notes of intriguing ideas. As a result, relevant data transforms into meaningful scripts.

Having acquired research data from design processes, we will search for principal patterns in clusters. This step aims to figure out frequent contextual practices of traffic measures use. In consequence, the stakeholders' choice, road user-traffic measures interactions and future product use might determine design requirements.

At last, those requirements mapped out from data analysis will manifest basic data patterns;

they translate requirements into a requirement map. The map will describe requirements clustering by similar features and following connections amongst different clusters.

Results

4. Results

This chapter describes the results of the scenario-based design research and the co-design session. The scenario-based design research results mainly describe empirical findings for the research gap, in ways of rounded scenarios and design requirements. Reflections on both research sources suggest a requirements map.

4.1. Scenario-based design results

4.1.1. Stakeholder analysis

The stakeholder analysis identifies new insight of stakeholders who associate with traffic measures for roadworks. In response to the first research sub-question, preliminary research characterizes three sorts of stakeholders. Regarding each category below and their associations, appendix A details the identification of five aspects—politics, technology, legal system, society and ecology.

1. Target groups: pedestrians, cyclists and civil engineer
2. Second peripheral stakeholders: municipality, project coordinator, contractor, scooters, motorists and policeman
3. Third peripheral stakeholders: construction workers, licensors, guideline-makers, Institute for road safety research and NEN

As mentioned in the methodology, figure 9 demonstrates the stakeholder classification matrix. The target stakeholders, at the upper right corner, have strong influence and interest in the design research. The second peripheral stakeholders have medium importance in supporting and realizing design in reality. While the third peripheral stakeholders remain less important of lower interest and influence.

The stakeholder analysis suggests the management of stakeholders. The results recommend that the design research has to actively manage the stakeholders who have the highest interests and prominence in traffic measures design. For those who have little influence and interest, the research maintains general communication with them. However, the criteria for evaluating stakeholders depend on the project's assumed interest and importance, not on actual situations of society.

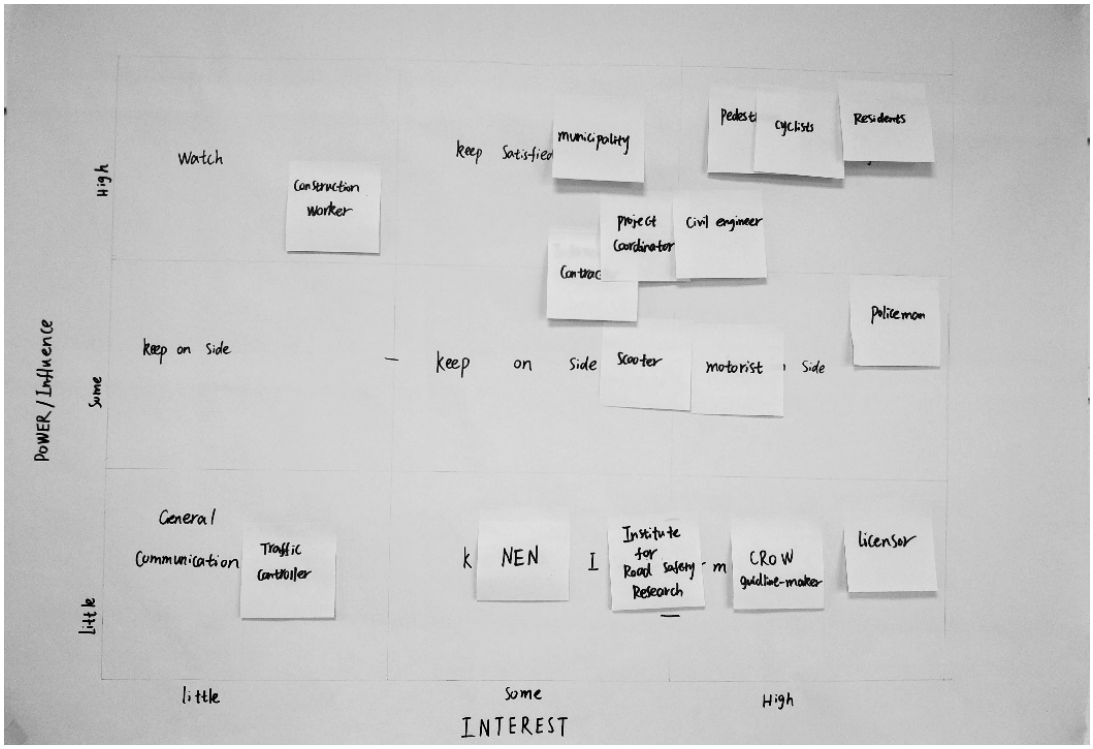


Figure 9. Matrix for identification of stakeholders based on importance and interest, created by the author

4.1.2. Case study

Turning now to the observational evidence on the case study of Amsterdam Hobbemakade. Research had concentrated on the stakeholders' behaviors in the area for a few days. Experimental findings confirmed the incompatibility between observed behaviors and road construction guidance. Road users are prone to behave disorderly when no guiding signs are around. The cyclists usually stop in front of the entrance and turn back to take different detours.

Similarly, pedestrians are apt to jaywalk in the same area as though nothing can stop them from traveling freely. The situation became unpredictable at night when the whole area is in darkness. As observed, road-users frequently entered into the wrong path and turned back for a few minutes.

4.1.3. Explorative scenarios

As explained earlier, the explorative scenarios summarize the preliminary findings from ethnography research. As the project progresses, explorative scenarios are produced to capture findings and used to gradually develop authenticity meaningfully. The following scenarios illustrate potential problems the traffic measures bring about to stakeholders.

Scenario 1. Actor: cyclist Person: Peyton

I'm a scientific researcher at the university. I go to work by bike every morning. I come across a work-zone closed by traffic measures whenever I go to work. I can see a mess behind traffic measures. They are quite annoying to me because I don't like being interrupted while riding. I must go to work on time and I quickly browse traffic signposts aside showing me the way to make a detour, I don't quite understand well though. I follow the direction the traffic measures lead me while being disoriented. The routes are unsmooth and crowded as I worry about hitting the traffic measures. Then I get off the bike and move on to exit…

Scenario 2. Actor: project coordinator Person: Jyar

Around 8 o'clock, I sit in my office to start looking at on-going projects in districts. Many problems can happen every time so I go to work-zones to communicate with them about every elements to make sure that everybody can work without problems. Now and then, I make calls with contractors to discuss validation of projects. In the discussion, stakeholders and I need to re-evaluate our plan for improvement for coordination between projects. Not all contractors follow the guidelines. Many thing are not properly dealt within or after works. As a result, I'm responsible for the mistakes when people are not behaving "rightly"…

Scenario 3. Actor: project manager Person: Pierce

In the morning, I sit in front of my computer. Having many plans in my mind, I screen my emails and respond right upon the arrival. Next, I supervise the project going on in Zuidas. I regularly attend meetings with colleagues in my office so I can make sure that everything is going well and avoid nuisance. I usually worry about the problems when our strategy doesn't perform in a right way. In fact, nuisance happens from time to time at project sites and problems are usually even harder to think of as solving a problem means a long time negotiation and test. There are few standards can tell you how to properly manage and steer all traffic flows.

Scenario 4. Actor: guideline maker Person: Edd

I work in a non-profit organization and make guidelines for public works. When we do a project, I organize a collaboration with a group of different stakeholders (including contractors, municipality and end-users) a few times a week, to decide our guidelines. I stick to principles to protect the safety of workers and people passing-by and try to avoid traffic jam as much as possible. However, local situations are dynamically complex for guideline-making and contractors don't understand guidelines while copying them on streets. I can do nothing with road-users when violation occurs. Balance among stakeholders are hard to achieve. To get

feedback, I go to the street and government to listen to complains that the use of traffic measures are seriously concerned.

Scenario 5. Actor: resident Person: Joy

When there are roadworks near my residence, I feel that I will be bothered by them for quite some time. It's morning and I put on my coat and I rush to my office. When I get out of my house I see the roadworks which are full of dirty traffic measures alongside and some stuff abandoned. At the moment when I cannot figure the "right" way to go through, I'd like to jaywalk in a shortcut as soon as I can move. When I'm off work in the evening, I've got to be careful again on this way back home. It is pretty annoying to me if you come across the same situation for a month…

Scenario 6. Actor: pedestrian Person: Erica

Traffic measures are so unclear that I have to read for a moment. Whenever I pass roadworks, I'm a bit upset to see street works occur in my neighborhood. Roadworks can easily cause disturbance on my way closured by traffic measures and the aisle is probably covered by unsteady steel plates. Without knowing other choices, I walk to another way around. Many traffic measures in detours make short trip awful since they are unproperly placed so I walk a longer way away than usual. At this moment, I have no idea where is the exit so I cross over the road to find a way out…

4.1.4. Personas

The result of persona construction is illustrated in Appendix B. Personas construction begins with ethnography research to constantly confirm stakeholders' characteristics (Grudin & Pruitt, 2003). The personas to formulate design hypotheses emphasize the role of road users, and focuses on who the product is designed for, who it is not, and what the design goals are (Miaskiewicz & Kozar, 2011).

Having personas in the scenario-based design approach, a designer, can cultivate an accurate understanding of target users. Rather than constructing general profiles, personas would bring the target users into real-life integrating their characteristics (Grudin & Pruitt, 2002; Gulliksen et al., 2003).

If the stakeholders are not explicitly understood, the information might be distorted. Misinformation is disadvantageous to the authenticity of personas. The limitation develops as soon as designers apply the flawed persona to design processes. Moreover, it would be a challenge when the participatory design incorporates persons into flexible contexts. Researchers need to follow up on the persona's progress, by re-establishing contact with

participants when required. A persona can often boil down to nothing, when external users are confused about the methodology (Flaherty, 2018).

4.2. Co-design in practice

4.2.1. Participant roles

Throughout the session, major roles have been identified: facilitator, observer and participant. Five stakeholders came from groups of cyclists, pedestrians, residents, and civil engineers. The ultimate goal of codesign session is to make explicit their lived experience and stimulate their creativity in their disciplines. Recruiting participants challenging and it's uneasy to contact people for the first time. The participants are all paid and agreed that they can spend their time in co-design session in their schedules; however, reaching coordination of participants from their different schedules was rather difficult. Thanks to a schedule coordination tool, every participant agreed to attend the co-design workshop at a specific time. As planned, five individuals participated in the co-design workshop. Thinking of efficiency, facilitators have to make sure that everybody can express in 2 hours. Each participant agreed with a consent form to reserve privacy rights during the session.

4.2.2. Co-design

To commence, each partaker receives a role they have to enact. They kept diaries for two weeks. Having no experience, keeping a design diary baffles them all the time. For this reason, the designer provided each of them an instruction to accomplish the tasks. Besides, photographs of case study in the diary package are assigned to help participants, but even so, participants were still confused about the way to keep diaries.

The co-design workshop bases upon time-wise and task-driven storyboard games (see in figure 9). Five participants in warm-up read personas, and subsequently, they collaborate to seek top five wishes. As planned, the workshop began with an introduction of the co-design workshop. In the discussion, a skilled participant led the team, so each participant can actively talk with each other. Once they came up with top five wishes for traffic measures, creating the storyboards began. A collaborative design toolkit called scenes, is introduced from the work of SAP Apphaus and adjusted by adding maps under illustrations, as illustrated in figure 10.

At the second step, facilitator provided participants with a tasks list and storyboard template, so as to help them be aware of passing time and moving the game forward. To start, the storyboard scene was given**:** road users are going to cross the roadworks through the square in Hobbemakade and they are forced to engage with traffic measures in this area. Prepared for five types of characters, each participant picked up a kind of character with which they kept throughout the game. Nevertheless, two participants picked the same characters even though

facilitator had stated that each person could only have one type per person. There was resistance and confusion when they articulated thoughts and created scenarios by fragmentary illustrations. Keeping silence for a minute, people started acting out.

Figure 10. Co-design toolkit, adapted from tools provided by Scenes™ SAP AppHaus (2019)

After preliminary exploration, participants started sharing stories. They wrote down reflective text on illustrations and placed them in the storyboard scene. The result of the storyboard supported knowledge sharing in current practice scenarios and participant's engagement. Thereafter, participants were pleased about results and adhered to the actual situations. The first storyboard objective is to let participants improvise the scene they created, whereas it was difficult for them to narrate a coherent story.

In the next stage, the facilitator present illumination technology; it could keep the session focused. Following this, the brainstorming produced a fair amount of innovative ideas and participants started working on a consistent future fiction by these ideas (figure 11 and figure 12). Surprisingly, participants finished the second storyboard faster than the first one, and they utilized pushpins to replace illustrations which was intentionally used for storyboards. This outcome represents the future practice scenario that will develop traffic measures concept in the future.

During the co-design process, participants' attitudes remained crucial in making workshop productive. It has been identified that they would retain their thoughts at first, but later they became active in team communication. Most of discussions were about latent problems the traffic measures bring about, including loss of orientations, uneven road surface and ineffective

communication between roadworks authorities and people (see Appendix D for co-design recordings).

Figure 11. Team discussion, captured by the author

Figure 12. Creating future scenarios on the storyboard, captured by the author

4.3. Co-design artifacts

This section explains the course co-design artifacts. The result description begins with the design diary and ends with a storyboard that demonstrates the use of traffic measures in current and future scenarios. Co-design activities could never be a final stage of design; however, it

enlightens an approach to establishing the groundwork for further design processes.

4.3.1. Design diary

The design diary provides various stories of traffic measures in neighborhood. It is an open-ended approach to record stakeholders' lives without a focus on specific objects. Several participants narrated what they have seen and felt about traffic measures in Amsterdam. By writing a diary, stakeholders gradually become aware of our research background. Common features depict that they spared efforts in mixed-used detours, imposed to unforeseen hazards like uneven road surface, wrong warning signs and even jaywalkers (see Appendix E1, E2, E3).

In summary, the five wishes from stakeholders are presented below. They can help researchers characterize fragmentary information into several branches of requirements:

1. Safety
2. Temporary light signs
3. Clear visible signs
4. Bilingual roadwork instructions
5. Suggestions for alternative routes/interactive map

By indicating safety at first, stakeholders want to stay safe during roadworks in all conditions. Nearly all of them concurred that many traffic measures are not equipped with enough lights, as street lights were shown pointless. Consequently, they wish for clear visible signs and temporary light to help them focus on road conditions. Following this, people could not read traffic signs because of language barriers and incomprehensible signposts. Also, moving within messy traffic measures was considered terrible when they lost orientations at night. At this point, stakeholders themselves need an interactive map to indicate on which route they can take a detour.

4.3.2. Current practice scenarios

The first storyboard sheds lights on user-traffic measures interactions in current roadwork scenarios. The storyboard relies on experiences obtained from diary keeping and knowledge sharing. Its results imply that using plenty of traffic measures in roadwork is not an optimal choice, perceived as chief causes of delays in people's daily commuting. Additionally, many cyclists prefer viewing urban landscape whilst cycling, and they would bypass the whole roadwork area. In particular, the lack of sufficient information, for example, roadwork map is shown to be a common struggle of going through traffic measure areas. Importantly, stakeholder's feedback demonstrates dangerous circumstances at night for the same reasons. Figure 13 describes the output of the current roadwork scenarios.

Figure 13. Storyboard illustrating current practice scenarios, created by participants

The storyboard represents a narrative to connect every participant's stories in the scene. Combing with this visualized scenario, participants improvised the following stories.

Scenario 1. Actor: resident and cyclist Person: Joy and Peyton

Joy lives near the Hobbemakade. Every day she felt being bothered by the roadwork and its traffic measures. When going to the lab in the morning, she complains: It's another day to cycle to the university…Humm…there are constructions going on?!?! Meanwhile, Peyton stands by the river and looks at the area, being hesitated: where is the nearest flower and water field?

Scenario 2. Actor: pedestrian Person: Erica

Erica was walking on a bridge when she found herself get lost in Hobbemakade and whined: I want to reach my workplace as fast as possible without taking any long alternative routes. I 'm confused. It takes my longer time. I want to check all information about this place like alternative routes to a less busy space.

Scenario 3. Actor: civil engineer and cyclist Person: Pierce and Jacob

After a while, Pierce came to supervise roadworks. As he observed the constructing activities, he was unsatisfied: those barriers are messy! Then he walked into work zones and soon he found a problem: it's unclear to me if the gas station nearby is open. After that, he looked people going aside and started wondering: hum…how do I get to work? As the sky gradually darkens, Jacob rode into traffic measures on a shared-use path, he later worried about his safety and complained: Oh no! There are no lights here. I hope I don't fall…I'm terrified of mopeds going super fast next to me!

The co-design story describes existing problems, yet varies from specific situations. Such

issues include uneven roads, unclear signs, narrow space enclosed by traffic measures within roadwork areas, no timely announcement and violations of intended temporary traffic rules, unknown detours and safety worries.

4.3.3. Future practice scenarios

The future roadwork scenarios focus on a lights-obligatory reflex field on outfits, one clear color bright enough for working, color connected to specific risks, lighting on the ground, piezoelectric lights, and red lights for reducing crimes. Notably, the future scenarios stress on temporary lights used on the road surface for navigation and warning traffic dangers. Alternatively, the features of variant colors and intensities associate with indicating risks within the roadwork area.

From the outcomes, stakeholders came up with a preliminary plan to suffice each requirement: a storyboard summarizes design ideas featuring following design principles. Less is more, is proposed on the grounds that nobody is happy with traffic measures crowding in streets. Easy light, suggests one color for one path. Color-connected, enables visualization of risks by intense colors. An early announcement offers comprehensive information about roadworks to people in advance. Figure 14 reveals the resolutions of identified problems. These pushpins along the road stand for lighting spotted on road surfaces. Figure 15 shows a stop sign standing in front of the area for a warning effect. When going inside, people would receive explicit guidance in mobile phones.

Figure 14. Storyboard illustrating future practice scenarios, created by participants

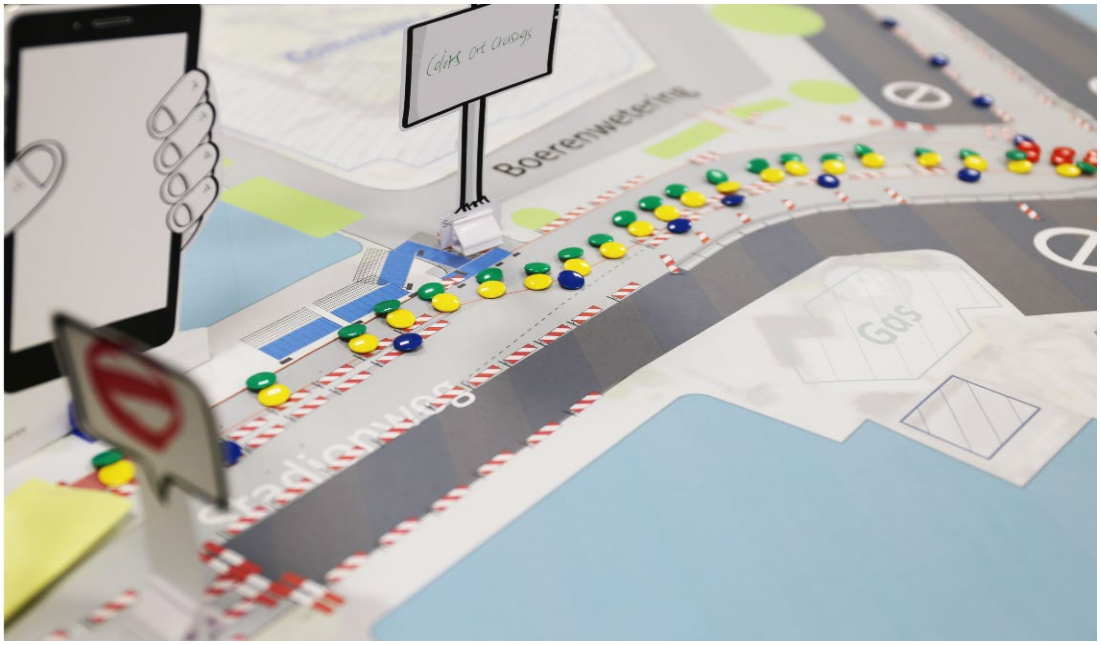


Figure 15. Storyboard details of future practice scenarios, created by participants

This storyboard envisioning traffic measures in future reversely, interprets an extensive meaning by which lights varied in colors and intensities in detours. However, the idea of co-design remains undetermined in product development. The contextual implications ranging from urban landscape to differentiated lights recommend a way traffic measures develops for improving users-product interactions. Future scenarios are shown below.

Scenario 1. Actor: resident Person: Joy

It's Friday evening, Joy leaves her laboratory at 6 o'clock. She just finished her research and felt a bit tired. On her way home, she feels upset as she knows that she has to pass through street works in Hobbemakade on a daily basis. Yesterday, the area was full of traffic obstacles and temporary signs. When approaching the roadwork area, she receives a message from an engineering authority. After a while, Joy notices a colored board of roadmap in street works, and she quickly checks out detours she'd like to go on. As she cycles to the work zone, she is surprised by the extra space where she can move on. Cycling along with vegetated barriers of 30 meters apart, she becomes refreshed and relieved from yesterday's experience. Vegetated barriers lighting a path by a color attract her because she prefers cycling for sightseeing than commuting.

Scenario 2. Actor: bicyclist Person: Peyton

Peyton stands by the river in the morning but this time she witnesses the roadworks area to be a traffic obstacles-free area. On her same way to the university, she sees an information board at a street entrance. Thanks to colored paths demonstrated on the information board, she

quickly figures out a cycling path in which she can avoid unprotected shortcuts. As a result, she moves with the guide and her frustration is saved by these vibrant plants along her path. Comparing to shortcuts, Peyton prefers to travel in a natural environment, especially when there is enough time for her to enjoy the beauty of Amsterdam. Until then she always made longer detours near flower and water areas but this time she can no longer cycle a long distance.

Scenario 3. Actor: pedestrian Person: Erica

Erica is a clothing store clerk. She walks home through the roadwork area after work. This time, she checks out ta message on her mobile phone about engineering activities. The message announces: "the redesign at Hobbemakade intersection will start on 3rd November and last until 1st December. By making more room for cyclists and pedestrians, we offer alternative routes for pedestrians in green. At the moment as Erica walks into the roadwork zone, she gets impressed with the local situation where each path is marked with a bright color in dark and only necessary traffic signs exist in particular at each entrance. Without any hesitation, she walks into a nicer alternative detour and sees Joy riding on the yellow path next to her green path.

Scenario 4. Actor: civil engineer Person: Pierce

It's 10:50 in the morning, Pierce leaves his office to inspect the road construction in Hobbemakade. Having received complaints from Jacob, he rearranges the work zone with fewer traffic measures and replaces concrete barriers with devises which illuminate areas by colorful lights. Since then, he hasn't received complaints just like last time and he doesn't have to hire more workers who are supposed to stand in traffic flow for communication. He can flexibly use lights to guide people by using an information board and digital message. Every access inside the work zone is illustrated by light uses. Whenever engineering activities change, he just adjusts content and positions of projected lights rather than removing or relocating concrete obstacles.

Scenario 5. Actor: bicyclist Person: Jacob

Jacob is a university engineering student. 5:45 PM on Friday, Jacob plans to visit his friends after a group meeting to celebrate the weekend. Before his journey, he receives a message about a road construction from the map. As he rides in the area, a wide lightened lane where cyclists are separated from walkers and vehicles appears in front of him. Consequently, he makes a detour without too much effort spent on watching out road conditions and mopeds moving faster. The temporary lights raise his interest as they brighten up the road surface in the dark and provide clear guidance on his way of cycling. At the moment, red lights are flickering at the crossing telling him about vehicles coming from elsewhere. In consequence,

the driver and he intentionally slow down before entering an intersection.

4.4. Design requirements

This section describes frequent highlights and patterns formulated to be critical requirements. Those requirements are gathered from scenario-based design and co-design, presenting a coherent line of well-developed scenarios.

4.4.1. Design requirements from scenario-based design

The scenario-based design is advantageous to lay a basis for requirements gathering. Though we separate the section with co-design, the scenarios-based design method plays profound roles in both research approaches. Centering stakeholders in research, scenarios are rich in essential requirements. Table 1 interprets frequent requirements of each type of co-design participant.

Table 1. Frequent practices related to traffic measures, source by the author

Stakeholders	Frequent practices
Bicyclist	● Taking longer detour for a limited time, like going to university in rush hours ● No habit of checking mailbox and cell phone information in free time ● Riding and walking in narrow space ● Having no sense of security cycling on a mixed-road for being scared by close faster traffic flow and bothering passers. ● Uneasy to focus on roads without illumination
Resident	● Being late for work due to the longer distance detour ● Lost orientation in the roadwork. ● Cycling for pleasure more than commuting. ● Cycling in beautiful urban landscape and being immersive at night ● lost orientation in the roadwork.
Civil engineer	● Use too many traffic measures ● Traffic measures are not timely removed. As a result, they cause disorders. ● Hard to communicate with road users
Pedestrian	● Walk a long distance for nothing ● Hit passers in a mix-used lane ● Don’t have enough information about alternative routes

As the literature review indicates, the environment exerts influence on people's traveling experiences and the way traffic measures perform. Previous studies conclude that the roadwork space sharing (Constant & Lagarde, 2010) affected by traffic measures placement and traffic conditions (Sas-Bojarska et al., 2016) are significant to a comfortable and safe environment. Other stimulating requirements on traffic barriers suggest vegetations that alleviate the disruption of roadwork and contribute to a livable street.

4.4.2. Design requirements from co-design

Translating data from co-design into requirements leads to pragmatic opportunities in several patterns. Once verified by users, research inferences are qualified to be design requirements. The first storyboard signifies that traffic measures are ineffective in space sharing for multiple types of road users. In response, clean and straightforward illumination on a detour are credible to enhance the communication with users. Following this, easy light ensures the way-finding and roadwork safety, through illuminating functional roads and roadwork areas at night. This concept aims to clean up graphic noise such as complicated traffic signs and obstacles and to provide suitable guidance on user's way-finding. The visualization of future scenarios specifies how the objects instruct road users by temporary ground lights. The lights are shown useful since users spare less effort in recognizing and understanding engineering information. Considering invisible safety hazards at night, participants also suggest risks indication supplying visible signs at dangerous spots, for instance, bumpy roadways and roadwork intersections.

An engineering principle refers to "less is more" to decrease the number of traffic measures. This principle is valuable to avoid using too many traffic measures in a limited space. On the one hand, the principle partly supports notions. For example, it reduces traffic noise and reinforces space utilization in roadworks arrangement. While it tries to reach a balance between light pollutions and light blockage, for the sake of the peaceful state of roadworks execution.

Comparable solutions arise in brainstorming. Personalized guidance shows potentials in helping people find their ways, as referred to an interactive map. This idea makes explicit unclarified detours for way-finding in the work zone. Particularly, a pinboard map driven by GPS, indicates alternative routes when placed before entrance at which a way-finding decision is made (Foltz, 1998). Besides, a digital map can create identities for the entire roadworks and available detours for different types of road users. In other conditions, the interactive map spreads audio messages when visual images are invisible.

Traffic signposts are useful in guiding road users. Project contractors often rely on guidelike

traffic signposts for in work conditions. However, traffic signposts can easily cause confusions. It might be owing to that direction boards usually stay too low to be noticed. If the signpost is unable to work properly, people tend to believe in their personal decisions. Furthermore, there have been many complaints about using a single language or wordy text on the signposts. To conclude, the reasons above lead to the requirements of high information boards, bilingual text for foreigners and prompt announcements.

4.4.3. Design requirements map

Through searching and pattering, the results of design research transform into four requirement domains: easy light, interactive map, less is more and traffic signpost. Different requirements are gathered and connected by potential meanings in circles. Within each circle, the requirements cluster by comparable features. Features correlate to elements in other circles, revealing the significance of requirements in overlapping areas (as shown in figure 16) .

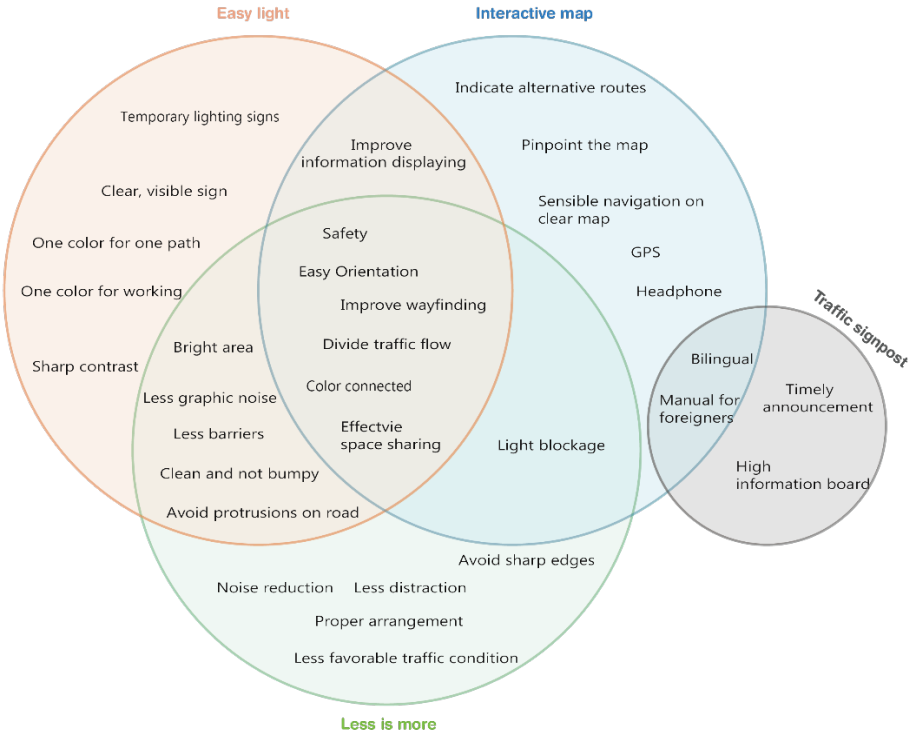


Figure 16. Requirements map, created by the author

The main finding here is the overall design landscape, defined as improvements to suffice important dilemmas related to the actual practice scenarios. The requirement map provides a reference to generate design ideas; they are confirmed and evaluated for their capacity to resolve problems. Indications among domains contain reflections towards the design ideas the designer can base upon, and therefore help recognize frequent concerns in design

stages. When requirements connect with those in other domains, new ideas may emerge. The requirements map could also facilitate communication amongst stakeholders, especially in design concept evaluation, because it simplifies the complicated results to designers and stakeholders.

Design ideation

5. Design ideation

5.1. Ideation approach

After a better understanding of the context and the requirements from design research, designers continued to evolve requirements into certain solutions based upon the co-design results and also created new ones. The co-design unfolds the coordination of multiple ideas. Owing to the limit of time, it's impossible to explore every viable approach for traffic measures development, instead a design solution is made by targeting a specific area where prioritization of substantial requirements comes forward. The co-design session revealed the main focus on illumination technology as mostly indicated by participants. Subsequently, defined requirements can shape scopes for traffic measures design, concerning the size, the configuration, the safety measures and the positive visual effects in surrounding areas. Prioritizing design requirements perhaps strengthens feasibility to resolve problems about the quality of roadworks and urban landscapes whilst maintaining the current construction efficiency.

As aforementioned, the ideation phase will concentrate on easy light and the requirements in the overlap of three spheres form the highest priority. The center overlapped requirements figure in three major patterns to be commonly recognized foundations for product design. The rest of requirements continue to be relevant in certain design specifications according to priority of distinct needs (see Appendix F for design ideation sketches) .

5.2. Design for temporary lights

Requirements prioritized:

The temporary lights encompasses all of the ways in which traffic measures with auxiliary illumination support people's way-finding and protect them from all predictable hazards. This idea reveals the paramount priority of requirements in the center overlap and the rest in easy-light sphere without improve information displaying (as seen in figure 17).

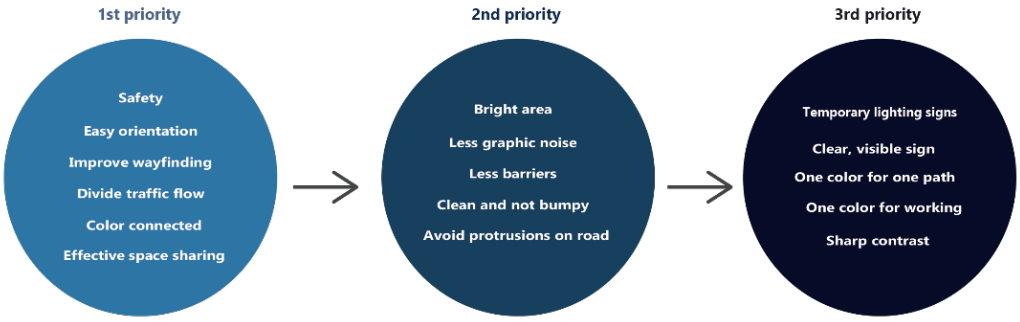


Figure 17. Temporary lights requirements prioritization, created by the author

Idea:

The goal of temporary lights would be to mark traffic lanes within road construction zones. Flexible road surfaces are covered by projected lights for lane splitting (see in figure 18). A working space that is properly organized by temporary lighting will be more useful and friendly than temporary traffic barriers. Once road users go into the projection area, an indication of orientation and specific risks is clearly provided. As for walkers and bikers, they are divided from motorized traffic flow by simply following “correct” colors. In total, three distinct colors are to be in service for lanes with the different functions-bicycle lane, sidewalk, vehicle path and intersections.

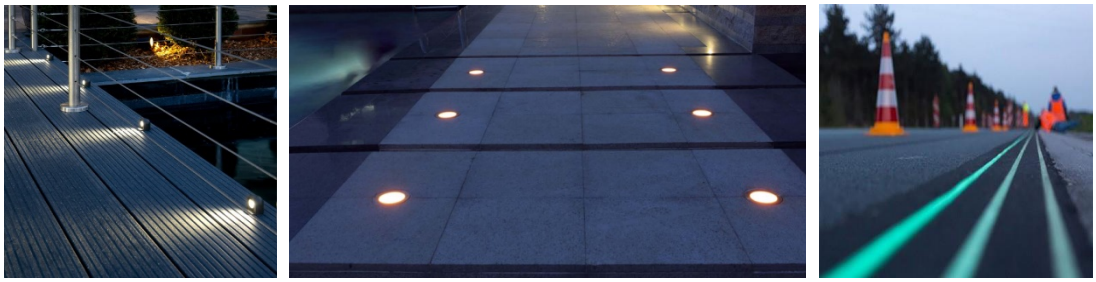


Figure 18. Ideas about temporary lights for roadworks

5.3. Interactive map

Requirements prioritized:

Ample experiences have shown an increasing interest in the sensible navigation and interactive map for roadworks. All arrangements in roadwork areas, of course, have to be clear and easy to be followed. To support this, the center overlapped requirements and improve information display take the first priority as a whole to promote efficient communication with individuals. These specify the need of proper communication in which users spare less effort in the journey. Other requirements within the interactive map including a bilingual version for foreigners are given the second priority (figure 19).

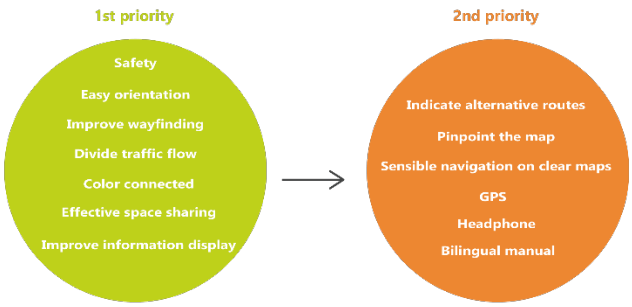


Figure 19. Interactive map requirements prioritization, created by the author

Idea:

As proposed, the interactive map can be either a mobile app or intelligent information board (figure 20). An intelligent map would reorder ongoing activities by making clear of the information on specific guidance-route planning, dangerous spots, work durations, daily work changes, etc. It is also important to keep road users adapted in different ways. For example, audio guide was recommended when cyclists might not able to check the phones. If necessary, this idea should also incorporate the design of information board in busy places to ensure everybody is informed.

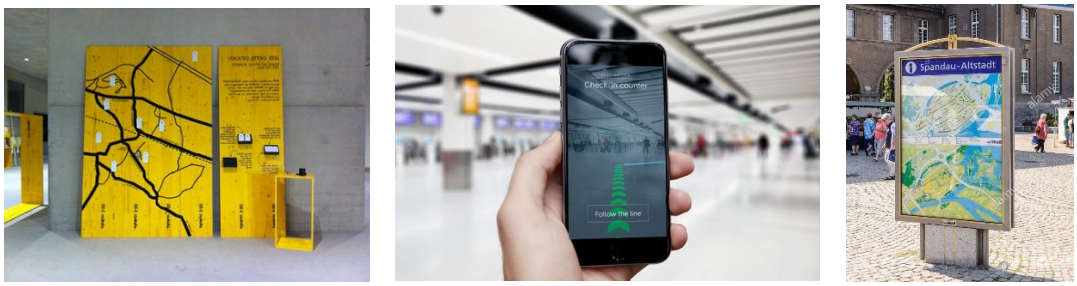


Figure 20. Ideas about interactive map for road users

5.4. Design for traffic signpost

Requirements prioritized:

During the research, stakeholders reflected relatively negative opinions towards the use of traffic signposts. The prioritization tends to highlights requirements to resolve information displaying problems. The requirements within traffic signposts and improve information displaying are the first reference in design (figure 21). With these, traffic signs are readable for all users, especially foreigners. Positioning at standard places and displaying noticeable content is also noteworthy for traffic signs design. This means that an announcement board has to contrast with the surrounding of busy roadworks. Specifying arguments above results in the second priority for the references between spheres of easy light and less is more, creating a visible and timely traffic announcement in discernible positions.

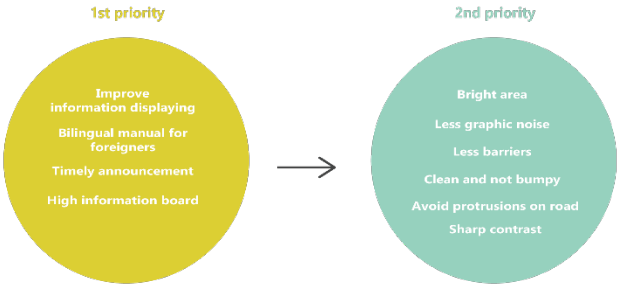


Figure 21. Traffic signpost's requirements prioritization, created by the author

Idea:

Both priorities generate an idea of traffic signs. Considering preferred circumstance for which traffic signs create, the users can notice and understand organization without effort. Necessary information will be illustrated to people and illuminated if it is invisible (as illustrated in figure 22).

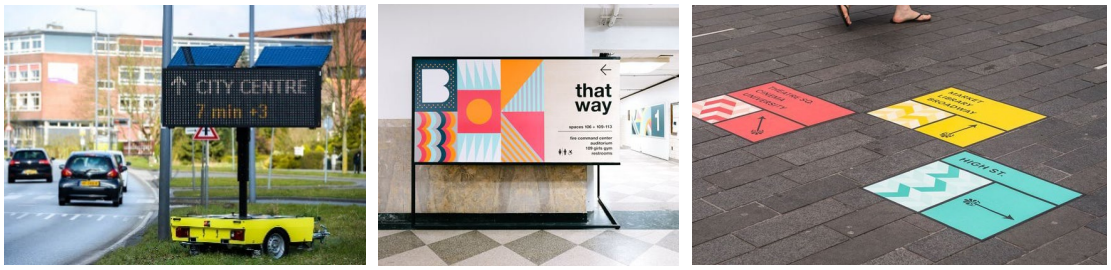


Figure 22. Ideas about traffic signpost design

5.5. Design for vegetated traffic guide

Requirements prioritized:

The traffic measure has many possibilities to meet stakeholders needs in development, both with regard to functionality and aesthetics. Things available in any cases are: temporary illumination, guiding signs, vegetation and less is more philosophy. Referring to the previous research regarding the frequent practice, vegetated traffic guide attempts to obtain a concurrence among different concerns. Further to the requirements of temporary light, vegetated traffic guide also coordinates the specifications in traffic signs (as shown in figure 23). After this, literature research positively suggest the adoption of vegetation in public space. Seeing that traffic illuminations would be rather limited in daytime, the traffic guide is likely to be useful under circumstances of night.

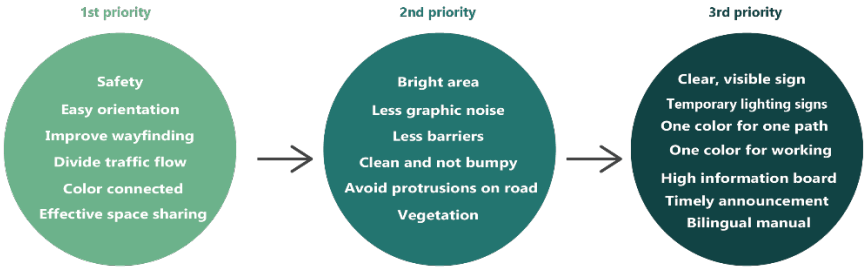


Figure 23. Vegetated traffic guide requirements prioritization, created by the author

Ideas:

Wanting to bridge the gap between roadwork measures and road users' experiences, to make a nice working environment during street works, vegetated traffic guide partly coordinates the requirements from several disciplines. Apart from the first ideation, vegetated traffic guide provides more defined characteristics such as vegetation on structures, hidden illumination, integration with barriers and guiding signs. Since it is set in urban space, the idea intentionally prevents graphic noise by replacing traffic barriers with plants to bring greenery to roadwork zones (figure 24).

Figure 24. Ideas about vegetated traffic guide

Final concept

6. Final concept

6.1. Concept selection

In the co-design session, one problem frequented in current practice scenarios, revealing that stakeholders usually take long-distance detours in roadwork spaces. Nearly none of them like spending too much time in detours, because they often lose bearings and have no sense of security in a mixed-use roadway. Another goal of the design is to make the roadwork area a friendly place, with greeneries, comprehensible signposts, understandable road planning, and visible road surfaces at night. On the design research question, many studies have tried out in road work areas of high traffic measures density, just as what has been discussed in the literature review. However, only a few of them touch the problem.

Referring to the design research question, the selection depends on how well the ideas can meet the requirements of human-friendly roadwork space and road users' experience.

"How can we ensure that temporary traffic measures can improve the work area as human-friendly public space that is safe, understandable and visually positive for road users and city image during the roadworks?"

As argued in co-design, a series of strategies that are helpful to achieve the research goal came out of the co-design brainstorming. The interactive map is a prospective approach to offer guidance, yet it is not the focus of this project. Traffic signposts design is shown suitable for improving pathfinding, but it cannot strengthen the safety threatened by excessive use of road signposts. Based on the outcomes of the future practice scenario, the temporary light concept is proposed for further development. Unlike previous ideas, progress has been made with traffic lights. Applied with illumination, the temporary lights show potentials to improve current roadwork scenarios, in ways of offering way-finding guidance and dividing lanes by traffic ground-light (as illustrated in Appendix G).

Furthermore, vegetation proves added-value in landscaping (see figure 25 and figure 26). As explained earlier, the effective space sharing and the comfortable environment are indicated in design requirements; vegetated traffic guide is feasible to make a change in co-designed road construction scenarios without contradicting other requirements. This improved design idea not only relates to the stakeholders who need safe street construction environment, but also to those who enjoy cycling for urban scenery.

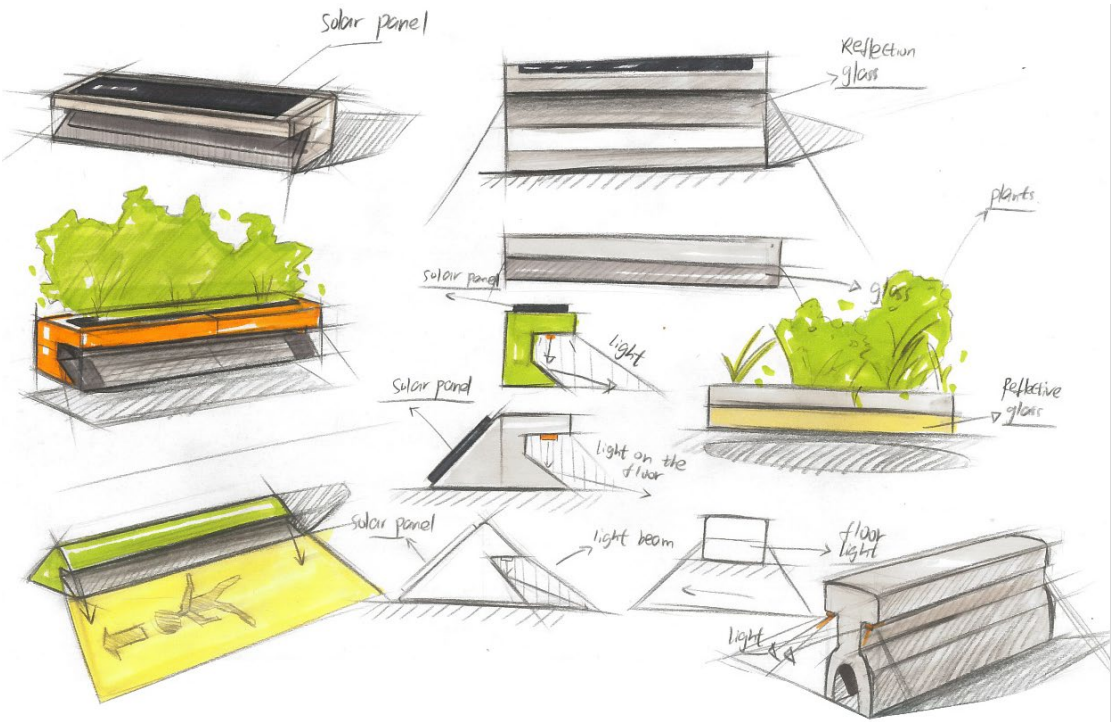


Figure 25. Temporary traffic lights sketches, created by the author

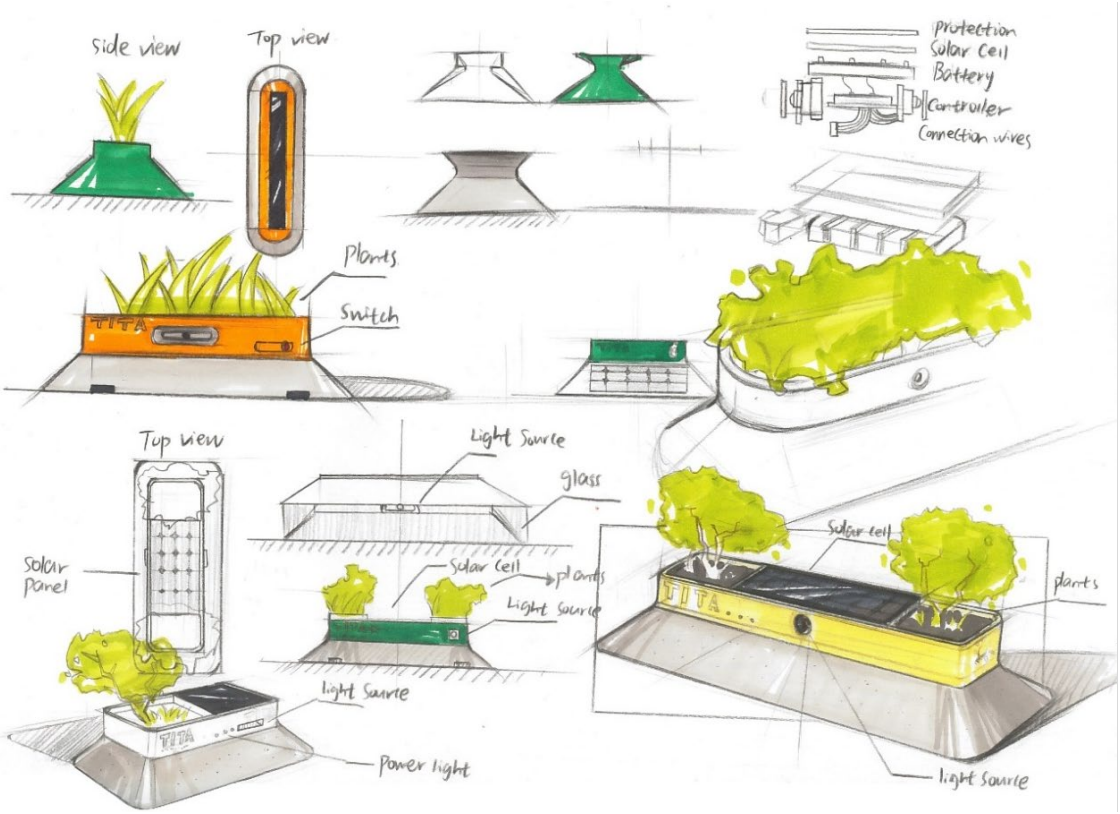


Figure 26. Vegetated traffic guide concept sketches, created by the author

6.2. Challenge statement-vegetated traffic guide

The biggest challenge for the design is to define a balance between road construction and human-friendly public space. As mentioned in design research results, the meaning of understandable and visually positive for our stakeholders accounts for effective space sharing, orientation keeping, precise information about alternative short detours and visual content in roadworks areas. In order to satisfy engineering professionals and road users over the issues, the designer determined to follow the implications of co-design results. Whereas the final design needs to ensure the feasible landing of technology. Without influencing the original effects of design ideation, the designer adapts the vegetation on the basis of co-design. Therefore, people will have connections to green space outside the roadwork space.

6.3. Concept description

The vegetated traffic guides are an alternative to concrete barriers in roadworks, in forms of lining up on edges of road construction areas. Like traditional barriers, this product creates effective space for project implementation and road use on a daily basis, by referencing three strategies from co-design: illuminating guidance, vegetation in roadwork zone and less is more.

Depicted in figure 27, the product has an electronic part and a concrete foundation. Powered by a solar system on top, a temporary light inside emits illumination on the road surface. At both sides, small shrub grows to form a botanical upper structure. The small shrub lower than 1 meter and mid-dense foliage is suitable for use, so as not to block traveling views in construction areas. On top of the surface, the solar system constitutes the main inner structure of function parts. Solar cells are protected by a protective film, and they transfer energy to a battery beneath. Inside, a controller empowers a beam projector to beam down on the road surface if activated. Since it has to be suitable for the harsh roadwork environment, the bottom part is made of durable cement materials to stabilize the whole frame.

Figure 27. Design of vegetated traffic guides, created by the author

The vegetated traffic barriers adopt a green color scheme, as illustrated in figure 28. Base on multisensory design principles, white associates calm and green colors relate to relieving stress and to the sense of safety (O'connor, 2011). The composition of white and green colors in traffic measures seeks to strengthen the continuity of urban greenery in the roadwork area. In a district is suffering from heavy construction, the appropriate use of greens can alleviate the negative effects caused by roadworks. On the other hand, greens' warning penetration is weaker than red and yellow (Xi, Xu & Chen, 2015). Green colors on traffic guides may not be suitable in special situations, for example, on highways. Furthermore, this color scheme would not be consistent with current Dutch guidelines on color selections.

Figure 28. Color scheme of final design, created by the author

6.4. Roadwork space arrangement

In accordance with the design research question, this section explains a strategy of how vegetated traffic guides can be used to suffice critical requirements. The principle "less is more" inspires the future practice scenario. This suggests that the number of traffic measures could be reduced to a minimum, only leaving a few of them for critical warning and closing off dangerous zones. Figure 29 demonstrates that the vegetated traffic guides use ground-lights along three functional roads: sidewalks, cycling paths and distributor roads. Separated by every 20 meters, three sorts of illuminated patterns are visible in detours. The reason behind the configuration is that road users tend to be careful and focused on less favorable traffic conditions. As discussed above, when a few traffic measures are around, the jaywalking cases decrease (Hine and Russel, 1993). That is to say, the current traffic measures are irreplaceable, because of the strong penetration effect at warning places.

The physical elements of design (such as plants, temporary lights, durable foundations, colors and their configurations) remain significant to reduce the construction disruption. In a roadwork area, every detour uses one color to guide its users. For example, cycling paths use pink arrows pointing towards accessible directions; this allows cyclists to distinguish and focus on the bicycle path. Uneven roads can also be illuminated by lighting patterns. Furthermore, the internet of things can realize the alignment of traffic guides, in order to avoid nuisances. Compared to other places, more attention must be paid to roadwork intersections. In this way,

motorists are aware of coming pedestrians and bicyclists, informed by a red warning pattern in front. Placing plants around the area reinforces the continuity with external urban greeneries and stimulates people's awareness of sustainable road engineering.

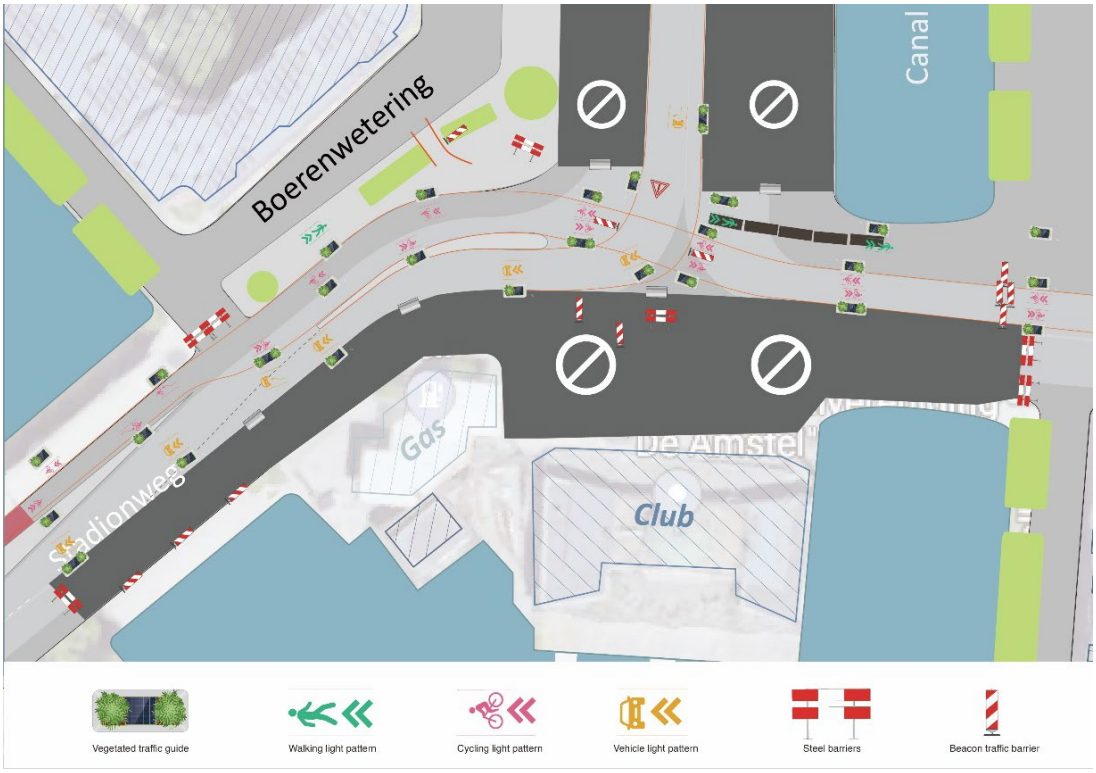


Figure 29. Vegetated traffic guide in roadwork space arrangement, created by the author

6.5. Concept scenarios

6.5.1. Entrance

The first scenario is about activities before entering into a road construction area. As we can see in figure 30, the vegetated traffic guide at the decision point is the first roadwork element with which stakeholders to be in touch. Unlike traditional traffic measures, the design softly informs oncoming people, working as an adaption process from sustainable urban atmospheres to working zones. Before entering the work zone, pedestrians receive elaborate information with mobile phones, told where they can go forward and do's and don'ts. The cyclists, however, could not check their phones regularly. Therefore, they can look up a big map alongside, to know the dedicated and colored cycling detour inside the area. In brief, the design at entrance helps road users collect sufficient information regarding the ongoing construction project.

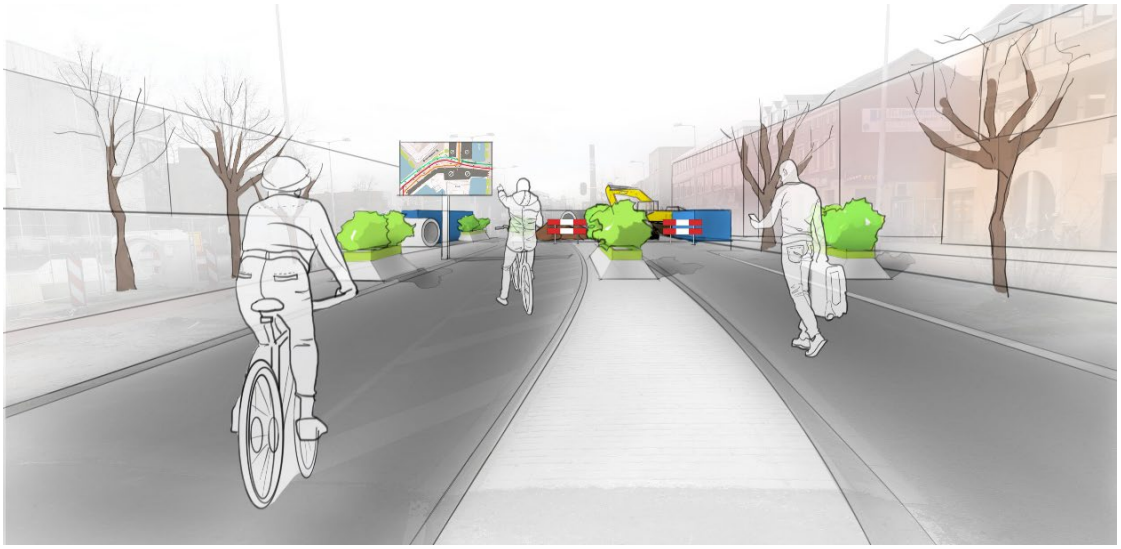


Figure 30. Concept scenario-Before entering the roadwork space, created by the author

6.5.2. Detour navigation

When traveling into the detour, road users navigate by ground lights, as shown in figure 31. The vegetated traffic guides produce narrow beams that are useful to distinguish dedicated detours in a mixed-use roadway. Different colors—red, green and yellow are assigned to roads used by different users. However, the design requires a small number of current traffic measures, to sustain roadwork orders and protect workers.

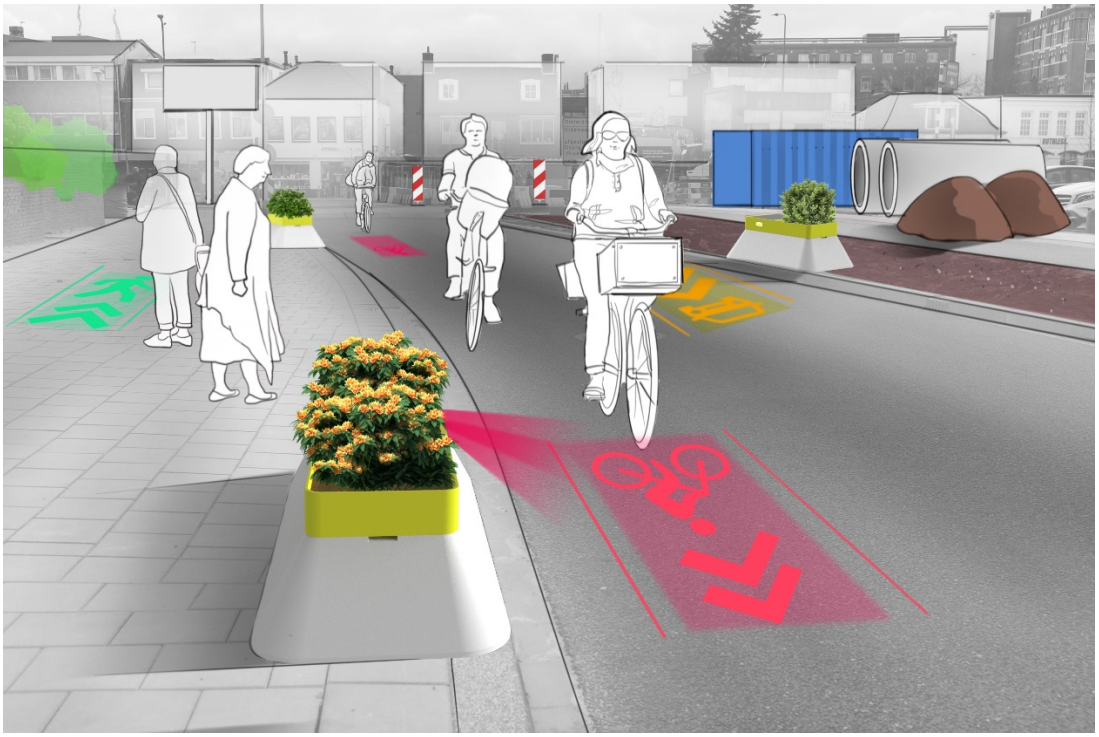


Figure 31. Concept scenario-Traveling in the roadworks space, created by the author

6.5.3. At intersection

Seeing that an intersection has a higher possibility to cause collisions, the design team focuses on collision predictions to ensure the safety of road users. Figure 32 illustrates an interaction between the vegetated traffic guides and the users at a crossing. When vehicles approach the intersection, they become threats to the safety of vulnerable road users. To address this, the vegetated traffic guides produce red warning beams in front of the crossing; vulnerable users can predict oncoming dangers. At the crossing, the traditional traffic measures needed to maintain traffic orders and divide traffic flows The beacon barriers, in particular, are appropriate to convey warnings and to prevent people from moving fast at dangerous spots.

Figure 32. Concept scenario-Traveling to a roadwork intersection, created by the author

6.5.4. Exit

Exercises that feature interactions in the exit of the roadwork area are shown in figure 33. This scenario describes how people travel out of the work zone. The vegetated traffic guides are sparsely located alongside, making a connection with external sustainable atmospheres. On the other side, the vegetated traffic guides open ways for pedestrians as well. The strategies to enhance the human-friendly and visual effective space suggests the minimum use of traffic measures and the use of greeneries. This can stimulate the awareness of sustainable road construction.

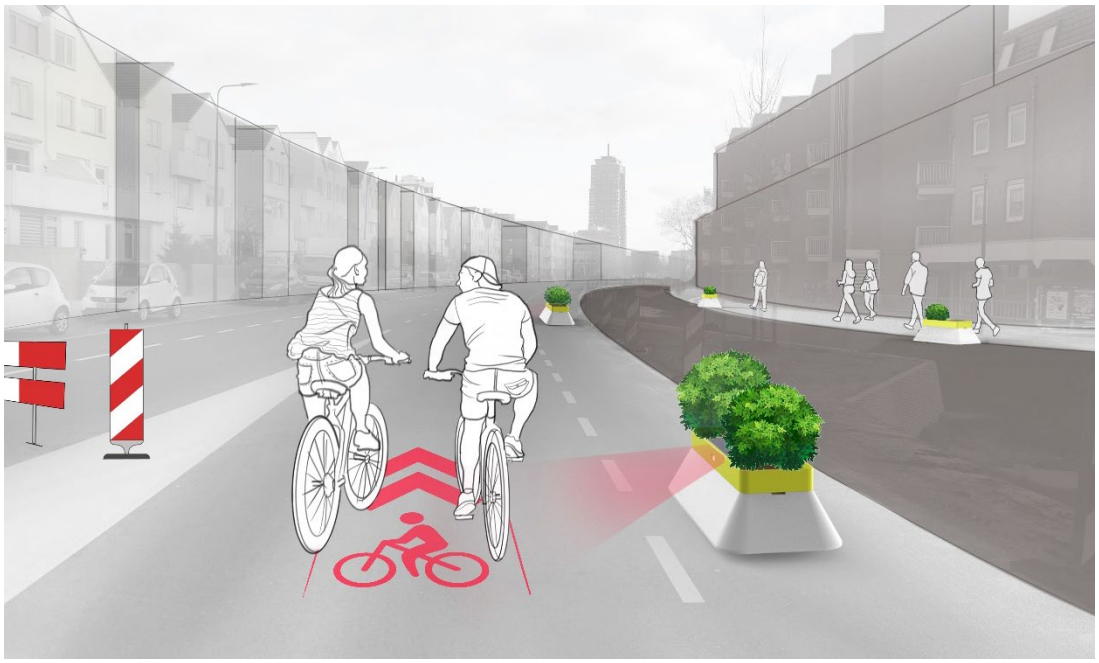
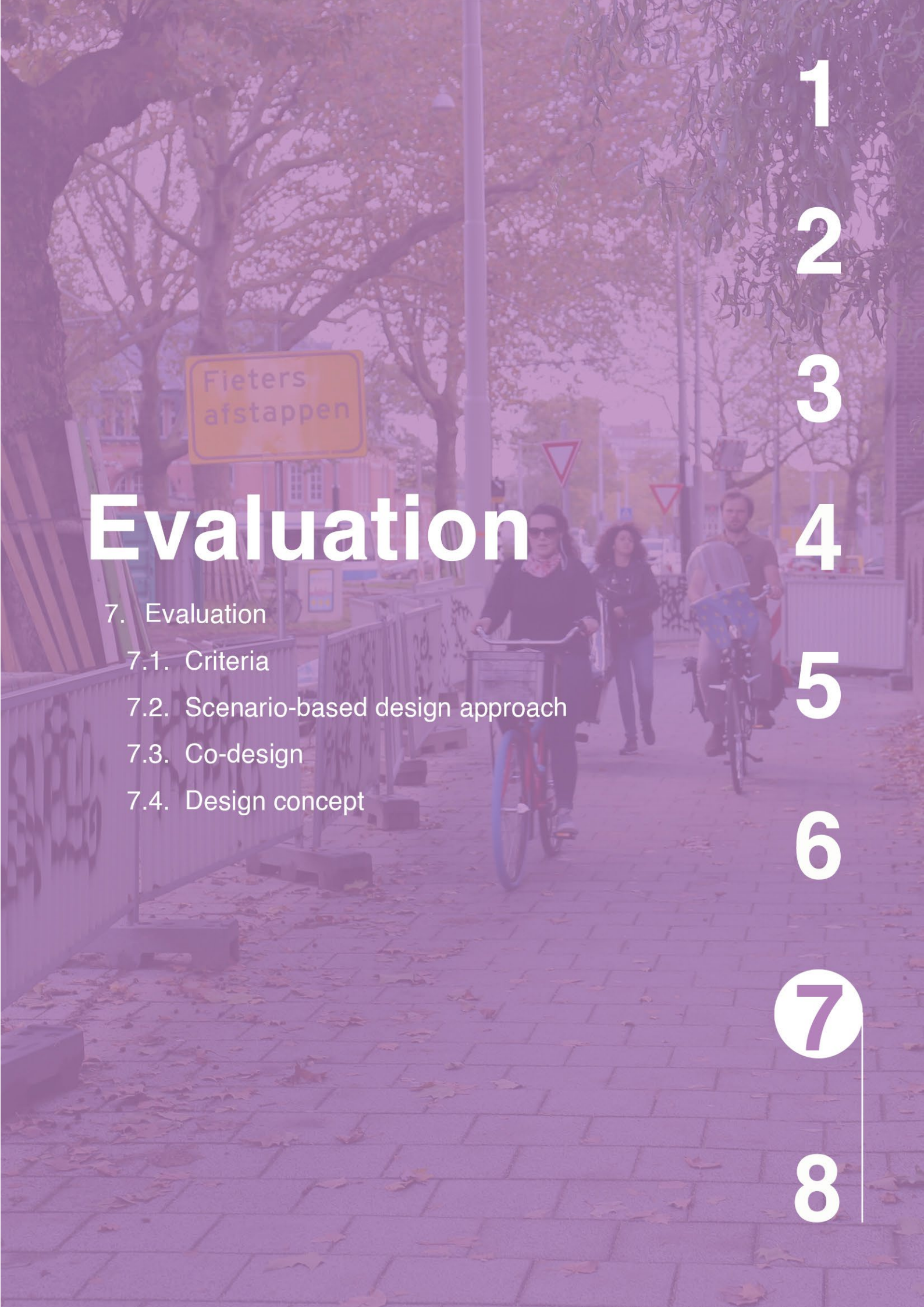


Figure 33. Concept scenario- Returning back to the sustainable urban space, created by the author



Evaluation

7. Evaluation

At the last stage of the design research, a comprehensive evaluation of the methodology and the design concept takes place. In the section that follows, the evaluation of methodology takes place based on evaluation criteria, and the design concept is evaluated with the concept scenarios and a physical prototype.

7.1. Criteria

The evaluation criteria partly roots in problem-solving capacity theory by Oulasvirta and Hornbæk (2016).

1. Effectiveness—How effective the methodology accomplishes the design research goal, and how effective the solution resolves the essential aspects of identified problems.
2. Transferability—How well the methodology and solution can be generalized or transferred to other contexts and problems.
3. The confidence of research solution—To what extent the solution can be trusted.

7.2. Scenario-based design approach

As regards the scenario-based design, the research freshly takes this approach to unclarified empirical problems of traffic measures. The SBPD approach sheds light on the empirical findings concerning how traffic measures in road construction affect road users' experience. Compared with traditional design approaches, the SBPD is effective to elaborate upon the essential aspects and fundamental factors of the problems. As regards the research gap of relevant studies, the research findings provide empirical evidence to the road users' behaviors in roadworks environments. Likewise, the insights gained from the SBPD approach assist the designer with design ideation.

In the case that stakeholders involved in public design issues, this SBPD approach is transferable to related contexts. Using scenarios to understand our stakeholders from the start shows a considerable problem-solving capacity, because it produces explicit knowledge regarding the user-product interactions and the relationships between different parties. Being core driving forces in urban product design, the scenario-based design method makes it easy for both designers to understand which aspects are important to them and underlying requirements.

Furthermore, the investigation by different approaches benefits scenarios building. A starting point for the design research could be to analyze stakeholders; the analysis determined the essential stakeholders who the scenarios should build upon. Information and data, for explorative scenario building, are gained from the interviews with traffic professionals. Although

the process is time-consuming, and the results could lead to biases, the personas are a favorable design approach to center users in design processes.

Even though the SBPD could produce insights into concerning problems, the scenario generation requires significant time investment. It is absolutely necessary to investigate and understand information from different sources. Translating the information into useful requirements which encourage scenario building is even more time-consuming. For this reason, receiving feedback on scenarios from stakeholders to make rounded scenarios was not fully achieved in this project. Still, the scenarios remain at the conceptual level, which is disadvantageous to the effectiveness.

7.3. Co-design

To explicate the actual and future practice scenarios, the designer used the design diary and referenced the explorative scenarios in the co-design session. It proved that the co-design completed its goals: identify user experiences, explore the design opportunities, and improve the roadwork settings. Combined with scenario-based design techniques, the co-design is effective to generate profound requirements and innovative countermeasures.

A starting approach of the co-design was to write design diaries. The lived experiences collected from diaries can help users cultivate deep understandings of concerning issues. Further, the information, in return, becomes the context of the co-design practice. The diary toolkit includes beautiful small items – ten postcards, a step-by-step instruction, a pen, a persona, several pictures of real roadwork case and an elegant package. They were prepared to have pleasurable appearance and feelings, and participants could have had a sense of being valued and finished the diary tasks comfortably.

On the other hand, a qualified probe has to properly ask questions and present design tasks in a proactive manner. A design diary, similarly, needs to be creative and communicative to ensure that users can finish it with personal significance. As such, designing a diary toolkit is not easy and this requires more time on thinking of diaries features.

The workshop materials, such as explorative scenarios and personas, ensured the quality of the co-design process and the outcomes. Hompe en Taselaar b.v. and Scenes™ provided diary tools and co-design storyboard illustrations, respectively. Taking these together, the designer and partakers could characterize unclarified contexts, essential factors and potential solutions.

Ensured by effectiveness, the co-design approaches in the research are confident in transferability. Organizing co-design by sensitizing, guiding participants to create actual scenarios and reflecting needs in future scenarios, could help attendants break knowledge-

sharing barriers, especially in traffic infrastructure design contexts. At first, five wishes arose through a discussion and participants could stick to the preferences while building actual practice scenarios. Building storyboards in current and future settings, encourage participants to think about core issues and to come up with solutions to solve these problems. Unfortunately, one participant of pedestrians has not returned the diary since rewarded. As such, the mistake limits the confidence of scenarios as well as following processes.

7.4. Design concept

So far, this section has theoretically and physically evaluated the design concept with one of engineering stakeholders. The designer executed the evaluation whilst presenting the concept scenarios and the prototype (see in figure 34). Taken these together, the evaluation produced straightforward visual effects on how the design concept performs in speculative reality. Regarding the effectiveness, the feedback remains critical. The stakeholder argued that the design concept is effective to improve the human-friendly atmosphere in roadwork sites, and clear to guide people going on right tracks. This positive feedback reflects the design following the co-design results and classification from the requirements map. Out of four design ideas, the vegetated traffic guide, in particular, accounts for the most acceptable requirements. It is also subject to future practice scenarios aiming to alleviate the tension between road users' experience and roadwork traffic measures.

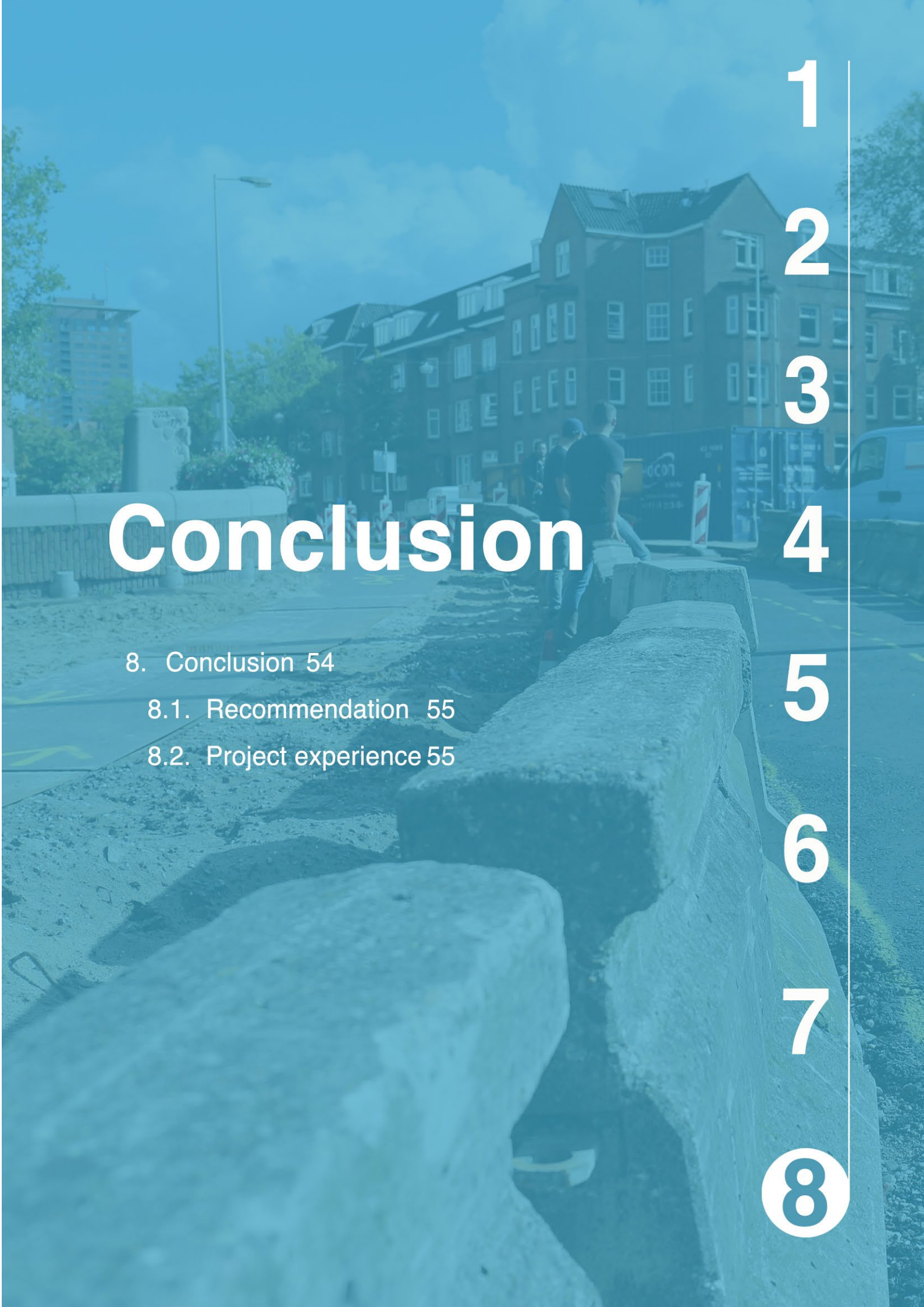
Figure 34. Concept prototype, captured by the author

However, the concept still remains at a conceptual level. One foreseeable issue that might deteriorate its effectiveness is illumination malfunctions. If illumination components break down, the design would be useless. In other words, situations will be even worse because people will not see the indications, and they are in danger of falling into work zones. The effectiveness of the concept depends on specific situations. For instance, the lighting part - laser beam would be invisible in the daytime. This makes the guidance invalid when no guidance is provided to

users. In consequence, the problem of confusion in detour may arise. In addition, the mobility of this temporary facility was critically questioned out of the heavy and nowhere to lift up. What can also be mentioned is vandalism, which contributes a potential threat to the security of this public property.

Another significant aspect of the concept is transferability. All things being equal, the concept contains values of generalizing in diverse working circumstances. Because it roots in a wide range of experiences obtained from different roadwork sites, the concept shows profound meaning in similar scenarios. On the other hand, transferability does not apply to short-term projects for several days. The research currently concentrates on designing for stationary traffic measures.

As for confidence, the stakeholder argued that the final concept has not fully achieved other requirements in this project; it may disappoint stakeholders who pursuit short-distance journeys and effective communication on an interactive map. To prove the usability, the evaluation recommends a further product test in real roadwork environment, not merely by principle. Therefore, it is indispensable to further assess the performance in different types of roadwork conditions at the next stages.



Conclusion

8. Conclusion

The main question of this project is how can we ensure that temporary traffic measures can improve the work area as human-friendly public space that is safe, understandable and visually positive for road users and city image during the roadworks. The main goal is to understand the user experiences of road users and propose a design solution for improving this experience during road construction. The project responds to the research question by a sustainable traffic measure – vegetated traffic guide, reflecting three co-designed strategies: illuminating guidance, vegetation in roadwork zone and less is more.

Throughout the study, the scenario-based design methodology is effective to explore stakeholders' insightful requirements and design opportunities. Driven by design scenarios, the co-design session facilitated participants to make concept storyboards. Both design approaches centered stakeholders in the design processes, explicating unclear empirical phenomenon and future scenarios of the use of roadwork traffic measures.

The empirical findings illustrate that road users spare significant effort to travel in a roadwork detour, and require more time to travel to destinations. A possible account for this problem is losing orientation in roadwork areas and collecting indicative information with difficulties. In addition, traveling in mixed-used detours attributes to the users' poor subjective safety. Hence, future practice scenarios suggested the requirements map to address those stated problems. In the design part, the vegetated traffic guide answered the design question.

The final concept in relatively long-term roadworks benefits road users for a trade-off among desirable requirements contributing to the visual effectiveness. Illuminated guidance combines temporary traffic lights and effective traffic measures management. Rather than placing many traffic measures, civil engineers can use one clear color on road surface; this enhances effective space sharing and helps to mitigate confusion in detours. The final concept eases the difficulty of traveling in detours and promotes pleasing atmospheres, which improves the human-friendly space.

Although the design concept shows prospects in project implementation, a stakeholder has expressed the concern considering illumination efficiency, product mobility and vandalism. Illuminating failure is a major concern. Disadvantages stand out when illuminated patterns are invisible due to breakdowns or strong sunlight; this would confuse people if no proper guidance is offered. To conclude, vegetated traffic guides initially satisfy the design research question. However, it is not enough to meet the required standard of human-friendly public space. The

factual performance of vegetated traffic guides is still unclear. Developing traffic measures requires multi-dimensional consideration. For example, traffic measures management, project implementation, communication and road users behaviors are determinant factors as well. For the sake of the concept's confidence and significance, substantial experiments in complex situations are essential for the next steps.

8.1. Recommendation

This scenario-based methodology can generate design requirements for the actual development of the traffic measure. The design research offers the way for engineering organizations to improve traffic facilities in road construction; it works well to elicit requirements from stakeholders. Of these requirements, the vegetated traffic guide is selected based on three strategies. Concerning the final concept, engineering organizations can gradually incorporate it into organizing projects in urban contexts in future. It is worth reminding that contractors must localize the practice of vegetated traffic guides in specific situations.

As for future works, the actual performance of vegetation traffic guide demands verification in real contexts. Future work needs to clarify whether solar energy is a reliable source for external illumination, whether the selected materials can adapt to harsh construction environments, whether the concept relieves workers from the burden of placing traffic measures. Wanting to realize the concept, the design team needs experiments in many circumstances with a realistic prototype. Secondly, future practice scenarios integrate multiple cooperative strategies. Owing to the time restriction, the designer does not pursue the synthesis of ideas further. For example, the interactive map is a mobile application to detail an ongoing project. The traffic signpost, as a supplement of the final concept, is promising to provide reliable directional guidance. Therefore, developing these strategies is equally important to promote user experience under the same subject.

8.2. Project experience

In the present-day of urbanization, road construction is inevitable in habitable districts. The consequent disruption is going to be one of the main concerns in modern societies. The report has found that involving stakeholders other than engineering experts can produce unexpected results. Therefore, engineering organizations could invite non-expert stakeholders to participate in decision-making processes helps to find the most acceptable way to execute projects in the city.

Incorporating generative techniques in expert interviews is productive in deep investigations. During the research, the expert interviews were in traditional Q&A ways. The author found it

unproductive to elicit experts' deep knowledge. In the last interview, collages were used. This design technique yielded critical reviews on his daily routines and stimulated the expert to start more conversations.

Inexperienced participants require attention in planning a co-design session. The participants reflected that the co-design session makes them confused, even though every step was presented to help them in co-creation. Only one participant who has participated in similar activities before can calmly meet the co-design challenges. Everything was new to inexperienced participants. When the participant started the conversation, other participants were hesitating the way to behave in such an event. Therefore, the co-design planner needs to think about beginners, as they would face more challenges than we thought. Moreover, it is found that the design diaries made participants confused as well. A reason behind this is that the designer had known the design diary, while participants were not; jump thinking in designing a diary toolkit is a problem. As a countermeasure, the designer must test the toolkit with some beginners before distribution.

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Appendices

Appendix A. Stakeholder identification

Stakeholders	Typical activities	What do we need from them	Perceived attitudes/risks	Risk if they are not engaged	Stake in the project
Municipality	A spokesman for traffic, air pollution and water quality	•Knowing the societal and political context •Commitment to societal changes	•Lack of ability and attention to traffic measures • Prefer better communication to problem-solving •Keep on learning new lessons	•Could create significant barriers to the adoption of the design concept •Lack of chances to formulate local context.	Less disruption; good communication; less noise and pollution← technology development
Licensor	•Will communicate contractors and license projects •Will comply with Dutchlegal system	•Guidance on traffic measures planning	•Worry about the abuse of traffic measures	•No consistency with legal system	Legally correct; situations must be created that can be enforced
Roadwork supervisor	•Manage several projects •Monitor the construction and maintenance of roads •assist workers and overcome problems	•Experience in traffic flow control and in how to avoid nuisance	•Unsatisfied with the use of traffic measures •Lacks abilities to make a change •Interested in the impact of traffic measures on urban environment	•lack of first-hand experiences	Good balance among traffic measures. roadworks and nuisance→all be clear, manageable and cause a little inconvenience
Construction worker	•Do groundworks •Look and check everything before machine-working •Placement of traffic measures	•Experienced staff to be involved in the design process •Dilemma-sharing	•Curious about the outcomes from the research	•Create uncontrolled factors in concept adoption into factual situations	Good visual conditions for visually impaired users

Heijmans	•Traffic engineer making plans for traffic measures	•Interested and want to improve traffic measuresbut it lacks investment and abilities for the improvement.	•Possibly get involved in design process •Contribute to implementing changes. •Experienced inernal users of traffic measures.	•Could create significant barriers to business adoption of the design concept.	
Haitsma Beton	•Design and produce top-quality precast concrete barriers and piles •Supply requisite engineering knowledge	•Experience in barriers engineering and production process •Possible interest in the project.	•Contribute to a sustainable and safe living environment. •Insistence on innovation	•Lack of understanding of technical and production requirements	Research findings; new product ideas
Project coordinator	•Make plans and coordinate the use of traffic measures •Impact on situation control among projects	•Commitment to implementing changes • Experience of how to avoid nuisance	•Worry about the abuse of traffic measures •Interested in new traffic signages	•Could create uncontrolled scope of changes	Less is more(simple); communicate the right information; flexible for situations
Traffic controller	•Guide traffic flows •Communicate with road-users •Keep the safety in areas	•Guidance of traffic flow control and communication skills with road-users	•High exposures in traffic flow •High cost to hire	•Less feedback about complaints •Less experience of traffic flow control	Be safe in traffic flows
Pedestrian	•Spare more effort of motion •Complain about work zone after passing by •Possibly see them every day	•Contribute to recommended changes and ideas. •Involved in design process and user test	•Negative view on traffic measures •Easily violate rules when becoming confused •Want to make a change	•Create significant barriers to the adoption of the design to user-group	Communicatate well; less confusion; less is morr, people'friendly

Scooter	•Spare relativelt more effort of motion •Have to take detours •Possible see everyday	•Contribute to recommended changes •Involved in design processes and user test	•Confusing, unpleasant and feeling bothered	•Create uncontrolled scope changes •create barriers to adoption of design concepts	Clear instruction and enough information
Cyclist	•Spare the most effort of motion •Can hardly choose their own ways •See everyday	•Involvement in design processes •Contribute to recommended changes and test	•Annoying, confusing, bothersome and uncomfortable	•Create numerous barriers to the concept realization • Uncontrolled scope of changes	Fast-speed lanes; good communication; attractive, smooth, clear and safe detour
Policeman	•Compliance to TM rules •Orders enforcement •Light influence	•Observation of road-users behaviors	•Less interest in the project. •Concerns about increased workload	•More violation cases	People follow the guidelines
Resident	•Live in concerned areas •Walk or cycle everyday through the area	•Recommendation for solutions •Daily activities samples •Feedback	•Have some interests in the project •Want environment to be safer and quieter.	•Focus missing •hard to realize the concept in reality	Clear of how to take detours; earlier announcement; nice looking
Motorist	•Direct influence •Stopped by traffic measures on routes	•May be involved in design processes •Scenario-acquisition of their activities	•Less concern about the project but more about the information collection	•lack scooter experience regarding the use of traffic measures	Good communication, be pleasant
Guideline-maker	•Make guidelines for contractors •Will discuss with multiple stakeholders	•Design requirements •Working guidelines	•Curious about outcomes •Pay attention to the ways it changes guidelines	•No chance to know technical and systematic requirments	workers can work safely; people passing by can be safe; try to avoid traffic jam→positive communication with road users; local

					situation are considered
Standards Committee NEN	•Make sure that agreement made by market are included in standards •Standardize agreement and keep up-to-date	•Knowledge about standrads and possibility to realization	•Partly involved in the project. •lack of clarity about how project will impact on situations.	•lack of knowledge support from standards •Less possibility to realize design	Research findings; possible new solutions
Institute for Road Safety Research	•Public knowledge sharing •Provide answers to road safety questions •Do the research	•Advice and recommendation to design concept •Road safety evaluation for the final design	No direct interest	•No advice	Research findings; proposed solutions to problems

Appendix B. Personas

Bio

Name: Joy
Age: 27
Role: Resident
Responsibility: Waiter in Café. Working at a Café near traffic measures, taking detours

Dilemmas

- Roadworks are troublesome
- Completely closed for cyclists
- Not clear on how long it will be closed

Core Needs

- Detour planning need to be improved
- Information-carried measures

Dream future

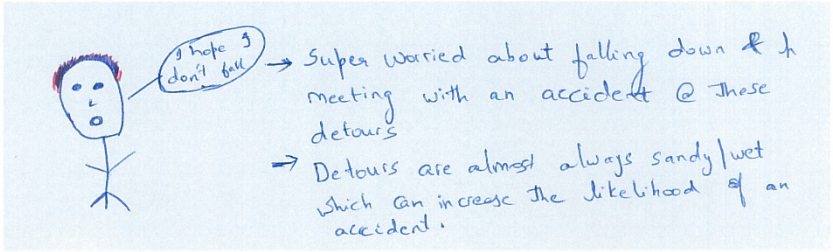
- Clear on how to take detours
- Earlier announcement
- Nice to be looked at and quiet in works

- access to interactive map will provide prices of detour
- Colours which afford her detour: attraction on road, water in vicinity, interesting architecture, music in surrounding, scenic, dynamic field

Typical activities

When there are roadworks near my residence, I feel that I will be bothered by them for quite some time. It's morning and I put on my coat and I rush to my office. When I get out of my house I see the roadworks which are full of dirty traffic measures alongside and some stuff abandoned. At the moment when I cannot figure out the "right" way to go through, I'd like to jaywalk in a shortcut as soon as I can move. When I'm off work in the evening, I've got to be careful again this way back home. It is pretty annoying to me if you come across the same situation for a month...

Figure 1. Persona of Joy



Bio

Name: Jacob

Age: 26

Role: Cyclist

Responsibility: represent all interests of cyclists in different ways, influence government and political decisions, report the plan of advice of cycling infrastructure and routes planning, publish magazines three times a year

Dilemmas

- The experience of following traffic measures are not positive at all.
- There is always a moment when I lose my way at the end of the detour.
- Believe myself instead of signs because they are always wrong and hard to be understood. Too little information in the detour causes disorientation
- Dangerous for cyclists in darkness
- As a stranger, you know nothing about roadworks at this place due to the lack of signs.

Core Needs

- Have clear information about routes of the detour in traffic measures.
- Want to be safe and comfortable in the detour.
- Cycling routes have to be smooth, spatially available.
- Visible barriers and signs

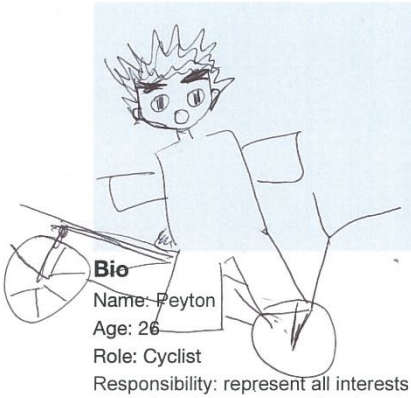
Future Goals

- Easy way to make a detour(attractive, smooth, clear and safe)
- Sufficient information in the detour
- Detour has to have the same standard as a normal path
- Signs are trustworthy

Typical Activities

I'm a scientific researcher at the university. I go to work by bike every morning. I come across a work-zone closed by traffic measures whenever I go to work. I can see a mess behind traffic measures. They are quite annoying to me because I don't like being interrupted while riding. I must go to work on time and I quickly browse traffic signposts aside showing me the way to make a detour, I don't quite understand well though. I follow the direction the traffic measures lead me while being disoriented. The routes are unsmooth and crowded as I worry about hitting the traffic measures. Then I get off the bike and move on to exit...

Figure 2. Persona of Jacob



Bio

Name: Peyton
Age: 26
Role: Cyclist
Responsibility: represent all interests of cyclists in different ways, influence government and political decisions, report the plan of advice of cycling infrastructure and routes planning, publish magazines three times a year

Dilemmas

- The experience of following traffic measures are not positive at all.
- There is always a moment when I lose my way at the end of the detour.
- Believe myself instead of signs because they are always wrong and hard to be understood. Too little information in the detour causes disorientation
- Dangerous for cyclists in darkness
- As a stranger, you know nothing about roadworks at this place due to the lack of signs.

Core Needs

- Have clear information about routes of the detour in traffic measures.
- Want to be safe and comfortable in the detour.
- Cycling routes have to be smooth, spatially available.
- Visible barriers and signs

Future Goals

- Easy way to make a detour(attractive, smooth, clear and safe)
- Sufficient information in the detour
- Detour has to have the same standard as a normal path
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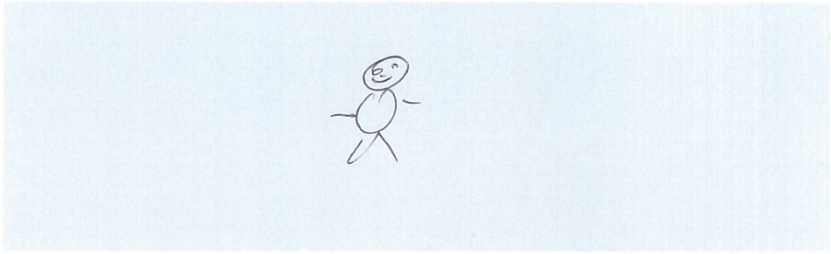
Typical Activities

I'm a scientific researcher at the university. I go to work by bike every morning. I come across a work-zone closed by traffic measures whenever I go to work. I can see a mess behind traffic measures. They are quite annoying to me because I don't like being interrupted while riding. I must go to work on time and I quickly browse traffic signposts aside showing me the way to make a detour, I don't quite understand well though. I follow the direction the traffic measures lead me while being disoriented. The routes are unsmooth and crowded as I worry about hitting the traffic measures. Then I get off the bike and move on to exit...

if it's not raining heavily at the moment I went out

Figure 3. Persona of Peyton



Bio

Name: Pierce

Age: 45

Role: civil engineer

Responsibility: Manager of ILT(integral Leiding Tunnel); team member to arrange coordination for all cables and pipes in Zuida; make strategies for energy plan and utilities;

Dilemmas

- Many traffic measures are too busy and unclear. Too much information for users and it's not clear to whom that information is for.
- A lot of mixed-ups, lots of red/white and yellow.->likely to contradict each other
- More traffic measures are not always better

Core Needs

- Legally correct and create a situation that can be enforced
- Ensure all traffic flows are guided well
- Road users must treat them seriously
- Find the balance between measures, works and nuisance

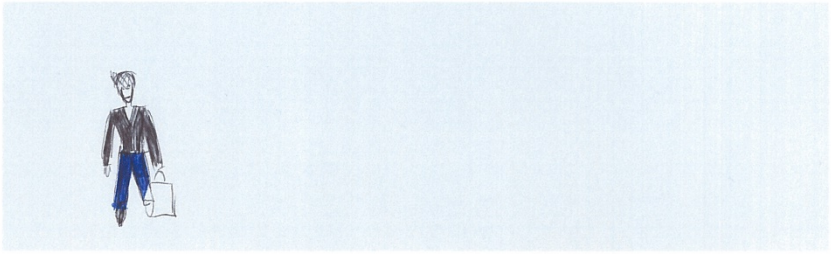
Future Goals

- All be clear, manageable, and cause a little inconvenience
- Combination of other activities must be carefully considered
- Assessment of traffic flows
- Better guidelines for urban area and therefore focus on cyclist and pedestrian

Typical Activities

I wake up early in the morning heading to my office in Zuidas. Having a lot of plans in my mind, I look up emails and respond right after the arrival. I regularly have meetings with colleagues in meeting rooms in a day so I can make sure that everything is going well and avoid nuisance. I usually worry about the problems that our strategy doesn't perform in the right way.

Figure 4. Persona of Pierce



Bio

Name: Eric
Age: 27
Role: Pedestrian
Responsibility: Working at a clothes shop near a roadwork, taking detours everyday

Dilemmas

- Roadworks block my way
- Make me walk in the vehicle and bicycle lane
- Not clear of how long it will be closed
- Longer distance in detours and waste my time

Core Needs

- Short walking distance
- Effective Information communication in advance
- No boring long-distance walking

Dream future

- Clear on how to take detours
- Earlier announcement
- If detour is inevitable, make detour a better experience

Typical Activities

Traffic measures so unclear that I could read for a moment. Whenever I pass roadworks, I'm a little upset to see a big mess. Roadworks always cause disturbance on my way that might shut down by traffic measures and the aisle is probably taken by unsteady steel plates. Without knowing other choices, I move forward on another way around. In the detour, I feel uncomfortable and I see many traffic measures are improperly placed on my way and I take more time to walk away. At this moment, I have no idea where is the exit so I cross over the road to find a way out...

Figure 5. Persona of Erica

Appendix C. Co-design session schedule

Diary-keeping

1) Read the explorative scenario and personas which are roughly pre-defined.
2) Map out your routines in surroundings when you engage with traffic measures by taking photos or drawing.
3) Take probes with you for a few days. Make records of your feelings and emotions when you see traffic measures.
4) Refine your explorative scenarios based on your experience
5) Write down functions you'd like to have or get rid of in the future

Co-design workshop

1)	Preparation and participants' self-introduction	10 min, 13:20PM
2)	Presentation: goals, game settings and rules.	10 mins, 13:40 PM
3)	Warm-up: read personas and write top goals with each other	10 mins, 13:45 PM
4)	Storyboarding: story improvisation of current practice scenario	25 mins, 14:10 PM
5)	Breaks	5 mins 14:15PM
6)	Presentation or explanation of storyboard they create	10 mins, 14: 25 PM
7)	Introduction about lighting technology and future scenarios	10 mins, 14:35 PM
8)	Brainstorming ideas for improvements	15 mins, 14:50 PM
9)	Storyboarding: future practice scenario-discussion of use	25 mins, 15:15 PM
10)	Presentation of storyboard	10 mins, 15:25 PM
11)	Evaluation of the co-design session	5 mins, 15:30PM

What if

1) What if participants don't come on time

Write emails two day prior to the Tuesday. It can be said: we have coffee prepared 15 minutes before the workshop. The session will officially start at 13.30PM

2) What if participants don't answer intended questions

We can provide guide questions and topics not the way. If participants think of nothing needed to improve with traffic measures, we can let them think of the whole roadworks area or road works at night and find out possibilities. Secondly, we would ask them to follow the personas and explorative scenarios which indicates a couple of ideas. Thirdly, introduce new technology and explore possibilities.

Appendix D. Design diary toolkit

Figure 6. Design diary package

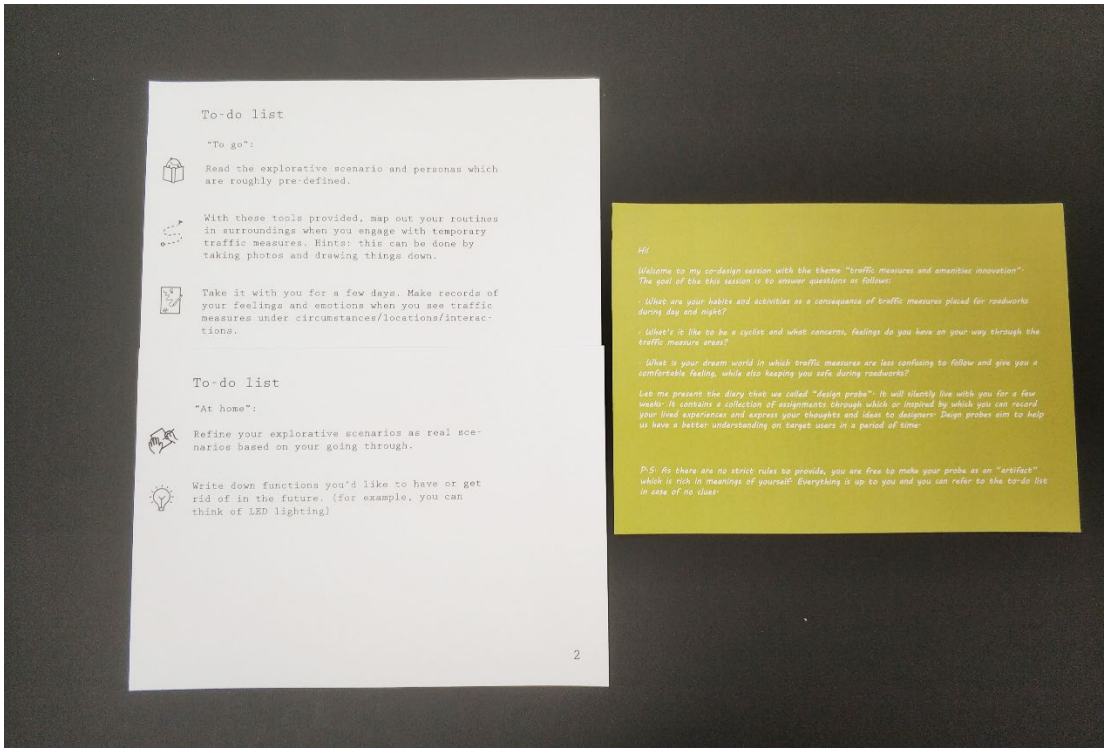


Figure 7. Design diary guidelines

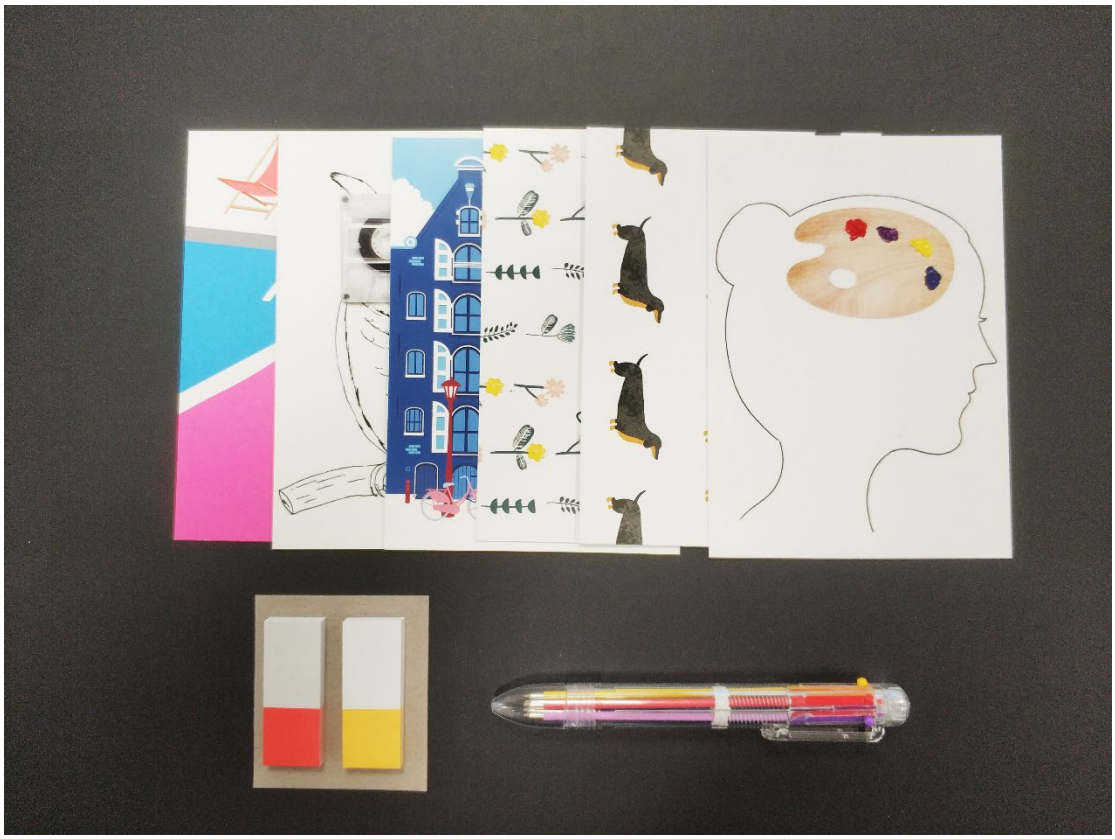


Figure 8. Design diary writing tools

Appendix E. Co-design recordings

Warm-up

Access to an interactive map-personalized, quickest way. She can go along river.

If she is going in home, she ‘d like to find out how to access nicely without distractions.

I’d like to suggest a good headphone and GPS.

Announcement board, because nowadays they are gold in day and no light at night, it makes you very nervous and many people are looking into direction(20 people). So I would suggest building up announcement board and close.

I would make less graphic noise and more contrast and make it higher position so people can see it. Sometimes, direction boards and bridges are so low that you cannot find them.

I think orientation points at night visible. For example the church tower as light house(measurement of orientation).

Some hotel are high so you know you know you can go this way, better than nothing.

Top wishes

Clear visible signs. I thinks a lot traffic measures don’t have enough light. Temporary lights or something. After the removal of traffic measures, the street lights become pointless.

Safety. Traffic measures surface are uneven, end with sand and something that can increase the chance of people’s falling. Safety is a very big pint there.

Interactive compass will help. At least you know the direction of south, west.

Most people they know the area. They go there every day. But in such a situation, so many visitors are getting abstractions.

Every day in my commute, I’d like to know alternatives I can use, I would be nice that you are here and you can go this way.

Helicopter

For me, I ‘m a cyclist. I wish I could have a guidance for foreigners since they are distractions to me and make me fell from my bicycle for five times. Not because of me, it was because of those foreigners…so I think manual for foreigners would be better.

Maybe the language can be another concern. The foreigners and even locals don't read warning signs.

Ture, nobody can read the forbidden signs because I have an experience that there are 500 bicycles parked in the city center. Maybe bilingual instructions.

The first storyboard creation

Scene 1: Road users are going to cross the roadwork and engage with a large number of traffic measures in this neighborhood of Hobbemakade.

He is supposed to move around. She was choosing a nice path…

She can finally reach her working space peacefully.

Peyton: Where is the nearest flow and water field?

Eric: I want to reach my workplace the fastest way possible without taking any long alternative routes, I'm confused. It takes me longer time, I want to check all information about his place.

Pierce: The barriers are messy! It's unclear to me if the gas station is open. How do I get to work?

Jacob: Oh no! There is no light here. I hope I don't fall down. I'm terrified of mopeds going super faster next to me!

Joy: It's another day to cycle to the university…Humm…There are constructions going on(shocked on the way)?!?!

Brainstorming

Currently, there are no differences between different functional routes for road-users.

In some places, you don't know where it takes you when you are asked to get of the bikes

Maybe the flying bus carry you all around in roadworks.

I remember an application in Slovakia, called flickering.

I remember in Eindhoven, there is a road with fluorescent light on the surface at night.

Easy-light(easy for people) for marking in the traffic roads.

Maybe the laser from above->VR or cyclist in light that you can follow with in the right way.

Flexible color skin for road surface.

Projector used for orientation to show the map for orientation, they are place in higher than normal traffic measures.

Maybe we can sue the pin on the map-> you pin a point, alternative routes can be shown.

Disabled people need to be taken care of. So we can think of light with temperature to help invisible people get orientation.

Flying bicycles can take you to the exit.

Red light can reduce crime rate so I prefer that.

One clean color which is bright enough for working.

Color connected to specific risk->different light colors to indicate that you need to be careful at this place, that place is safer to go on.

Obligatory reflex field on your outfits that everybody at traffic measures can see you.

Lighting on the ground.

Look clean, roads are not bumpy, fast…

The second storyboard creation

One color for one path.

Plan better in advance-> we don't read signs ->get the app on mobile phone to receive message from the beginning of the route. Can be indicated by voice message.

Traffic measures->less is more, we don't put so many traffic measures, nobody is happy with it(current situation). Or no traffic measures at all and we can let people manage the traffic themselves. Then you need to indicate the roadworks area for road-users and stop signage in the beginning to indicate where the roadwork starts.

Evaluation

Instruction is not clear, for example the diary-keeping.

Appendix F 1. Design diary of resident Joy

My participation on "Traffic Measures and Amenities Innovation" should be a proof of value of human contribution to the universe of urban space.

What are your habits and activities as a consequence of traffic measures placed for roadworks during the day and night?

I've grown a little disillusioned about chance of adapting easily to every new urban environment thanks to alignation given by European regulations. Promise of freedom in Amsterdam softens vigilance and lack of prior introduction to city rules makes you observe and follow. Many times iterations are reflections on incorrect steps of other people - here Human Factor builds up and abstract intentions of rules are hard to be assumed.

I like emptier roads, since I cycle for pleasure more than to commute. I keep my good vibes and pleasure of dynamic image given through loveliest urban landscape. I like to observe my surrounding. At night it is even more immersive, thanks to unfinished list of varieties of lights in Amsterdam, it feels as ephemeral take on psychedelic crossing of milky way close up.

I like to choose a different road.

****

What is it like to have a roadworks near the residence and what concerns, problems and feelings do you have?

In short: lateness to work, complete loss of orientation - as such fail to reach place of destined appointment. Fear of shame of excuses. Seek for mercy in helicopters sliding above, unlimited. Restless activity on maps, desperate bothering bypassers. I ask myself how quickly can i die before completely lose dignity. Sometimes I cry. There are only few lit lighthouses in the city - towers of lit vantage point, that can serve as orientation nest. It is beautiful cosmos at night- quiet and immortal in architecture, just very impractical for newbies. Insecurity of existential fear feels like being newborn anytime I reach my hostile rented room. It makes me a little less extroverted. If it's warm, I lose myself into the moment of dropped plans and ride through for pleasure, bitter sweet images, FOMO rises cortisol.

****

What is your dream world in which traffic measures are less confusing to follow and give you a comfortable feeling, while also keeping you safe during roadworks?

I’d love to see less graphic noise : Information and direction boards made in colours, which respect contrast and readability standards, positioned at standard places and clean. Lit highlight

points, sensible navigation, unifying and precise map app with lower battery consumption. Evenly deployed info kiosks - interactive maps accessible at vast and less busy spaces (parks, large squares, complex roundabouts, distant peripheries). Compass.

There was a presumption of predefined personas given but since I had not have access to them, I'll write in first person.

Figure 9. Road construction and traffic measures use situations

Appendix F 2. Design diary of cyclist Jacob

December 5, 2019

It's been a relatively traffic free day so far near my house. I live near a school and every morning around 8, there are rows of cars driven by their parents. Every car has one child and one driver which is strange as Enschede is a small city and they can easily implement car pooling. It has been raining quite a bit recently and because of the leaves on the road, this creates a slippery surface on the road which makes me ride slow and very carefully. I went to University and there was no construction going on anywhere nearby today. The slippery roads with leaves has no solution as far as I think unless the municipality decides to clean the leaves regularly.

December 6 2019

I took a trip to Amsterdam today whereas on my way to the train station, I fell off my bike. It's a funny story. I wasn't speeding or riding rashly but I fell because of the unevenness of the bicycling track. If you have ever cycled in Netherlands, there is a small gap at the side of the cycling track for drainage purposes and my bike tyre got stuck there and I fell. Maybe, this wouldn't have happened if the roads had small led lightings or the gradient between the cycle track and the drainage space was even. Maybe this wouldn't have happened if there was no construction going on Haaksbergerstraat as well and then I would not have taken this route. Construction work over here has been ongoing from 6 months now and its absolutely annoying because I use that road quite a bit to go to friends places and I have to take long detours to reach there.

December 7 2019

It was a usual day to university today and it takes about 10-12 minutes of cycling there. What I find very strange is the cycle crossing on my way to the campus. I have to cross the highway and while crossing, I need to make a decision if I should quickly try to cross before the vehicle comes or wait until it passes. I think this sort of decision making can lead to severe fatalities. This one time, I saw a guy who was almost hit and this could have been fatal for him, the car driver and the other vehicles coming fast behind the car. Maybe a sensor or a light which could indicate the cyclists if it's safe to go or not based on how far the car is and how fast it is going could work wonders and reduce accidents.

December 8 2019

I was home all day today and did not bike anywhere. A quiet day at home.

December 9 2019

I took a small trip to visit a friend who lives near action in Enschede. I didn't realize how much these temporary traffic measures affect me until I started writing this diary. An entire main road (Oldenzaalsestraat) has been shut for about 7-8 months now and they have made these tiny temporary tracks where people cycle in and walk there at the same time. It feels like a disaster waiting to happen. Moreover, because of rains there are puddles and people and cyclists try to avoid it leading to an even narrower space. I understand that the government has the need to shut off roads and services for maintenance or whatever, but in an advanced country like Netherlands where they shut a street down for 6-8 months is extremely surprising.

December 10 2019

I finish university early and decide to go to the city centre to the Indian food store to buy groceries. I take the GJ Van Heekstraat to reach city centre and I am terrified of riding on this street. The bicycle lane is right next to the main road and the problem here is that the main road is extremely narrow. I am literally millimetres away from speeding cars. One tiny misjudgement and I am dead. A scary prospect indeed. There are no other alternative traffic measures over here but I am faced by some detours as soon as I reach Ripperdastraat. That street has been shut for repairs for about 8 months now and I have to go all the way into city centre and take alternative routes.

December 11

A usual day where I had to go to university to finish work and lo and behold there was a small construction going on outside Zuidhorst. It didn't affect cyclists but I think it blocked the road for cars to pass. What was surprising to me was there were no signs or anything that the construction is going on and this can be a dangerous precedent in case of any mishaps. I did not see anything else the whole day but surely the small construction site could have small signs or they could have just cordoned off the area.

December 12

I didn't have class today and it's a relaxing day at home. I went to the supermarket though and I realize that cobbled roads are super annoying to cycle on. No traffic measure anywhere on my way or back though and it's a pretty uneventful day for me.

December 13

I had a long day at university and now I am off to a party at a friend's place. He lives on Boulevard 1945. It's far and its already late whereas, I decide to go. As soon as I reach, Tromplaan, I get stopped by the police and I am fined for not having turned on my bicycle lights. I cycle on and reach Haaksbergerstraat and the temporary traffic measures there have no light anywhere and it is absolutely scary to be cycling on this street. I should maybe fine the municipality now because they don't have lights here. LED lighting which is extremely cheap could be so useful for pedestrians, cyclists and vehicles in this situation. It's a simple solution and Netherlands being so tech savvy makes me wonder why they haven't implemented this yet. The ride back home is the same. Being slightly intoxicated, it is even harder to focus on the road without lights.

December 14

It's a Saturday. Finally I can relax at home whereas unfortunately I have exams next week so I have to just sit at home and study for the next 2 days.

December 15

Home

December 16

I had one class today and now I'm off to the central station to bid adieu to a friend who is leaving Enschede. This, being a small town doesn't have too much traffic or temporary traffic measures compared to the bigger cities. As I was thinking about this, I am faced with a major hassle in the city centre near Café ThunderBird. Due to the entire stretch of Oldenzaalsestraat shut down, there is a narrow gap to cross the street and this has lots of people walking here as well. I see some people cycling while some people walking with their bikes next to them. There is an electric bike who wants to go super fast and scare everyone in this tiny path and this is such a hassle.

December 17

Today, I have to go to Amsterdam for the workshop. I bike to the city centre and take the train to Amsterdam. I reach Amstel station and walk to the centre without witnessing anything. The workshop is done and I have 2 hours to kill before I can board my train back and I walk around Amsterdam enjoying the sights. I don't remember the exact location but somewhere on Prinsengracht, a bridge was shut down for vehicles and only open to cyclists and pedestrians. There were no street lights and overall it was such a mess. Several cars would come up all the way to the sign and then realise it was blocked. The high beams of the cars on people's faces

along with tourists walking all over the street made it a prime target for an accident waiting to happen. Either better signages or street lights or LED lighting for the traffic measures would have helped immensely in this situation.

Appendix F 3. Design diary of cyclist Peyton

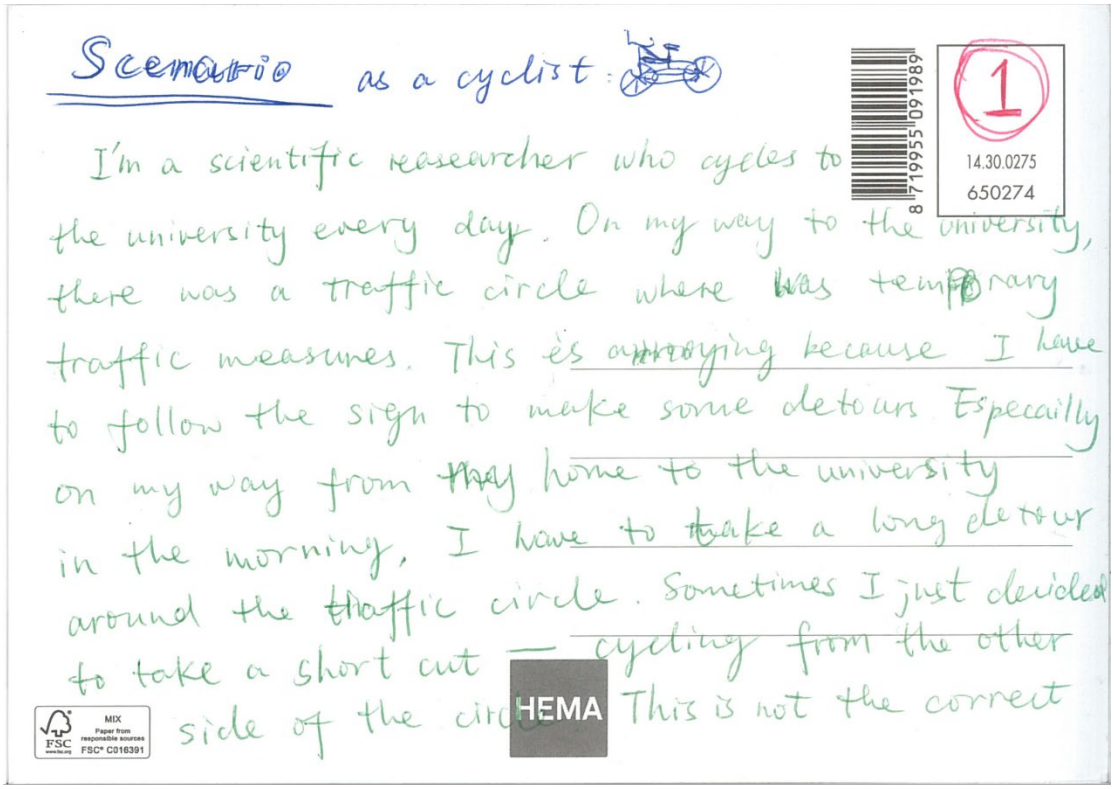


Figure 10. Lived experiences with traffic measures, written by Peyton

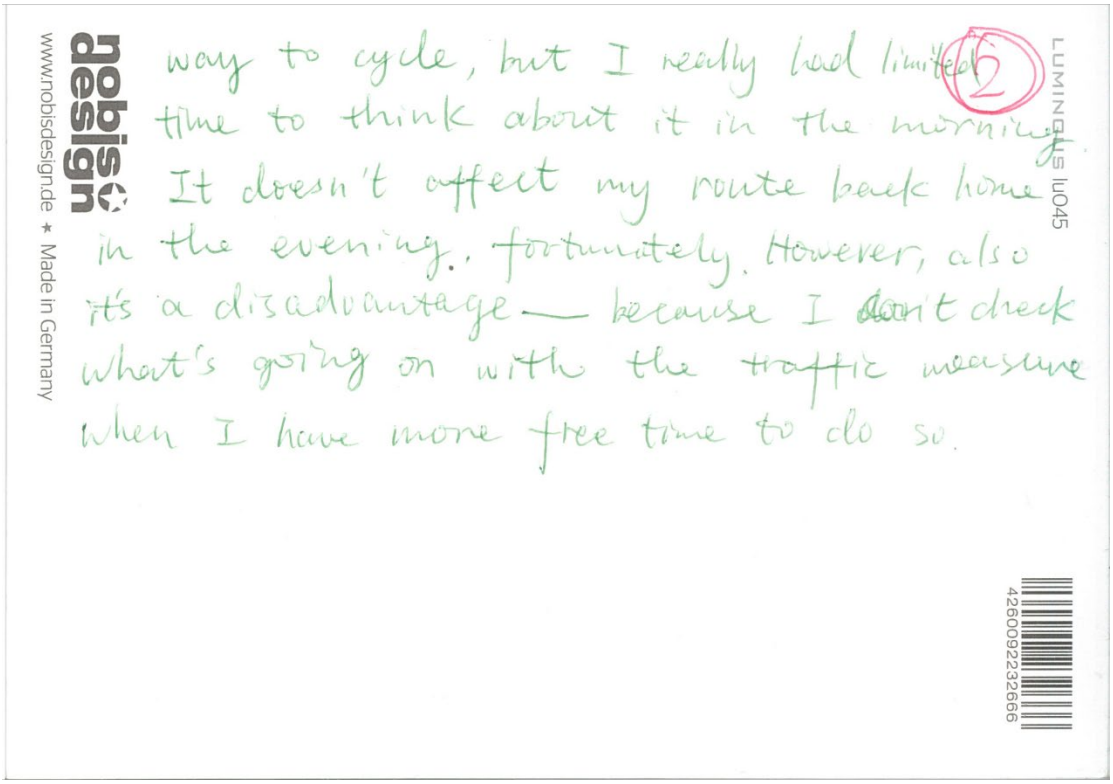


Figure 11. Second page of lived experiences with traffic measures, written by Peyton

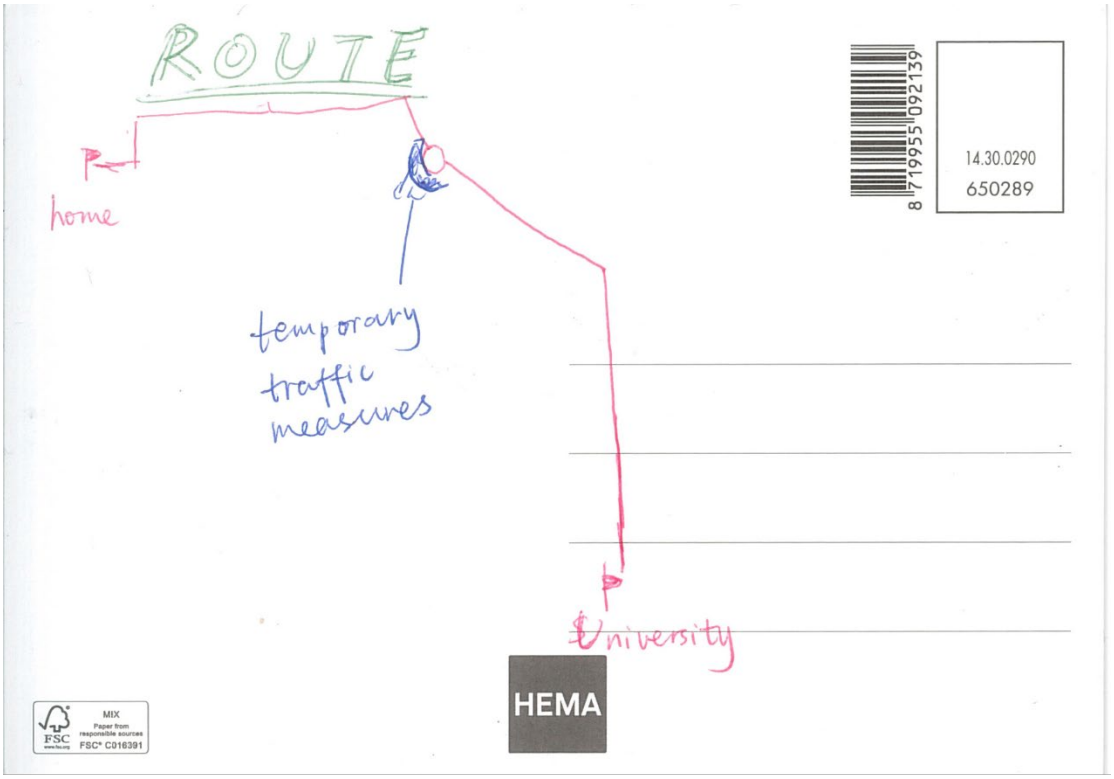


Figure 12. Traveling routes of Peyton

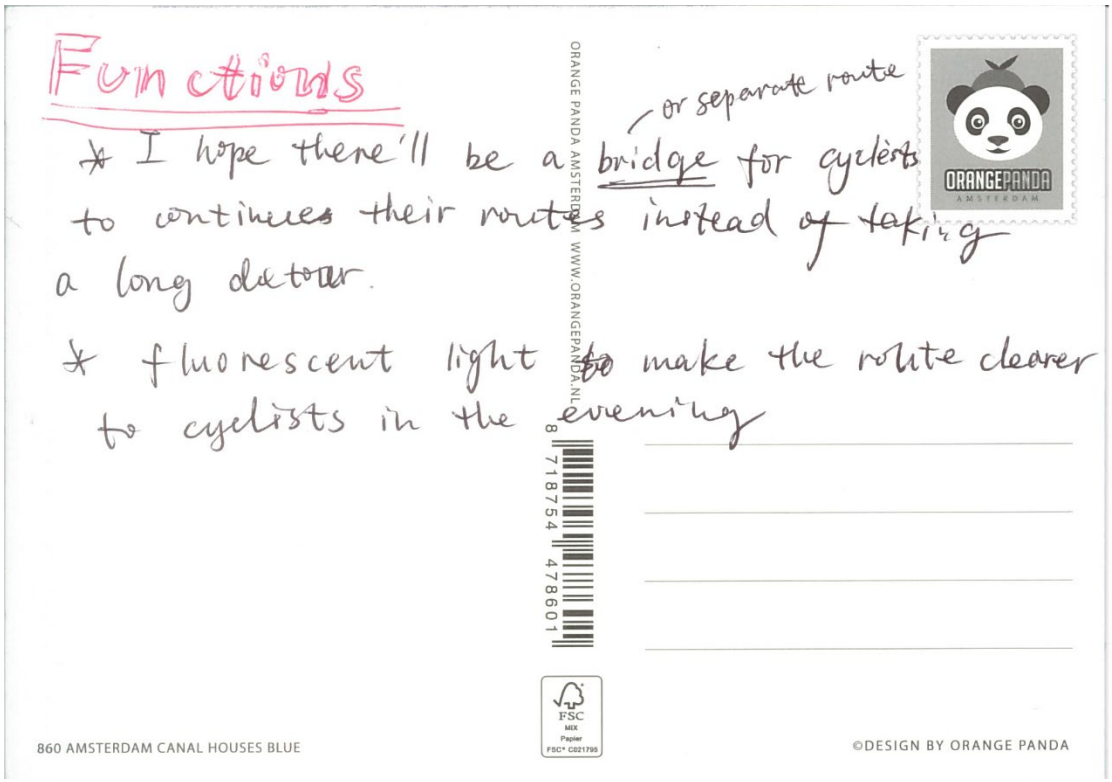


Figure 13. Peyton's Desirable functions of traffic measures

Appendix G. Design ideation sketches

Below, the appendix demonstrate an ideation process before reaching the final design concept.

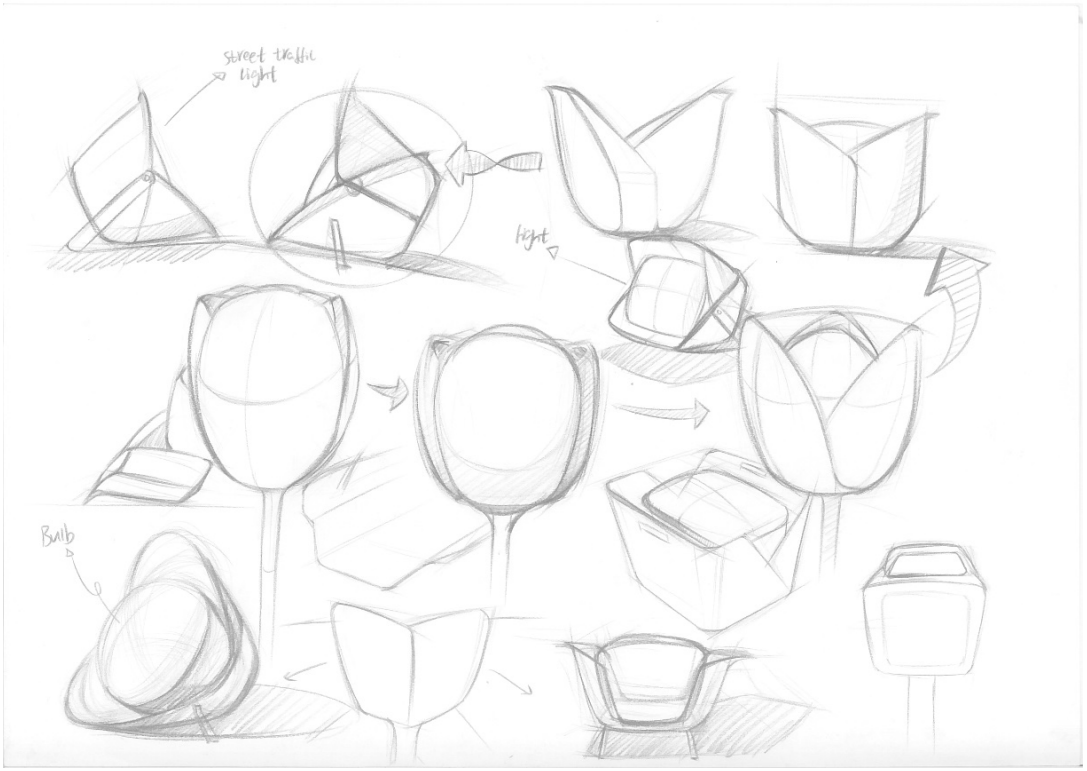


Figure 14. Bionic tulips design of temporary light

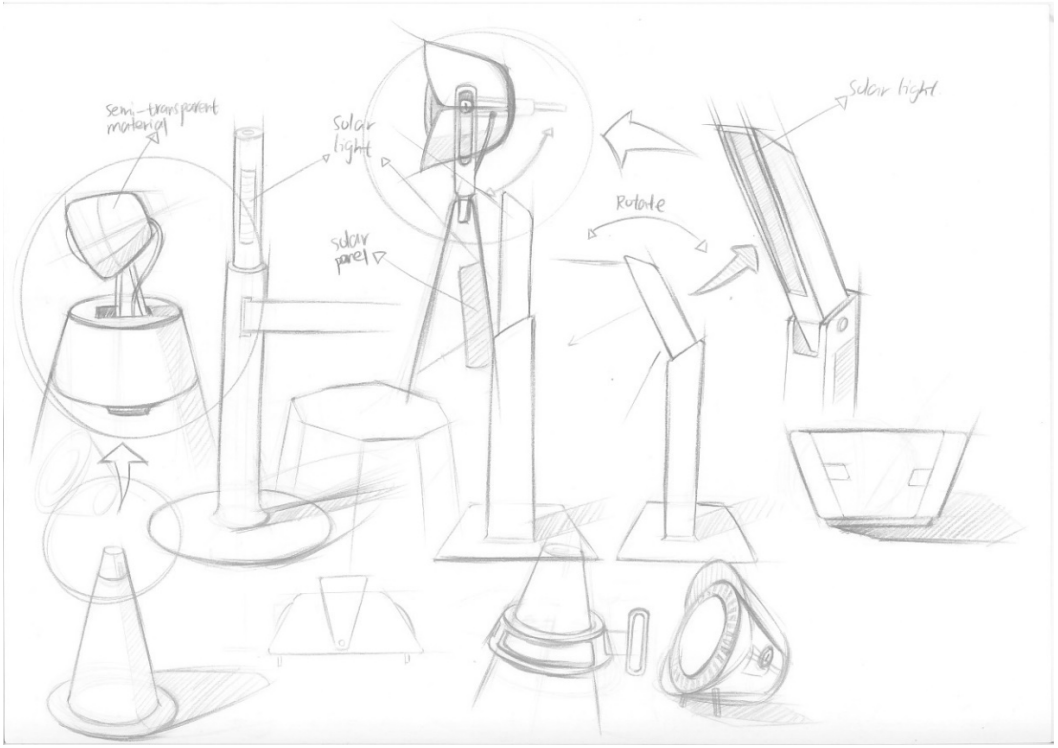


Figure 15. Bionic design of tulips of traffic cones

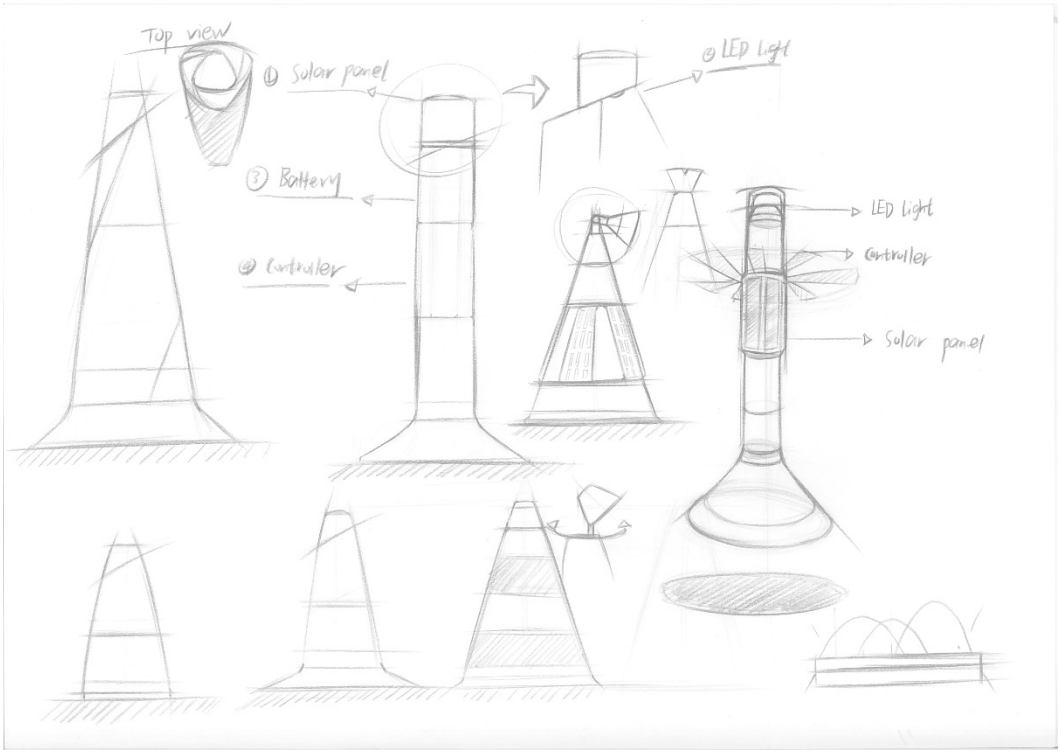


Figure 16. Traffic cones design with solar panels

Figure 17. Redesign of traffic beacons

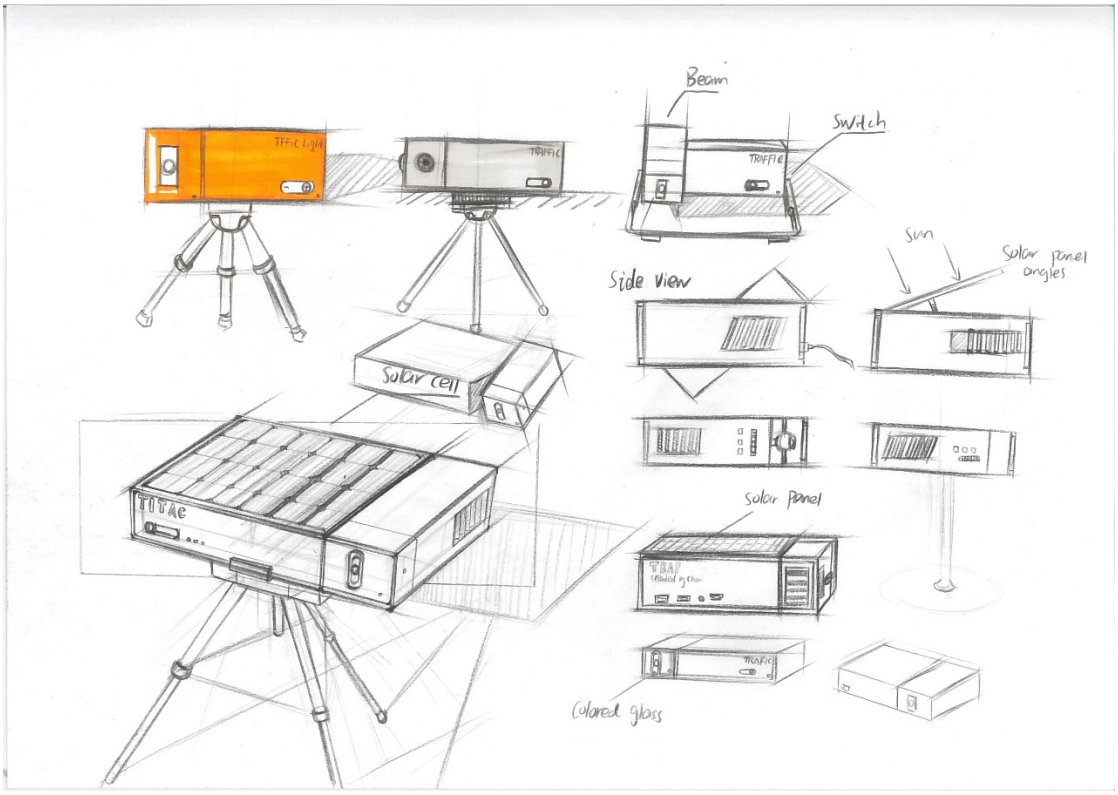
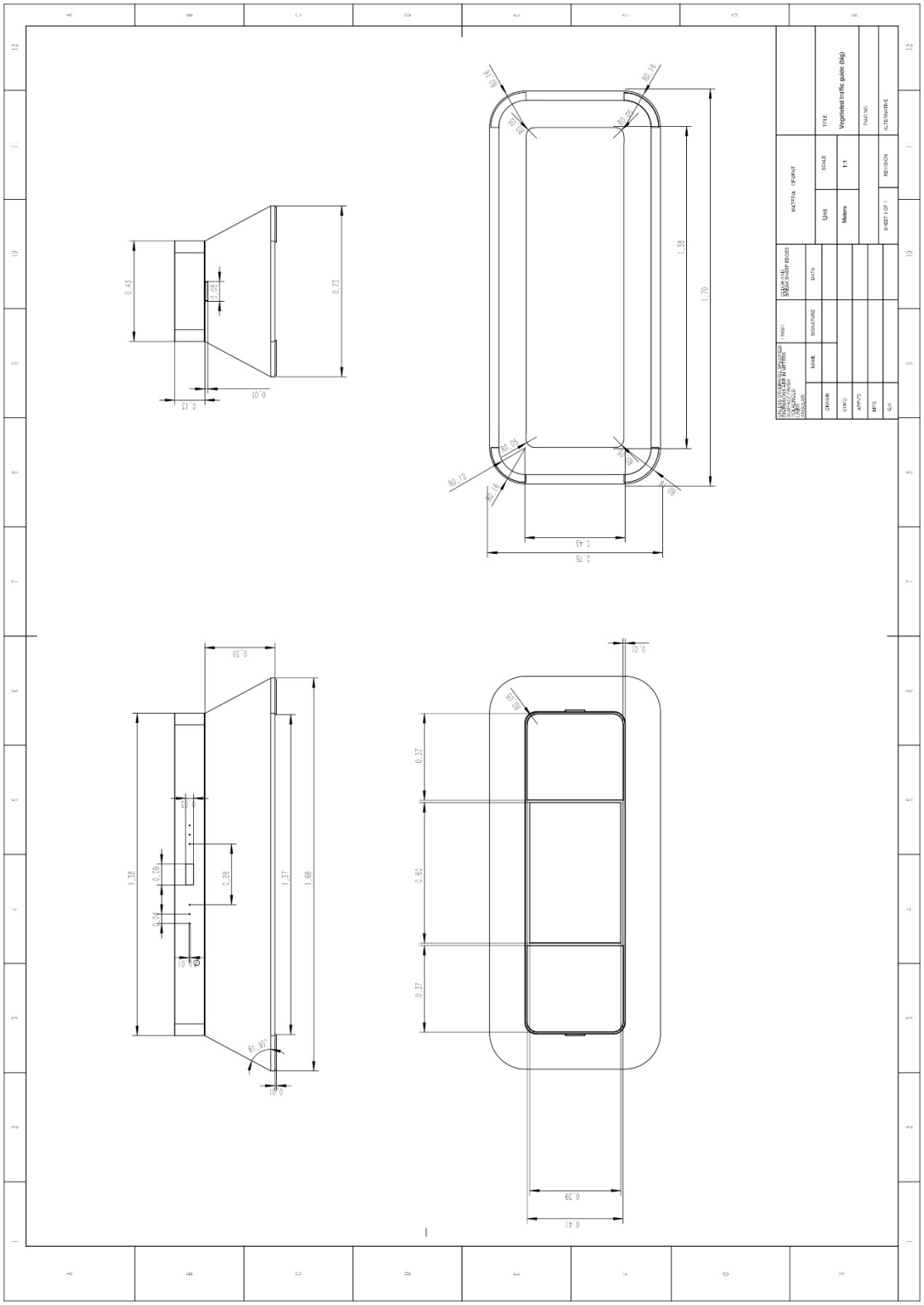
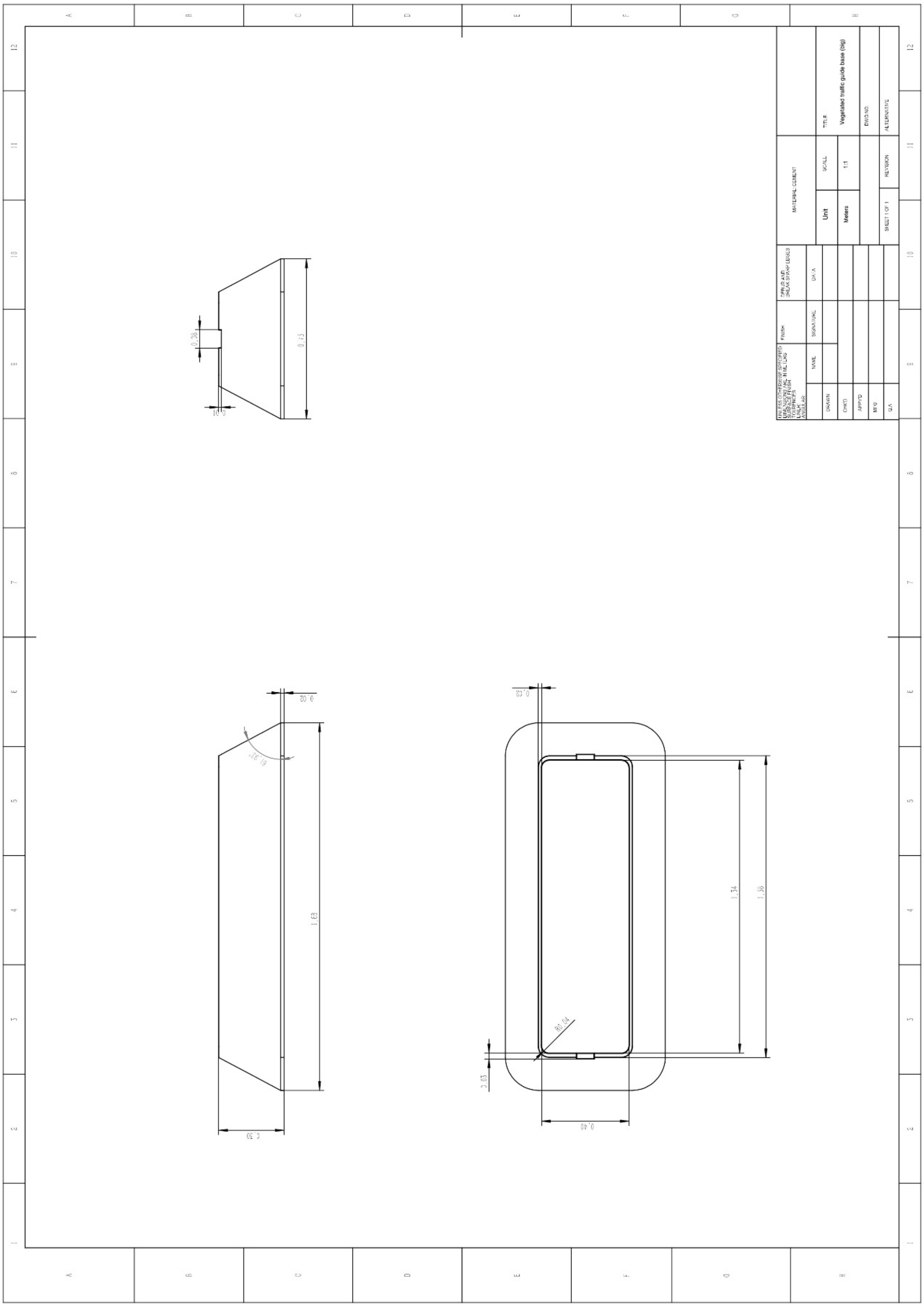


Figure 18. Design of a ground-light producer

Appendix H. Design dimension drawings

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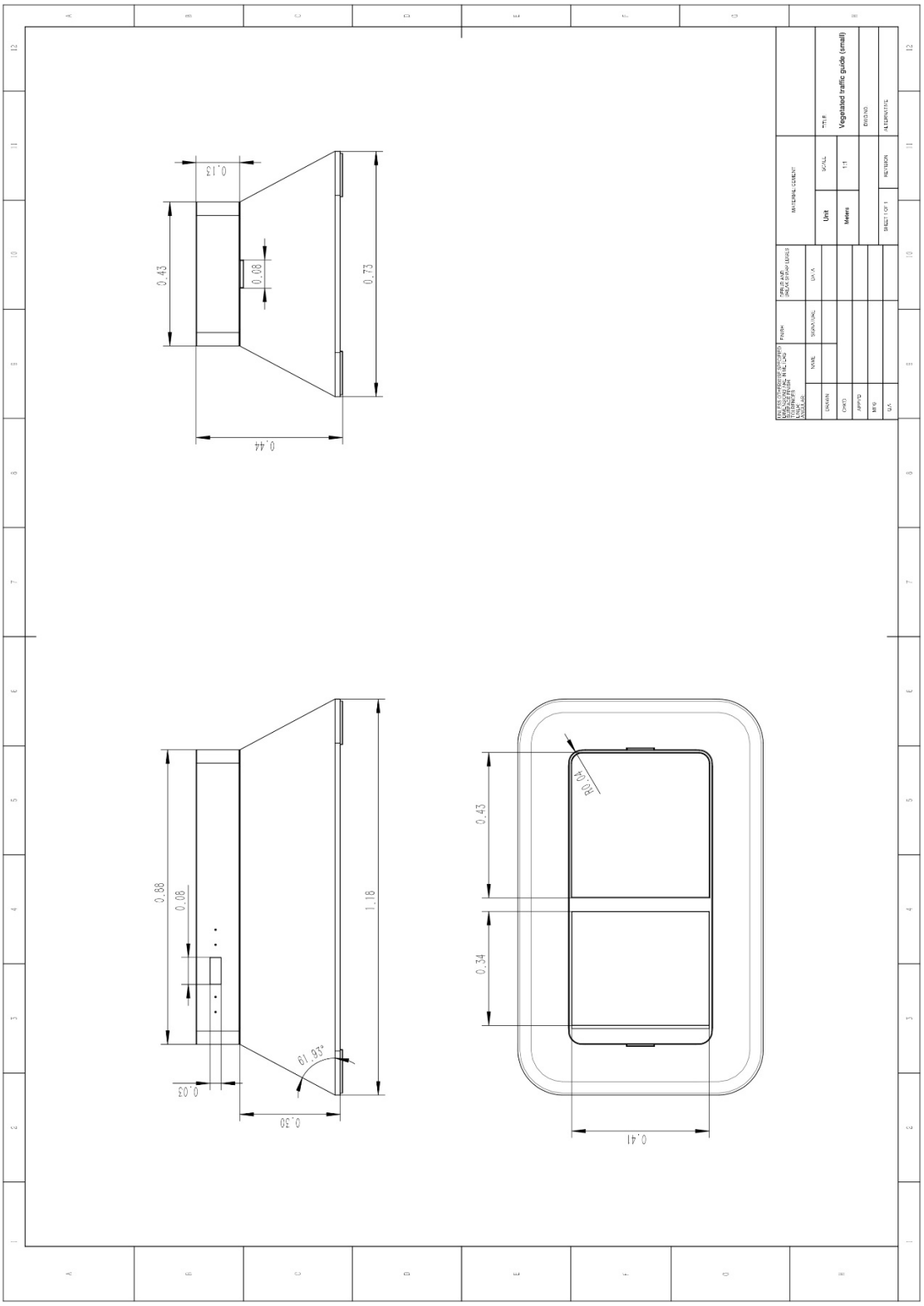
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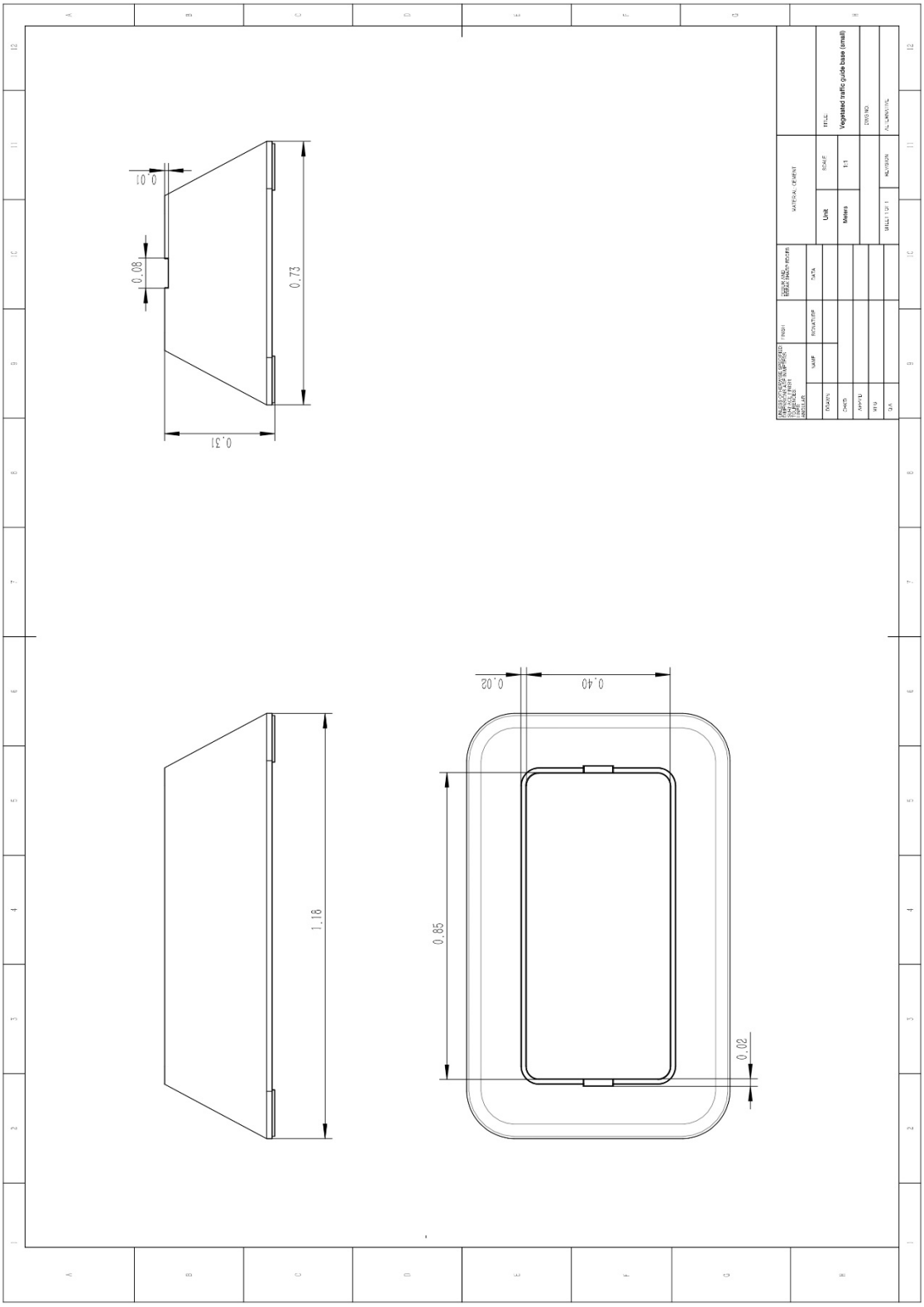
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