Obesogenic environments; we have a better insight in what their characteristics are.
3.1 Aim of this thesis

The research included in this doctoral thesis was conducted to get a better insight into the ways in which physical, social, economic and policy environmental factors are associated with obesity-related behaviours and obesity in adults. I mainly focused on urban environments. The results from the included studies and their interpretation have been described in detail in Part 2 of this thesis. The chapters in Part 2 describe the methodology of virtual audits to characterise obesogenic environments and the exploration of if, how and for whom certain elements of the physical, social, economic and policy environment are associated with obesity-related behaviours. In this general discussion (Part 3) a summary of the methodology and main findings will be provided. Further, overall reflections with regard to the findings from the studies will be provided and recommendations for future research and policy are considered.

3.2 Summary of the main findings

The central research questions that have been addressed in this thesis were:

1) Which factors in the physical and social environments of adults have consistently been linked to adult weight status?

2) How can we define, measure and operationalise factors in the physical and social environments that may contribute to obesity risk across different regions?

3) To what extent, via which pathways and for what subgroups are physical, social, economic and political environmental factors associated with obesity-related behaviours and obesity in adults?

Research question 1

In Chapter 2.1 and 3.1, a systematic review of the scientific literature regarding potential physical and social environmental determinants of adult weight status was provided. Chapter 2.1 showed that in the available scientific literature to date only few environmental factors could consistently be linked to adult weight status. This result stood even after taking methodological quality of the studies into account, when distinguishing between studies using perceptions of the environment and studies using objective measures, and stratifying studies by continent in which the study was conducted. Most studies had been conducted in the US, and these studies showed that land use mix and urban sprawl were relatively robust correlates of adult weight status. This led us to conclude that, with the exception of urban sprawl and land use mix in the US, studies to date do not allow firm conclusions regarding potential physical environmental determinants of adult weight status.\[1\] Based on these findings and reflecting on issues brought up in several of the included studies, we made a number of recommendations for future studies relating physical environmental factors to weight status:

1. To take into account moderating and mediating effects, to get a better understanding of why (via which pathways) and for whom environmental characteristics matter;

2. To study environmental factors in an area that provides sufficient variation;
3.1 Aim of this thesis
The research included in this doctoral thesis was conducted to get a better insight into the ways in which physical, social, economic and policy environmental factors are associated with obesity-related behaviours and obesity in adults. I mainly focused on urban environments. The results from the included studies and their interpretation have been described in detail in Part 2 of this thesis. The chapters in Part 2 describe the methodology of virtual audits to characterise obesogenic environments and the exploration of if, how and for whom certain elements of the physical, social, economic and policy environment are associated with obesity-related behaviours. In this general discussion (Part 3) a summary of the methodology and main findings will be provided. Further, overall reflections with regard to the findings from the studies will be provided and recommendations for future research and policy are considered.

3.2 Summary of the main findings
The central research questions that have been addressed in this thesis were:

1) Which factors in the physical and social environments of adults have consistently been linked to adult weight status?
2) How can we define, measure and operationalise factors in the physical and social environments that may contribute to obesity risk across different regions?
3) To what extent, via which pathways and for what subgroups are physical, social, economic and political environmental factors associated with obesity-related behaviours and obesity in adults?

Research question 1
In Chapter 2.1 and 3.1, a systematic review of the scientific literature regarding potential physical and social environmental determinants of adult weight status was provided. Chapter 2.1 showed that in the available scientific literature to date only few environmental factors could consistently be linked to adult weight status. This result stood even after taking methodological quality of the studies into account, when distinguishing between studies using perceptions of the environment and studies using objective measures, and stratifying studies by continent in which the study was conducted. Most studies had been conducted in the US, and these studies showed that land use mix and urban sprawl were relatively robust correlates of adult weight status. This led us to conclude that, with the exception of urban sprawl and land use mix in the US, studies to date do not allow firm conclusions regarding potential physical environmental determinants of adult weight status.[1] Based on these findings and reflecting on issues brought up in several of the included studies, we made a number of recommendations for future studies relating physical environmental factors to weight status:

1. To take into account moderating and mediating effects, to get a better understanding of why (via which pathways) and for whom environmental characteristics matter;
2. To study environmental factors in an area that provides sufficient variation;
3. To take into account both objectively measured and subjectively measured environmental features, because they are likely to represent different but equally ‘true’ exposures to the environment;

4. To realise that the use of administrative units may be ill-suited to examine environmental effects on health, and that alternative approaches should be examined;

5. To differentiate between causation and correlation. While longitudinal and (natural) experimental studies have the advantage of allowing for temporal associations, we may approximate causation in cross-sectional studies by taking into account residential self-selection (endogeneity).[1]

Chapter 3.1 showed that the literature regarding social environmental determinants of obesity was scarcer, and -more importantly- also very heterogeneous. This heterogeneity in the definitions and metrics of social environmental factors limited the comparability of study results. Also here, the literature mainly originated from the US. The strongest associations with weight status were found for social capital and collective efficacy, although even for these social environmental factors few studies found significant associations. This may be due to the fact that social environmental factors were generally ill-defined; the fact that the study designs applied did mostly not allow for detection of meaningful associations; or because there was indeed no association between exposure –social environment- and outcome –weight status-. Given the lack of consistent definitions, measurements and associations, the conclusion of this review was that the research conducted to date does not provide robust scientific evidence for relations between social environmental factors and adult weight status.[2]

Research question 2

In chapter 1.1, 1.2 and 3.2, different ways of defining and measuring ‘obesogenic environments’ were described. This was done in light of the European SPOTLIGHT project, on which most studies in this thesis were based. To generate sufficient variation in environmental factors, we used a novel neighbourhood sampling approach that resulted in a random selection of 60 neighbourhoods that differed in terms of socioeconomic status and residential density (two measures that have been consistently associated with overweight). Given the need for harmonised data collection across different areas across Europe, we explored ways of collected such data validly and reliably. The systematic literature review on which chapter 1.1 was based showed that ‘virtual audits’ were moderately to highly valid and reliable, and saved time in comparison with ‘field audits’. [3] Chapter 1.2, which describes the validation of the SPOTLIGHT Virtual Audit Tool (S-VAT), showed results consistent with those shown in the systematic review: the SPOTLIGHT virtual audit showed moderate to high inter-rater and intra-rater reliability as well as criterion validity. Again consistent with the findings from the systematic review, validity and reliability of more ‘objective’ measures (e.g. presence of bicycle lanes) was higher than of more ‘subjective’ measures (e.g. aesthetics).[4] As the literature review presented in chapter 3.1 showed that only few studies truly examined the contextual effects of social factors (most used individual measures of social constructs as a proxy for social environmental constructs),[2] chapter 3.2 describes the identification of ‘truly contextual’ social constructs associated with obesity-related behaviours, obesity and self-rated health. We operationalised contextual social networks and social cohesion in three different ways: an ecometric
score, a score that aggregated individual scores to the neighbourhood level, and the aggregated score adjusted for individual level scores. Although, based on theoretical consideration the ecometric score was preferred, the results showed that in practice the ecometric score was not sufficiently able to distinguish between individual and contextual variation, and the less laborious aggregated scores provided similar results as the ecometric scores.[5]

**Research question 3**

Chapter 2.2, 2.4, 2.5, 2.6, 3.2, 3.3, 3.4, 4.1, 4.2 and 5.1 describe results of a series of studies into what physical, social, economic and political environmental factors were associated with obesity-related behaviours and/or weight status. With regard to physical environmental factors, we found that the objective presence of destinations in a neighbourhood was associated with healthier obesity-related behaviours across different European regions.[6] In another large population based sample we also found that supermarket proximity was associated with weight status.[7] Across European regions, we found that objective spatial access to fast food outlets was not, but perceptions of availability to fast food outlets was associated with fast food consumption (but not obesity).[8] With regard to social environmental factors, we found that higher levels of neighbourhood social cohesion and social networks was associated with better self-rated health, lower odds of obesity and higher odds of high fruit consumption, but also with higher odds of prolonged sitting and lower odds of transport-related physical activity across European regions.[5] Social networks characteristics, such as network density, intensity of relations and size of the network, were associated with higher vegetable consumption, higher levels of physical activity and lower levels of sedentary behaviours in the Netherlands.[9] With regard to economic environmental factors, we showed that higher levels of neighbourhood income inequality were associated with higher body mass index across different European regions.[10] Also, higher dietary costs were associated with higher consumption of fruit and vegetables in UK adults.[11] Finally, affordability of foods in supermarkets was associated with consuming healthier diets in the UK.[12] With regard to political environmental factors, we showed that regional policies that change land-use and public transport amenities have the opportunity to change levels of active commuting in New Zealand.[13]

Chapter 2.3, 2.5 and 3.3 provide some insight into how environmental factors are associated with obesity-related behaviours and obesity. We studied the factors associated with socioeconomic differences in neighbourhood perceptions across Europe, and found that both individual and environmental factors were associated with neighbourhood perceptions. Main factors explaining these socioeconomic differences in neighbourhood perceptions were social cohesion and objectively measured environmental factors.[14] To unravel the potential underlying mechanisms of environment-obesity associations, we examined the extent to which perceived availability of fast food outlets and fast food consumption explained the association between spatial access to fast food outlets (based on objective environmental measure) and obesity in European adults. We hypothesised that higher objectively assessed spatial access to fast food outlets would be associated with perceived availability and usage of fast food outlets, that this would be associated with higher levels of fast food consumption, and that this would be associated with higher odds of obesity. Results showed that perceived availability and usage of fast food outlets was associated with fast food consumption. However, objective access to fast food outlet was not associated with obesity nor with fast food
consumption.[8] Finally, we explored whether the association between network characteristics and obesity-related behaviours could be explained by similarities or differences between the behaviours of individuals and their network members, or by the social support received from the network. Although several network characteristics were associated with healthier obesity-related behaviours in this Dutch sample, we did not find evidence that receiving social support for healthy behaviours or similarities between network members’ behaviours could explain this association.[9]

Chapter 2.2, 2.4, 4.1 and 4.2 identify subgroups for whom associations between environmental factors and obesity-related behaviours or obesity were stronger. Findings in European adults suggested that the association between presence of neighbourhood destinations and obesity-related behaviours was stronger in individuals perceiving many barriers towards healthy behaviours. That is, presence of recreational facilities, parks and bicycle lanes were not associated with physical activity in adults perceiving no barriers to be physically active, but these associations were significant for individuals perceiving many barriers to be physically active. For food consumption, we found that presence of destinations was important in both individuals perceiving no barriers and individuals perceiving many barriers towards healthy eating. However, the associations were much stronger in individuals perceiving many barriers than in individuals perceiving no barriers towards healthy eating.[6] Data from a sample of UK adults showed that socioeconomic status, dietary costs and fruit and vegetable intake were interrelated. Educational attainment, household income and dietary costs were all independently associated with fruit and vegetable intake. However, socioeconomic position and dietary costs also interacted, such that dietary costs were more strongly associated with F&V intake for people with low socioeconomic status than people with high socioeconomic status.[11] Other results from the same UK dataset showed that both socioeconomic status (educational attainment) and supermarket proximity were independently associated with body mass index, overweight and obesity. Findings also showed relative excess risk of being overweight or obese due to interaction between socioeconomic status and supermarket proximity, such that those having lowest educational attainment and living farthest away from the nearest supermarket were 2.4 times more likely to be overweight and 4.3 times more likely to be obese.[7] Results from another study in this UK dataset showed that both dietary costs and supermarket proximity were independently associated with dietary quality. However, combining these factors, resulting in a measure reflecting ‘affordability’ of foods purchased from supermarkets, showed that this combined measure was more strongly associated with dietary quality than accessibility (proximity of supermarkets) alone.[12]

3.3 Methodology

3.3.1 Limitations

Although all studies that are part of this thesis have been conducted with great care, all studies had their methodological limitations and there thus may be uncertainty about whether the findings from the population under study are true for other populations (external validity) and whether the observed associations are “real” (internal validity). Several types of bias (systematic error in the design, conduct or analysis of a study[15]) may have occurred with consequences for the external and internal validity of the studies presented in this thesis.
First, selection bias may have resulted in an exposure-outcome association specific to our study sample rather than what would be observed in the total population. In all studies included in this thesis, a selection of the population of interest participated in the studies. Individuals interested to participate in a study may be more health-conscious than individuals who are less interested. Since we did not have any information of non-participants, it is difficult to know if the included individuals are a representative sample of the population of interest. Especially for the participants of the SPOTLIGHT survey, where –first of all– only one urban area per participating country was included, generalization of the results to urban areas across Europe in general should be done with care. Furthermore, the overall response rate was 10.8%, and it is likely that women, younger, higher educated and healthier people were over-represented.[16] Additionally, in all studies included in this thesis, a White population was over-represented, while it is known that obesity and obeseigenic behaviours vary by ethnicity or race. To reduce further selection of participants in the analysis phase, missing data were imputed if >5% of the data were missing. Complete case analysis (only including those respondents who provided information on all variables of interest) would likely result in biased estimates.[17,18] In the case of the forecasting study (chapter 5.1) we found results that are likely to be context-specific, such as the fact that higher levels of population density were not associated with higher odds of active commuting.[13]

Bias is also most likely to have occurred due to the cross-sectional design of the included studies (except for the review studies and the forecasting study); i.e. the measurement of exposure and outcome took place at the same moment in time. This hampers the causal inference as selection and causation cannot be disentangled. Associations between living in a neighbourhood with recreational facilities and being physically active may actually represent an association between a motivation to be physically active and choosing a neighbourhood that suits these wishes. To limit the chances of reverse causation, analysis plans were built upon and supported by theoretical frameworks, and where possible we took variables on residential self-selection into account. Yet, a cross-sectional design evidently still strongly limits the interpretation of moderating and mediating roles of the variables under study. Further, there may be a time lag between exposure to environmental factors and a change in behaviours or health outcomes, which limits the interpretation of the observed associations.

Second, information bias may have occurred. In large-scale population studies with a broad scope (such as the SPOTLIGHT study), environmental perceptions, obesity-related behaviours and health outcomes are often measured using self-report questionnaires. Information bias in studies using self-report measures may occur due to recall bias (recent exposures are remembered better or in more detail due to the presence of the outcome), due to reporting or social desirability bias (individuals give the answers they suspect the researchers want to get), or observer bias (when the researcher steers the participant in a certain direction of answering).[15] As an example of reporting bias, a sub-study of the SPOTLIGHT project showed that individuals over-reported their physical activity despite data being collected with an internationally validated self-report tool.[19] Same-source bias (or cognitive dissonance bias – part of reporting bias) occurs when individuals with less favourable obesity-related behaviours adjust their beliefs to match their actions.[20] For example, individuals who are not physically active may report that there are no physical activity facilities available in their neighbourhood, either because they are not aware of the facilities since they do not use them, or to justify their behaviours. However, in most studies we were able to measure at least the exposure measure objectively, ruling out any same-source bias.
In all studies included in this thesis, information bias with regard to the outcome measures may have been limited due to the use of standardised research protocols, and, in case of the SPOTLIGHT survey, an online survey (which may have limited social desirability bias and observer bias). In the Fenland cohort, weight status was objectively measured by trained clinicians.

To avoid misclassification of the exposure, data collection of the environmental measures took place in a systematic way by trained researchers. Misclassification bias arises when the tools used to classify exposure or outcome do not have sufficient sensitivity and/or specificity. In case of the SPOTLIGHT virtual audit tool, a validation study was conducted, showing moderate to high criterion validity, inter-rater reliability and intra-rater reliability of the tool.[4] In the Fenland cohort, food environment data used represents the most accurate of its kind in the UK.[21] However, as the plausible time lag between moment of exposure and development of the outcome is usually not measured (as in all studies included in this thesis), misclassification of exposure may still have occurred.

Third, residual confounding may have distorted the ‘true’ associations. In all studies included in this thesis, potential confounding variables had been considered before data collection. This ensured that all confounding variables of interest had been measured and could thus be accounted for. Given the number of confounding variables of interest, multivariable models were deployed in most studies in this thesis. Yet, in the study on the associations between social network characteristics and obesity-related behaviours, the number of participants included in the study did not allow for the adjustment for key sociodemographic variables.

Finally, ‘positive result bias’ is a highly prevalent type of bias that may have occurred in the studies included in this thesis as well. When expected results are found, researchers tend to rationalise their choice of study design and methodology, while, when unexpected results are found, this is often attributed to methodological limitations. We aimed at avoiding this influence of course, and the fact that a large team of experienced researchers collaborated in the preparation of the different manuscripts combined in this thesis, this type of bias may have been contained as best as possible.

### 3.3.2 Strengths

The studies included in this thesis benefitted from a number of strengths. The SPOTLIGHT study was undertaken in five European countries, which increases the external validity of these findings as compared to single country studies. Further, the innovative (random) sampling design of the SPOTLIGHT study ensured a variety of neighbourhoods from which we randomly invited adult participants. Although participants of the Fenland cohort are more highly educated and less ethnically diverse than the wider UK population, it is a sample representative of the Cambridgeshire population. Participants of the New Zealand Household Travel survey were also selected from randomly selected neighbourhoods, and sampling weights were used in the analysis to account for potential selection bias arisen in the sampling process.

Within the SPOTLIGHT project, data was collected on a wide range of variables, which enabled to assess the broader context in which behaviours take place. Besides data on neighbourhood perceptions, the social environment, obesity-related behaviours, sociodemographics, health and weight status and individual perceived barriers, we also asked questions about duration of residency, spending time in the neighbourhood, reasons for choosing a neighbourhood or using neighbourhood facilities. This allowed us to explore whether these factors (some of which may be a proxy for residential self-
selection) confounded the observed associations, moderated the associations or mediated the associations. As we collected data on a range of relevant lifestyle behaviours,[22] we were able to address both sides of the energy balance equation, i.e. energy intake and expenditure. The Fenland cohort, New Zealand Household Travel Survey and the Hoorn Prevention study provided information on very specific variables, such as cost of food items, duration and mode of commuter trips and characteristics of social network members. This allowed for the investigation of hypothesis-driven investigations. It needs to be noted though, that the broad selection of variables is still a selection of variables, and some relevant confounding, moderating and mediating variables (think of parental characteristics, chronic diseases, the indoor environment, etc.) thus have been excluded.

Collecting objective data on physical environmental factors across multiple countries is a challenge. Not all countries involved in the SPOTLIGHT project had Geographic Information Systems (GIS) data (freely) available, and if they were available, they were often not comparable, because information on different factors had been collected in different ways across the different regions. This is why we explored alternative options for including objective information on the physical environment at the start of the project. On the basis of the systematic review, the use of remote imaging seemed a time-saving and inexpensive way to collected harmonised data across different European countries. The tool we developed had many advantages compared to previous tools, most importantly that it assessed both the food environment, the physical activity environment as well as the aesthetics and land use of neighbourhoods. With the use of state-of-the-art technology (Google Streetview-based virtual neighbourhood audits in combination with an online survey), the SPOTLIGHT filled an important research gap by gaining knowledge on obesogenic environments across European countries.

Further, because most of our data was hierarchically structured (participants in neighbourhoods in countries) we deployed multilevel analysis when appropriate.[23] Multilevel analysis allows for the non-dependence of associations. That is, when individuals are grouped in some way (for example because they live in the same neighbourhood), their characteristics tend to correlate stronger within such a group (e.g. within the neighbourhood) than between such groups (e.g. between different neighbourhoods).[24] Independence of associations –and thus absence of ‘clustering’– is one of the assumptions for regression analysis. When this assumption is violated, there is a high chance of false positive associations; i.e. detecting associations that are not ‘true’. [25] By deploying multilevel analyses and thus ‘adjusting’ for clustering within neighbourhoods, we increased the validity of our results. Moreover, in the SPOTLIGHT project, we took into account the clustered structure of the study design during the planning phase of the study. Similarities between subjects in the same cluster tends to reduce the power of the study. That is, analyses that take into account the hierarchical structure of the data often require a larger group of participants to detect statistically significant effects. As such, we conducted a power calculation for clustered data.

As previously mentioned, we also considered the implications of missing data. Complete case analysis (only including those respondents who provided information on all variables of interest) is likely to result in biased estimates.[17,18] In the SPOTLIGHT project, missing data were imputed if >5% of the data were missing. In accordance with suggestions for reporting on handling missing data, we specified the method of multiple imputation and provided results from sensitivity analyses on unimputed data in all manuscripts.[26]
Finally, the articles included in this thesis contributed to filling a major research gap by taking a multidisciplinary and integral approach in the study of obesogenic environments: studies were conducted across different urban regions (across Europe), both sides of the energy balance were taken into account, we combined geographic data with behavioural data, examined mediation, moderation and confounding and used different statistical approaches in answering the research questions. I.e., we adhered as much as possible to the recommendations summarised in the systematic review in chapter 2.1. Our approach was built on earlier evidence and existing theories of obesogenicity, and as such contributed to unravelling real-life complexities by studying mediating and moderating pathways.

3.4 Interpretation of findings and recommendations for future research
Comparing the results presented in this thesis with previous literature is challenging, given the variety of associations investigated across different contexts. A physical environmental factor that emerged as a key variable related to weight status was the presence of destinations in the residential neighbourhood. Although neighbourhood destinations had not been identified as a consistent correlate of weight status in literature reviews,[1,27,28] a recent international study showed that proximity to local destinations was consistently associated with BMI across 17 cities across 12 countries.[29] The finding that social environmental factors such as social cohesion and social network characteristics were associated with obesity-related behaviours and obesity is not new.[30,31] However, our studies used data from different areas and contexts, thus providing more robust evidence for such associations. Although the literature on economic environmental factors is somewhat scarcer, our findings are in concordance with previous findings that healthier diets are generally costlier,[32–34] and that price and affordability plays an important role for consuming healthy diets.[35–37] In the forecasting study, we emphasised the importance of greater context-specificity,[38–40] as several factors (earlier related to more general physical activity behaviours, such as population density) were not related to active commuting. Yet, this study showed the potential of regional policies that target parking prices and public transport frequency.

In this thesis we mainly focused on identifying and defining constructs that may represent the obesogenic environment. Whereas results from previous studies were mainly based on the findings from areas with limited geographical variation, the studies included in this thesis showed that many of the variables were important across the different regions and neighbourhood types. On the basis of the findings we may conclude that the obesogenic (residential neighbourhood) environment includes, at a minimum, a lack of destinations, lack of social cohesion and social networks, lack of public transport facilities, and lack of affordable, healthy foods. We also made a start with exploring via which pathways and for which groups these environmental factors influence behaviours and weight status, but these findings also highlighted the complexity of these associations. If possible, we aimed to focus on weight status, next to behaviours, because it needs to be ascertained that changing the environment will contribute to curbing the rise in prevalence of obesity, and not just improve one behaviour while possibly deteriorating another. For example, higher levels of social networks and social cohesion were associated with higher levels of fruit consumption and lower levels of obesity, but also with higher levels of sedentary behaviours and lower levels of transport-related physical activity. Of course fruit
consumption is only a proxy for a healthy diet and healthier diets do not necessarily contain fewer calories, but these findings highlight the need of a holistic approach that take into account interactions between different types of environments, different types of behaviours and different groups of people. For example, we may hypothesise that higher levels of social networks and social cohesion promote physical activity in neighbourhoods with many opportunities for physical activity, but may hinder physical activity in neighbourhoods with fewer opportunities for physical activity.

The use of a novel neighbourhood audit tool allowed for the data collection of comparable, affordable and precise data on potential obesogenic characteristics of neighbourhoods.[4] The content of the tool was based on existing neighbourhood audit tools, and findings from the literature review conducted for this thesis.[1] In a recently published SPOTLIGHT study, we observed that the physical environmental factors we studied tend to cluster in neighbourhoods. Four neighbourhood clusters that differed in food environment, recreational facilities and active mobility features were observed. These clusters were unequally distributed across urban regions: neighbourhoods from London and Paris regions appeared to be heterogeneous in terms of the prevalence of these clusters, whereas those from the Randstad (Netherlands), Ghent and Budapest regions seemed to share more similarities.[41] Neighbourhoods in the London region were mostly characterised by a high level of recreational facilities, whereas Paris neighbourhoods were characterised by high urban densities and a strong presence of food outlets. The Randstad, Ghent and Budapest neighbourhoods were characterised by lower residential densities and greener areas, together with a very low percentage of streets with food and recreational facility items compared to London and Paris neighbourhoods. The novel approach used in this study provided multidimensional constructs of obesogenic characteristics that may help target at-risk neighbourhoods more efficiently than isolated features.[41] It needs to be noted that the studies presented in this thesis only focused on urban environments, thus results may not be generalizable to rural environments.

Despite the fact that we identified a number of relevant concepts that form part of the obesogenic environment, and attempted to better understand the role of these variables in the different potential pathways towards obesity, there are still many uncertainties about how exactly the physical and social environments we live in influence our behaviours, body weights and health. This thesis contributed to filling important research gaps, but many challenges remain.

**A first main challenge** pertains to the measurement of ‘exposure’ to obesogenic environments. Exposure measurement is one of the greatest challenges in epidemiology. Professor Willett, the well-known nutritional epidemiologist from Harvard has said: ‘The first step facing an epidemiologist… is to specify the conceptual ‘true’ exposure. The answer will often be less than obvious since, in one sense, every measure is a surrogate for a more proximal cause of disease.’[42] Compared to, for example, microbiology, measurement of exposure in geographic or social epidemiology is highly complex. This is mainly due to the fact that specific exposures cannot be studied in isolation.[43] The measurement of exposure of the obesogenic environment is hampered by three broad factors. First, there may be no necessary nor sufficient causes for obesity; single environmental components often make only a small contribution to the aetiology of obesity. Second, the interval from onset of environmental exposure to appearance of obesity often goes unmeasured in epidemiological studies. Third, previous exposure to obesogenic environments is often not measureable.[43] Therefore, a great deal of attention is given to the operationalization of exposure. Also of importance is the measurement
of the exposure dose (possibly a cumulative exposure dose) and the aetiological exposure time window.

Given the fact that no necessary or sufficient environmental causes of obesity have been identified thus far, the importance of ‘exposure’ to environmental variables in a certain neighbourhood, area or place may differ between persons.[44] As such, research must focus on the relevant behavioural context when studying neighbourhoods or areas. Recent studies demonstrated that when residents drew their own neighbourhood boundaries, which are likely to represent the area they use in daily life, the resulting units differed from pre-defined areas such as administrative neighbourhood boundaries or circular buffers around the home.[45–47] Pre-defined neighbourhoods may therefore not represent the actual accessed or used environment.[48] As such, measuring the ‘actual’ exposure to the environment needs more attention, as incorrect estimations of neighbourhood boundaries could easily lead to an absence of associations, or a presence of associations that do not reflect true associations (that are relevant).[49] Within the SPOTLIGHT study, we asked individuals to draw the boundaries of what they regarded as their neighbourhood. We found that these self-defined neighbourhoods varied in size according to both individual factors (age, educational level, duration of residence and attachment to neighbourhood) and contextual factors.[45]

One way of defining ‘actual exposure’ is to study the ‘use’ of environmental factors. ‘Activity space’ is defined as the set of locations that an individual has direct contact or interaction with, as a result of the execution of their daily activities.[50,51] Activity spaces are based on core geographic principles, such as ‘distance decay’, referring to the decreased likelihood of a human-environment interaction as a function of distance (given the added time, cost and effort to travel longer).[52] One study included in the systematic review described in chapter 1.1 assessed the association between food retailers and overweight using both neighbourhood (administrative unit) exposure and activity space exposure. Higher average exposures to fast food outlets and full service restaurants were found with the activity space measurement than with the neighbourhood measurement.[53] Activity spaces are often measured with GPS-trackers; study participants wear a device that tracks their geographic locations during a fixed period (e.g. a week). Another option is to ask individuals about the facilities they recently used, including the exact addresses of these facilities, to retrospectively measure their activity space. Travel surveys, such as the New Zealand Household Travel Survey used in chapter 5.1, allow for the exploration of several types of environments, in this case both the home and the commuter environment.[13] This is important as a focus on the residential neighbourhood only is likely to underestimate the associations between environmental factors and outcomes of interest.[54]

It also needs to be noted that the studies in this thesis mainly focused on ‘meso-level’ environments (the neighbourhood). Some behaviours (such as sedentary behaviours) may be mainly triggered by micro-environments such as family influences, design of the home, and the indoor workplace environment.[55] Moreover, for some groups (such as elderly persons) the home environment may be the main ‘enabler’ or ‘barrier’ for physical activities. However, many policies (not traditionally thought of as health policies, but that could have important health implications) such as housing policy or urban planning policy affect the meso or macro level environment instead of the micro environment. Targeted interventions at the workplace or in the homes of specific subgroups could be part of an integrated approach to prevent and reduce obesity.
In the studies presented in this thesis we did not have information on activity spaces of our participants. Nevertheless, all measures of exposure to environmental factors were based on the distance decay principle; we assumed that there was a higher likelihood of human-environment interactions within the near proximity. Near proximity was ambiguously defined as either presence or density in the local (residential) neighbourhood or as distance to the nearest unit of interest (e.g. supermarkets). These approaches have known limitations, such as not placing any weight on facilities that are closer nearby than others (in the case of presence or density), or assuming that only the nearest facility (and not other facilities that may be only slightly farther away) is of importance. In chapter 2.5 we used a ‘potential accessibility index’ that takes into account the presence of facilities within a certain area, combined with placing more weight on the facilities that are most close by. The fact that this measure of ‘exposure’ to fast food outlets was not associated with fast food consumption, while crude presence of fast food outlets alone was, may be an indication that not just the activity space (likelihood of ‘use’), but also the ‘awareness space’ may play a role.

All places that an individual has some knowledge of (even without visiting them) constitutes their ‘awareness space’. Again, the principle of distance decay plays an important role; a person will have greater awareness of places that are geographically proximal than places that are farther away. The concept of awareness space stems from the field of human geography and is often used to predict criminal behaviour. It is hypothesised that all individuals have a mental map of their surroundings, and this map help them successfully carry out daily activities given their time limits and spatial mobility. This concept has not explicitly been applied to public health research thus far, but it is likely that individuals’ perceptions of their local environment reflect their awareness space. Indeed, when reporting on perceptions of the local neighbourhood, individuals rarely have the administrative neighbourhood boundaries at mind, and they can only recall features of their local environment that they are aware of.

There is little knowledge about the concordance of the ‘activity space’ and the ‘awareness space’. Unless, of course, ‘objective’ measures of the neighbourhood environment may be viewed as ‘activity space’ (with more or less precision of the relevant ‘space’) and perceptions of the neighbourhood environment as awareness space. Several studies have reported on a relatively large disagreement between perceived and objectively measured environmental features. This is problematic when individual perceptions are used as a measure of objective presence of features in an area, but can also be viewed as added value when measuring different dimensions of environmental exposure. Perceptions may differ more from objective measures due to older age, overweight status, lower education and income, lower level of physical activity and shorter duration of residency in the area; these factors may potentially be viewed as determinants of ‘awareness space’ as well.

If objective measures of the neighbourhood environment may be viewed as ‘activity space’ and perceptions of the neighbourhood environment as ‘awareness space’, there is significant learning from studies such as the SPOTLIGHT study where both objective and subjective measures of the environment have been incorporated. For example, when linking perceptions of the neighbourhood environment to cycling behaviours, we found that inhabitants of neighbourhoods that were perceived to have better street connectivity and to have lower traffic speed levels, but also neighbourhood perceived to be polluted and neighbourhoods perceived as being less pleasant to walk or cycle in, had higher levels of cycling for transport. In a study using objective measures of the cycling
environment, results showed that living in neighbourhoods with more streets where speed limits are ≤ 30 km/h, with more bicycle lanes, with traffic calming devices being absent, more trees present, more litter present and with more parked cars that form an obstacle on the road was associated with being more likely to engage in cycling for transport.[64] Roda et al. then used a novel approach to compare the concordance between objectively measured and perceived environmental factors: they quantified concordance by plotting the results from a multiple correspondence analysis and calculating the distance between perceived and objectively measured data. This resulted in an overall agreement that was moderate and showed that agreement varied by environmental feature. For example, a better match was observed in high residential density neighbourhoods than in low residential density neighbourhoods.[65] This indeed suggests that perceptions are more than just a reflection of objective environmental features. Yet, theoretical frameworks thus far have mainly classified neighbourhood perceptions as a mediating variable in the association between objective neighbourhood features and behaviours. However, neighbourhood perceptions may be viewed as independent ‘exposures’ or moderating variables as well, if the perceptions indeed represent a different concept of exposure. Possibly, ‘true’ exposure could be defined as a combination of both activity and awareness space, but to study this further may represent significant methodological challenges.
Figure 3.1.1. Different ways of defining ‘exposure’, from Thornton et al. 2011.[66] Pre-defined areas (administrative units, street network buffers and Euclidean buffers (‘as the crow flies’) differ highly. Moreover, this is an example where the individual actually does not use many destinations close to the home address.
comparable across different settings. Based on differences in other contextual variables (e.g. country-level wealth, crime) and the characteristics of the population under study (e.g. older adults), absolute levels of environmental factors may be positively related, have no effect or be inversely related to the outcome. For example, if ‘land use mix’ (the range of land uses, including residential, commercial and industrial, that are co-located) is measured using the same tool across different areas, a one-unit increase may not be associated with higher levels of physical activity in an area where the land use mix is relatively high, while in areas where land use mix is more limited, a one-unit increase on the same scale may be associated with a significant increase in physical activity. This corresponds with the idea of Lytle that as availability and accessibility of healthy opportunities increase, the influence of the physical environment may decline and the influence of personal choice and social influence may increase.[69] Concluding, without knowing the minimum and maximum values (expecting some kind of ceiling effect of the beneficial effect of, for example, land use mix) at which a measure has an influence on behaviours and health, it may be risky to assume the same shape for each area under study. Combined with a certain expected degree of measurement error, graded exposure measures in the form of tertiles, quartiles or quintile may provide a conservative estimation of dose-response effects of environmental factors.

**Figure 3.1.2.** The potential contribution of individual, environmental and social factors to eating behaviours, according to Lytle (2009).[69]

The International Physical Activity and Environment Network (IPEN) recently published a number of papers examining the built environmental correlates of physical activity and body mass index. In one of their studies, they show that, while some environmental perceptions were found to be consistently associated with walking and cycling, some associations differed between cities.[70] Another publication from the same study showed that associations of body mass index with perceived residential density differed by city.[28] However, despite the fact that built environment features differed highly between cities,[71] some associations between objectively measured built
environmental factors and physical activity were (after adjustment for other environmental factors) similar across the different cities.[72] That is, net residential density, intersection density (the number of intersection in an area) and public transport density were consistently associated with physical activity across 14 cities worldwide. This suggests that there are some built environmental factors of ‘universal’ importance, at least for physical activity. Such international studies with a continuum of environmental variation make a major contribution to this field of research.

A second challenge pertains to the definition of ‘obesogenic’ neighbourhood characteristics; defining the ‘healthfulness’ and ‘unhealthfulness’ of neighbourhoods. Many studies combine different types of food stores into ‘healthy’ or ‘unhealthy’ food outlets. For example, supermarkets are usually considered healthy, while often the majority of products sold are more likely to be in the unhealthy range.[73,74] Indeed, in chapter 2.3, higher presence of supermarkets was associated with higher levels of vegetable and fish consumption, but also with higher levels of fast food consumption. Although this may be due to confounding by other environmental exposures (e.g. the co-location of fast food outlets and supermarkets, which we attempted to adjust for), it may also indicate that the supermarket offers ample opportunities to buy unhealthy foods including fast-food-like ready meals. Naturally, the decision on which types of food outlets are healthy or unhealthy depends on the definition of healthy and unhealthy foods. Until there is increased consensus about which specific products are considered healthy and unhealthy (75) – which may be an illusion, because many foods can be consumed in moderation, but will be considered unhealthy if eaten more frequently and/or in larger quantities –, it may not be useful to start classifying food outlets in more detail (for example by performing an in-store assessment of the products sold [74]).

A third challenge concerns accounting for selection effects in environment-behaviour associations, also referred to as self-selection. This limits the interpretation of the extent to which environment-behaviour associations can be attributed to the environment, and the extent to which these associations should be attributed to sociodemographic or attitudinal factors. Residential self-selection refers to the tendency of people to choose places of residence based on their abilities, needs and preferences and often results from either sociodemographic or preferential features. Residential self-selection becomes a problem when selection factors are not appropriately controlled for. This happens when the observed explanatory variables are correlated with the unobserved variables; endogeneity bias.[76] A frequently overlooked point is that residential self-selection can be either direct or indirect. In the context of built environment effects on physical activity, bias due to a direct relationship will arise if already physically active individuals select neighbourhoods based on their activity-supporting amenities.[77] Indirect self-selection may lead to bias if low income families choose a neighbourhood based solely on the affordability of housing, if these neighbourhoods contain inadequate physical activity resources, and if the families are less physically active.[77] Lacking adjustment for residential self-selection could cause an underestimation[78] as well as an overestimation of associations between environmental factors and behavioural outcomes.[79] As most studies account for the sorting effect of sociodemographics, direct self-selection effects (attitudinal factors or preferences) remain the primary challenge of assessing environmental determinants of health behaviours.[80]
Thus far, only a few studies were able to adjust for (residential) self-selection. Zick et al. examined whether the association between neighbourhood walkability and BMI remained similar after adjustment for the decision to live in a walkable neighbourhood.[81] They used an instrumental variables approach; using a variable (instrument) that does not belong to the explanatory equation but is correlated with the explanatory variable of interest. This showed that not taking into account residential self-selection underestimated the associations. In an overview study, Cao et al. grouped all studies examining the role of self-selection into nine methodological categories: direct questioning, statistical control, instrumental variables, sample selection, propensity score, joint discrete choice models, structural equations models, mutually dependent discrete choice models and longitudinal designs.[82] For example, propensity scores create equal groups of ‘exposed’ and ‘unexposed’ by matching individuals on multiple individual differences, under the assumption that there is no correlation between unobservable characteristics and the outcome of interest.[81] In chapter 2.5 we used statistical control to adjust for a role of residential self-selection in the association between access to fast food outlets and obesity. We found that statistical control for reasons for choosing a neighbourhood and preferences to stay in the neighbourhood barely affected the effect estimates. This may be due to the fact that residential self-selection is less likely to play a role for dietary habits than for physical activity: e.g. people tend to choose a neighbourhood on the basis of being able to do the groceries by bike, and less so on the basis of whether fast food outlets are present. In turn, this may be due to the fact that many more opportunities for eating are available compared to explicit opportunities for physical activity. Concluding, it needs to be better understood what are reliable ways of dealing with residential self-selection and for which associations this is of importance.

A fourth challenge concerns the contribution of the built environment to social inequalities in health. Only very limited published research is available on whether environment-behaviour associations are similar across socioeconomic groups, and there is a lack of studies investigating whether changes in the built environment affect high and low socioeconomic groups equally. Kamphuis et al. showed that neighbourhood aesthetics contributed moderately to socioeconomic differences in walking among older adults, and that this was mainly explained by individual cognitions towards physical activity.[83] Similarly, feeling unsafe and having a small social network contributed to socioeconomic differences in sports participation in adults.[84] This is in concordance with Australian[85,86] and Swedish[87] studies showing that both physical and social environmental factors may contribute to socioeconomic inequalities in physical activity. Household and food shopping environmental factors were not found to contribute to socioeconomic inequalities in diet though.[88] The SPOTLIGHT study was not specifically designed to study the contribution of the physical and social environment to socioeconomic inequalities in health behaviours and weight status. Nevertheless, we examined whether socioeconomic differences in neighbourhood perceptions existed, whether these were consistent across the different regions, and what factors contributed to these differences. As expected, residents of socioeconomically deprived neighbourhoods had less favourable neighbourhood perceptions. Quantifying the contribution of the different factors under study showed that the objective physical environment contributed much less to these socioeconomic differences than the social environment.[14] Another project within the SPOTLIGHT study showed that residents in low SES neighbourhoods ate less fruit and vegetables, drank more sugar-sweetened beverages and had a higher BMI than residents in high SES neighbourhoods.[89] We also found that transport-related physical
activity, leisure time physical activity and vegetable consumption mediated the association between neighbourhood type and BMI.[90] Residents in low SES/low residential density neighbourhoods reported lower levels of transport-related physical activity, leisure time physical activity and vegetable consumption than residents in neighbourhoods of high SES and high residential density. These behaviours in turn were associated with having a higher BMI.[90] Thus, as expected from previous literature,[91,92] low SES/low residential density neighbourhoods may be viewed as the most obesogenic neighbourhoods. That is, low SES/low residential density are neighbourhoods in which the sum of surroundings, opportunities and conditions have the highest influence on promoting obesity.[90]

Future studies with better measures of socioeconomic indicators (more detail about educational attainment; absolute levels of income; occupational status) should quantify the contribution of social cohesion to socioeconomic inequalities in health behaviours and weight status. This is important for the design of intervention studies that are informed by the results from (cross-sectional) observational studies; if socioeconomic groups are differentially affected by changes in the environment, such interventions may only exacerbate socioeconomic inequalities. In general, environmental-level interventions are viewed as much better opportunities to reduce socioeconomic inequalities in health than individual-level interventions, as high and low educated individuals are equally affected. Therefore, chapter 5.1 explicitly investigated regional policy scenarios that would not differentially affect high and low socioeconomic groups. Examining interactions between socioeconomic status and built environmental factors showed that some built environment factors differentially affected the active commuting behaviours of high and low income participants. Therefore, the forecasting focused on variables that did not disadvantage the low income participants.[13] Future studies may want to focus on identifying policies aiming to change the obesogenic environment that are explicitly beneficial for disadvantaged populations.

As emphasised in the systematic review described in chapter 2.1, ‘it needs to be understood which health-related activities people conduct where, when, for how long, with whom and so on. […]’.[1] This requires an integral approach that incorporates time (duration and fluctuation of behaviours), space (geographical location of environmental features), place (the meaning of these locations for individuals), social context (peers pushing towards unhealthy behaviours or pulling towards healthy behaviours), economic influences (does income remain the single most influential factor?[93]), and knowledge about the interplay between different obesity-related behaviours.[94,95] These considerations should be incorporated in a theoretical framework regarding the environmental determinants of obesity-related behaviours and obesity.

3.5 Implications for theory
As described in the general introduction (Part 1), socio-ecological frameworks formed the basis of the current thesis. Most of the observed associations provided support for pathways described in the EnRG framework.[96] This suggests that such ecological models are ‘valid’ for studies such as the present (although this is of course also a bit of a self-fulfilling prophecy, as the hypotheses under investigation were based on the EnRG model). Nevertheless, the socio-ecological models leave room
for alternative pathways as well. For example, the EnRG model proposes that cognitive factors such as motivational and self-regulatory skills (which includes individual perceived barriers to behave healthily) mediate the association between environmental factors and energy balance-related behaviours. However, we showed that, especially if these cognitive factors are not directly related to the environment (e.g. lack of time), they could also moderate the environment-behaviour association. Moreover, in chapter 3.3 we did not find any evidence for a mediating role of social support and social norms in the association between social network characteristics and obesity-related behaviours. This may be a result of the study designs used which were not suitable for investigating the direction of mediating and moderating variables (which cannot be distinguished from exposure measures in cross-sectional studies) or could mean that there are other potential pathways (potentially including feedback loops) that explain the role of these mediating and moderating variables. As such, socio-ecological models may benefit from a number of extensions.

First, further evolution of socio-ecological frameworks may benefit from the incorporation of hierarchy models. As described before, this corresponds with the idea of Lytle that as availability and accessibility of healthy opportunities increase, the influence of the physical environment may decline and the influence of personal choice and social influence may increase.[69] A well-known example of a hierarchy model is Maslow’s hierarchy of human needs.[97] The pyramid of needs describes that humans first of all have physiological needs; the physical requirements for human survival. After physiological needs come safety needs; physical safety (safety from war, natural disasters, abuse), financial security (money for housing, food and clothing) and a safety net against accidents and illness. The third level of human needs is interpersonal and involves feelings of belongingness: intimacy, friendship, and support from relatives and colleagues. The fourth level encompasses self-esteem, which can be derived from the respect gained from others as well as an internal self-esteem (self-confidence, strength, competence and motivation). The last human need in the pyramid is self-actualization; the realization and desire to accomplish everything that one can.[97] Van Lenthe et al. demonstrated that being in a higher level of the hierarchy was associated with healthier food choices, although the hierarchy of needs could not explain socioeconomic differences in diet.[98] A different type of hierarchical structure of determinants of obesity-related behaviours and health is the hierarchy of walking needs, developed by Alfonzo. This hierarchy of walking needs is integrated within a socio-ecological framework of walking.[99] The first need proposed was feasibility, which refers to mobility (which is in turn affected by age, weight, physical condition), time and other responsibilities (child care). Feasibility is followed by four needs related to urban form, namely: accessibility, safety, comfort and pleasurability.[99] This suggests that aesthetics and natural environments (representing pleasurability) will only start to play a role when the needs of accessibility, safety and comfort are met. Giles-Corti et al. suggest to test whether micro-scale environmental attributes are of added value when the macro-environment is meeting certain needs.[39] Hierarchical models are potentially highly valuable for the guidance of policy and community interventions as they can be applied across different contexts. However, it would also require better understanding of the impact of and interaction between different contextual factors over the life course (perhaps, when individuals get older, they may take a step downward from comfort to safety, as safety requirements are no longer met).

It would be useful to incorporate the concept of time into conceptual frameworks too. First, time-use is an important element that determines how much environmental factors can explain at most (if an individual is home-bound thus spends no time in their neighbourhood, his or her behaviours are not
A systems-oriented, multilevel model displaying individual and environmental exposures (‘risk regulators’) in relation to body weight, adapted from Glass and McAtee.[101,102]

As suggested by Glass and McAtee,[101] socio-ecological models also include feedback loops that reflect, for example, selection effects (reasons for choosing certain neighbourhood, facilities or behaviours). Finally, ecological models should better specify the position of socioeconomic indicators. In current models, they are often viewed as moderating variables in the association between environmental factors and behaviours.[103] As suggested by van Lenthe et al., socioeconomic position can also be placed at the start of the causal diagram, affecting material conditions at the household level, which in turn affects accessibility and availability, psychosocial conditions, and cultural conditions at the neighbourhood and work level.[104]
The Foresight report published an extremely detailed framework that indicates a range of pathways through which a wide variety of environmental factors can affect weight status. It contains an exhaustive array of potential factors involved that may do more justice to the complexity of real life than the ‘simpler’ socio-ecological frameworks. However, it does not help simplify reality (as models are mostly intending to do) and the model does not help understand in what areas, under which circumstances and for which groups why some factors are more important than others.

Concluding, future socio-ecological models may include a hierarchy of environmental factors, a clear position of socioeconomic indicators, feedback loops that indicate the dynamics of individual intensions and attitudes and environmental perceptions, and if possible, an indication of time.

### 3.6 Implications for practice

Although we were unable to provide proof for causal relations, the evidence presented in this thesis may be one stepping stone towards translating evidence to practice. Even with longitudinal observational or natural experimental designs, it may be that watertight causal proof will never be available. The studies presented in this thesis at least highlight the importance of social factors, urban design, and price of parking and eating healthily in health promotion, and the need to account for individual differences in socioeconomic, perceptions and behaviours.

Given the extent of the obesity epidemic in terms of prevalence, costs and mental and physical health consequences, one may wonder how much longer we should wait for watertight evidence from science. Perhaps it is justified to implement environmental changes that are likely to have a positive impact on obesity-related behaviours. Either way, environmental changes that are not based on health considerations are implemented regularly without any evidence base (think about opening new fast food outlets or building a highway).

The research presented showed that urban sprawl, residential density and presence of destinations are factors that are likely to increase accessibility of facilities and walkability and cycleability of the neighbourhood.[1,6,70] Although it may be unlikely that European countries will reach the extent of urban sprawl that is observed in the United States or Australia, there are lessons to be learnt. In 1993, the Dutch Ministry of Housing, Spatial Planning and the Environment made plans to account for the forecasted population growth in the Netherlands. The most important element was building new neighbourhoods outside, but close to, the existing city centres. Informally, they are called ‘VINEX’ neighbourhoods, named after the briefing note ‘VIerde Nota Ruimtelijke Ordening Extra’. Gradually expanding existing neighbourhoods would strengthen the importance of existing shopping centres and facilities and protect natural areas by concentrating urban developments around existing cities. Despite the fact that most of these developments include safe and attractive walking and cycling routes,[105] distance to shopping and leisure facilities from VINEX neighbourhoods is usually greater than from the ‘traditional’ urban neighbourhoods.[106] The inhabitants are therefore less likely to use active transportation for their daily activities. Additionally, social cohesion in these neighbourhoods is often lower due to the high levels of mobility.[106] These consequences or urban sprawl are also experienced in other contexts[107] and some solutions may be offered on the basis of the findings from this thesis. One solution is to provide better public transport facilities (that require
walking/cycling to and from transit stops) so that the ‘new’ neighbourhoods are better connected to existing neighbourhoods. Not only the number of transit stops, but also frequency of public transport may be an important reason for choosing public transport over driving.[13,108,109] New infrastructure that connects two areas in a way that promotes active travel has shown to pull away from driving and push towards active travel.[110] Increasing job accessibility by improving the ratio between housing, offices and other land uses may also be a promising strategy.[13,111]

Increasing the number of food outlets and recreational facilities is also likely to increase accessibility of facilities and walkability of a neighbourhood. The few (natural) experiments that have been conducted with food outlets so far have not shown significant changes in diet or obesity.[112,113] Moreover, the addition of extra facilities to a neighbourhood may also have unintended effects, such as people moving away from the neighbourhood, for example because a newly built supermarket is a ‘high-end’ supermarket that is not affordable for low income households. In the UK, newspapers have been writing about the ‘Waitrose-effect’. Waitrose is a high-end supermarket, and having a Waitrose supermarket in the neighbourhood has been linked to increased housing prices.[114–116] The same may apply to expensive gyms. This may mean that there is a need for setting rule for where and what type of food outlets or recreational facilities can open. For example, in San Francisco, chain stores may apply to expensive gyms. This may mean that there is a need for setting rule for where and what type of food outlets or recreational facilities can open. For example, in San Francisco, chain stores must provide evidence that their store is appropriate for the neighbourhood.[114,117,118]

Overall, the recommendation would be to implement multi-level interventions and policies, which target both individual and environmental aspects that can help prevent obesity. Compernolle et al. demonstrated that multi-level obesity prevention interventions have the potential to reach a large amount of people, including those who would benefit most.[119] Ideally, not only physical environmental factors (availability and accessibility of facilities that promote ‘healthy’ behaviours), but also social (social networks that provide social support), economic (pricing strategies) and policy environmental factors (rules about new food outlets or pedestrian friendly zones) should be considered as part of multi-level interventions and policies.

### 3.7 Conclusions

The research presented in this thesis shows that the obesogenic (residential neighbourhood) environment includes, at a minimum, a lack of destinations, lack of social cohesion and social networks, lack of public transport facilities, and lack of affordable, healthy foods. Despite uncertainty with regard to the causal nature of these associations, these results further confirm that contextual (‘upstream’) factors should be taken into account in the promotion of healthy behaviours and prevention of obesity.

Evidently, more research is needed to better understand how environment-behaviour associations differ between regions and populations and via which pathways environmental factors influence behaviours. Nevertheless, the present thesis provided important entry-points for further addressing these ‘why’ and ‘how’ questions. Finally, the results from this thesis confirm the importance of adopting socio-ecological models that take into account the interaction between individual-level and environmental-level factors in explaining obesity-related behaviours and obesity.
References general discussion


29 Pickett KE, Kelly S, Brunner E, et al. Wider income gaps, wider waistbands? An ecological study


3.7


Chatman DG. Residential self-selection, the built environment, and nonwork travel: Evidence using


93 Rehm CD, Moudon AV, Hurvitz PM, *et al.* Residential property values are associated with obesity among women in King County, WA, USA. *Soc Sci Med* 2012;75:491–5.


Panter J, Griffin S, Dalton AM, *et al.* Patterns and predictors of changes in active commuting over


112 Cummins S, Flint E, Matthews SA. New neighborhood grocery store increased awareness of food access but did not alter dietary habits or obesity. *Health Aff* 2014;33:283–91. doi:10.1377/hlthaff.2013.0512


