Bend the butt

The waste hierarchy applied on cigarette debris which leads to the proposal of implementing the permanent cigarette filter.

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Abstract

Cigarette butt debris forms an environmental problem. When the cellulose acetate cigarette butts find their way to the ocean, they fall apart into microplastics. Moreover, the toxic components in cigarette butts as a result of the combustion of tobacco leak into the environment when the butts are not disposed properly. This integration project analyzes and compares directions to solve this problem in order to propose a solution.

The solution directions are identified by applying the waste hierarchy. These solution directions are analyzed and compared by constructing a design matrix. Within this design matrix all identified directions are evaluated with the use of multiple criteria. The five directions with the highest score serve as an input to create designs which are assessed in a newly constructed design matrix.

Eventually, the results showed a preference for creating a permanent cigarette filter which is a filter that can be reused for multiple times. This filter has a high potential for decreasing the amount of plastic littered through cigarette butt debris without changing the smoking experience significantly. Furthermore, this design is effective in the long-term. However, the development and implementation of this design requires a significant investment and effort, since a the permanent filter does not exist yet and a new logistic system is needed to prevent harmful residues from being exposed to the environment.

This study emphasizes the need to find an appropriate solution for the cigarette butt debris problem with a socio-technical approach which considers all involved stakeholders and the environmental circumstances.

Contents

List of Abbreviations

KPI - Key Performance Indicator
AHP - Analytic Hierarchy Process
PR - Plastic reduction
HRR - Harmful residue reduction
AH - Added Hazards
SE - Smoking experience
CE - Consumer effort
CH - Consumer health
CA - Consumer awareness
PC - Producers' costs
MC - Municipalities' costs
LTE - Long-term effectiveness
R - Realization

Chapter 1: Introduction

Cigarette butt debris forms an environmental danger for human beings and (sea)animals. (Torkashvand, Sobhi, & Esrafili, 2020). The littered cigarette butts find their way to the ocean carried through drains and rivers. While researching the marine litter in 2009, cigarette butts were the most counted litter (Andrady, 2015). Cigarette butts leak their toxic components and microplastics in the aquatic environment, which is toxic to some aquatic organisms and fish (Torkashvand et al., 2020). Furthermore, filter leachates may have negative effects on the quality of drinking water and result in bioaccumulation in the food chain that could form a threat to human health (Wallbank, MacKenzie, & Beggs, 2017).

Every day, billions of cigarettes are littered in the world (Torkashvand et al., 2020). This results in cigarette butts being the most collected item of the Oceans Conservancy's International Coastal Cleanup for the last 25 years (Rath et al., 2012). The impact of a single cigarette butt can be neglected, however 845,000 tons of cigarette butts are estimated to be littered in the world every year (Novotny et al., 2009).

Cigarette filters consist mainly of cellulose acetate fibers and combustion products of tobacco. More than 15,000 cellulose acetate fibers are packed closely together with the binding agent glycerol triacetate in one filter (Torkashvand et al., 2020). Furthermore, cigarettes contain more than 150 components which are classified as highly toxic, because of the mutagenic and carcinogenic potential. The highest concentration of these toxic compounds can be found in the filters and the residual of the tobacco after the consumption of the tobacco (Araújo & Costa, 2019).

When cigarette butts are discarded in nature, the toxic components, micro- and nanoplastics leak into the (aquatic) environment. Due to the complex composition of cellulose acetate in cigarette butts and the added plasticizers , the biodegradation is hindered significantly (Araújo & Costa, 2019). In fact, a cigarette butt is never fully degraded, but dissolved in micro- and nanoplastics when cellulose acetate is exposed to ultraviolet radiation or movements (Stel, 2019).

This study aims to propose a design which has a high potential to decrease or eliminate the negative effects of cigarette butt debris to the living environment of human beings and animals worldwide.

Chapter 2: Problem Analysis

In this chapter the problem of cigarette butt debris is analyzed by performing a stakeholder analysis, obtaining a system description and set a scope for this research. This analysis leads to the goal which aims to identify the most promising design which decreases or eliminates the negatives effects caused by cigarette butt litter.

2.1 Stakeholder analysis

Wierenga states that a stakeholder of a problem is a person, group of persons, or institution affected by treating that problem (Wieringa, 2014). Moreover, the boundaries of the research are set by these stakeholders. In this section the stakeholders are analyzed and prioritized with respect to their interest and power towards the problem which is illustrated in figure 2.1.

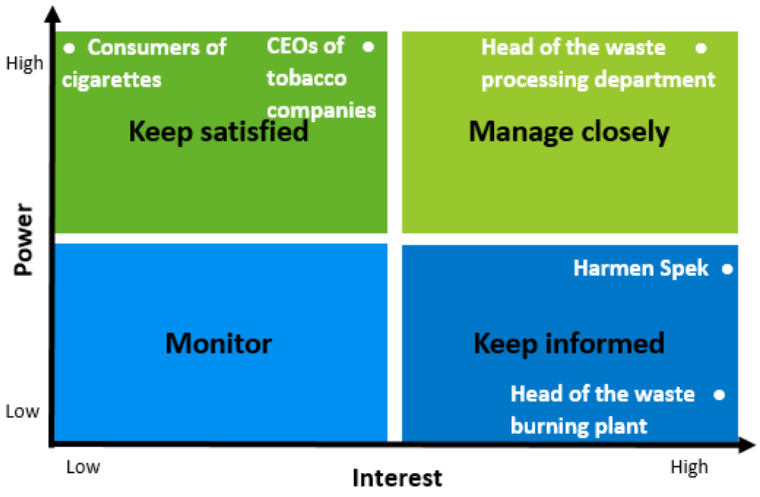

Figure 2.1: The stakeholders classified according to their power and interest.

Innovation & solution manager of The Plastic Soup Foundation, Harmen Spek, introduced the problem of cigarette butts being a high contributor to the plastic soup and is a stakeholder with high interest. Moreover, he advised to narrow the scope of the analysis to a specific area. In this project the municipality of Groningen is chosen, since it forms a representative city for the rest of the Netherlands. Subsequently, the following stakeholders can be identified.

The head of the waste processing department of the municipality of Groningen is classified as a highly prioritized stakeholder. He/she has an influence on the disposal of cigarette butts, since he/she has the resources to accommodate the disposal. Moreover, the goal of this department is to have a clean and environmental friendly city. To achieve this goal, it is required to control and decrease the amount of cigarette butt debris within the municipality.

Furthermore, consumers of cigarettes are stakeholders, which are highly prioritized because of their high influence. Consumers decide how to dispose their cigarette butts. Currently, the direct impact of cigarette butt litter is negligible for the smokers themselves (Cope et al., 1993). This leads to a small interest in the disposal of cigarette butts (Wallbank et al., 2017), which is one of the main causes of cigarette butt debris. Therefore, awareness of the impact of cigarette butt litter has to be created. Moreover, the proper disposal of cigarette butts needs to be easy and convenient for the consumers.

The head of the waste burning plant of Wijster forms a stakeholder, since his/her plant is burning the cigarette butts together with the residueal waste (interview with Maurie Mutsaers, appendix C.3). This stakeholder has interest in a proper way of processing waste. Minimizing the release of toxic substances as a result of burning waste forms a requirement for this stakeholder.

The CEOs of tobacco companies are considered as stakeholders which need to be satisfied, since their interest in the problem is not clear and their influence is high. Research on cigarette filters has pointed out that tobacco companies do not want to take responsibility for cigarette butt litter (Hoek et al., 2019). However, a number of tobacco companies made donations to clean-up organizations (Chapman, 2006). Moreover, these companies have influence in solving the problem, since they bring the cigarette filter into existence.

2.2 System: production and disposal of cigarette butts

In order to deal with complex problems, the system in which this problem emerges needs to be examined (Jackson, 2003). The chain of cigarette butts in the municipality of Groningen with the previous mentioned stakeholders is illustrated in figure 2.2 (interview with Maurie Mutsaers, appendix C.3). The system boundary is the production and disposal of cigarette butts, since the stakeholders with the highest influence are active within this boundary. The input of this system are the raw materials used to make filtered cigarettes. The output of this system are the burned collected cigarette butts and cigarette butts that end up in nature affecting (sea)animals and the environment.

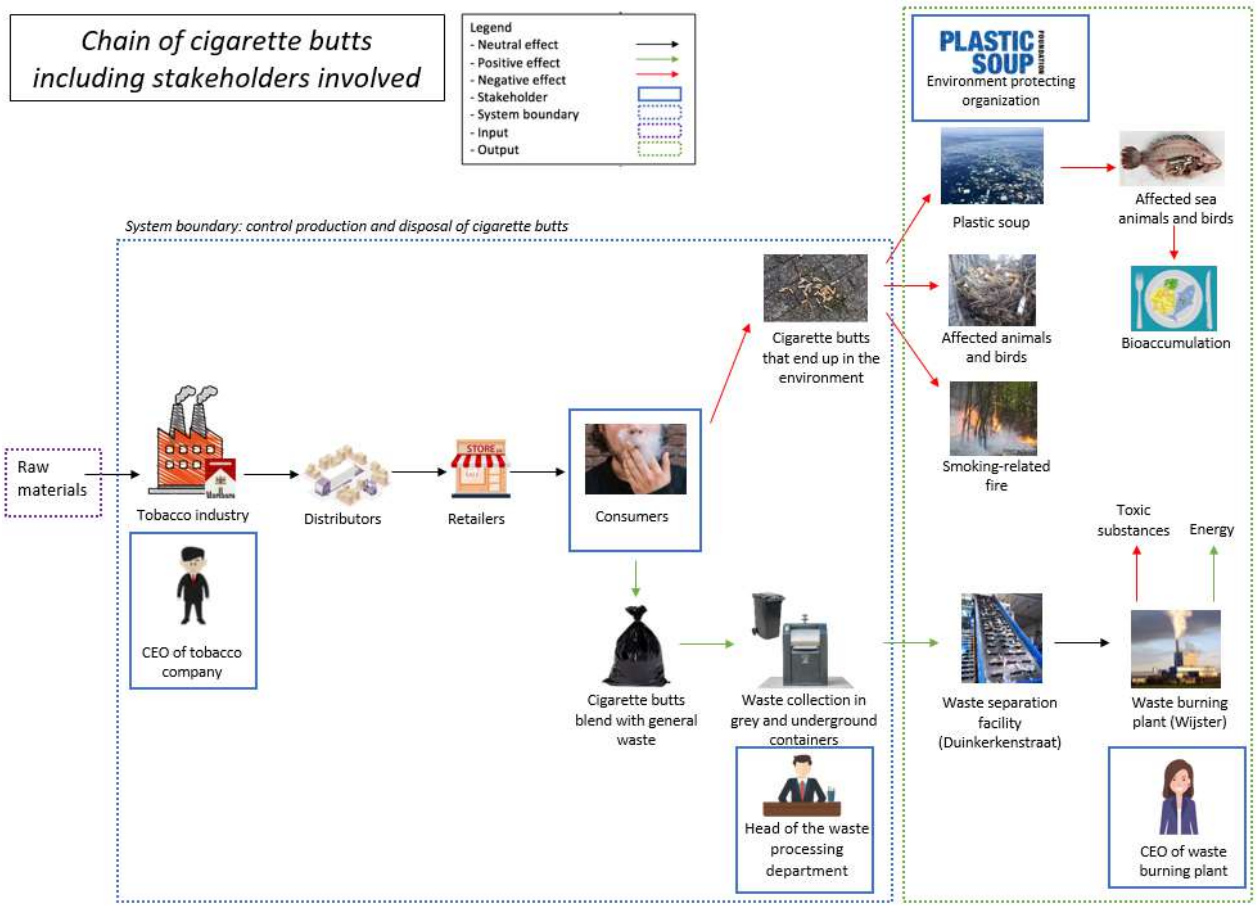

Figure 2.2: The chain of cigarette butts including the stakeholders involved. Within this figure a system boundary, the input and the output are clarified.

2.3 Scope: apply the waste hierarchy

To deal with waste in general, the waste hierarchy can be applied (figure 2.3) (Cooper, 2019). The most preferred option is the highest level of this hierarchy; for cigarette butts this means to 'prevent' the plastic filters. The second level will conclude in a reduction of the use of cigarette filters. The third level intend to reuse cigarette butts without pre-processing. The fourth level strives to recycle cigarette butts, which means using the raw materials of the waste for a new purpose. The fifth level, recovery, is a method which incinerate the cigarette butts to extract energy. The lowest level is disposal, which is identified as cigarette butt littering.

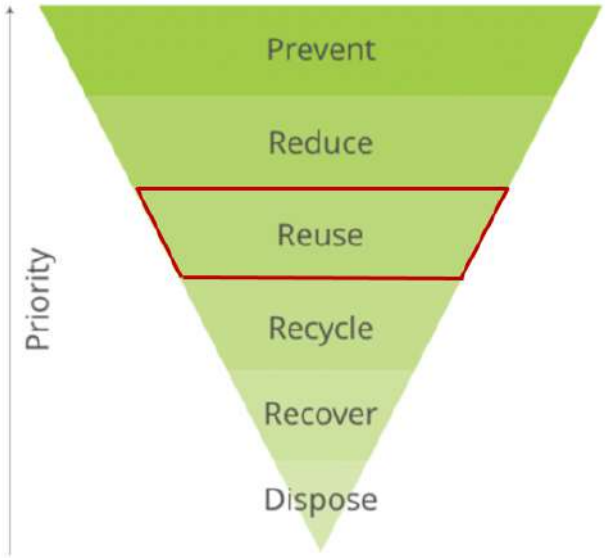

Figure 2.3: The waste hierarchy (Cooper, 2019)

Currently, the municipality of Groningen burns their collected cigarette butts with the residual waste. This is not optimal because when plastic is burned, toxic substances are exposed to the atmosphere (Verma et al., 2016). In order to make the processing of cigarette butts more optimal, the butts can be collected separately and transported to recycling companies such as Terracycle (Terracycle, 2018). This company requires separate and dry cigarette butts in order to recycle recycle this waste. Therefore, the focus lies on separate collection of cigarette butts for the levels 'recycle' and 'recover'.

Eventually, the six levels of the waste hierarchy form the scope of this project, since these levels are used to identify solution directions. In chapter five, this scope is narrowed down to the level 'reuse' which lead to the proposal of the permanent cigarette filter.

2.4 Problem statement

Cigarette butt debris forms an environmental danger for animals and human beings, since microplastics and harmful residues leak into natural water as a result of cigarette butt waste. In 2025, the consumption of cigarettes is expected to reach nine trillion per year, of which most cigarette butts will be littered in nature (Novotny et al., 2009). Consequently, the following problem statement is formulated:

"Cigarette butts littered in the environment have negative effects on the living environment of human beings and animals worldwide."

2.5 Design goal

The goal of this project is to propose a design which aims to decrease or eliminate the negative effects of cigarette butts littered in the environment. When this goal is reached, the proposal can serve as a starting point for other researchers which might be able to solve the cigarette butt debris problem. Consequently, the following design goal is formulated:

"Propose a design which has a high potential to decrease the negative effects of cigarette butt debris."

Efficacy

When this report initiates other researches to find a solution to the cigarette butt debris problem, the negative effects of cigarette butts littered in the environment can be eliminated. Furthermore, this research uses the municipality of Groningen to obtain knowledge about the possibilities and constraints of the municipality for the development and implementation of a selected design. However, this design can be applied on multiple municipalities in the Netherlands, since possibilities and constraints do not differ significantly.

2.6 Methods

Literature research

Literature research is used to identify and analyse solution directions and the key performance indicators (KPIs) which are used to assess the solution directions. This literature can be obtained using resources as Smartcat, Web of Science, PsycInfo, SocINDEX and news articles.

Interviews

Interviews with stakeholders are conducted to obtain knowledge about the possibilities and constraints of the municipalities. Kars Ottens; member of the project team of City Management, Richard Zwarts; an associate of Municipal councillor Glimina Chakor and Maurie Mutsaers; employee of the waste processing department of the municipality Groningen are interviewed. Furthermore, a questionnaire is used to obtain a rough estimation of the opinions of consumers about the cigarette butt debris problem.

Chapter 3: Design Matrix

In this section of the report a design matrix is constructed which serves as a tool to select the most promising solution direction to cigarette butts littered in the environment. This method is combined with the analytic hierarchy process (AHP). Firstly, solution directions are derived from the waste hierarchy which serve as alternatives according the AHP method (Cooper, 2019). Secondly, KPIs are selected with the use of the problem statement, the stakeholders of this project and literature research, which serve as criteria. Finally, the body of the design matrix consists of the assessment of each solution direction according to the KPIs. Moreover, the priority amongst criteria is established with the use of pair-wise comparison. Eventually, the obtained score of each solution direction is used to select a top five.

3.1 Alternatives: solution directions

The solution directions derived from the waste hierarchy are illustrated in figure 3.1. These directions are obtained using the principles of the waste hierarchy and literature research. In this section the solution directions are shortly explained.

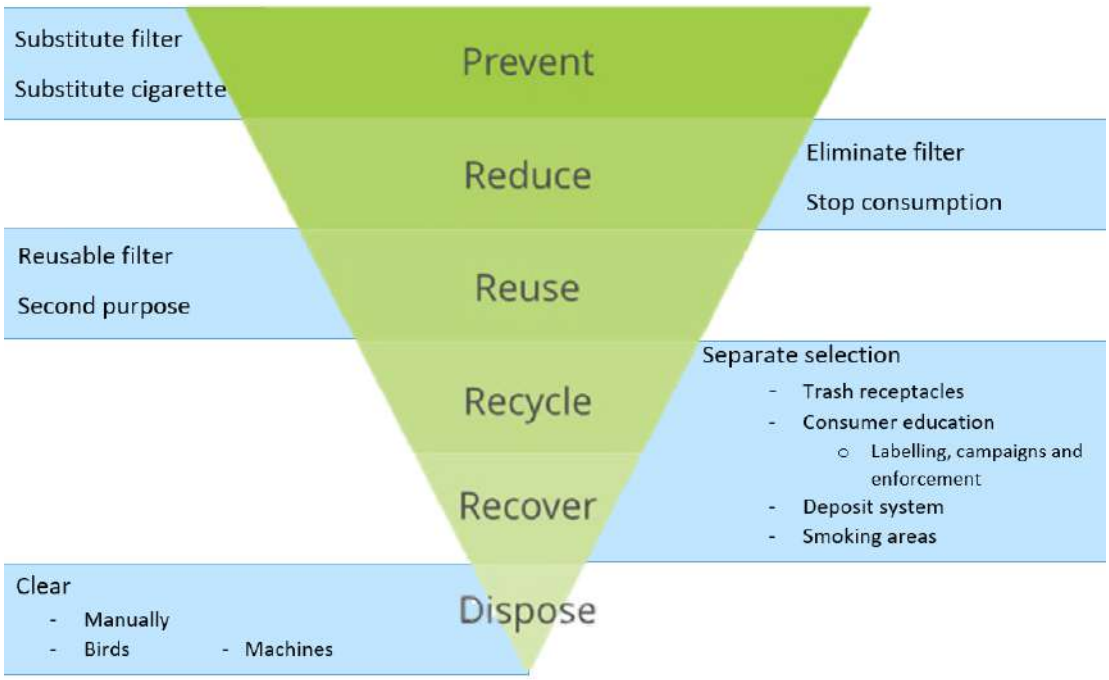

Figure 3.1: Identified solution directions per level of the waste hierarchy

1. Substitute cigarette filter

The first direction is to substitute the cellulose acetate cigarette filters with biodegradable cigarette filters which do not contain plastic. This design has already been developed and tested by researchers and tobacco companies (Joly & Coulis, 2018)(Novotny et al., 2009).

2. Substitute cigarette

The second direction is to substitute the cigarette as a whole. Multiple products are sold on the market which attempt to substitute the conventional cigarettes (Bickel et al., 2018).

3. Eliminate cigarette filter

Stop incorporating cigarette filters into cigarettes decreases the number of filters. Researchers examined this design (Hastrup et al., 2011) (Blum & Novotny, 2018).

4. Stop consumption

Reducing the consumption of cigarettes, results in a decrease in the number of littered cigarettes butts as well.

5. Reusable cigarette filter

A redesigned filter that can be reused without putting any effort into this filter reduces the amount of cigarette butts. In this solution direction, the number of reuses should be maximized.

6. Second purpose

Cigarette butts can be used for a second purpose without being processed. For example, using cigarette butts as a control tool against dengue and malaria, since cigarette butts showed toxic to larvae of mosquitoes (Dieng et al., 2018).

7. Trash receptacles

When optimal trash receptacles are provided, the number of littered cigarette butts can be decreased. Research shows that people litter less when the availability of trash receptacles is increased (Bator, Bryan, & Wesley Schultz, 2011).

8. Labelling

Cigarette packages can be labelled with educative quotes (Novotny & Slaughter, 2014). This can be compared with the educative quotes about health hazards of cigarettes, in which research showed a positive link between health warnings and quitting attempts (Borland et al., 2009).

9. Campaigns

Campaigns can stimulate the correct disposal of cigarettes and make the consumers aware of the consequences of their littering behavior. An example of an effective campaign is #BinTheButt of Keep Britain Tidy (KBT, 2018).

10. Enforcement

Enforcement can be used against littering of cigarette butts (Patel, Thomson, & Wilson, 2014). An experiment of the Environment Protection Authority showed increased binning rates as a result of enforcement (EPA, 2019).

11. Deposit system

A deposit system for cigarette butts can be developed. The consumer pays a deposit when buying cigarettes which is returned when the consumer returns the cigarette butts to the retailer. This can be compared with the deposit system for plastic bottles, which proved to be successful (Schuyler et al., 2018).

12. Smoking areas

Smoking areas reduce the area in which smoking is permitted. Therefore, it alleviates the collection of cigarette butts and has the potential to reduce cigarette butt debris (Fagan et al., 2019).

13. Manually

Cigarette butts can be collected manually during clean-up actions (Rath et al., 2012).

14. Birds

Birds can be used for the collection of smoking debris as well. Birds are trained to bring cigarette butts to a device which gives them a reward in return (Schilperoord, 2017).

15. Machines

The final identified solution direction is using automated machines which collect cigarette butts separately.

3.2 Criteria: KPIs

In this section KPIs are selected which serve as criteria in the design matrix. In order to provide a clear overview, the KPIs are categorized in three categories: environmental aspects, social aspects and feasibility aspects. This is illustrated in figure 3.2. Firstly, the categories are elaborated on. Secondly, the KPIs are shortly explained.

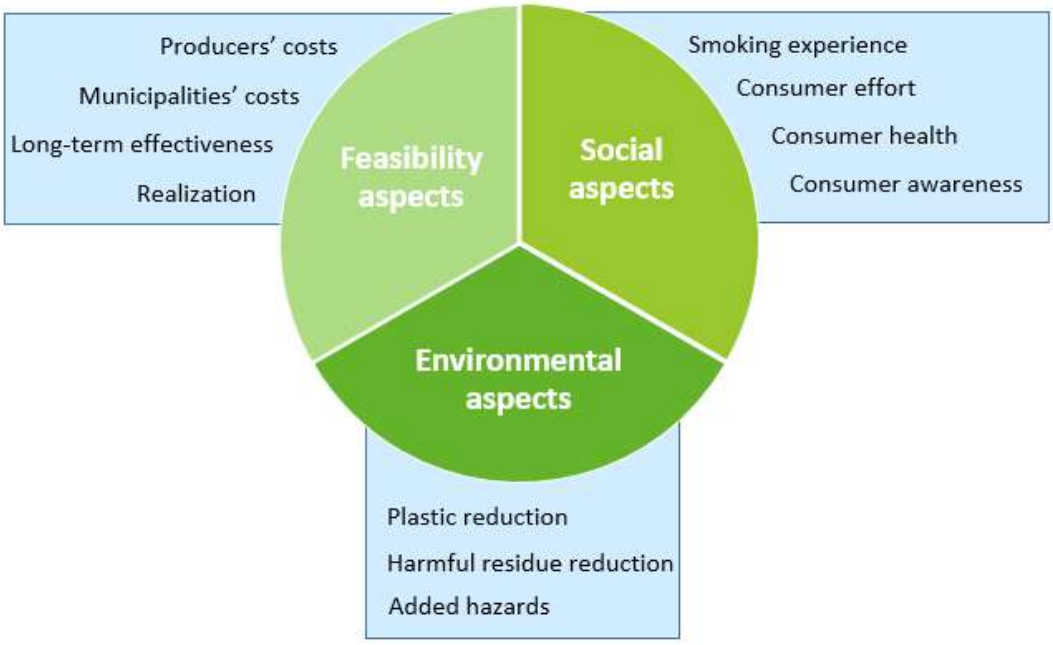

Figure 3.2: Identified KPIs coupled arranged according to the three categories.

The environmental aspects are identified based on the problem statement, since the selected solution directions should aim to decrease or eliminate the negative effects on the living environment of human beings and (sea)animals.

The social aspects are based on the stakeholders: consumers. The consumers of cigarette butts plays a key role in this project, since the consumers form the demand of cigarettes and thus cigarette filters. Moreover, the consumer's choice in disposal directly results in negative or positive effects. This results in a category of KPIs which tend to measure in which degree the chosen design will be accepted by the consumer.

The feasibility aspects are based on the stakeholders: the municipality of Groningen and the tobacco companies. These stakeholders should follow the design direction and have a significant influence on the realization of the eventual design. This results in a category of KPIs which tend to measure in which degree the chosen design is feasible.

1. Plastic reduction (PR)

The amount of littered plastic resulting from the amount of littered cigarette butts contributes to negative effects of cigarette debris (Torkashvand et al., 2020). This results in the KPI: plastic reduction, which measures the degree to which the chosen design decreases the amount of plastic littered through cigarette butts.

2. Harmful residue reduction (HRR)

The toxic components present in a cigarette butt contribute to the negative effects of cigarette debris as well. This results in the KPI: harmful residue reduction, which measures the degree to which the chosen design decreases the amount of toxic components exposed to the environment.

3. Added hazards (AH)

Spikman is an engineer who does research on collecting cigarette butts. In an interview, he mentioned the problem of creating new environmental problems while coping with the problem of cigarette butt debris (Schilperoord, 2017). This results in the KPI: added hazards, since the design constructed to decrease the negative effects of cigarette butt litter should not result in new negative effects to the environment.

4. Smoking experience (SE)

Research shows that a change in the smoking experience can play an important role in the implementation of a design (Novotny et al., 2009). This results in the KPI: smoking experience, which measures the degree in which the smoking experience changes in terms of taste, feeling and shape.

5. Consumer effort (CE)

The effort required for a consumer to dispose their litter forms an important factor. The availability and the accessibility of trash receptacles has a positive connection to the decrease of the possibility people will litter (Bator et al., 2011). This results in the KPI: consumer effort, which measures the degree of effort required for consuming and disposing cigarette butts.

6. Consumer health (CH)

The cigarette filter was initially added to the cigarette to reduce the amount of tar in tobacco smoke, since tar has negative effects on the health of consumers of cigarettes (Hastrup et al., 2011). The design chosen should not remove this filtering purpose or add any health hazards. This results in the KPI: consumer health, which measures the degree in which the health of consumers is affected by the introduced design.

7. Consumer awareness (CA)

Creating awareness about the effects of litter plays a factor in the amount of waste littered in the environment. Campaigns in anti-littering which encourage and educate consumers to correctly dispose their waste, for example 'Do the Right Thing' and 'Neat Streets', increased awareness and resulted in reduction of litter found in the environment in Australia (Willis et al., 2018). This results in the KPI: consumer awareness, which measures the degree in which the awareness of consumers is increased.

8. Producers' costs (PC)

Required costs form an important factor for the producers of cigarettes. For example, one of the three leading tobacco companies, Philip Morris International, states to aim at providing superior returns to their stakeholders (Calantzopoulos, 2019). This results in the KPI: producers' cost, which measures the extend of costs associated with the development and implementation of the designs for the producers of cigarettes.

9. Municipalities' costs (MC)

Kars Ottens, head the team projects of City Management Groningen, points out that a limited budget forms an important constraint in solving the cigarette butt problem (interview Kars Ottens, appendix C.2). This results in the KPI: municipalities' costs, which measures the extend of costs associated with the development and implementation of the designs for municipalities.

10. Long-term effectiveness (LTE)

The effectiveness of a design can change over time, which can be undesirable. This results in the KPI: long-term effectiveness, which measures the change in effectiveness of the introduced design with respect to time.

11. Realization (R)

Eventually, the chosen design should be realizable, otherwise implementing a design would not make sense. This results in the KPI: realization, which measures in which extend the design can be realized based on previous attempts and reasoning.

3.3 Weights of KPIs

Every criteria (KPI) mentioned is given a weight, since the importance of the criteria vary. The weights are allocated to the criteria, using the visions and values of tobacco companies, the consumers of cigarettes and the municipality of Groningen. The opinions of these stakeholders are discussed in this section and eventually the priority of criteria with respect to each other is examined.

3.3.1 Stakeholders' visions and values

Tobacco companies

Overall, tobacco companies appear to have health-improving intentions; however, these intentions can be questioned. The tobacco industry uses lobbyist and litigation to delay or prevent governmental actions to reduce or ban smoking (Chapman, 2006; Daube, Moodie, & McKee, 2017). Furthermore, tobacco companies claim to aim at less harming alternatives to cigarettes, meanwhile cigarettes remain the most produced product (Daube et al., 2017; Lancet, 2019). Furthermore, tobacco companies claim that smokers are the cause of the cigarette butt litter problem and are the source towards a solution as well (Hoek et al., 2019). However, certain tobacco companies have taken action to reduce cigarette butt litter. British American Tobacco and Philip Morris International have spent 2.089 USD and 247,454 USD, respectively, to facilitate butt litter reduction in Australia (Chapman, 2006).

Conclusion Research has pointed out that tobacco companies do not take responsibility for cigarette butt waste yet. However, because of the donations made towards butt reduction, a small interest in the 'plastic reduction' and 'harmful residue reduction' can be concluded. Eventually, tobacco companies show interest in increasing their profits and market share, which shows a moderate priority in 'producers' costs'.

Consumers of filtered cigarettes

A questionnaire is used to provide an overview of the vision and values of consumers of filtered cigarettes. An online survey tool is used, named 'Survio'. A number of 21 consumers of cigarettes responded to this survey of which the sex and age are unknown. This survey can be seen as a quick tool to obtain a rough estimation of the opinions of consumers. The questionnaire including the results per question can be found in appendix D.

The results of the questionnaire are summarized and depicted in table 3.1. First of all, all criteria are labelled important, since the majority of the responders find all of the criteria very important or important. To determine which criteria have the highest priority for the consumers of cigarettes, the answers 'totally not important' and 'not important' are combined and the answers 'important' and 'very important' are combined.

Criteria/ importance	PR	HRR	AH	LTE	SE	CE	CH	CA
(Totally) not important	3	2	2	1	6	5	3	1
Neutral	8	4	3	1	5	6	4	2
(Very) important	10	15	16	19	10	10	14	18

Table 3.1: The opinion of consumers of cigarettes

Conclusion 'Long-term effectiveness' with 19 votes and 'consumer awareness' with 18 votes for important turned out to have the highest priority to consumers. This results in a strong importance for consumers towards these criteria. Secondly, the criteria 'added hazards' with 16 votes, 'harmful residue reduction' with 15 votes and 'consumer health' with 14 votes for important show a moderate importance for consumers. Eventually, the criteria with the lowest amount of votes for important are 'plastic reduction', 'smoking experience' and 'consumer effort' with all 10 votes. This results in a small importance for consumers towards these criteria.

An important aspect to notice is that it takes two extra votes for a criteria to change from a moderate to a strong importance. Moreover, it takes 4 extra votes for a criteria to change from a small to a moderate importance. This shows a high sensitivity for the results of this questionnaire. However, this questionnaire be used to make a rough distinction in criteria according their importance towards consumers.

Municipality of Groningen

First of all, the concerns about litter by the municipalities in the Netherlands are described on the website of 'NederlandSchoon' (Bouma, 2018). This results in a strong importance for municipalities towards the criteria 'plastic reduction' and 'harmful residue reduction'.

Secondly, Kars Ottens, member of the project team of City Management, explained that the budget available for dealing with cigarette debris is limited and forms a constraint (interview with Kars Ottens, appendix C.2). This makes the criteria 'municipalities' costs' of strong importance for the municipality.

Another constraint acknowledged by Kars Ottens are the future plans to make Groningen a smoke-free city (interview with Kars Ottens, appendix C.2). This indicates a reduced importance for long-term effectiveness.

Eventually, the government of the Netherlands does not make cigarettes illegal, even though

it is known that cigarettes form a danger to the health of the consumers (Hastrup et al., 2011). However, regulation sets a maximum amount of tar per cigarette of 10 mg in order to reduce these health hazards (RIVM, 2018). This indicates a moderate importance towards the criteria 'consumer health'. Moreover, the coalition agreement of the municipality Groningen provides a clear overview of the priorities of the altermen. The focus points in this report are healthy residents and becoming a CO2 neutral city (Oudsten, 2019). This indicates a moderate to strong importance towards the criteria 'consumer health' and 'added hazards'.

Conclusion The criteria 'plastic reduction', 'harmful residue reduction' and 'municipalities' costs' have a strong importance. Furthermore, the municipality shows a moderate priority towards 'consumer health' and 'added hazards'. Eventually, the criteria 'long-term effectiveness' is found less important.

3.3.2 Resulting weights of the criteria

In order to obtain weights for the mentioned criteria, the importance of each criteria need to be determined and this importance need to be translated to a grade. With the use of this grade a pair-wise comparison matrix can be constructed, which lead to the criteria weights.

Translate importance to a grade

The extend of importance can be acknowledged to the criteria combining the previously mentioned visions and values of the stakeholders. Moreover, since the designs should contribute to the decrease of the negative effects of cigarette butt litter, importance is acknowledged to the criteria 'plastic reduction', 'harmful residue reduction', 'realization' and 'long-term effectiveness'. The division of importance is illustrated in figure 3.3 on the left side. The translation of this importance coupled to a grade is illustrated on the right side of figure 3.3. The criteria within one group are of equal importance which are graded with grade one with respect to each other. Moreover, for every increase of importance two extra points are acknowledged. For example, if a criteria is categorized with strong importance, the grade 3 is acknowledged for this criteria with respect to the criteria that are categorized with small importance.

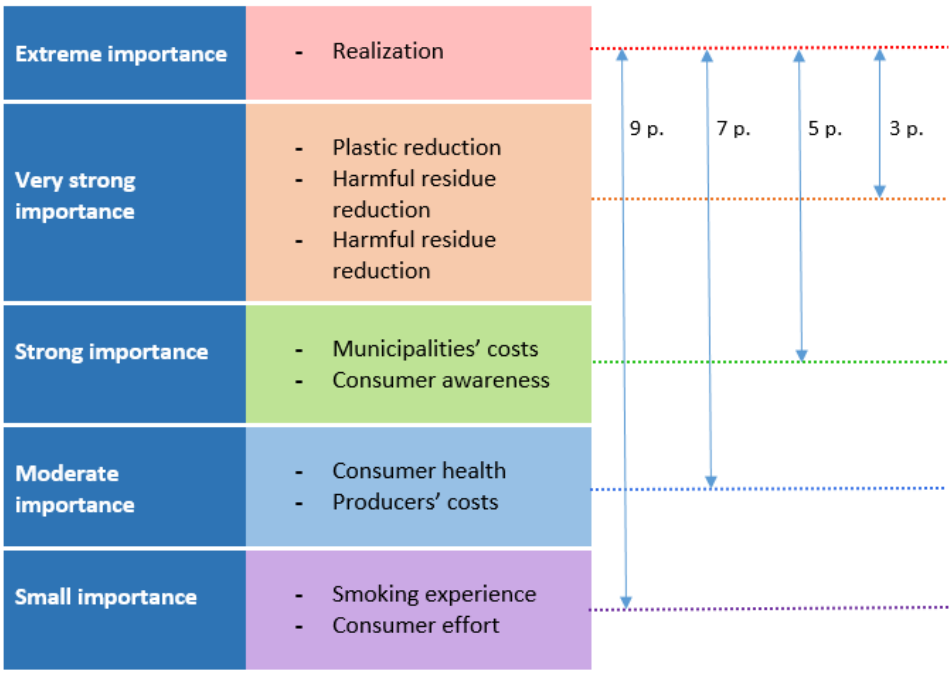

Figure 3.3: Left: criteria coupled to their importance. Right: the coupled grades between groups of importance.

Pair-wise comparison matrix

Firstly, with the use of the obtained grades, a pair-wise comparison matrix is constructed. This is illustrated in table 3.2. Secondly, in order to obtain the criteria weights, this matrix is normalized by dividing every element in the column with the sum of that specific column. The normalized pair-wise comparison matrix is illustrated in table 3.3. Eventually, to obtain the weights of each criteria, the sum of each row is taken and averaged by dividing this value by the number of criteria, namely eleven. The sum and the eventual criteria weights are illustrated in table 3.4. Moreover, the constructed pair-wise comparison matrix proved to be consistent, since the consistency ratio (CR) is equal to 0.027 which is smaller than the standard 0.1 (Saaty & Tran, 2007). The calculation of CR is explained in appendix A.

Pair-wise comparison matrix	PR	HRR	AH	SE	CE	CH	CA	PC	MC	LTE	R
PR	1	1	5	7	7	5	3	5	3	1	0,33
HRR	1	1	5	7	7	5	3	5	3	1	0,33
AH	0.20	0.20	1	3	3	1	0.33	1	0.33	0.20	0.14
SE	0.14	0.14	0.33	1	1	0.33	0.20	0.33	0.20	0.14	0.11
CE	0.14	0.14	0.33	1	1	0.33	0.20	0.33	0.20	0.14	0.11
CH	0.20	0.20	1	3	3	1	0.33	1	0.33	0.20	0.14
CA	0.33	0.33	3	5	5	3	1	3	1	0.33	0.20
PC	0.20	0.20	1	3	3	1	0.33	1	0.33	0.20	0.14
MC	0.33	0.33	3	5	5	3	1	3	1	0.33	0.20
LTE	1	1	5	7	7	5	3	5	3	1	0.33
R	3	3	7	9	9	7	5	7	5	3	1
Total	**7.55**	**7.55**	**31.67**	**51**	**51**	**31.67**	**17.40**	**31.67**	**17.40**	**7.55**	**3.05**

Table 3.2: Pair-wise comparison matrix including the sum of each column depicted in the last row.

Normalized pair-wise comparison matrix	PR	HRR	AH	SE	CE	CH	CA	PC	MC	LTE	R
PR	0.13	0.13	0.16	0.14	0.14	0.16	0.17	0.16	0.17	0.13	0.11
HRR	0.13	0.13	0.16	0.14	0.14	0.16	0.17	0.16	0.17	0.13	0.11
AH	0.03	0.03	0.03	0.06	0.06	0.03	0.02	0.03	0.02	0.03	0.05
SE	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.04
CE	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.04
CH	0.03	0.03	0.03	0.06	0.06	0.03	0.02	0.03	0.02	0.03	0.05
CA	0.04	0.04	0.09	0.10	0.10	0.09	0.06	0.09	0.06	0.04	0.07
PC	0.03	0.03	0.03	0.06	0.06	0.03	0.02	0.03	0.02	0.03	0.05
MC	0.04	0.04	0.09	0.10	0.10	0.09	0.06	0.09	0.06	0.04	0.07
LTE	0.13	0.13	0.16	0.14	0.14	0.16	0.17	0.16	0.17	0.13	0.11
R	0.40	0.40	0.22	0.18	0.18	0.22	0.29	0.22	0.29	0.40	0.33

Table 3.3: Normalized pair-wise comparison matrix.

Criteria	Sum of the rows	Citeria weights
Plastic reduction	1.60	0.15 (15%)
Harmful residue reduction	1.60	0.15 (15%)
Added hazards	0.38	0.03 (3%)
Smoking experience	0.19	0.02 (2%)
Consumer effort	0.19	0.02 (2%)
Consumer health	0.38	0.03 (3%)
Consumer awareness	0.79	0.07 (7%)
Producers' costs	0.38	0.03 (3%)
Municipalities' costs	0.79	0.07 (7%)
Long-term effectiveness	1.60	0.15 (15%)
Realization	3.11	0.28 (28%)

Table 3.4: The sum of the rows of the normalized pair-wise comparison matrix and the resulting criteria weights

3.4 Design matrix

The examined alternatives and criteria including the criteria weights are used to obtain the design matrix, illustrated in figure 3.4 at the end of this chapter. The assessment of the solution directions with respect to each criteria is explained in appendix B. Eventually, the score of each design can be calculated by multiplying the grades with the criteria weights and take the sum per design. The scores of the design directions are included in the design matrix.

3.4.1 Sensitivity analysis

A sensitivity analysis is performed for the criteria 'long-term effectiveness' and 'realization' applied on the solution direction 'substitute filter'. These two criteria are chosen, since they have the highest weights and thus the highest influence on the eventual amount of points. Table 3.5 illustrates the change in the final points when the assessment of the two criteria change. The current assessment and amount of points is underlined in this table. The eventual amount of points is highly sensitive to changes in the assessment with respect to the criteria 'realization'.

Current points = 4	LTE = 1	LTE =2	LTE = 3	LTE = 4	**LTE = 5**
R = 1	3	3	3	3	3
R = 2	3	3	3	3	3
R = 3	3	3	3	4	4
R = 4	3	4	4	4	**4**
R = 5	4	4	4	4	4

Table 3.5: Sensitivity analysis of the criteria 'long-term effectiveness' with respect to 'realization' applied on the solution direction 'substitute filter'.

3.4.2 Top five solution directions

The design matrix results in eight solution directions with 4 points. In order to narrow the selection of the most promising solution directions, two decimal points are added to the scores and the top five is selected and illustrated in table 3.6. In the next chapter, these directions are used to extract detailed designs.

Solution direction	**Points**	**Rank**
Substitute filter	3.93	1
Substitute cigarette	3.87	2
Reusable filter	3.86	3
Campaigns	3.77	4
Trash receptacles	3.76	5

Table 3.6: Top five solution directions ranked from most desirable design to less desirable design.

Goal/KPI				Environmental aspects			Social aspects				Feasibility aspects				Total score
				Plastic reduction	Harmful residue reduction	Added hazards	Smoking experience	Consumer effort	Consumer health	Consumer awareness	Producers' costs	Muni-cipalities' costs	Long-term effective-ness	Reali-zation	
Weight				**15%**	**15%**	**3%**	**2%**	**2%**	**3%**	**7%**	**3%**	**7%**	**15%**	**28%**	
Prevent	Substitute filter			5	1	4	3	5	3	5	3	5	5	4	4
	Substitute cigarette			4	4	2	2	5	3.5	5	3	5	5	3	4
Reduce	Eliminate filters			5	5	5	2	5	2	5	5	5	5	1	4
	Stop consumption			5	5	5	1	1	5	5	1	4	5	1	4
Reuse	Reusable filter			4	4	4	4	4	3	2	3	5	5	4	4
	Second purpose			2	2	5	5	3	3	2	5	5	2	1	2
Recycle	Separate collection	Trash receptacles		3	3	3	5	4	3	2	5	3	4	5	4
		Consumer education	Labelling	2	2	5	5	3	3	5	4	5	3	5	4
			Campaigns	2.5	2.5	4	5	3	3	5	5	4	3	5	4
			Enforcement	4	4	5	5	3	3	3	5	4	1	4	4
		Deposit system		2	2	4	5	2.5	3	2	5	3	4	5	3
		Smoking areas		2	2	3	4	4	2	2	5	4	5	5	4
Disposal	Clear	Manually		1	1	3	5	5	2	1	5	4	1	4	2
		Birds		4	4	3	5	5	3	1	5	3	4	3	3
		Machines		4	4	2	5	5	3	1	5	3	1	4	3

Figure 3.4: Design matrix as a tool for decision-making. The solution directions are depicted on the vertical axis and the KPIs are depicted on the horizontal axis.

Chapter 4: In-Depth Design Matrix

In this chapter the same approach of constructing a design matrix is applied. However, in this chapter the alternatives are designs extracted from the top five solution directions of the previously constructed design matrix, namely 'substitute cigarette filter', 'substitute cigarette', 'reusable cigarette filter', 'campaigns' and 'trash receptacles'. These detailed designs are assessed using the previously identified KPIs with their previously established weights. Again, this in depth design matrix serves as a tool to select the most promising design.

4.1 Alternatives: detailed designs

The first step is to obtain detailed designs using the top five solution directions of the previous chapter combined with literature research. An overview of the identified designs per solution direction is provided in figure 4.1. The selected designs are shortly explained in this section.

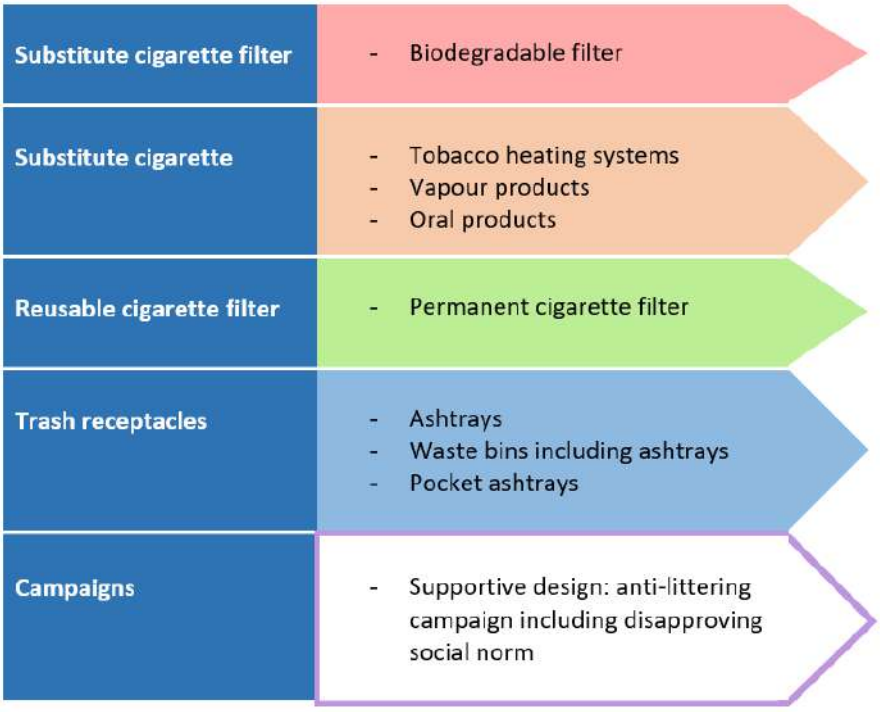

Figure 4.1: The identified designs per solution direction including the identified supportive design delineated in purple.

1. Biodegradable filter

The design which substitutes the cigarette filter should have a significant increased biodegradability within every environment, should not result in change in taste and should have sufficient tar filtration according to regulations. The biodegradable filters designed by Brown & Williamson Tobacco Company have not been implemented because of the change in taste of the cigarette (Novotny et al., 2009). Furthermore, the tested degradable cellulose filters only show an improved degradability within a composting bin (Joly & Coulis, 2018). Additionally, regulations prescribe a maximum amount of tar inhalation per cigarette of 10 mg in the Netherlands (RIVM, 2018). The newly obtained biodegradable filter should be incorporated in all filtered cigarettes and should be sold separate for other forms of tobacco consumption.

2. Tobacco heating systems

One selected product which can substitute the conventional cigarette is a tobacco heating product. A leading tobacco company, Philip Morris International, is developing such a tobacco heating system; the IQOS. This device heats the tobacco to 350°C instead of 600°C. Moreover, this device still requires special kind of cigarette which includes a cellulose acetate filter (Peitsch, 2017). This design is illustrated in figure 4.2.

Figure 4.2: The IQOS: a tobacco heating system (Peitsch, 2017).

3. Vapour products

Another product which is able to substitute tobacco cigarettes are vapour products, also known as e-cigarettes. Vapour products are mostly rechargeable devices, using a battery to heat a liquid in order to create vapour which can be inhaled. These liquids mostly contain nicotine, flavourings, propylene glycol, glycerol and water. Moreover, the liquids can manually be refilled. This design is illustrated in figure 4.3.

Figure 4.3: The Vype eTank Pro 2: a vapour product which can be refilled (BAT, 2017b).

4. Oral products

The final product which tempt to substitute tobacco cigarettes are oral products, such as snus, moist snuff and tobacco-free nicotine pouches. These products can be placed orally under the lip such that the body absorbs the nicotine (BAT, 2017b). Snus and moist snuff contain tobacco leafs and pouches mostly contain nicotine, sweeteners, flavourings, pH adjusters, fillers and stabilisers (HAYPP, 2019). Additionally, modern oral products are in development in order to offer different flavours and nicotine levels according to the demand of the consumers. An example of nicotine pouches is illustrated in figure 4.4.

Figure 4.4: ZYN Nicotine Pouch (CSNews, 2019).

5. Permanent cigarette filter

A permanent cigarette filter should be able to be reused for 23 times, should be durable, should not result in change in taste and should have sufficient tar filtration according to regulations. A number of reusable filters are on the market. The majority of the offered filters can be used for 5-20 cigarettes, are cleanable and have a modular design. After the filter is cleaned, it can be used again. If a part of the filter wears it can be replaced, which makes the filter durable (Thompson, 2018). However, most available reusable filters are designed to be placed on a filtered cigarette. Moreover, the conventional cigarette filters should be removed of cigarettes and a reusable filter should be sold coupled to the cigarette packages in order to force the consumers to use such a device. This requires the permanent filter to be reused 23 times, since a package contains 19 to 23 cigarettes. When this system is adopted, it can be combined with a deposit system in order to repair the old reusable filters and provide the consumer with a new reusable filter. An example of this design is illustrated in figure 4.5.

Figure 4.5: Old filtered cigarettes design (left) versus new filtered cigarettes design (right).

6. Ashtrays

This design includes placing decorated ashtrays on areas with a high possibility of cigarette butts being littered in a high density, since a high density of decorated ashtrays shows to be more effective than a low density of non-decorated ashtrays (Cope et al., 1993). Moreover, such areas are near bars, cafes, liquor stores, convenience stores, grocery stores, restaurants and traffic signals (Marinello et al., 2020). An example of a decorated outdoor ashtray is illustrated in figure 4.6.

Figure 4.6: Example of a decorated outdoor ashtray (Erdi, 2019).

7. Waste bins including ashtrays

This design entails placing waste bins which include an ashtray. An example of such a waste bin is illustrated in figure 4.7. These waste bins should attract attention, should be placed with high density and should be placed on areas with a high littering possibility as well.

Figure 4.7: Example of a decorated outdoor waste bin including an ashtray (Archiproducts, 2019).

8. Pocket ashtrays

The last design is dispensing pocket ashtrays. The municipality of Groningen already had a number of trials in which they handed out pocket ashtrays (Interview Kars Ottens, appendix C.2). These ashtrays are made of heat-resistant material and are 99,9% airtight, to keeps odors insight. Moreover, text can be printed on the pocket ashtray. An example of an ashtray is illustrated in figure 4.8. For the eventual design, the imprints of these

pocket ashtrays should contain educational quotes about the environmental consequences of littering cigarette butts to increase the awareness of consumers. Moreover, the pocket ashtrays should be dispensed multiple times in areas with a high possibility of cigarette butts being littered to ensure all consumers will adopt this device. Pocket ashtrays should be available at cigarette selling points as well.

Figure 4.8: Example of a pocket ashtray (Slobbe, 2019).

Supportive design: Anti-littering campaign including disapproving social norm

The designed campaign should contain a disapproving social norm and does not require an inconvenient, costly and difficult change. Campaigns which include disapproving social norm have increased effects on the behaviour of the human exposed to this campaign (Bolderdijk et al., 2013). Therefore, a campaign should make clear that littering cigarette butts in the environment is disapproved by the majority of inhabitants. The campaign of Keep Britain Tidy, #BinTheButt, can be used as an example, since it has shown to be a successful campaign (KBT, 2018). Furthermore, when the campaign reaches governments and tobacco companies as well, it could trigger them to become active in implementing solutions to ban plastic filters equally to the campaign Beat the Microbead of The Plastic Soup Foundation (TPSF, 2019).

Eventually, the campaign should be supported by disposal facilities in order to make the disposal of cigarette butts easy, since research points out that the effects of campaigns increase if the change in behaviour required is convenient, not costly and easy (Bolderdijk et al., 2013). Therefore, this design is classified as a supportive design rather than a design.

4.2 Design matrix

Similarly to the first constructed design matrix, this in-depth design matrix is constructed using the previously identified criteria, the previously identified weights and the newly determined alternatives. This design matrix is illustrated in figure 4.9. The assessment of the designs according to each criteria is explained in appendix E.

4.2.1 Top three designs

This newly obtained design matrix results in six designs with 4 points. In order to narrow the selection of the most promising designs, two decimal points are added to the scores to achieve a top three, illustrated in table 4.1. The permanent cigarette filter forms the proposed design and is discussed and validated in chapter 5.

Design	**Points**	**Rank**
Permanent cigarette filters	4.11	1
Vapour products	4.10	2
Pocket ashtrays	3.85	3

Table 4.1: Ranking of designs according the newly obtained design matrix.

Design/KPI		Environmental aspects			Social aspects				Feasibility aspects				Total score
		Plastic reduction	Harmful residue reduction	Added hazards	Smoking experience	Consumer effort	Consumer health	Consumer awareness	Producers' costs	Municipalities' costs	Long-term effectiveness	Realization	
Weight		**15%**	**15%**	**3%**	**2%**	**2%**	**3%**	**7%**	**3%**	**7%**	**15%**	**28%**	
Biodegradable filter		5	1	4	5	5	3	1	3	5	5	4	4
Substitute cigarette	Tobacco heating products	1	4	3	4	4	3	1	5	4	5	3	3
	Vapour products	5	5	4	3	4	3.5	5	5	4	5	2.5	4
	Oral products	5	4	5	2	5	4	5	5	4	5	1.5	4
Permanent cigarette filter		5	3	5	5	4	3	2.5	3	5	5	4	4
Trash receptacles	Ashtrays	3	3	3	5	3	3	3	5	2	2	5	3
	Waste bins including ashtrays	3	3	4	5	3	3	3	5	2.5	2	5	4
	Pocket-ashtrays	3	3	4	5	4	3	5	5	3	3	5	4

Figure 4.9: In-depth design matrix. The designs are depicted on the vertical axis and the KPIs are depicted on the horizontal axis.

Chapter 5: Design

In this chapter the most promising design, the permanent cigarette filter, is applied in the previously obtained chain of cigarette butts. With the use of this analysis, requirements for the design are obtained and used to obtain a requirement checklist. Eventually, a SWOT-analysis is performed to evaluate the proposed design.

5.1 The chain of permanent cigarette filters

Firstly, the chain of cigarette butts is revisioned with a down scaled version of the scope described in chapter one, namely reuse. This scope is chosen with the use of the previously obtained design matrices and introduces the permanent cigarette filter which changes the chain of cigarette butts to the chain of permanent cigarette filters. This chain is analyzed and illustrated in figure 5.1. The most significant changes in this system are:

1. Tobacco companies producing and selling a newly produced product, namely a cigarette package including unfiltered cigarettes and a permanent filter;
2. Consumers of cigarettes are consuming unfiltered cigarettes combined with a permanent filter which has to be retained for the whole package;
3. The amount of plastic which ends up in the environment is significantly decreased;
4. The amount of harmful residues in used cigarette filters is significantly increased;
5. Permanent cigarette filters are added to the regular waste stream.

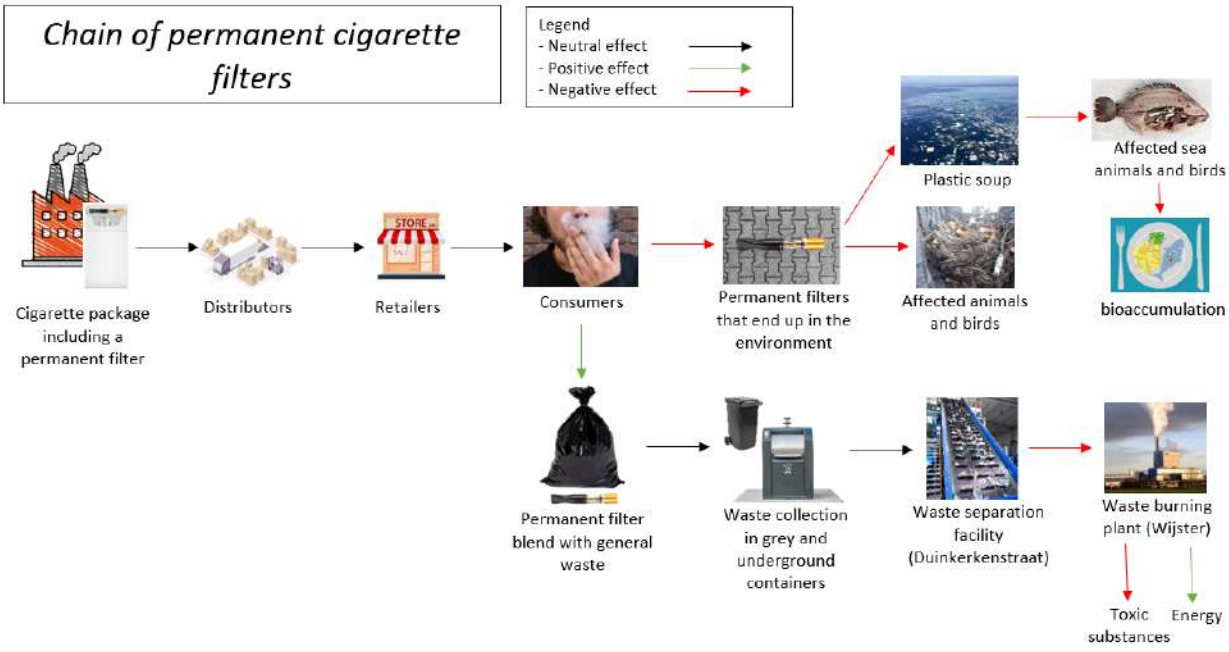

Figure 5.1: The chain of permanent cigarette filters.

5.2 Requirements for the permanent cigarette filter

With the insights obtained from the analyzes of the chain of permanent cigarette filters, requirements for the redesign of the conventional cigarettes can be identified. Firstly, these requirements are categorized as technical requirements and customer requirements. Secondly, the categorized requirements are translated to a requirement checklist.

Technical requirements

- **Reuse:** the permanent cigarette filter should be able to be reused 19 to 23 times to align with the amount of cigarettes per package.
- **Production costs:** the production of one permanent filter should be less or equally expensive as producing 19 to 23 disposable filtered cigarettes to maintain a sustainable business.
- **Investment costs:** the investment costs to develop a permanent filter, develop production tools and machines and redesign the production line should be kept as low as possible.
- **Composition of inhalation:** the toxic components in an inhalation of a cigarette coupled to a permanent filter should be minimized according to regulations, namely a maximum of 10 mg tar, 1 mg nicotine and 10 mg carbon monoxide per cigarette (EU,

2014).

- **Recycling:** the disposed filters should have the ability to be recycled easily.
- **Cleaning:** the permanent cigarette filters should have the ability to be cleaned easily in order to be circulated.

Customer requirements

- **Full consumption:** consumers should be able to smoke the whole cigarette.
- **Attach, remain and detach filter:** consumers should be able to easily attach and detach the permanent filter and this filter should remain attached during smoking the cigarette.
- **Carry and secure filter:** the cigarette package should contain a proper place to carry and secure the permanent filter.
- **Taste:** the inhalation from cigarettes with a permanent filter should taste the same as the inhalation from conventional cigarettes.
- **Accessibility:** the permanent cigarettes should be sold together with the unfiltered cigarettes to make the permanent filter accessible.

Requirement checklist

The customer and technical requirements can be translated into a requirement checklist according to the engineering principles of Pahl and Beitz (Pahl & Beitz, 2013). In this checklist the requirements are identified as a demand when it is of high importance that the requirement is met and as a wish when the requirement is less important. The obtained requirement checklist is illustrated in figure 5.4 on the end of this chapter. In this figure, material properties are supported with research about the properties of cellulose acetate filters (Rustemeyer, 2004) (Podraza, 2001).

5.3 SWOT-analysis

In this section the strengths, weaknesses, opportunities and threats are analyzed to validate the proposed design. The SWOT-analysis is illustrated in figure 5.2. The elements in the SWOT-analysis are shortly explained in this section.

Figure 5.2: SWOT-analysis of the permanent cigarette filter

Strengths

1. Plastic reduction: when the material of the redesign is chosen sufficiently, the amount of plastic littered through cigarette debris decreases significantly;
2. Long-term effective: when this design is implemented, the effectiveness does not change over time;
3. Customer satisfaction: the redesign does not result in significant changes to the smoking experience of consumers of cigarettes.

Weaknesses

1. Extensive research and development: the development and implementation of this redesign requires extensive research and development for the producers of cigarettes;
2. Option to litter: the redesign does not eliminate the opportunity for consumers to litter the filter in the environment;
3. Harmful residue accumulation: the harmful residues as a result of the combustion of tobacco accumulate in the permanent cigarette filter;

4. No separate collection: the design does not provide a way to separately collect the filters, consequently the filters will blend with the general waste and are burned with the residual waste.

Opportunities

1. Marketing tool: making cigarettes environmentally friendly can be a marketing strategy in the same way implementing filter to make cigarettes less harmful to the health of the consumers can be seen as a marketing strategy (Blum & Novotny, 2018);
2. Decreased possibility of litter: the redesign of the filter can arouse the appearance that it is hazardous waste and eliminates the believe that filters are biodegradable, which might result in a decreased possibility that consumer will litter the filter in the environment (Root, 2019);
3. Circulation: when the used permanent filter is cleaned, it can be reused again which enables circulation of the permanent cigarette filter. This circulation can be facilitated with the use of a deposit system at the retailer of cigarettes, which is illustrated in figure 5.3. The retailer is responsible for collecting used permanent filters and providing cleaned permanent filters. The cleaning of the filters can be performed by a cleaning facility.
    - Separate collection: when the previously mentioned system is implemented, separate collection of depreciated permanent filters is enabled which can be recycled by recycling companies.
    - Control harmful residues: when the previously mentioned system is implemented, the cleaning of the filter and processing the harmful residues can be controlled by regulatory authorities.

Threats

1. Too high investment costs: the research and development efforts might be to costly;
2. Unreachable design: a possibility exists that a sufficient permanent cigarette filter can not be designed;
3. Remaining tobacco: the redesign of the cigarette filter might not be able to provide full consumption of the tobacco to the consumers;
4. Unfeasible circulation: the circulation of the permanent cigarette filters illustrated in figure 5.3 might be impossible to realize, since it requires extensive logistics and close cooperation and communication between all mentioned stakeholders.

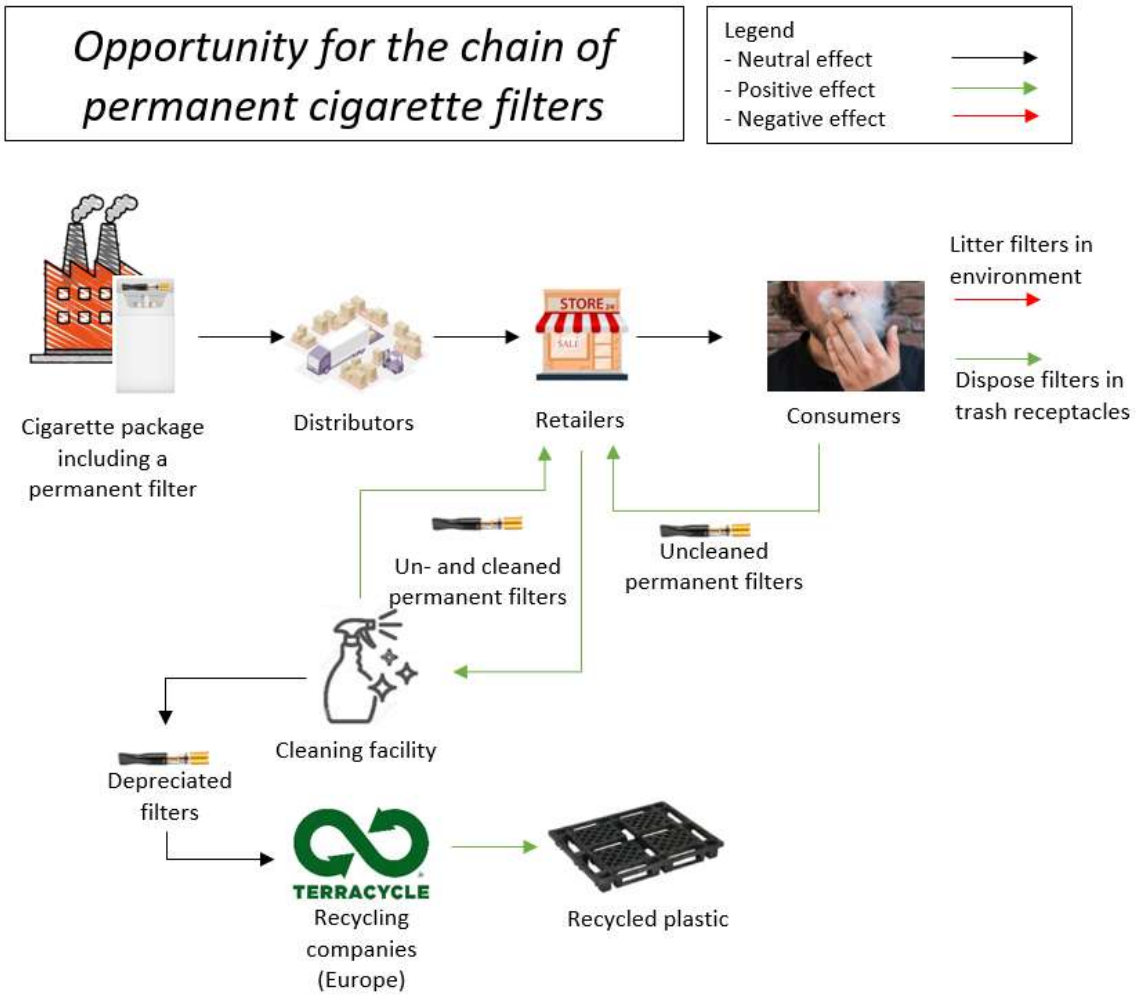

Figure 5.3: Chain of permanent cigarette filters when the filters are circulated.

Requirement list for a permanent cigarette filter	
D(emand) W(ish)	Requirements
	1. Geometry: dimensions of the design Permanent cigarette filter:
D	- Maximum length: 5.4 cm
D	- Maximum width: 1.2 cm
D	- Maximum height: 2 cm
D	- Should fit in the cigarette package.
W	- Should be easy to clean.
	Mechanics
D	- Should be reused for 23 times.
D	- Able to attach, detach and remain secured while smoking the cigarette.
D	- Filtering properties such that the total smoke consist of a maximum of 10 mg tar, 1 mg nicotine and 10 mg carbon monoxide.
W	- An inhalation should taste the same as a cigarette with a disposable cigarette filter.
	Material
W	- Environmental neutral material or material which can be recycled.
D	- Nontoxic.
D	- Tasteless.
D	- Resistant to a temperature of 900°C.
W	- Should take a beating.
	Signals
W	- A signal should arise to indicate that the filter needs cleaning.
	Safety
D	- Should be safe to use.
	Ergonomics
W	- The cigarette filter should fit with the design of the unfiltered cigarettes and should arouse the appearance that it is hazardous waste to encourage people not to litter.
	Transport
D	- Dimensions of the product should be favourable to be transported in a cigarette package.
	Recycling
W	- The permanent cigarette filter should have a modular design, such that depreciated parts can easily be replaced and recycled.
	Costs
D	- The production of one permanent filter should be less or equally expensive as producing 19 to 23 disposable filtered cigarettes.
W	- The investment costs to develop and implement a permanent filter, should be kept as low as possible.

Figure 5.4: Requirement checklist for permanent cigarette filters

Chapter 6: Discussion

This report provides new insights in the relationships between solution directions which deal with cigarette butt waste with respect to environmental, social and feasibility aspects. This results in a proposed design which corresponds to the 'reuse' level, which shows that the highest level is not always the most preferred level.

The findings from this study suggest that introducing a permanent cigarette filter shows the highest potential to decrease the negative effects of cigarette butt debris. However, when the design is validated, it appears that the weaknesses and threats outweight the strengths and opportunities. This is mainly because the logistics to decrease the harmful residues exposed to the environment are not present. The design matrix, which was used as a tool to select this design, did include the criteria 'harmful residue reduction'. The proposed design is assessed with a neutral grade with respect to this criteria, since the design shows opportunities to decrease the harmful residues by cleaning the permanent cigarette filter sufficiently. However, these opportunities are not validated in the design matrix.

Furthermore, the obtained weights of the criteria could differ when a larger perspective was applied. The criteria weights are established by obtaining an overview of the values and visions of the stakeholders combined with the problem statement. Firstly, the values and visions of the consumers of cigarettes are based on a questionnaire with 21 responders, which can be improved by performing a more detailed questionnaire with a broader field of responders. Secondly, more members of the municipality of Groningen could have been interviewed to provide an in-depth understanding of their opinion. Eventually, no representative of a tobacco company could be interviewed, which could have provided more knowledge concerning the capabilities and visions of tobacco companies.

Another point of interest are the selection of the top five solution directions and the top three designs. Multiple designs result with an equal score, since the assessment of the designs with respect to the criteria can not be performed with high precision. However, two decimal points are added in order to select solution directions and designs. This can not be fully justified, since other solution direction and designs might have a higher potential in solving the cigarette butt debris problem.

Eventually, the results of this research suggest a design extracted form the 'reuse' level of the hierarchy, while other researchers which stressed the importance of the cigarette butt debris problem mostly focus on 'prevent' (Joly & Coulis, 2018), 'reduce' (Blum & Novotny, 2018) and collection of the cigarette butts to 'recycle' (Araújo & Costa, 2019; Novotny

et al., 2009; Novotny & Slaughter, 2014). This can be explained with the fact that these studies are more exploratory rather than applied research.

Chapter 7: Conclusion

This integration project aims to identify the most appropriate design to contribute to solving the cigarette butt debris problem in view of the circumstances. Based on the selected designs and the introduced criteria which are in line with the needs and desires of the involved stakeholders, it can be concluded that creating a permanent cigarette filter is the most suited design. This permanent cigarette filter is a reusable filter which is sold together with a package of unfiltered cigarettes. Eventually, this design showed to be insufficient to be implemented, since the design requires new extensive logistic steps to decrease the toxic components littered in the environment through the filters.

The used approach provided a clear overview of all possible design directions and contributed to a broad assessment of these design directions with respect to the identified criteria. The permanent cigarette filter is selected, since it has a high potential for decreasing the amount of plastic littered through cigarette butt debris, is effective in the long-term and does not result in significant changes in the smoking experience for the consumers of cigarettes.

This research illuminates the shortcomings of the selected design as well. By performing a SWOT-analysis, it becomes clear that the harmful residues that accumulate in the permanent cigarette filter can only be prevented from being littered when a new logistic system is implemented. This new logistic system requires a deposit system and cleaning facilities that does not exist yet. Moreover, the depreciated filters need to be recycled. Furthermore, close cooperation of the stakeholders is required to the create the circulation of permanent cigarette filters. Eventually, the design itself requires high investments for research and development, which has a possibility of failing.

As a recommendation, future work on this topic should focus on how the toxic residues can be dealt with in a less complex manner. This research can focus on the technical possibilities of a redesigned permanent filter or can focus on simplifying the logistics needed. Another point of interest which can be further researched are the remainder of identified designs and the implementation of these designs.

Eventually, the design proposal contributes in decreasing the negative effects of cigarette butts, since the proposed design can serve as a starting point for other researchers to build upon. Moreover, this research can serve as a foundation for making decisions in waste management, since it provides an overview of most possibilities.

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Appendices

Appendix A: Consistency

In order to calculate Consistency Ratio (CR), the Consistency Index (CI) and the Random Index (RI) need to be determined.

A.1 Consistency Index

Before the Consistency Index can be calculated, the Weighted Sum Value (WSV) need to be obtained by multiplying each element per column of the non-normalized pair-wise comparison matrix with the criteria weight (CW) of that column. The newly obtained matrix with the calculated WSV are illustrated in table A.1.

	PR	HRR	AH	SE	CE	CH	CA	PC	MC	LTE	R	**WSV**	**CW**
PR	0.15	0.15	0.15	0.14	0.14	0.15	0.21	0.15	0.21	0.15	0.09	1.69	0.15
HRR	0.15	0.15	0.15	0.14	0.14	0.15	0.21	0.15	0.21	0.15	0.09	1.69	0.15
AH	0.03	0.03	0.03	0.06	0.06	0.03	0.02	0.03	0.02	0.03	0.04	0.39	0.03
SE	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.03	0.19	0.02
CE	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.03	0.19	0.02
CH	0.03	0.03	0.03	0.06	0.06	0.03	0.02	0.03	0.02	0.03	0.04	0.39	0.03
CA	0.05	0.05	0.09	0.1	0.1	0.09	0.07	0.09	0.07	0.05	0.06	0.82	0.07
PC	0.03	0.03	0.03	0.06	0.06	0.03	0.02	0.03	0.02	0.03	0.04	0.39	0.03
MC	0.05	0.05	0.09	0.1	0.1	0.09	0.07	0.09	0.07	0.05	0.06	0.82	0.07
LTE	0.15	0.15	0.15	0.14	0.14	0.15	0.21	0.15	0.21	0.15	0.09	1.69	0.15
R	0.45	0.45	0.21	0.18	0.18	0.21	0.35	0.21	0.35	0.45	0.28	3.32	0.28

Table A.1: The pair-wise comparison matrix in which each element of each column is multiplied with the CW and the obtained WSV.

The Consistency Index can be calculated using the obtained values for WSV and CW and formulas A.1 and A.2.

$$\lambda \max = \frac{\sum \frac{WSV}{CW}}{11} = 11,42 \tag{A.1}$$

$$CI = \frac{\lambda \max - n}{n-1} = \frac{11.42 - 11}{11 - 1} = 0,04 \tag{A.2}$$

A.2 Random Index and Consistency Ratio

The value for the Random Index is a constant value coupled to the number of criteria. In this case, eleven criteria are used, which results in RI = 1.52 (Saaty & Tran, 2007). With the use of the obtained CI and RI, CR is calculated using formula A.3.

$$CR = \frac{CI}{RI} = \frac{0.066}{1.52} = 0.043 \leq 0.1 \tag{A.3}$$

Appendix B: Grade Assessment

B.1 Plastic reduction

This KPI measures the degree in which the chosen design decreases the amount of plastic littered through cigarette butts. How the grades are assigned is illustrated in table B.1.

Plastic reduction	Grade
0 - 20%	1
20 - 40%	2
40 - 60%	3
60 - 80%	4
80 - 100%	5

Table B.1: The decrease of plastic coupled to a grade.

Substitute filter

When a filter does not contain plastic, the amount of plastic littered per cigarette butt is totally eliminated. This design results in a plastic reduction of 100%.

Substitute cigarette

Substitution of the cigarette results in a completely new product. An identified product which can serve as a substitute are the electronic nicotine delivery systems (Bickel et al., 2018). These electronic nicotine delivery systems, mostly consist of plastic (Lerner et al., 2015). However, these systems can be used many times. This results in a reduction of 80%.

Eliminate filter

The cigarette does not contain plastic when the filter is removed. Consequently, the amount of plastic littered within these cigarettes is decreased with 100%.

Stop consumption

When the consumption of cigarettes is stopped, cigarette butt debris will stop exist. This results in a plastic reduction of 100%.

Reusable filter

The design of a reusable filter results in a plastic reduction from 50% to 99.99%. When the redesigned filter can be reused once, a reduction of 50% is achieved since one filter is needed instead of two. Equally, when the redesigned filter can be reused multiple times, the plastic reduction will approach 100%. This percentages fall under grade 3, 4 and 5. An average of those grades is taken which results in grade 4.

Second purpose

Finding a second purpose for cigarette butts results in plastic reduction, since the cigarette butts are reused and not littered. However, after the cigarette butts served this second purpose, they have to be disposed as well and the disposal can not be controlled with this measure. Moreover, the research available on this design suggests using the cigarette butts as a control tool against dengue (Dieng et al., 2018). This is not a purposeful tool for all consumers, since dengue affects half of the world population (Messina, 2019). The plastic reduction will decrease with 0% to 50%, with an average of 25%.

Trash receptacles

An experiment measured a decrease of 54% in cigarette butts found in a specific area after placing decorative ashtrays (Cope et al., 1993).

Labelling

Labelling cigarette packages with educative quotes about the environment can be compared with quotes which point out the health hazards of consuming cigarettes, since it both tries to educate and activate consumers of cigarettes. A research on the effectiveness of these health warnings on cigarette packages measured that an average of 39.1% of the interviewed consumers tried to quit smoking as a result of health warnings on cigarette packages (Borland et al., 2009). This percentage is used to assess this design.

Campaigns

Educative campaigns aim at increasing the knowledge of people to change their behaviour. The campaign of Keep Britain Tidy, #BinTheButt, focus on increasing awareness of consumers and make throwing cigarette butts on the ground socially unacceptable. As a result of this campaign, 83% of the litterers claimed the campaign encouraged them to bin their butts (KBT, 2018). However, it has not been proved that these consumers actually binned their butt. Another campaign, Beat The MicroBead of the Plastic Soup Foundation, showed to be successful. The campaign started in 2012 and up to now 448 brands from 119 manufacturers promised to make their products microbead-free ((TPSF, 2019)). However, this campaign focus on changing regulations instead of the behavior of consumers. Contrarily, knowledge as a source of changing the behaviour of people has

a limited effect because of the lack of motivational force if consumers do not have an important personal value for protecting the environment (Bolderdijk et al., 2013). Because of the conflicting knowledge about the effectiveness of campaigns on decreasing cigarette butt litter, this design is graded with a 2.5.

Enforcement

In an experiment, researchers measured a binning rate of 62% during the timespan in which enforcers were present (EPA, 2019).

Deposit System

The deposit system for cigarette butts is compared with the existing deposit system for plastic bottles in order to assess this design. Research shows that the proportion of containers found within coastal litter in states without a container deposit legislation is approximately 40% higher than states with such legislation (Schuyler et al., 2018). This comparison can be justified, since both objects are litter that consist of plastic. However, cigarette butt litter can be seen as less obvious litter which is littered as a common practice which differs from more obvious litter such as plastic bottles (Cope et al., 1993). Moreover, the effectiveness of a deposit system can depend on multiple variables, such as the price of the deposit and the availability of return facilities.

Smoking areas

Introducing smoking areas can be seen as a tool to decrease the surface of the littered area. Moreover, an experiment of Keep Britain Tidy showed a decrease of 34% in littering behavior after the implementation of smoking areas (Charman, 2015).

Manually

In the annual Ocean Conservancy's International Coastal Cleanup 1,684,183 cigarette butts were collected by volunteers in the United states in 2007 (Novotny et al., 2009). In this same year, 360 filtered cigarettes were consumed in the United States (Novotny et al., 2009). Thus, the collected butts during the ICC is approximately 0.0005% of the amount consumed.

Birds

The concept of using birds to pick up cigarettes and collect them properly is not tested yet. When this design is realized it strives to clear the environment from cigarette butts fully. The grade 4 is chosen for this design, since there is no direct evidence that the cigarette butts are cleared fully from the environment.

Machines

The concept of using machines to pick up cigarettes and collect them properly is not designed and tested yet. When this design is realized it strives to clear the environment from cigarette butts fully. The grade 4 is chosen for this design, since there is no direct evidence that the cigarette butts are cleared fully from the environment.

B.2 Harmful residue reduction

This KPI measures the degree in which the chosen design decreases the number of toxic components littered through cigarette butts. How the grades are assigned is illustrated in table B.2.

Harmful residue reduction	**Grade**
0 - 20%	1
20 - 40%	2
40 - 60%	3
60 - 80%	4
80 - 100%	5

Table B.2: The decrease of harmful residues coupled to a grade.

The grades of the designs substitute cigarette, eliminate filters, stop consumption, second purpose, trash receptacles, labelling, campaigns, enforcement, deposit system, smoking areas, manually, birds and machines are assigned in a similar way as the grades of plastic reduction.

Substitute filter

Substitution of the cigarette filter from a plastic filter to a biodegradable filter does not solve the problem of the leachates of toxic components when the cigarette butt is exposed to fluids (Torkashvand et al., 2020).

Reusable filter

When a filter is reused, the filter still contains the harmful combustion products of tobacco . These filters need to be washed or replaced properly, in order to prevent toxic leachates. How the filters are cleaned, depends on the design of reusable filter. An example of a reusable filter, the TarGard Permanent Cigarette Filter System, uses a brush to clean the filters (Thompson, 2018).

B.3 Added hazards

This KPI measures the degree in which the chosen design creates new environmental hazards. How the grades are assigned is illustrated in table B.3.

Added environmental hazards	Grade
Major environmental hazards	1
Medium environmental hazards	2
Small environmental hazards	3
Minor environmental hazards	4
No environmental hazards	5

Table B.3: The kind of environmental hazard coupled to a grade.

Substitute filter

The production of biodegradable cigarette filters might be more polluting than the production of traditional cigarette filters. However, these differences will be minor.

Substitute cigarette

The extend in which extra environmental hazards are added depends on the replacement of the cigarette. Electronic nicotine delivery systems, an example of a substitute, mostly contain a lithium-ion batteries, LED lights, microprocessors, metal castings, wires and plastics (Lerner et al., 2015). These components form medium environmental hazards when they are not disposed properly (Lerner et al., 2015).

Eliminate filters

Eliminating the cigarette filter will not result in added environmental hazards, since this design does not require any extra objects or production features.

Stop consumption

Stopping consumption will not result in added environmental hazards, since this design does not require any extra objects or production features.

Reusable filter

The production of a reusable cigarette filter might be more polluting then the production of the traditional cigarette filter. This might result in extra environmental hazards. However, these differences will be minor. Moreover, when the cigarette filter is reusable, less filters have to be produced.

Second purpose

Using cigarette butts for a second purpose does not result in any additional environmental hazards, since further processing is not required.

Trash receptacles

Trash receptacles need to be produced and maintained. Moreover, after the collection of cigarette butts, the butts need to be transported to a waste plant for further processing. The production, maintenance and transport might be polluting when fossil fuels are used. This results in a small environmental hazards added.

Labelling

Labelling cigarette packages with educative quotes about the environment will not result in extra environmental hazards, since only the imprint of the cigarette packages need to be changed.

Campaigns

Campaigns can be executed online or with the use of tangible resources. Nevertheless, campaign resources will never result in small to major environmental hazards.

Enforcement

Enforcement to decrease the amount of cigarette butts being littered requires enforcers, fines and administration. This does not result in added environmental hazards

Deposit System

Implementing this design, results in consumers of cigarettes collecting and transporting cigarette butts themselves, which is not polluting for the environment. However, return systems need to be produced and maintained. Eventually, the cigarette butts need to be transported for further processing. Thus, this design results in minor environmental hazards.

Smoking areas

When smoking areas are introduced, the density of cigarette butts in a specific area might increase drastically. Further research is needed to discover if a higher density of cigarette butts can result environmental hazards for that specific area. This results in a neutral grade, namely 3.

Manually

When the cigarette butts are cleared from the environment using manpower and collection tools, minor environmental hazards are brought into existence. Furthermore, after the collection of cigarette butts, the butts need to be transported to a waste plant for further processing. The production of collecting tools and the transportation of the cigarette butts added up result in small environmental hazards.

Birds

No extra environmental hazards occur while collecting cigarette butts, since birds are doing the work. However, a machine which collects the butts from the birds and gives them a reward in return is required. These machines need to be produced and maintained. Moreover, after the collection of cigarette butts, the butts need to be transported to a waste plant for further processing. The production and maintenance of collection machines and the transportation of the cigarette butts added up result in small environmental hazards. Additionally, further research is needed to discover if this design affects the birds which are used.

Machines

Machines to collect cigarette butts need to be produced, maintained and use fuel during the collection. When all these features are executed using fossil fuels, this can result in extra pollution to the environment. Moreover, after the collection of cigarette butts, the butts need to be transported to a waste plant for further processing, which also might be polluting when fossil fuels are used. This results in medium environmental hazards.

B.4 Smoking experience

This KPI measures the degree in which the chosen design changes the smoking experience for the consumer. How the grades are assigned is illustrated in table B.4.

Change in smoking experience	**Grade**
Complete change	1
Large change	2
Medium change	3
Small change	4
No change	5

Table B.4: The change in smoking experience coupled to a grade.

Substitute filter

Brown & Williamson Tobacco Company, a tobacco company, developed and tested five biodegradable filters. All these biodegradable filters were not implemented because of the change in taste of inhalations (Novotny et al., 2009). This can be classified as a medium change in smoking experience.

Substitute cigarette

Substituting the cigarette with a different product changes the smoking experience largely to completely. The electronic nicotine delivery systems imitate the cigarette closely. However, this product is still very different from the traditional cigarette in terms of taste, appearance and feeling.

Eliminate filters

Adding filters to cigarettes resulted in lighter taste, which results in taking larger puffs (Kozlowski & O'connor, 2002). When the filter is removed from the cigarette, the taste of the cigarette changes drastically. This can be classified as a large change.

Stop consumption

Consumers which stop smoking cigarettes totally eliminate the smoking experience. This can be seen as a complete change.

Reusable filter

Substituting the conventional filter with a reusable filter could result in a change in taste of inhalations similarly to the design 'substitute filter'. However, since the filter can be made of the same materials, this change can be limited, resulting in a small change in smoking experience.

Second purpose

When the cigarette butts are used after the consumption of cigarettes, the smoking experience itself does not change.

Trash receptacles

The placement of trash receptacles does not affect the smoking experience.

Labelling, campaigns and enforcement

All these designs aim on educating the consumer to avoid littering behavior. This does not change the smoking experience.

Deposit system

A deposit system starts to affect the smoker after the consumption, thus it does not change the smoking experiences.

Smoking areas

The introduction of smoke areas affect the smoking experience, since the consumers are not free to smoke wherever they want anymore. This is classified as a small change.

Manually, birds and machines

All these designs aim on clearing a littered area, which does not result in any changes in the smoking experience.

B.5 Consumer effort

This KPI measures the degree in which the chosen design requires additional effort of the consumer from smoking to the disposal of cigarettes. How the grades are assigned is illustrated in table B.5.

Required effort	Grade
Major effort	1
Large effort	2
Medium effort	3
Low effort	4
No effort	5

Table B.5: The amount of required consumer effort coupled to a grade.

Substitute filter, substitute cigarette and eliminate filters

These designs all aim to change the initial design of the cigarette (filter) and do not require any effort of the consumers themselves.

Stop consumption

A major effort is required of consumers to stop the consumption of cigarettes. Cigarettes contain nicotine which is classified as a highly addictive drug, which falls under the same criteria for dependence on alcohol, cocaine and heroin (Henningfield et al., 1998).

Reusable filter

This design also aims on changing the initial design of the cigarette filter. However, this design requires a low effort of the consumer, namely to connect the filter before smoking and to disconnect the filter after smoking a cigarette.

Second purpose

Using the cigarette filter for a second purpose requires the consumers to preserve their cigarette butts and transport them to the place where these butts can be reused. This can be classified as a medium effort.

Trash receptacles

With this design, a small effort is required of consumers to dispose their cigarette butts, since this design makes the disposal more easy.

Labeling, campaigns and enforcement

All these designs aim on educating the consumer to avoid littering. These designs require effort from the consumer to preserve their cigarette butts and dispose them properly without offering the consumer a trash receptacle. This results in a medium effort.

Deposit system

A deposit system requires the consumer to preserve its cigarette butts and transport them to the intended deposit points. The effort for the transport to these return points depends on the amount and scattering of such points. This classifies this design with medium to large effort.

Smoking areas

This design requires consumers to transport themselves to a smoking area before smoking, which is classified as a small effort.

Manually, birds and machines

All these design aim on clearing a littered area, which does not result in any added effort for the consumers themselves.

B.6 Consumer health

This KPI measures the degree in which the chosen design affects the health of the consumers, additional to the effects of smoking itself. In this assessment, the health effects of microplastics and toxic components leachates are not taken into account. How the grades are assigned is illustrated in table B.6.

Effect on health	**Grade**
Large negative effects	1
Negative effects	2
No effects	3
Positive effects	4
Large positive effects	5

Table B.6: The effects on the health of consumers of cigarettes coupled to a grade.

Substitute filter

Substitute the cellulose acetate filter with a biodegradable filter aims in fulfilling the same filtering properties. Consequently, this design does not have an influence on the health of the consumers.

Substitute cigarette

Replacing the traditional cigarette can result in positive effects for the health of the consumer, since the toxic components of tobacco smoke are not inhaled anymore. In case of the electronic nicotine delivery systems, research showed that e-cigarettes are less toxic than traditional cigarettes with tobacco. However, within this research scientific evidence concerning the toxicity of e-cigarettes is lacking because of the absence of a standardized research setting (Wang, Liu, & Song, 2019). Consequently, this design results in no effects or positive effects.

Eliminate filters

Filters are initially added to the cigarette for health reasons, namely to reduce the amount of tar in cigarette smoke (Hastrup et al., 2011). Nevertheless, other research shows that filter ventilation does not decrease health hazards for the consumer. The consumers increase their puff volume, number of puffs and number of cigarettes smoked and obstruct the filter holes with their fingers, which is called compensating behavior for the lower tar proportion (Kozlowski & O'connor, 2002). This results in negative health effects to no effects.

Stop consumption

Stop consumption of cigarettes results in a large positive effect on the health of the consumers, since the consumption of tobacco is accountable for the death of approximately 6 million humans in the world every year (Erazo & Nes, 2017).

Reusable filter

Substitute the cellulose acetate filter with reusable filter aims in fulfilling the same filtering properties. Consequently, this design does not have any influence on the health of the consumers.

Second purpose

Using cigarette butts for a second purpose might affect the health of humans being close to these cigarette butts. Research about this is not available. This results in a neutral grade, namely 3.

Trash receptacles and deposit system

This design aims on encouraging consumers to dispose their cigarette butts properly and does not change the composition of the cigarette itself. This results in no influence on the health of consumers.

Labelling, campaigns, enforcement

All these designs aim on educating the consumer to avoid littering behavior and does not change the composition of the cigarette itself. This results in no influence on the health of consumers.

Smoking areas

Smoking areas result in a higher density of smokers in one area. This can have negative health effects, since the probability of inhaling second-hand smoke is increased. This results in added harm for the health of the consumer, since the global burden of disease of second-hand smoke is approximately 1% higher than from smoking tobacco directly (Singh & Lal, 2011). This can be classified as a negative effect on the health of consumers.

Manually, birds and machines

All these design aim on clearing a littered area and does not change the composition of the cigarette itself. This results in no influence on the health of consumers.

B.7 Consumer awareness

This KPI measures the degree in which the chosen design increases the consumer awareness about the environmental hazards of cigarette butts. How the grades are assigned is illustrated in table B.7.

Increase in awareness	**Grade**
No increase	1
Attention raised about cigarette butt disposal	2
Increased awareness on correct disposal	3
Increased awareness on the negative effects	4
Increased awareness on the negative effects and correct disposal or not needed	5

Table B.7: The increase in awareness coupled to a grade.

Substitute filter, substitute cigarette and eliminate filters

The awareness of the environmental hazards of cigarette butts is not increased when these designs are implemented, since all designs focus on redesigning the conventional tobacco cigarette. However, awareness is not needed, since the cellulose acetate filter is eliminated.

Reusable filter

The implementation of a reusable filter does not aim on educating the consumer of cigarettes on the disposal of their cigarette debris. However, when consumers are forced to reuse their filters, attention may rise for cigarette butt disposal.

Stop consumption

This design focuses on eliminating the consumption of cigarettes. When this goal is reached, awareness about the disposal and negative effects of cigarette butts is not needed.

Second purpose

Using cigarette butts for a second purpose does not aim on educating the consumer of cigarettes on the disposal of their cigarette debris. However, when consumers are forced to reuse their filters, attention may rise for cigarette butt disposal.

Trash receptacles, deposit system and smoking areas

All these designs do not aim on educating the consumer on their disposing behavior. However, the implementation of these measures can arouse attention towards the disposal of cigarette butts.

Labelling and campaigns

Labelling cigarette packages with educative quotes about the environmental hazards of cigarette butts and campaigns which aim on educating people on these environmental hazards both increase awareness on the negative effects and disposal of cigarette butts.

Enforcement

With this design, consumers who litter are directly corrected in their littering behavior. This results in increased awareness of correct disposal.

Manually, birds and machines

These designs all focus on clearing littered areas after consumers littered their cigarette butts. These designs do not create awareness on correct disposal or the negative environmental effects of cigarette debris.

B.8 Producers' costs

This KPI measures the amount of costs which are incorporated with the development and implementation of design for the producers of cigarettes. How the grades are assigned is illustrated in table B.8.

Costs related to the development and implementation	Grade
High investment costs and high long-term costs	1
Low investment costs and high long-term costs	2
High investment costs and no (or low) long-term costs	3
Low investment costs and no (or low) long-term costs	4
No costs	5

Table B.8: Costs related to the development and implementation of the design coupled to a grade

Substitute filter and reusable filter

These two designs require a high investment, since a new filter needs to be developed and implemented. Furthermore, these designs both will not result in long-term costs for the producers, since the production of a different kind of filter will not significantly change the production costs.

Substitute cigarette

Tobacco companies are already developing alternatives for cigarettes (Calantzopoulos, 2019). These substitutes for cigarettes might need further development to fulfill the needs of the

consumers of cigarettes. Furthermore, there might be long-term costs when the sale of these substitutes is less beneficial than the sale of cigarettes.

Eliminate filters

Stop incorporating filters in cigarettes will not result in additional costs, since this does not result in any extra production or major modifications in the production line.

Stop consumption

When sales of cigarettes decrease the profits of tobacco companies decrease as well, since cigarettes are the most produced products of these companies (Daube et al., 2017).

Second purpose

Giving a second purpose to cigarette butts without any modification will not result in any additional costs for the producers of cigarettes.

Trash receptacles, campaigns, enforcement, deposit system, smoking areas, manually, birds and machines

Research shows that most tobacco companies find themselves not accountable for the cigarette butt waste (Hoek et al., 2019). Consequently, the producers of cigarettes are not held accountable for the costs for placing trash receptacles, enforcement, implementing a deposit system, creating smoking areas or clearing the environment from cigarette butts.

Labelling

The implementation of labels on cigarette packages will only require a low investment, since the layout of the package and the print machine need to be changed.

B.9 Municipalities costs

This KPI measures the amount of costs which are incorporated with the development and implementation of the design for the municipalities. The grades are assigned equally to the grades of 'Producers' costs', illustrated in table B.8.

Substitute filter, substitute cigarette, eliminate filters and reusable filter

All these designs aim to change the current cigarette, which can be accomplished by the producers of cigarettes. This does not result in any costs for the municipalities.

Stop consumption

Consumers of cigarettes need to stop smoking themselves, which does not result in costs for the municipalities. However, municipalities can encourage smokers to stop using campaigns or legislation.

Second purpose

Giving a second purpose to cigarette butts without any modification will not result in any additional costs for the municipalities.

Trash receptacles

Trash receptacles are already developed. The investment for the municipality includes purchasing these receptacles and implementing them. The long-term costs include the maintenance of these trash receptacles and further collection of cigarette butts.

Labelling

Adding labels to cigarette packages is a modification performed by the producers of cigarettes. This does not result in any costs for the municipalities.

Campaigns

Knowledge about creating a successful campaign is available. Moreover, examples of successful campaigns available can be used to develop a new campaign (KBT, 2018) (TPSF, 2019). This results in low investment costs. Long-term costs include the circulation of a campaign, which can be held low using existing channels.

Enforcement

Since enforcement procedures already exist, a low investment is required. However, this design requires enforcers on a daily basis which is costly. These costs can be paid using the revenues from the tickets. The municipality Zaanstad increased the ticket for illegal waste dumping to €182 to make enforcement cost-covering (Hamming, 2018). This tactic can also be applied for the enforcement of cigarette butt litter to keep long-term costs low.

Deposit system

Implementing a deposit system can require a large investment, since a deposit system need to be developed and implemented. Furthermore, the long-term costs include maintenance of this system and further collection of cigarette butts.

Smoking areas

The implementation of smoking areas does not include a significant modification, which results in low investment costs. Consequently, smoking areas require small to negligible upkeep.

Manually

Clearing areas of cigarette butts can be done on a voluntary basis, based on previously organized clean-up actions. Organizing a clean-up falls under a low investment, which need to be repeated which results in low long-term costs.

Birds

The system that encourages birds to collect cigarette butts is not fully developed yet, which results in large investments required to develop and implement this system. When this design is implemented, the long-term costs include the maintenance of the machines and the further collection of cigarette butts. These costs are identified as low long-term costs.

Machines

Machines that are able to collect cigarette butts are not fully developed yet, which results in large investments to develop these machines. When this design is implemented, the long-term costs include the maintenance of the machines and the further collection of cigarette butts. These costs can be seen as medium long-term costs.

B.10 Long-term effectiveness

This KPI measures in which extend the design retain its original value on the long-term. How the grades are assigned is illustrated in table B.9.

Long-term effectiveness	**Grade**
Major effort needed to retain value	1
Large effort needed to retain value	2
Medium effort needed to retain value	3
Small effort needed to retain value	4
No change in value over time	5

Table B.9: Effort needed to remain the value of the design coupled to a grade.

Substitute filter

The value of an implemented biodegradable filter does not change over time.

Substitute cigarette

The value of using substitutes for the tobacco cigarette does not change over time.

Eliminate filters

The value of a cigarette without a filter does not change over time.

Stop consumption

The value of eliminating smoking completely does not change over time.

Reusable filter

The value a filter that can be reused does not change over time.

Second purpose

The value of using cigarette butts for some second purpose significantly decreases when this second purpose is fulfilled and the cigarette butts are classified as waste again. This might result in large efforts to remain this value.

Trash receptacles

In order to remain the value of trash receptacles, these receptacles need to be emptied and maintained. This can be seen as a small effort.

Labelling

The effect of labels with warnings of cigarette butts affecting the environment might decrease on the long term. This results in a neutral grade, namely 3.

Campaigns

The value being exposed to campaigns which educate on the negative effects of cigarette butts might decrease on the long term. This results in a neutral grade, namely 3.

Enforcement

An experiment on using enforcement of control the disposal of cigarette butts shows a decrease of 12% in binning rate when the enforcers are removed (EPA, 2019). In order to remain the value of enforcement, enforcers need to be present at all times, which can be classified as a major effort.

Deposit system

In order to remain the value of deposit systems, the return systems required need to be emptied and maintained. This is classified as a small effort.

Smoking areas

The value of a market area intended for smokers does not change over time.

Manually

The effect of a clean-up action is only temporary. These clean-ups need to be organized over and over in order to clear new cigarette butts being littered, which is a large effort.

Birds

Birds will continuously clear the littered areas and train other birds with the use of copying behavior (Schilperoord, 2017). For this design to be long-term effective, the collection machines should be emptied and maintained, which is a small effort.

Machines

The effect of clearing an area using machines is only temporary. These machines has to work on a regular basis to clear new cigarette butts being littered, which can be classified as a major effort.

B.11 Realization

This KPI measures in which extend the design can be realized based on previous attempts and reasoning. How the grades are assigned is illustrated in table B.10.

Size of limitations to realization	Grade
Major limitations to realization	1
Large limitations to realization	2
Medium limitations to realization	3
Small limitations to realization	4
No limitations to realization	5

Table B.10: Limitations present to realization coupled to a grade.

Substitute filter

Tobacco company Brown & Williamson already developed and tested five biodegradable filters. These filters were not implemented because of the change in taste (Novotny et al.,

2009), which can form a small limitation towards the realization of substituting the plastic filters.

Substitute cigarette

Tobacco companies will not stop producing cigarettes as long as there is a demand for their cigarettes (The Lancet, 2019). Therefore, the the demand of customers need to shift to alternatives or the government needs to change the regulations to realize this design. Even though alternatives for cigarettes are on the market since 2006 (Noel, Rees, & Connolly, 2011), cigarettes remain the most sold product (Daube et al., 2017). However, a number of studies shows an increase in the amount of e-cigarette users (Santos, 2018). This results in a neutral grade 3.

Eliminate filters

Filters are implemented to reduce the amount of tar inhaled and to change the taste of cigarettes (Hastrup et al., 2011)(Kozlowski & O'connor, 2002). This change of a cigarette might form a limitation towards the realization of this design. Moreover, regulation sets a maximum amount of tar per cigarette of 10 mg in the Netherlands, which can not be reached without using a filter (RIVM, 2018). This results in a major limitation to realize this design.

Stop consumption

The fact that cigarettes are damaging to the health of the consumers is known since 1950 (Peto et al., 2000). Yet, most consumers of cigarettes failed to quit smoking (Jesus et al., 2016). Furthermore, a tobacco control policy, MPOWER, which stands for Monitor, Protect from smoke, Offer help to quit, Warn about danger, Enforce and Raise taxes showed to be insufficient in most countries that implemented this policy (Britton, 2017). This shows that major limitations towards the realization of this design exist.

Reusable filter

Reusable filters already exist, for example the TarGard Permanent Cigarette Filter System (Thompson, 2018). However, these filters need to be further developed and implemented to make the use of reusable filters convenient. Resistance of regulation or the development of these filters might form small limitations.

Second purpose

Research available on this design suggests using the cigarette butts as a control tool against dengue (Dieng et al., 2018). This is not a purposeful tool for all consumers, since dengue affects half of the world population (Messina, 2019). The fact that the other half can not

use the cigarette butts for this purpose forms a major limitation towards the realization of this design.

Trash receptacles

Placing trash receptacles has already been done by municipalities. This results in no limitations towards the realization of placing trash receptacles.

Labelling

Cigarette packages are already labelled with health warnings (Borland et al., 2009), which implies that including warnings about the environmental hazards of cigarette butt debris can be implemented without significant limitations.

Campaigns

Examples of successful executed campaigns are available (KBT, 2018) (TPSF, 2019). This shows that important limitations towards the development and circulation of campaigns do not exist.

Enforcement

The enforcement of dumping cigarette butts is covered by dumping street waste, which is established in the waste ordinance of the municipality Groningen. However, the Public Prosecution Service decided to exclude this violation from enforcement (interview Richard Zwarts, appendix C.1). This results in a small limitation towards the realization of this design.

Deposit system

Examples of working deposit systems are available, for example the deposit system for beverage containers, electronics, lead-acid batteries, motor oil, tires and various hazardous materials (Walls, 2012). This shows that important limitations towards the development and implementation of a deposit system do not exist.

Smoking areas

In a pilot of Keep Britian Tidy an intervention, 'smoking zones', is executed in order to encourage consumers to dispose their cigarette butts correctly (Charman, 2015). Within this pilot, no limitations exist.

Manually

Multiple clean-up actions has been carried out, for example the annual International Coastal Cleanup (Novotny et al., 2009). These clean-ups do not encounter any limitations, except

from finding enough volunteers, which can be classified as a small limitation.

Birds

The design which aims to use birds to collect cigarette butts is still in its prototype phase. Moreover, research about the health concerns to the birds is still required, which can form a significant limitations towards the realization of this project (Schilperoord, 2017).

Machines

Street-sweepers for different kinds of waste already exist, which results in no to small limitations in developing a machine for developing a cigarette butt clearing machine.

Appendix C: Interviews

C.1 Interview with Richard Zwarts

In this interview with Richard Zwarts, associate of Municipal councillor Glimina Chakor, the focus lies on the regulations to control cigarette butt litter. Richard Zwarts explains that in the municipality of Groningen enforcement is not used to control cigarette debris, since the Public Prosecution Service decided to exclude this violation from enforcement. Despite the fact that dumping cigarette butts is illegal and covered by dumping street waste, which is established in the waste ordinance of the municipality Groningen.

C.2 Interview with Kars Ottens

The goal of this interview was to obtain introductory information about the cigarette butt problem and how the municipality of Groningen copes with this problem. Kars Ottens, member of the project team of City Management, explained the measures the municipality is taking and refers to the Facebook-page 'Groningen Schoon Dankzij Mij'. He made clear that most activities which aim on solving the cigarette butt problem are informative, for example giving presentations on primary schools about the effects of litter. Furthermore, Kars told about the distribution of pocket ashtrays in Groningen. Eventually, Kars pointed out that the budget available for dealing with cigarette debris is limited and forms a constraint. Moreover, the municipality of Groningen is planning to become a smoke-free city, which forms a second constraint for facilitating the disposal of cigarette butts.

C.3 Interview with Maurie Mutsaers

In this interview, Maurie Mutsaers, employee at the municipality of Groningen, explains how waste is processed in Groningen. She tells me that the municipality of Groningen has two ways to collect residual waste: with the use of the grey containers and with the use of underground containers. People who use a grey container separate their residual waste from organic waste and people who use the underground containers do not have to separate their organic waste. The separation of organic waste is performed afterwards in a special facility. The residual waste in the grey containers is collected one in the two weeks. The underground containers give a signal when they almost reach their full capacity, consequently the residual waste is collected. The collected waste is transported to a separation facility at the Duinkerkenstraat. Metals, multiple types of plastic bottles and plastic/carton packages are separated from the waste. After this process, the organic waste is transformed to green gas in a facility next to the separation facility. The separated

plastics and metals are transported to specialist to be processed in Europe. The actual residual waste is transported to a waste plant in Wijster. At this plant the waste is burned to generate energy. Cigarette butts mostly end up in this final waste stream.

Appendix D: Questionnaire

D.1 Introduction

The following paragraph is used as an introduction in the questionnaire.

Research shows that cigarette butt debris has negative effects on the living environment of human beings and animals worldwide. These negative effects are caused by the leachates of toxic components contained in these filters after smoking tobacco and the formation of microplastics. This problem should be tackled by finding and implementing solutions. This survey tests the priority of criteria for the consumer.

D.2 Questions

The following questions are used in the questionnaire. The results are illustrated in figure D.1 to D.8.

Give for every statement the importance in your opinion.

1. When I dispose my cigarette butt, I find it ... that no plastic will end up in the environment.

a. Totally not important

b. Not important

c. Neutral

d. Important

e. Very important

#	Antwoord	Antwoorden	Ratio
●	Heel onbelangrijk	0	0 %
●	Onbelangrijk	3	14,3 %
●	Neutraal	8	38,1 %
●	Belangrijk	6	28,6 %
●	Heel belangrijk	4	19,0 %

Figure D.1: Results of the first question

2. When I dispose my cigarette butt, I find it ... that no toxic components end up in the environment.

a. Totally not important

b. Not important

c. Neutral

d. Important

e. Very important

#	Antwoord	Antwoorden	Ratio
●	Heel onbelangrijk	0	0 %
●	Onbelangrijk	2	9,5 %
●	Neutraal	4	19,0 %
●	Belangrijk	12	57,1 %
●	Heel belangrijk	3	14,3 %

Figure D.2: Results of the second question

3. When a solution to the cigarette butt litter problem is found, I find it ... that this solution is CO2-neutral.

a. Totally not important

b. Not important

c. Neutral

d. Important

e. Very important

#	Antwoord	Antwoorden	Ratio
●	Heel onbelangrijk	0	0 %
●	Onbelangrijk	2	9,5 %
●	Neutraal	3	14,3 %
●	Belangrijk	14	66,7 %
●	Heel belangrijk	2	9,5 %

Figure D.3: Results of the third question

4. When a solution to the cigarette butt litter problem is found, I find it ... that this solution is effective in the long run.

a. Totally not important

b. Not important

c. Neutral

d. Important

e. Very important

#	Antwoord	Antwoorden	Ratio
●	Heel onbelangrijk	0	0 %
●	Onbelangrijk	1	4,8 %
●	Neutraal	1	4,8 %
●	Belangrijk	10	47,6 %
●	Heel belangrijk	9	42,9 %

Figure D.4: Results of the fourth question

5. When a solution to the cigarette butt litter problem is found, I find it ... that the smoking experience (taste, feeling, style) remains the same.

a. Totally not important

b. Not important

c. Neutral

d. Important

e. Very important

#	Antwoord	Antwoorden	Ratio
●	Heel onbelangrijk	1	4,8 %
●	Onbelangrijk	5	23,8 %
●	Neutraal	5	23,8 %
●	Belangrijk	5	23,8 %
●	Heel belangrijk	5	23,8 %

Figure D.5: Results of the fifth question

6. When a solution to the cigarette butt litter problem is found, I find it ... that I do not have to put effort in the disposal of my cigarette butt.

a. Totally not important

b. Not important

c. Neutral

d. Important

e. Very important

#	Antwoord	Antwoorden	Ratio
●	Heel onbelangrijk	1	4,8 %
●	Onbelangrijk	4	19,0 %
●	Neutraal	6	28,6 %
●	Belangrijk	8	38,1 %
●	Heel belangrijk	2	9,5 %

Figure D.6: Results of the sixth question

7. When I buy cigarettes, I find it ... that these cigarettes result in minimal harm towards my health.

a. Totally not important

b. Not important

c. Neutral

d. Important

e. Very important

#	Antwoord	Antwoorden	Ratio
1	Heel onbelangrijk	0	0 %
2	Onbelangrijk	3	14,3 %
3	Neutraal	4	19,0 %
4	Belangrijk	11	52,4 %
5	Heel belangrijk	3	14,3 %

Figure D.7: Results of the seventh question

8. I find it ... that I am aware of the consequences of cigarette butts littered in the environment.

a. Totally not important

b. Not important

c. Neutral

d. Important

e. Very important

#	Antwoord	Antwoorden	Ratio
1	Heel onbelangrijk	0	0 %
2	Onbelangrijk	1	4,8 %
3	Neutraal	2	9,5 %
4	Belangrijk	14	66,7 %
5	Heel belangrijk	4	19,0 %

Figure D.8: Results of the eighth question

Appendix E: Grade Assessment II

E.1 Plastic reduction

Explanation about the assessment of this KPI is provided in appendix B.1.

Biodegradable filter

When all filters are replaced by biodegradable filters, plastic in cigarette butts is fully eliminated.

Tobacco heating products

HEETS are tobacco units specially designed for the use of the tobacco heating product, IQOS. HEETS contain a cellulose acetate mouthpiece filter including mouth-end papers (PMI, 2019b). However, the percentage of cellulose acetate in a cigarette (17.7%) is higher than in a heating tobacco product (14.6%) (PMI, 2019a). Nonetheless, this difference does not result in a plastic reduction over 20%.

Vapour products

Most vapour products consist of plastic including a plastic cartridge containing the e-liquids (Lerner et al., 2015). British American Tobacco is producing a vapour product in which the e-liquid can be refilled, which results in only one cartridge required for the lifespan of the device (BAT, 2017b). The lifespan of most vapour products can be increased since the parts of these products can individually be replaced. Therefore, the reduction of plastic is graded with a 5.

Oral products

Oral products, like snus, moist snuff and pouches do not contain plastic (HAYPP, 2019)(BAT, 2017a). This substitute of cigarettes fully eliminates plastic ending up in the environment.

Permanent cigarette filter

The initial design is to start selling a reusable filter per package of cigarettes and later on force consumers to reuse this filter for multiple packages. This initial design already accomplishes a reduction of plastic of 95%, when one filter is used instead of 20 disposable filters.

Ashtrays

In a research of John Cope, an experiment shows a decrease of 54% in cigarette butts found in an area after placing a high density of decorated ashtrays (Cope et al., 1993).

Waste bins including ashtrays

The plastic reduction as a result of placing waste bins which include an ashtray can be compared by placing ashtrays, which results in a decrease of 54% in cigarette butts.

Pocket ashtrays

The effectiveness of pocket ashtrays in decreasing the amount of cigarette butts littered in the environment is assessed with the same grade as the other two trash receptacles, since exact information does not exist.

E.2 Harmful residue reduction

Explanation about the assessment of this KPI is provided in appendix B.2.

Biodegradable filter

Substitute the cellulose acetate filters with biodegradable filters does not change the amount of remaining harmful residues inside the filter.

Tobacco heating products

The Onassis Cardiac Surgery Centre and a research of the university of Bern claims a toxic component reduction of 70% in the damp produced by the IQOS (K.E. Farsalinos et al., 2018) (Auer et al., 2017), which is used for assessing this design.

Vapour products

With the use of vapour products, e-liquids are vapourized. This process does not result in any combustion products of tobacco which can end up in the environment.

Oral products

Moist snuff and snus contain tobacco leafs and flavourings. However, no combustion products of tobacco are released, since these products are not burned. Moreover, a review research which examined the components of smokeless tobacco products shows a percentage of 30-35% tobacco in these products (McAdam et al., 2019). Nonetheless, tobacco is exposed in the environment if the oral products are not properly littered. However, it is less harmful than the combustion products of tobacco and oral products contain less tobacco.

Permanent cigarette filter

Harmful combustion products of tobacco will still accumulate in a reusable filter (Araújo & Costa, 2019). However, the proposed design can be cleaned such that these harmful residues will not be exposed in the environment. Moreover, this is a measure that should be executed by the consumer of cigarettes, which creates the possibility that cleaning is not performed properly. Moreover, when the retailers of cigarettes are responsible for the cleaning, this possibility is decreased and the amount of harmful residues littered in the environment is reduced significantly. Therefore, this design is assessed with a neutral grade.

Ashtrays, waste bins including ashtrays and pocket ashtrays

These designs all aim on prevent cigarette butts from being littered in the environment. When this is fulfilled, the amount of cigarette butts (containing plastic and harmful residues) in the environment is reduced. These designs are assessed in a similar way for plastic reduction.

E.3 Added hazards

Explanation about the assessment of this KPI is provided in appendix B.3.

Biodegradable filter

The production of biodegradable cigarette filters might be more polluting than the production of traditional cigarette filters. However, this difference will be minor.

Tobacco heating products

Tobacco heating products require a battery-powered device to consume tobacco. The production of these devices adds up to the production of HeatSticks (HEETS) which might result in small added environmental hazards.

Vapour products

Vapour products require a battery-powered device which replaces the cigarette. Therefore, the production of cigarettes is replaced by the production of these more durable devices. This might result in minor hazards.

Oral products

Oral products made of tobacco leafs or natural fibers (HAYPP, 2019) replace the cigarette. This does not result in any added environmental hazards.

Permanent cigarette filter

The production of a reusable cigarette filter might be more polluting than the production of the traditional cigarette filter. This can result in extra environmental hazards. However, when the cigarette filter is reusable, less filters have to be produced. This results in no added environmental hazards.

Ashtrays

Placing ashtrays requires producing and maintaining these ashtrays. Moreover, the collected cigarette butts need to be transported in order to be recycled. When the production of ashtrays, maintenance of ashtrays and transportation of cigarette butts is not performed in an environmentally friendly way, this can result in small environmental hazards.

Waste bins including ashtrays

In this design, a similar amount of environmental hazards are present as for the placement of ashtrays. However, the transportation of the cigarette butts can be combined with the transportation of other waste. This results in minor environmental hazards.

Pocket ashtrays

This design requires the production and dispense of pocket ashtrays. Maintenance and transportation is not required, since consumers of cigarettes maintain their ashtrays and transport the cigarettes themselves. However, this design collects cigarette butts together with the residual waste. Therefore, effort is required to separate the cigarette butts from the total waste. This results in minor added environmental hazards.

E.4 Smoking experience

Explanation about the assessment of this KPI is provided in appendix B.4.

Biodegradable filter and permanent cigarette filter

These two designs focus on changing the cigarette filter without changing the properties such as taste, feeling and shape. These designs results in minor to no changes in smoking experience

Tobacco heating products

Instead of smoking tobacco, this device enables the consumer to inhale vapour from heated tobacco which aims to create the same taste and feeling as smoking a cigarette (Peitsch, 2017). However, the smoking experience significantly changes in terms of shape, since a device is needed to consume the HeatSticks.

Vapour products

Vapour products create vapour from a liquid which can be inhaled and is produced with different flavours and concentrations of nicotine, which aims to create a superior taste for the consumer. However, the smoking experience significantly changes in terms of shape, since a device is needed to consume this liquid. Moreover, this liquid does not contain tobacco, which can form a constraint to deliver the tobacco experience.

Oral products

Oral products vary in the formulation, flavour and amount of nicotine (Hatsukami et al., 2011), which makes it a product that can be customized to according the consumers taste. However, oral products are completely different in terms of feeling and shape, since the consumer does not inhale smoke anymore.

Ashtrays, waste bins including ashtrays and pocket ashtrays

All these three designs do not affect the smoking experience, since they all concern the disposal of cigarette butts.

E.5 Consumer effort

Explanation about the assessment of this KPI is provided in appendix B.5.

Biodegradable filter

This design does not require any effort, since the consumer is not expected to do anything different with the changed filter.

Tobacco heating products and vapour products

These two designs require a minor extra effort, since the consumer need a device to consume liquids or HeatSticks. This device need to be powered and carried.

Oral products

Using oral products instead of consuming cigarettes does not require a significant amount of extra effort from the consumers.

Permanent cigarette filter

This design requires a minor effort to reuse the permanent cigarette filter.

Ashtrays and waste bins including ashtrays

These two designs require a small amount of effort from the consumer to dispose their cigarette butts, since the availability of ashtrays is increased.

Pocket ashtrays

This design forms a minor extra effort required from the consumers, since they are expected to carry a device with their cigarette butts to dispose their butts in a waste bin when these are available.

E.6 Consumer health

Explanation about the assessment of this KPI is provided in appendix B.6.

Biodegradable filter and permanent cigarette filter

Both designs aim on changing the conventional cigarette filter without changing the initial properties. Thus, these designs do not result in any effects on the health of consumers, since the filtering properties will not change.

Tobacco heating products

The inhalations of HeatSticks using the tobacco heating device IQOS contain lower levels of some toxicants and higher levels of other toxicants compared to cigarette smoke. Similarly, this heating device results in higher risks of some diseases and lower risk of other diseases (Glantz, 2018), resulting in a neutral grade.

Vapour products

Most researchers conclude that using vapour products is less harmful to the health of the consumer than smoking. However, the degree in which health risks are decreased is not agreed on. Moreover, research about the long-term health effects is not available (K. Farsalinos, 2018). This results in no effects to positive effects.

Oral products

An example of an oral tobacco product, snus, delivers lower concentrations of a number of harmful chemicals than cigarettes. Although, depending on the kind of snus, oral products can contain higher doses of nicotine. Overall, health risks of snus are significantly lower than the health risks of smoking (Foulds et al., 2003) (Gartner, 2007).

Ashtrays, waste bins including ashtrays and pocket ashtrays

The effects on the health of the consumers of cigarettes does not change, since these designs all focus on increasing correct disposal of cigarette butts and not change the cigarette.

E.7 Consumer awareness

Explanation about the assessment of this KPI is provided in appendix B.7.

Biodegradable filter

Replacing the cellulose acetate filter with a biodegradable filter without notice will neither increase awareness about the negative effects of littered filters nor about correct disposal of these filter. This awareness is still required, since the risk that harmful residues end up in the environment is still present.

Tobacco heating products

Tobacco heating products do mainly focus on providing a less harmful way of consuming tobacco to the consumers of cigarettes, not on creating awareness about cigarette debris. Since this design does not eliminate the cellulose acetate filters, creating awareness does not become superfluous.

Vapour products and oral products

Vapour and oral products do not incorporate cigarette filters, which makes creating awareness on the negative effects of cigarette filter superfluous.

Permanent cigarette filter

When this design is implemented, the consumers of cigarettes are forced to reuse their filter which results in a raise of attention towards cigarette butt disposal or even create awareness on correct disposal. For this design, the grade 2.5 is assessed.

Ashtrays and waste bins including ashtrays

By increasing the facilities for consumers to correctly dispose their cigarette butts, awareness for this disposal can be increased.

Pocket ashtrays

When pocket ashtrays contain educative quotes and are dispensed personally an increased awareness about the disposal and the negative effects of cigarette butt debris can be reached.

E.8 Producers' costs

Explanation about the assessment of this KPI is provided in appendix B.8.

Biodegradable filter and permanent cigarette filter

Using the same reasoning as the assessment of the first design matrix, these two designs only require a high investment.

Tobacco heating products, vapour products and oral products

These three designs do not result in any significant costs for the producers of cigarettes, since these products are already developed and can be sold in the same manner they currently sell cigarettes. However, further development might be needed to improve these systems, which results in investments.

Ashtrays, waste bins including ashtrays and pocket ashtrays

Using the same reasoning as the assessment of the first design matrix, the producers of cigarettes are not held responsible for the costs of placing ashtrays, placing waste bins which include an ashtray or dispensing pocket ashtrays.

E.9 Municipalities' costs

Explanation about the assessment of this KPI is provided in appendix B.9.

Biodegradable filter, tobacco heating products, vapour products, oral products and permanent cigarette filter

Using similar reasoning reasoning for assessing grades as done in the first design matrix, the municipalities are not accountable for the costs of these designs.

Ashtrays

Placing a high density of decorated ashtrays requires an investment. Long-term costs originate, since ashtrays need to be maintained and emptied. Moreover, the cigarette butts need to be shipped to recycling companies.

Waste bins including ashtrays

The costs of the municipalities of this design can be assessed with the grade 2.5. This design is slightly less costly than placing separate ashtrays, since maintaining and emptying the ashtrays can be combined with maintaining and emptying the regular waste bins.

Pocket ashtrays

Dispensing pocket ashtrays requires a low investment (Waste, 2019). Furthermore, the consumers of cigarettes are held responsible for the maintenance and emptying of these ashtrays. However, long-term costs exist for the separation of the cigarette butts from the total waste. This is classified as low/high long-term costs, which result in grade 3.

E.10 Long-term effectiveness

Explanation about the assessment of this KPI is provided in appendix B.10.

Biodegradable filter

As soon as the biodegradable filter is adopted in all filtered cigarettes it does not lose its value on the long-term.

Tobacco heating products, vapour products and oral products

When consumers of cigarettes stop smoking and start using one of the substitutes proposed in these designs, the value will not decrease over time.

Permanent cigarette filter

Similarly to the biodegradable filter, the value of the permanent cigarette filter will not decrease over time. Moreover, the value of this design could increase when it is fully adopted and a deposit system is developed.

Ashtrays and waste bins including ashtrays

The possibility that the decorations incorporated on the ashtrays and waste bins including ashtrays lose their effectiveness on the long-term because of the decrease of novelty is credible (Cope et al., 1993). Therefore, effort is required to remain the novelty of this decorations. Furthermore, on the long-term effort is required to remain transporting and recycling the cigarette butts.

Pocket ashtrays

An experiment on dispensing portable beach ashtrays showed an abandonment rate of 1.5% (Widmer et al, 2010), which gives a reason to assume a long-term effectiveness of pocket ashtrays. However, research on the long-term effectiveness of portable ashtrays is not available. Furthermore, similarly to the two previously mentioned designs, long-term effort is required to remain transporting and recycling cigarette butts.

E.11 Realization

Explanation about the assessment of this KPI is provided in appendix B.11.

Biodegradable filter

Biodegradable filters do exist; however, currently properties of these developed biodegradable filters are not sufficient to fully substitute the conventional cigarette filter. This mainly concerns the taste of inhalations (Novotny et al., 2009). When improvements can not be obtained, limitations evolve. Furthermore, literature points out that filters are incorporated in the cigarette initially to make cigarettes more acceptable and addictive for current and future smokers (Blum & Novotny, 2018). Consequently, cigarette filters can be seen as a marketing tool. When tobacco companies are able to make smoking more acceptable by selling environment friendly filtered cigarettes, this can serve as an extra motivation to overcome this limitation.

Vapour products

Public Health England characterised e-cigarettes as less harmful alternatives to cigarettes, although approximately 16% of smokers within the United Kingdom uses vapour products (McKeganey, 2017). In interviews with smokers in the United Kingdom, the majority of the reasons why smokers are reluctant to switch to these devices were the preference for tobacco instead of 'chemical' liquids and the perception of unreliable devices (McKeganey, 2017). This can form large to medium limitations for the realization of this design.

Tobacco heating products

The nature of the formation of vapour is the main difference between tobacco heating products and vapour products. Tobacco heating products form vapour from tobacco, which makes it more compatible with cigarettes. This results in removing one main limitation towards realization from vapour products, which results in a medium limitation towards the realization of this design.

Oral products

Substituting cigarettes with oral products, such as snus, seems realizable because of the success in Sweden. However, the sale of snus in most countries fail, even though no legal boundaries exist towards the sale of snus. Apparently, the use of smokeless tobacco is a culture-bound habit which is unlikely to be established in other countries (Gartner et al., 2007). Moreover, snus is a product which is mostly held orally for 13 to 15 hours a day, which requires a commitment of consumers to switch to these products (Gartner et al., 2007). These two reasons form large to major limitations towards the realization of this design.

Permanent cigarette filter

Reusable cigarette filters do exist; however, currently properties of these developed reusable filters are not sufficient to fully substitute the conventional cigarette filter. This mainly concerns filtering properties (Thompson, 2018). When improvements can not be obtained, limitations evolve. However, using similar reasoning as the assessment of a biodegradable filter for this criteria, tobacco companies have an increased motivation to overcome this limitation.

Ashtrays and waste bins including ashtrays

Limitations towards placing ashtrays or waste bins which include an ashtray do not exist, since this is already executed extensively.

Pocket ashtrays

Limitations towards the dispense of pocket ashtrays do not exist, since the municipality of Groningen already distributed some pocket ashtrays during trials (Interview Kars Ottens, Appendix C.2). Moreover, Copenhagen, Gijón and Paris dispensed pocket ashtrays as well (Waste, 2019).