Passengers’ fear of crime at train stations: the influence of the built environment

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In order to create better public transport environments and encourage more people to use public transport, it is important to have a comprehensive understanding of passengers’ experience of train stations and their urban surroundings. A crucial perspective is citizens’ fear of crime at train stations, which is higher than in other public places and can discourage the use of public transport. This thesis targets passengers’ fear of crime, their experiences of the built environment at S-train stations and the station neighbourhoods in the Copenhagen metropolitan area. The results reveal a strong connection between a station neighbourhood’s general characteristics and passengers’ fear of crime at the local station. This thesis suggest a categorization of station neighbourhood types in the Copenhagen metropolitan area and explore how their income levels and urban form influence passengers’ experience of train stations. The research uses the concepts of Transit Oriented Development and Crime Prevention Through Environmental Design and provide suggestions for the future design and governance of stations to achieve sustainable public transport. The study contributes to the international body of knowledge on passengers’ fear of crime at train stations.
PASSENGERS’ FEAR OF CRIME AT
TRAIN STATIONS: THE INFLUENCE OF
THE BUILT ENVIRONMENT

PhD thesis
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and

The Danish Transport, Construction and Housing Company
PhD Thesis
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In loving memory of my father J.C. Strandbygaard
Dansk resumé

"Passagerers oplevelse af utryghed på S-togsstationer: betydningen af det byggede miljø omkring stationerne"


Analysen er baseret på metoder og teorier fra Crime Prevention Through Environmental Design (CPTED), som indeholder viden om hvad der kan forebygge utryghed og kriminalitet gennem design og planlægning, transit-oriented development (TOD) som er kollektiv transport-orienteret byplanlægning, og endelig urban typomorfologi, som er typologisering og klassificering af urbane karakteristika.

Analyserne er baseret på metoder og teorier fra Crime Prevention Through Environmental Design (CPTED), som indeholder viden om hvad der kan forebygge utryghed og kriminalitet gennem design og planlægning, transit-oriented development (TOD) som er kollektiv transport-orienteret byplanlægning, og endelig urban typomorfologi, som er typologisering og klassificering af urbane karakteristika.

Forskningen er baseret på casestudier af de 84 S-togsstationer i hovedstadsområdet og deres stationsnære byområder, og gør brug af arkitektoniske analyser, GIS kortlægning og statistiske beregninger. Dette er kombineret med feltarbejde og indsamling af både kvalitative og kvantitative data, for at kunne skabe et nuanceret billede af casestudierne.

Forskningsresultaterne viser tre hovedtyper af stationsnære byområder i S-togsnetværket. En sammenligning mellem typerne og oplevelsen af utryghed dokumenterer en sammenhæng mellem lav indkomst i det stationsnære byområde og høj utryghed på stationen, men også at bytypen er mere signifikant for oplevelsen af utryghed end niveauet af indkomst, et markant forskningsresultat inden for urban forskning. En analyse af 13 S-togsstationer og deres byrum, baseret på internationale TOD design-guidelines for stationer og deres omgivelser, viser, at oplevelsen af tryghed og opdyrkning af byliv omkring stationen er underprioriteret på S-togsstationer.

Abstract

The objective of this thesis is to explore passengers’ experience of fear of crime at S-train stations and the possible relation to the stations’ surrounding environments. The thesis consists of three articles each exploring different layers of the research with the aim of unfolding train passengers’ fear of crime in relation to the built environment.

The analysis is based on case studies of 84 S-train stations and their neighbourhoods in the Copenhagen metropolitan area. The S-train is the local rail network in the regional development plan, the Finger Plan.

The method of analysis is typomorphological, defining urban types based on their patterns and spatial characteristics. Because the focus is passengers’ experience of fear of crime in public space the spatial analysis is guided by Crime Prevention Through Environmental Design principles.

The analysis outlines three main station neighbourhood types and several subcategories of combinations between the three. When compared with passenger surveys of fear of crime at the S-train train stations, the results exhibit a relationship between the types of station neighbourhood form and passengers’ fear of crime at the associated station. When comparing station neighbourhood form with income, the results show that fear of crime at stations is strongly correlated with low income in the station’s neighbourhood. However, a significant research result is that when adjusting for income, passengers’ experience of fear of crime still follows the same type of neighbourhood form. This result underlines the influence of urban spatial characteristics on passengers’ experience of fear of crime.

An analysis of thirteen representative S-train stations and their vicinities according to international design guidelines for transit-oriented development (TOD) is performed to look at the urban space surrounding the stations. The analysis reveals that the Finger Plan is a regional public transport-oriented development, however, several of the stations’ surrounding urban areas show a prevailing tendency to neglect the pedestrian design scale and design dimensions related to safety.

The thesis’ research results provide knowledge on passengers’ experience of stations. It contributes with perspectives on and insights into S-train stations and their neighbourhoods in Copenhagen and can assist the transport industry in improving passengers’ experience of train stations.

Contributions from the research is a CPTED design analysis tool for public transport environments and recommendations for Danish TOD practice.

The thesis contributes with novel research results to the existing international body of knowledge on passengers’ fear of crime at train stations.
Acknowledgements

I would like to thank Innovation Fund Denmark, DTU, and the Danish Transport, Construction and Housing Agency, for supporting this project. I also warmly thank Hvidovre Municipality and Høje Tåstrup Municipality for participating in the project with information and insight, as well as with funding. Also thank you to the Passenger Pulse and especially Lars Wiinblad for cooperating with me and providing the important qualitative data on passengers’ perception of public transport.

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A loving thought and many thanks are due to my dear husband Mogens for keeping up with me and supporting me during the project, and to my kids, Hannah and Asger, for reminding me that the most important things in life are very simple.

I would also like to thank my parents for supporting the research financially, my mother for reminding me that mental health is more important than anything else, and my father for taking a great interest in research.
Preface

Years ago, when I first moved to Copenhagen, I felt the atmosphere at S-train stations was something else, something that made me alert.

The station was a different environment than the rest of the city’s public space, it was like the city fell apart or changed its face around the station, like a patchwork poorly stitched together.

I kept an eye with other people at the station. I never used the train alone after dark if I was in a deserted urban area. Cameras have no effect on me, I know there are in a closed circuit, no one watches you on a screen and comes to your assistance.

There was no rational explanation for why I should be more exposed to danger at a train station than anywhere else in the city’s public space. There was just something about S-train stations, and this ‘something’ could possible discourage other people like me from using the train.

When, as an architect, I started working for DSB on passengers’ perceptions of safety at train stations, I immediately starting looking at the stations’ surrounding areas but this was quickly annulled because it was outside DSB’s premises. Later working at the Copenhagen Municipality’s Administration for Technology and Environment (Teknik og Miljøforvaltningen) the urban areas close to S-train station were not only associated with social problems but also with administrative headaches.

The S-train stations’ environments seemed very complex. What was actually influencing the passengers’ perceptions of these places?

To find out I applied to Innovations Fund Denmark for an Industrial Ph.D. in the public sector in cooperation with the Danish Transport, Construction and Housing Authority and the Technical University of Denmark’s Department of Civil Engineering.

This research explores elements in the built environment that influence passengers’ experience of fear of crime at S-train stations.

Sofie Kirt Strandbygaard, Lejre, December 2019
Definitions of terms

CPTED: Crime Prevention Through Environmental Design. Urban planning and design strategies that aim to deter offences and allow individuals to feel in control of their own environments. It therefore covers spatial structuring, the location of different functions and building and landscape design, as well as supporting territoriality, surveillance, access control, target hardening, maintenance and image.

DSB: Danish State Railways. A government-owned corporation (Independent Public Company) which operates passenger traffic on the Danish state railway network.

Banedanmark: Rail Denmark. A government agency under the Ministry of Transport and Housing responsible for maintenance and traffic control on the state-owned railways.

Fear of Crime: An overall term covering a mosaic of emotional reactions created by environments that make people feel vulnerable to becoming victims or by expectations of danger, such as fear, worry, anxiety and vulnerability. This affective state is often associated with certain physiological changes, like increased heart rate, decreased salivation etc. Fear of crime can result in protective measures and avoidance behaviour.

Isovist: Also called viewshed or visual field. The visual space available from a single viewpoint.

Neighbourhood: The S-train station’s neighbourhood is defined by the urban area within an 800-meter radius around the station. It is based on TOD guidelines, which defines this area for urban growth and development, corresponding to a ten-minute walking distance to the station in the centre of the circle.

Passenger Pulse: (Passagerpulsen). A consumer watchdog at the Danish Consumer Council whose goal is to improve public transport systems for passengers in Denmark.

PCA: A station’s passenger catchment area. American TOD literature has defined the PCA as a half-a-mile radius (roughly 800 meters) around each station. Researchers and practitioners advise adjusting the PCA according to local cultural predilections. Danish PCA is also called ‘the urban core area close to the station’ (Det stationsære kerneområde), a walkable distance of 600 meters that is supplemented by ‘the urban area close to the station’ (Det stationsnære område), a radius of 1200 meters for urban developments with access to stations.

Perceived safety: The perception of feeling safe, a reverse description of fear of crime. See ‘Fear of crime’.

Placemaking: The creation of socially sustainable urban public places using a multi-faceted approach that draws on the local community’s collective engagement and on the design of public spaces, sidewalks, street inventories, facades and landscaping that contribute to people’s happiness and well-being. It involves activating public spaces to support community feeling, but it can also be applied to major urban structures for citizens and tourists alike.
Public space: In this dissertation, the train station and its surrounding area is referred to as public space, because the premises are open urban space accessible to the public, although it is owned and governed by the companies DSB and Banedanmark. In a contemporary definition of public space, stations resemble areas such as malls which are open to the public but where democratic rights like public speaking and demonstrations cannot take place and ‘undesirables’ (the homeless, beggars, drunks) are excluded. However, as stations have fewer patrons, larger flows of people and thus a lower degree of territoriality, they present more opportunities for undesirables and also anti-social behaviour.

Public transport network: Buses, trains, the metro, light rail, airplanes, ferries etc. all operate on a schedule, being interconnected and available to anyone with a ticket. In America this is referred to as ‘public transit’ or ‘mass transit’.

Streetscape: The street, its sidewalks, facades and entrances, and the elements that together form its character.

TOD: Transit-oriented development. An urban development involving public transport nodes with moderate and high-density housing, which, along with public services, jobs, retail and other services, create communities that are both socially and environmentally sustainable by promoting walking, cycling and the use of public transport.

Transit: The American term for local public transportation, e.g. transit-oriented development, city transit, transit environments or mass transit. The equivalent British term is ‘public transport’.

Urban density: Urban density can be defined in terms of the number of people inhabiting a given area, the building density (Floor Area Ratio) or the level of activity in an urban space, measured in different ways. In this thesis the term is used to express a feeling of urbanism with reference to the density of building volumes and the activity of place.

Urban design: Urban design can operate at many scales, from the macro-level of urban structures and zoning regulations to the micro-level of street furniture and lighting.

Urban form: The physical characteristics of a built-up area, including its shape, size and a particular configuration of elements.

Viewshed: A visual distance of approximately 100 meters from a single viewpoint, also called ‘the visual field’ or ‘isovist’, which is the volume of space visible from a given point.

Walkability: A term that describes how friendly an area is to walk in. It is influenced by the standard of the pedestrian paths or pavements, and the qualities related to the experience of a place by foot, such as urban activities, building facades, visual quality, diversity, enclosure, street networks etc.
List of figures

Figure 1. The Passenger Pulse. Passengers’ reason for concern………………………………19
Figure 2. National Rail Passenger Survey. Passengers’ reason for concern……………….…..19
Figure 3. The seven Crime Prevention Through Environmental Design Principles..............21
Figure 4. Types of urban form in Barcelona.................................................................27
Figure 5. The Finger Plan from 1947...........................................................................35
Figure 6. The S-train network on the background of a socioeconomic map.........................36
Figure 7. The Copenhagen metropolitan area’s public transport rail network..................37
Figure 8. Avedøre S-train station..................................................................................38
Figure 9. Herlev S-train station....................................................................................39
Figure 10. Diagram for TOD .......................................................................................40
Figure 11. Diagram of the Finger Plan.........................................................................41
Figure 12. Ownership at S-train stations......................................................................43
Figure 13. Ownership at regional train stations.........................................................43
Figure 14. Ownership at station areas ......................................................................43
Figure 15. CPTED guide: Principle drawing of the area of analysis .......................49
Figure 16. CPTED guide: results compared in a radar chart ..................................49
Figure 17. CPTED guide: A section of the guides table..............................................49
Figure 18. Examples of neighbourhood A,B and C.................................................52
Figure 19. Examples of station neighbourhood styles Ac and Bca.................................52
Figure 20. A probability density plot of safety in the station neighbourhoods ..........53
Figure 21. Table of urban types’ safety score............................................................54
Figure 22. A probability plot of income per capita in neighbourhood A, B and C........55
Figure 23. The relationship between fear of crime, income and station neighbourhood types...55
Figure 24. A table with analysis of 13 S-train stations according to TOD design guidelines….57
Table of contents

1 Introduction ........................................................................................................... 1
  1.1 Aims, objectives and core arguments......................................................... 7
2 Theoretical foundation ....................................................................................... 11
  2.1 Historical points of departure of the theories and their interrelationships .... 11
  2.2 Crime theory related to fear of crime............................................................ 14
  2.3 Crime Prevention Through Environmental Design......................................... 20
  2.4 Typomorphology .......................................................................................... 26
  2.5 Transit-oriented development........................................................................ 28
3 Methods and data .............................................................................................. 31
  3.1 Data............................................................................................................... 32
  3.2 The case-study area...................................................................................... 35
4 Main text contributions of the study .............................................................. 45
  4.1 Article 1.......................................................................................................... 45
  4.2 Article 2.......................................................................................................... 46
  4.3 Article 3.......................................................................................................... 47
  4.4 Abstract for NJAR.......................................................................................... 48
  4.5 Proceedings of a Ph.D. symposium ................................................................. 49
  4.6 Report ’Public transport nodes as urban spaces:’......................................... 50
5 Conclusions ....................................................................................................... 51
  5.1 Research results............................................................................................ 51
  5.2 Reflections on the limits of the research...................................................... 61
  5.3 Suggestions for the indstry............................................................................ 63
6 References ......................................................................................................... 66
7 Appended articles ............................................................................................. 75
  7.1 Understanding passengers’ fear of crime at train stations through neighbourhhood types: a study of the Copenhagen metropolitan area............................................................................
  7.2 Fear follows form: a study of the relationship between neighbourhood type, income and fear of crime at train stations ............................................................
  7.3 Is it Transit-Oriented Development? A case study of S-train stations in the Copenhagen Finger Plan........................................................................................................
1 Introduction

The central aim of this thesis is to contribute with information and perspectives on the topic of passengers’ experience of fear of crime at train stations. This is a subject that has received little attention within academic research in the Danish context, but is nevertheless of great importance because it influences both the image and individuals’ use of public transport. This study targets the relationship between passengers’ experience of fear of crime at the station and the station’s surrounding neighbourhood. The aim is to explore the possible influence urban environments have on passengers’ experience of stations. The research is based on case-studies of S-train stations and uses a combination of quantitative and qualitative data and analysis to complete the investigation. The research provides suggestions for the public transport sector in regards of looking at stations from a wider urban perspective. It addresses public transport from the angle of those who use the network and experience the constructions, the architecture and the urban planning: the passengers.

This introductory chapter has two sections. The first section is an introduction to the research theme, the focus of research and the nature of the study. The second section presents the aims, objectives and core arguments via an overall view of the research and an introduction to the articles and research questions.

Fear of crime at train stations

A public transport journey is what passengers experience from door-to-door, and train stations are focal parts of such journeys because they are physical buildings of architecture and engineering, and places of convergence in urban neighbourhoods. In rail networks such as the metropolitan S-train, all kinds of people use stations, and chief executives can sit next to homeless people on the train. Some people commute to and from the same train station for years and see it as an integral part of their everyday life in the city, and others may only occasionally catch an S-train station on their way home from a party late at night.

A train station encompasses a duality, two strings of logic, one relating to transport, the other to the city. The first requires practical, logical and secure engineering structures. The second is a public space that citizens pass through on a daily basis. It must guide passengers, provide comfort and most importantly be perceived as safe. Research on passengers’ experience of public transport has shown that if the environment at and around the train stations is perceived as unsafe, passengers may choose another route, not travel after dark or avoid using public transport altogether if they have an alternative (D’Arbois De Jubainville and Vanier, 2017; Loukaitou-Sideris, 2005 p.104; Warr, 2000 p.481).

Passenger surveys and criminology research show that citizens’ feelings of safety in public transport is lower than in other public places and that their fear of crime far exceeds the actual risk of becoming a victim of crime (CrimeConcern, 2004; P. Cozens et al., 2003 p.188). In Denmark 25 percent of passengers have felt unsafe at S-train stations during the last six months (Passagerpulsen, 2019 p.5). In Copenhagen municipality 18 percent feel unsafe in urban areas close to S-train stations (Københavns Kommune, 2019 p.5).

When train stations and their surrounding environments in general are perceived as unsafe urban areas, this poses a significant societal problem, as the core task of public transport is to make it possible for citizens of all dispositions to move about freely, to go to work, attend school or practice football in another neighbourhood. Public transport supports social sustainability and socioeconomic opportunities. Those who feel most unsafe are especially women, children, the elderly, the disabled and those who are socioeconomically vulnerable (Abenoza et al., 2018; D’Arbois De Jubainville & Vanier, 2017; Yavuz & Welch, 2010; Pantazis,
It is virtually the same groups that tend to be “captive public transport users” or “captive riders”, those who have no alternative to public transport (Zhao et al., 2014).

It is important to cater for this group of passengers; they are key customers, our ‘benchmark’ for the experience of train station environments. The use of public transport is important for the social, economic and environmental sustainability of urban areas, and we need as many people as possible to use public transport. If the aforementioned group of passengers feel safe and comfortable at train stations then other passengers will have a positive experience as well.

Fear of crime

This thesis is concerned with passengers’ experience of safety at S-train stations. The notion of safety has both an objective and a subjective dimension. The first involves safety from exposure to injury or loss such as being victimised by an accident. The second is a subjective feeling of being safe from harm and the rational or irrational feeling that something crime-related might happen based on a variety of social or environmental cues (Ceccato, 2013 p.2). In criminological research, this question regarding personal safety translates into the term “fear of crime”, the reverse of feeling safe. The term is used to describe the key focus of this thesis.

Fear of crime covers a mosaic of feelings and emotional reactions not only related to the immediate fear of becoming a victim but also heightened alertness caused by urban settings that consciously or unconsciously make people feel vulnerable (Warr, 2000 p.454). Fear of crime is created by situations and settings that make people feel vulnerable to victimisation, however, vital for understanding of the emotion of fear of crime is that it is related to environmental or social cues and not necessarily to crime itself: “… it will also be important to remember that the sites, situations, or general socio-economic, demographic and media conditions that create fear may not necessarily relate to actual risks of victimization or patterns of crime” (Brantingham and Brantingham, 1995 p.6).

The factors that influence fear of crime at train stations are manifold and therefore much more complex to analyse than timetables and fares. Not only the built environment can influence this experience, but all the physical and social elements that a public space encompasses in its complexity.

Fear of crime in relation to the built environment

The thesis focuses on passengers’ experience of fear of crime at train stations in relation to the built environment, a topic that has attracted very little research attention in a Danish context. Traffic engineers have sophisticated programs for predicting the use of public transport networks based on models of possible transit, local jobs, car ownership, etc., but their models do not account for the actual experience of being a passenger: the physical environments that influence our experience of daily life and patterns of travel.

This research seeks to explore how the built environment influences passengers’ experience of safety and model the findings into numeric data for comparison and correlation of other types of data informing planners and engineers. The project is driven by a core interest in finding out why train stations and their surrounding urban spaces are often perceived as unsafe.

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1 S-train stations are regarded as public space. See Definition of terms p.IX
The case-study

The research is based on case studies of the 84 S-train stations in the Finger Plan, the Copenhagen’s post-war regional development plan from 1947. The S-train network is shaped like a hand with railway-fingers into the region and the palm of the hand in the centre of Copenhagen.

The stations were constructed between 1937 and 2016. The system has seven lines and app. 360,000 passengers a day. The Copenhagen region has 1,845 million inhabitants and during a normal day public transport covers 20% of travelled person km in the region, and 33% in rush hour. Buses have the biggest number of passengers per day, but S-trains have the highest transport share of travelled km per person, followed by buses, regional trains, and then the metro (Trafikstyrelsen, 2011 p.2).

S-train stations are designed as open premises that are part of the urban pedestrian flow, there are no ticket booths or turnstiles, and most stations are unmanned apart from the largest stations in the centre of Copenhagen. A typical S-train station has visual contact to the surrounding area from the open platform. At stations built after 1960, approx. 40, the tracks are on an embankment overlooking the area, and the station has a tunnel entrance with staircases and an elevator to the platform level.

The Copenhagen metropolitan area has a well-developed regional public transport network, but how is the quality of urban space around S-train stations, and how do passengers experience S-train stations?

The quantitative passenger survey behind the research

This research of fear of crime in a regional transport network could not have been possible without the unique dataset from the Danish National Passenger Survey. Passengers’ experience of safety at stations is investigated in these unpublished surveys conducted by DSB from 2009 to 2015 and later by the Passenger Pulse² from 2015 to 2018. The questionnaire used for the surveys is the same, but the survey was taken over by an independent organisation to ensure that the data would be made publicly available. DSB conducted 87,545 interviews in 2009-2015, and Passenger Pulse (Danish Consumer Council, 2019) conducted 37,904 interviews in 2016-2018. The question concerning safety reads: “How satisfied are you with safety at the station?” Passengers are asked to rate their feelings of safety on a scale from 0 to 10, 0 being unsafe and 10 being safe.

The survey suffers from several methodological problems as described in Section 3.1 Data, however, the large amount of data available makes it possible to draw conclusions on passengers’ experiences of the different stations in the S-train network.

The survey is based on the passengers’ most frequently used departure station. Approximately 80% of all S-train passengers either walk or cycle to the departure station and thus experience the surrounding urban area (Trafikstyrelsen, 2009), and furthermore, the stations are open integral parts of their urban surroundings.

On the basis of this, the passenger survey of fear of crime at stations is used as an indicator for the experience of the station’s urban surroundings. The research consists of two scales of urban analysis: first the 800 m radius around the station, also defined in Danish planning as Det stationsnære område (the area near the

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² A consumer watchdog at the Danish Consumer Council whose goal is to improve public transport systems for passengers in Denmark.
station) (Peter Hartoft-Nielsen, 1997), defined in the research project as station neighbourhoods; second, the 100 m viewshed around the stations, the public space of arrival area and roads leading to the station.

The quantitative passenger survey was based on a generalised question about safety. However there was no qualitative survey to explore what passengers were actually afraid of. Therefore a qualitative survey was initiated for this study.

The qualitative passenger survey

The qualitative survey initiated for this research was initially undertaken with a group of students from urban planning course no. 19955 in September 2018. They conducted qualitative interviews based on a detailed questionnaire at five selected S-train stations.

After discussion of the results of the students’ surveys with the Passenger Pulse, the Passenger Pulse performed a similar survey in October 2018, directing almost the same qualitative survey questions to their passenger panel. The Passenger Pulse collected 1,408 answers from the qualitative questionnaires (Passagerpulsen, 2019b).

The passenger survey revealed that 35% of the passengers had experienced fear of crime in the urban space around the station. The most common reason for passengers to feel unsafe is anti-social behaviour from other citizens, the tunnel entrances, the access roads to the platforms and poorly lit areas in general. The results show that 41% always feel safe using the S-train after dark. 38% sometimes experience fear of crime after dark and 8% always. Furthermore, several passengers describe the stations and their surrounding areas as deserted (Passagerpulsen, 2019 p.23).

In June 2019 a similar survey was conducted on a national scale, revealing that 25% of all passengers have experienced fear of crime at a train station within the past six months, 25% experience this because of lack of other passengers and 22% because of lack of personnel (Passagerpulsen, 2019 p.5). This is consistent with the data from the S-train stations.

The surveys document what elements the passengers react to with fear of crime at stations, and points towards areas in the stations’ urban surroundings that influence their experiences of using public transport.

The qualitative survey is the first of its kind in Denmark regarding the experience of fear of crime at train stations and their surroundings.

Research hypothesis

S-train stations are designed as an integral part of the urban surroundings, however, traditionally they are not governed nor regarded as part of the urban neighbourhood: The station, platforms, tracks and front courts

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3 Public transport passengers who have agreed to participate in surveys. The survey methodology is described in Section 3.1 Data

4 The methodology of the survey is described in Section 3.1 Data.
belong to the DSB (Danish State Railways) and Banedanmark (a Danish company responsible for maintenance and traffic control of the rail infrastructure) and the surrounding area of public space, parking and access roads belong to the local municipality.

In order to extend knowledge of the relationship between passengers’ experience of S-train stations and the stations’ surrounding urban environment, the following research hypothesis has been devised:

*There is a direct connection between passengers’ experience of fear of crime at the station and the character of the surrounding urban layout*

Several research questions emerged as the hypothesis was being tested and the research evolved. The questions are set out in the following section and answered in the thesis’s three core articles, each of which unravels different layers of the hypothesis.

**The nature of the study**

The academic background and framework for the study

This PhD research was started at the Danish Technical University’s Department of Transport with the Danish Transport, Housing and Building Authority as an industrial partner. After eight months of study the department was closed down. The study was continued at the Department of Civil Engineering, the section for Design and Processes conducting research in insulation materials, sustainable certification and design assessment tools of building processes.

The research was a quest to investigate a problem of great importance, namely passengers’ experience of fear of crime at stations. This tendency of fear of crime at stations was observed at previous employment at DSB and Copenhagen Municipality. The academic background is architecture and the study quickly became eclectic as this is how many architects go about their work. The research method for the thesis was developed for the purpose of investigating a problem, not to test a theory or develop a theoretical framework. Due to its interdisciplinary and problem-oriented nature, the project has an eclectic theoretical foundation. It borrows from different methods, concepts and theoretical schools in order to investigate a phenomenon related to fear of crime and urban design.

The research builds on case studies and uses various research methods in an interdisciplinary setup together with qualitative and quantitative data. The theories are named in the order they are used in the articles. The thesis uses three strands of interrelated theories:

1. Crime Prevention Through Environmental Design (CPTED) is the overarching concept because it targets people’s experience of fear of crime. CPTED uses a set of concepts that aims to reduce fear and prevent crime via the built environment, therefore CPTED theories exist in the background through all the analyses performed.

2. Typomorphology is the study of urban form derived from studies of typical objects, spaces and their relationships. It is used to group the case-studies and create an overview of the different station neighbourhoods’ spatial and architectural characteristics.

3. Transit-oriented development(TOD) consists of urban planning and design guides that aim to increase public transport ridership by densifying urban structures and creating high-quality public spaces of mixed-
use, walkable, sustainable neighbourhoods around stations. It is used to reduce sprawl, decrease use of cars, and support socially and environmentally sustainable communities.

The overall practical aim of the research is to encourage more people to use public transport, the target of TOD. However, the focus is passengers’ experience of fear of crime at stations, therefore CPTED plays an important role. Typomorphological analysis provides an overview of the large number of case studies and the characteristics of the different station neighbourhoods.

**Limits to the research**

It is important to underline that any attempt to explain fear of crime at train stations via the built environment only represents a small fragment of the complexity of a social phenomenon influenced by a range of subjective/perceptual and social structural factors (Box et al., 1988). Furthermore this analysis covers far from all aspects. Parameters that influence the experience of fear of crime at stations go beyond the built environment of architecture and landscape: people exhibiting anti-social behaviour, hearsay and the reputation of an area as well as levels of human activity play an important role. Perhaps even more important is the role of the environmental “backcloth” that influences the experience of place: time of day or night, season, whether local premises serve alcohol, gatherings of young people, etc. On top of everything else are the emotions and associations related to travelling and train stations, such as noise, hard acoustics, stress, problems with traffic information and crowdedness. Not all passengers react to the environmental cues the same way. Their experience of these factors depends on their susceptibility to fear of crime and disposition for being vulnerable, as described in Section 2.2.

**Overview of the thesis:**

The thesis is divided into seven chapters. This chapter introduces the theme of the thesis and outlines the structure of the research as presented in the articles.

The second chapter is the theoretical foundation and historical point of departure. It describes how the discourse that citizens’ behaviour and well-being was related to planning and architecture began, how the research interest in crime and fear took off, and the later development of placemaking and crime-preventive design. The notion of fear of crime originates from criminology and the following section describes the term, aspects of individuals’ reactions, and the crime opportunity theories related to CPTED and criminological research at train stations. The last three sections of chapter two describe the three conceptual methods used; Crime Prevention Through Environmental Design, Typomorphology and Transit Oriented Development.

The third chapter presents the methodology of the study and the quantitative and qualitative data used. The chapter describes the case study, the S-train stations, the Finger Plan and Stationsnærhedsprincippet, the Danish pendant to TOD’s Pedestrian Catchment Area. Lastly the chapter touches upon ownership and administration of the S-train stations and their surroundings.

The fourth chapter comprises the main text contributions from the study: a brief summary of the three main articles, the abstract describing the CPTED tool for urban planning and design, and the initial draft of the CPTED tool drawn up for a PhD symposium. The last text is an evaluation of station redesign projects partly funded by the Danish Traffic, Housing and Construction Agency, investigating how investments made support the passenger experience.
The concluding Chapter Five is divided into four sections: first, the research results from the articles; second, reflections on the limits of the research; third, suggestions for industry; and fourth, a brief comment on research process.

The sixth chapter is literature references followed by Chapter Seven, the three main research articles in their full length.

1.1 Aims, objectives and core arguments

This research explains a relationship of causes and effects in the urban environment by supplying a small fragment of a complex picture. The research contributes to knowledge about people’s experience of fear of crime in urban space. The study focuses on how the built environment in urban public space may influence passengers’ experiences of train stations. However, urban research is immensely complex as cities contain thousands of parameters that can influence such experiences. These parameters can be completely invisible from one approach and yet nonetheless determine outcomes. An example is the study of two train stations in Perth, Australia, where one station was designed to be safe using Crime Prevention Through Environmental Design (CPTED) and one was not. Interestingly, the passenger surveys showed the opposite of what was expected, that the “least safe” station was actually regarded as the safest. This led to an exploratory investigation suggesting that the effectiveness of station design was mediated by the local environment and its associated image. This image factor involves the influence of hearsay concerning an area, something that is difficult to account for and complicated to measure (P. Cozens & Van der Linde, 2015).

This study uses an interdisciplinary research approach to explore the relationship between urban form and fear of crime, and seeks to adapt qualitative assessments to numerical data in order to create an interface with quantitative data from the public transport network. The qualitative assessments are related to passengers’ fear of crime, a topic that is often overlooked and underestimated in Danish traffic planning as it concerns how places are experienced, an intangible topic that belongs to the social sciences.

The key research hypothesis of the investigation: There is a direct connection between passengers’ experience of fear of crime at stations and the character of surrounding urban layouts is explored through six research questions answered in three key research articles.

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5 To my knowledge there has been no research on this topic in a Danish public transport context
The first two articles are analytical and explore the correlation between fear of crime and urban space. The research contribution is a definition of urban neighbourhood types within a Danish context and shows how urban forms are correlated to fear of crime and income. The third article is both analytical and normative and looks more closely at the urban space within 100 m of the station in order to compare the urban design layout to international transit-oriented development guidelines.

The aim of the first article is to investigate if there is a relationship between passengers’ fear of crime at train stations and the stations’ urban surroundings. In order to do so, the stations’ urban areas need to be categorised to allow comparison with passenger data. This introduces the first research question: How can the surrounding neighbourhoods of S-train stations be categorised according to spatial characteristics associated with fear of crime in order to compare the passenger surveys with types of urban space?

This question is answered in the first article, “Understanding fear of crime at train stations through neighbourhood types: a typological study of the Copenhagen metropolitan area”. It is a large-scale analysis of 84 S-train stations and their surrounding urban structures. The article groups stations on the basis of their surrounding urban characteristics and shows their relation to passengers’ perceptions of safety at stations. The article establishes a relationship between passengers’ experiences and the stations’ urban surroundings.

The passengers’ experiences of fear of crime at the train stations are correlated with the stations’ urban surroundings.

The station neighbourhood types are correlated with residents’ income level and with passengers’ fear of crime at train stations.

The word *correlation* is used despite the fact that the categorising of urban space is based on a subjective evaluation and that there are few representative subcategories in the case study.
Article two correlates the station neighbourhood types with residents’ income levels, which are a strong indicator for socioeconomic status. The relationship between passengers’ fear of crime at train stations and the stations’ neighbourhood type may be caused by socioeconomic patterns, as socioeconomically vulnerable citizens are more susceptible to fear of crime. In order to check if fear of crime is related to socioeconomically vulnerable structures the article analyses to what extent the fear of crime and urban patterns is related to income. The questions: How is passengers’ fear of crime at the stations related to the station neighbourhoods’ income level? and How influential are the different urban types for the experience of fear of crime when adjusted for income levels? are answered in the second article, “Fear follows form: a study of the relationship between neighbourhood type, income and fear of crime at train stations”. It presents the argument that the experience of urban form overrules differences in income levels based on numeric values, underlining the fact that fear of crime not only affects stations in low-income areas but also follows urban form into higher income areas as well. The article explores how fear of crime is related to income in urban areas, as well as linking income to urban patterns by means of GIS mapping.

A detailed analysis of urban space within 100 m of S-train stations based on international transit-oriented development (TOD) design guidelines, focusing on the perception of space. The article outlines initial steps to accommodate TOD guidelines in Danish planning praxis.

The third article, “Is it Transit-oriented development? A case study of the Copenhagen S-train stations in the Finger Plan” is an analytical, prescriptive and normative text. It takes a closer look at the urban design solutions at thirteen S-train stations within approx. one hundred metres of the stations. The research question: How do the Danish S-train stations’ close vicinities correspond with international design guidelines for Transit-oriented development? is posed to analyse how the stations’ urban design solutions support the experience of safety and the use of public transport. The analysis follows TOD design guidelines and identifies discrepancies between the guidelines and the urban layout at S-train stations and Danish planning practice. The results are compared with passengers’ comments on site-specific places in the case studies; suggestions are made to revise the TOD guidelines to make them applicable to the Danish context; and local scale urban solutions are examined to determine whether they support the regional scale public transport network of the Finger Plan. The article explores whether international TOD guidelines are applicable to Danish practice and

7 Prescriptive in this context is understood as suggestions for design or courses of action, and normative offers a subjective opinion of the viewpoints or analysis that guides a design.
answers the research questions: *Are TOD guidelines relevant in a Danish planning context?* and *Do parameters in Danish urban design practice require an alteration of the TOD design recommendations to accommodate Danish planning?* The article is prescriptive and takes the initial steps towards developing Danish TOD guidelines.

The investigation establishes new insights regarding S-train stations, urban planning in the Copenhagen metropolitan area and how urban form influences passengers’ perceptions of train stations. It also outlines future research avenues and makes recommendations for policymakers and practitioners within the industry.
2 Theoretical foundation

The three conceptual methods used in the thesis are Crime Prevention Through Environmental Design (CPTED), typomorphology and Transit-oriented development (TOD). Because the thesis is eclectic in its nature, the individual theoretical components used for the analysis have not been explored to the same extent as would be expected in a project with one theoretical core focus. Rather, relevant theoretical insights have been elicited from each of the three approaches with the specific intention of analysing the practical problem of fear at train stations.

The first section of this chapter gives a brief introduction to three conceptual methods’ theoretical and historical points of departure. A focal point of the study is the experience of fear of crime. The term has its origins within criminology, therefore an introduction to crime theory in relation to fear of crime and the built environment follows this section. The chapter’s last three sections address the three different conceptual methods.

2.1 Historical points of departure of the theories and their interrelationships

This section introduces the theories’ historical points of departure, discusses their interrelationships and examines their focus on the design of the urban environment as significant for citizens’ wellbeing and for the proper use of the city.

Urban segregation and place

The historical context of the theoretical perspective that crime and fear are linked to the built and natural environment originates in the Chicago School of Sociology. Their research focused on how social processes in the city could influence the community balance and social organisation. An early publication by Park and Burgess divided the city into concentric zones with different social perspectives and linked delinquency rates to specific urban zones, the core principle being that place matters (Park and Burgess, 1925). Then followed the most influential contribution to the Chicago School, the ‘social disorganisation theory’ by Shaw and McKay (Shaw & McKay, 1942) that links crime and juvenile delinquency to certain urban areas characterised by social disorganisation. The core principle of the theory is that the local community has a substantial influence on whether a person engages in criminal activity or not. The theory explains the occurrences of crime on the basis of the local neighbourhood’s capacity to restrain its residents from violating norms (Doran and Burgess, 2012 p.33; Markowitz et al., 2001). The social disorganisation theory originally focused on the connection between social disorganisation and crime, but later encompassed fear of crime (Taylor and Covington, 1993; Markowitz et al., 2001).

The Chicago School represents a theoretical shift from focusing on the individual as the key problem to explaining the occurrence of crime from a societal and place-based environmental point of view. Research since has demonstrated how hot spots of crime are rooted in situational conditions in urban areas influenced by social aspects, urban layout and routine activities (Uittenbogaard, 2014; Weisburd, Groff and Yang, 2012; Brantingham and Brantingham, 1993). This relationship also applies to hot spots of fear of crime (Abenoza et al., 2018; Doran and Burgess, 2012), although the hot spots of fear of crime and crime do not necessarily occur under the same conditions, as elaborated in Section 2.3.
Place matters

The discourse that human behaviour and wellbeing are related to the urban environment was strengthened in 1961 when Jane Jacobs published ‘Death and Life of Great American Cities’ in which she attacked current modernist city planning and slum renewal for creating social problems and destroying street life – in her view the most important part of the city (Jacobs, 1961).

At this time urban planning was dominated by the interpretations of the Swiss-born French architect Le Corbusier (1887-1965) and CIAM’s (The International Congress of Modern Architecture 1928-59) visions of the ideal city characterised by residential high rise buildings, streets made for cars and monofunctional urban areas of industry, offices, residential areas or leisure and shopping (Grönlund, 2013). These new urban environments reduced street life as the result of segregated functions which created discontinuous urban activity. Street designs also provided little enclosure and few eyes on the street, and the escalating use of cars meant that people started to spend more time in traffic and less time on the streets (Calthorpe, 1993; Felson and Cohen, 1980; Gehl, 1971).

Jane Jacobs is mentioned here because her ideas and approach to city planning branched off into several influential planning concepts such as Crime Prevention Through Environmental Design or Placemaking, which are also integrated in Transit-oriented development strategies (see Section 2.5). Jacobs was a journalist and a grassroots activist who ended up having a significant influence on contemporary urban planning. She addressed citizens’ interactions with the built environment, considering how the design of cities could create sustainable urban communities with street life and community cohesion, and how poor design could result in the opposite (Jacobs, 1961). Her studies were based on observations of street life, and although her writings have been criticised for being anecdotal and for projecting a romanticised view of the industrial cities of the late 19th century (Zukin, 2011), her observations resulted in prescriptive guidelines that became a new set of urban design principles. She underlined the importance of street life, urged that buildings should be orientated towards the street to encourage natural surveillance by the residents, and called for public and private space to be clearly separated to indicate ownership, create guardianship and guide the use of streets. Her guidelines were used as a methodological lever in the development of the CPTED concepts (Gibson, 2016 s.31).

Urban design, fear and crime

Where Jacobs’ principles for urban planning represent the soft inclusive approach to crime prevention, Oscar Newman’s book “Defensible Space”, published eleven years later, used Jacobs’ principles in a more defensive design that aimed at deterring criminal intentions (Newman, 1972). Newman was an architect and not against modernist planning like Jacobs, but he agreed with her criticism of layouts, planning authorities’ patronising and authoritarian mindset, and buildings which were firstly designed as large scale shapes and only secondly as human residences (Scherg, 2013 p.17). ‘Defensible Space’ is the cornerstone in Crime Prevention Through Environmental Design as it is the first design guide for crime preventive design. Newman’s aim was to improve modernist social housing in the US and he thus took on a pragmatic approach by trying to improve what seemed an inevitable way to build large residential housing (Grönlund, 2012 p.286).

It is important to recognise that the modernist building structures were suited for the industrialisation of building processes; they were cheap, quickly built, could house the rapidly growing population and cater for urbanisation. They were therefore initially welcomed in most of the world, however in many places these urban environments were soon criticised and detested, as they resulted in areas with little street life, a lack of
community cohesion and crime problems (Grönlund, 2013). This tendency was linked to a string of unfortunate societal parameters at the time, such as the residents living in such buildings being of a different cultural background, with no attachment to the labour market or local social networks (Grönlund, 2013 p.8). These social problems were complex and highly influenced individuals’ perception of the built environment. Later generations of CPTED have addressed the social aspect (Saville, 2003).

Placemaking

Jacobs’ urban design guidelines aimed to create urban life and neighbourhood cohesion. In the decades that followed research based on observations of urban life became popular and has had a significant influence on the urban design guidelines of today. Jacobs is categorised as belonging to the urban planning approach called Placemaking, the core of which is that place matters. Placemaking uses a multifaceted approach that draws on the local community’s collective engagement and on the design of public spaces, sidewalks, street inventories, facades and landscaping that contribute to people’s happiness and well-being (Placemaking, 2019). A significant Danish architect within this framework is Jan Gehl, whose ideas about human scale design, bicycle paths, streets for pedestrians and not for cars have gained great influence in urban planning projects around the world (Gehl, 2020; Gehl, 2010; Gehl, 1971). A critique of Gehl’s work, however, refers to the image of ‘trouble free’ public space. Urban designers such as Gehl are paid to create pleasant visions of urban streets and places but, as Professor of Architecture Margaret Crawford from Berkeley argues, the actual role of public space is to contribute to the process of creating an equitable and democratic society and reality is not always suited to serving coffee outdoors: ‘These Placemakers paint a socially benign and aesthetically purified picture of public space that completely fails to acknowledge the exclusions and inequities that exist in actual public space’ (Crawford, 2019 00:07:15-00.07:26).

Practitioners and academics related to Placemaking consider understandings of streetscapes, navigation in cities, what people prefer to look at, where they prefer to walk or sit, how humans navigate in urban spaces, and what indications of private or public ownership they respect (Appleyard, 1981; Whyte, 1980). They contributed a recognition of the role of human behaviour in the built environment, something that has since been recognised as paramount for successful urban design.

Urban environments and public transport

Placemaking is an important part of Transit-oriented development(TOD) (Calthorpe, 1993). TOD originated in the US as a reaction to extensive sprawl, traffic congestion and pollution. The concept promotes dense, mixed-use urban structures around a public transport node, to establish an alternative to cars and to promote walking, biking and the use of public transport (R. Cervero et al., 2002 p.2). The founding father of TOD, Peter Calthorpe, was inspired by traditional concepts of neighbourhood units from New York and European post-war development plans of rail infrastructure (Carlton, 2009 p.9).

The key to successful TOD is to create a sense of place and a positive urban environment around a station (Ewing and Barholomew, 2013 p.10). TOD has a strong connection to the founding concept that place matters, and that the experience of streets and street life is fundamental for the use of a public transport node. It is a concept, or a set of design guidelines, that is tailor-made for public transport environments and also incorporates CPTED concepts to promote safety. But whereas the focus of the CPTED methodology is crime prevention and fear reduction, the focus of TOD is on the optimal development of public transport environments. TOD is thus a wider concept because it points to organisational problems as well as to urban design challenges. The two approaches complement each other but are also in tension with each other; indeed some CPTED practitioners question the overall TOD guidelines because they involve parameters (such as mixed-
use and permeable and interconnected streets) that boost opportunity crimes (P. M. Cozens, 2008). Both CPTED and TOD methodologies need adaptation for cultural predilections, and the aforementioned critique suggests a more defensive use of CPTED than manifested in the Danish planning approach. Here CPTED methodology is used to guide and promote certain behaviour, and permeable streets are regarded as an advantage for urban life and natural surveillance (Grönlund, 2012 p.288).

Urban form and travel patterns

Urban typomorphology is used in this project to identify types of station neighbourhoods based on the patterns of the built environment. Contemporary urban typomorphology dates back to the mid-20th century. It defines the physical and spatial structures of cities by describing the urban form based on classifications of buildings and urban spaces by type. Several schools within urban typomorphology share a critical view of modernist planning, because the modernist buildings and their related spaces dramatically changed the layout and use of cities (Moudon, 1994 p.306). Typomorphological analysis illustrates how the patterns of urban form changed dramatically during the 20th century, from being dense and pedestrian-oriented to open and discontinuous patterns in the car-oriented city (Levy, 1999 p.81).

The pattern of urban form, the streetscape and street network have a strong effect on travel patterns, encouraging citizens either to enjoy walking in a dense mixed-use neighbourhood, or to take the car in open structures of urban sprawl, even for short distances. Research into urban patterns and the use of public transport has been going on for years and has provided separate context-dependent research results on walking, cycling and the use of public transport and cars (Park et al., 2018 p.277; Stead and Marshall, 2001).

TOD and research on travel patterns and urban form uses a typomorphological approach: an urban typology with high network connectivity has many intersections, few dead-ends (cul-de-sacs) and a high directness of links. Extensive use of public transport requires an urban form that supports the use of the station via land-use diversity, density and street network design (K. Park et al., 2018 p.282; R. Cervero & Kockelman, 1997 p.199). This design parameter is important in sustainable urban development, where high connectivity will increase pedestrian activity. But equally or more important for pedestrian activity and the use of public transport nodes are perceptions of safety, a pedestrian-friendly environment, the design of facades and amenities, attractive landscaping, lighting and seating areas (Suzuki, Cervero and Luchi, 2013 p.XX.).

2.2 Crime theory related to fear of crime

A key component for this dissertation is ‘fear of crime’, therefore this section introduces the historical outset of the term, its definition in academic research, aspects of individuals’ reactions to fear of crime, and how the environmental components of train stations taps into fear of crime. Finally it briefly sums up criminological theories related to train stations in order to illustrate the connection to opportunity crime addressed in the CPTED, the framework used to guide the analysis of urban space.

The outset of research in crime and fear

The term fear of crime emerged in the 60s in the US when national public opinion polls began to ask questions about the public perception of crime. At this time racial and economic problems and societal changes had caused an increase in crime that continued up until the 1990 and the modernist social housing projects,
as criticized by Jane Jacobs, had higher levels of crime and juvenile delinquency rates (Newman, 1972). The findings from the national opinion polls were published in the report ‘The Challenges of Crime in a Free Society’ from the President’s Commission on Crime and the results were alarming. The conclusion forthright argued that fear of crime was destroying the quality of life of many Americans. What the committee saw as the most dangerous result of fear of crime was the citizens’ fear of strangers, which could damage social order, mutual trust in society and make streets and public places more dangerous (NIJ, 2019; Doran and Burgess, 2012 p.1; PCLEAJ, 1967). This started the extensive research in fear and crime in the US and began the focus on residential and urban planning concepts that could prevent and reduce these tendencies (Hale, 1995; Newman, 1972). Fear of crime became an important area of criminological research and is today one of the most researched topics in contemporary criminology (Doran and Burgess, 2012 p.3; Warr, 2000 p.452).

Fear of crime

It is important to define how the term ‘fear of crime’ is used in this thesis because it is a broad term within criminological literature and often slightly misunderstood outside the field of criminology.

The survey question used to measure passengers’ fear of crime at the train stations is defined by DSB in the national passenger surveys, firstly conducted by DSB and later The Passenger Pulse (see section 3.1). The question reads “How content are you with safety at the station?” (Hvor tilfreds er du med tryghed på stationen?). In criminological research, this question regarding personal safety translates into the term fear of crime, the reverse of feeling safe.

Fear of crime is understood as the anticipation of possible threats or as a reaction to environmental or social cues, like darkness, littering, vandalism or the rowdy behaviour of fellow passengers, and not an immediate danger like a verbal threat of harm or someone pulling a knife (Warr, 2000 p.454). Arguably the first feeling is related to environmental and social cues causing anxiety, the second to the immediate sense of danger. As research on fear of crime captures anxiety more than the actual fear of becoming a victim, the term is somewhat misleading, though now established in research. As sociologist Mark Warr writes: “As sentient and symbolic beings, however, humans have the ability to anticipate or contemplate events that lie in the future or are not immediately apparent. Hence people may experience fear merely in anticipation of possible threats or in reaction to environmental cues (e.g., darkness, graffiti) that imply danger. Psychologists commonly use the terms fear and anxiety to differentiate reactions to immediate threats (fear) from reactions to future or past events (anxiety). This terminological clarity has not been adopted in research on fear of crime, but it appears that most measures of fear are designed to capture anxiety rather than fear of victimization.” (Warr, 2000 p.454).

Fear of crime is an emotion often described in literature as a subjective rational or irrational feeling that something wrong could happen, which translates into a whole range of feelings such as worry, anxiety, fear etc. (Vanderveen, 2006 p.18; Garofalo, 1981 p.840). Often quoted sociologist Kenneth F. Ferraro defines fear of crime as “an emotional response of dread or anxiety to crime or symbols that a person associates with crime’ (Ferraro, 1995, p. 4)”. These definitions of fear of crime can rightly be criticised for being too broad as it makes it difficult to distinguish fear from sadness, anger or despair (Warr, 2000 p.453).

Fear of crime can cause citizens to constrain their lifestyles, freedom of movement and daily routines by adopting avoidance behaviour (D’Arbois De Jubainville and Vanier, 2017; Doran and Burgess, 2012; LaGrange, Ferraro and Supanicic, 1992). Avoidance is documented as one of the most frequent behavioural responses to fear of crime (Garofalo, 1981). This can mean avoiding public transport, underground car parks,
and certain neighbourhoods after dark or specific routes or areas if one is unaccompanied. This occurrence of avoidance behaviour due to fear of crime is the driver of this study as it can influence the passengers’ use of S-train stations if they perceive them as being unsafe.

The paradoxical nature of fear of crime is the often shown discrepancy between fear and actual risk, for example, being in a forest at night can cause fear of crime despite the very low risk of a perpetrator standing amongst the trees. Thus, there is frequently a fear of deserted areas where the risk of meeting an offender is low, but fear of crime is high (Goffman, 1972). The so-called “paradox of fear” includes occasions when fear of crime exceeds the real risk of crime, or when people are most fearful of the types of crime that occur least frequently (Warr, 2000 p.466). A forest at night is an example of environmental cues (like darkness, low prospect, no surveillance) that triggers our sense of safety so strongly that our logic steps in the background. Professor of human geography Rachel Pain also describe the paradox between fear and violence as the as a mismatch between the types of locations in which physical violence usually occurs and the locations in which women usually fear violence. An example is the occurrences of sexual assaults which are much more frequent in private space than in public (Blobaum, 2005 p.467; Pain, 1997). Another example of the paradox of crime are when women and the elderly are the most afraid despite their statistical lower risk of becoming victims. Mark Warr illustrates in a survey sample study from Seattle that the age and sex differences in fear are largely a function of differential sensitivity to risk meaning that the relation between fear and perceived risk varies amongst young and old, male and female (Warr, 1984). This relates to the demographic theories for individuals’ reaction to fear of crime in the following section.

The escalating crime and fear of crime that emerged in the 1960s was set of by economic and social changes, but most important in this research’s context is the urban post-war developments of segregated, modernist structures that amplified social problems and fear of crime (Newman, 1972; Jacobs, 1961). This resulted in intellectual criticism of urban environments and social problems, and gave birth to theories of crime, fear of crime and perceptions or experiences of urban environments as described in this section.

Aspects of individuals’ reaction to fear of crime

It is impossible to remove the individual’s social background from its experience of environment, and therefore surveys of fear of crime must be interpreted with caution. Passengers on public transport experience fear of crime based on their own personal features (sex, background, age etc.) and the social and the physical environment around them. The three main theories explaining these relationships are demographic theories, social theories and environmental theories.

Demographic theories examine whether individuals’ fear of crime is associated with having previously been victims of crime or feelings of vulnerability because of personal dispositions etc. Demographic theories examine if a particular demographic group is more vulnerable than another. A demographic group can be defined by, for example, age, gender or education (Farrall et al., 2007; Warr, 2000; Taylor and Hale, 1986; Skogan and Maxfield, 1981). In this study the nine years of passenger data on fear of crime is used as a general information about passengers’ experience of the stations and therefore no information on the genders different experiences. However, the survey made by The Passenger Pulse based on their board of volunteers reveals an expected differentiation in experience of fear of crime between male and female (see section 3.1)

Social theories argue that the social disorganization of an area leads to fear of crime. This theory was initially used to explain the occurrence of neighbourhood crimes (Shaw & McKay, 1942), but it now also encompasses fear of crime, proposing that a community’s social disorganization, such as the lack of common
values within the community, can lead to fear of crime (Doran and Burgess, 2012 p.31; Taylor and Covington, 1993; Sampson, R.J. Groves, 1989). Some of the station neighbourhoods on the S-train network have or have had severe social problems and a very bad reputation. One of these is Avedøre where the station is just next to ‘Big House’(Store Hus) a large residential building block inspired by Le Corbusier’s Unite d’habitation8, Big House has had a history since the 70s of drug sale and severe social problems amongst the families living there. The area’s history of social disorganisation as well as the image of the area has arguably influenced the perception of fear of crime at the station (this relates to the geographical juxtaposition see 2.3 CPTED).

Crime has a tendency to be more overt in socio-economically vulnerable neighbourhoods, where, for example, drug-dealing takes place in public spaces as opposed to wealthy neighbourhoods, where it takes place in private homes (Felson and Eckert, 2019; Saxe et al., 2001). Covington and Taylor found that social incivility, use of drugs, drunken behaviour, shouting, etc., on the one hand, and physical incivility, graffiti and broken windows on the other are both significantly associated with measures of fear, though the link between social incivility and fear of crime was by far the stronger of the two (Covington & Taylor, 1991). The implication is that ‘disruptive social behaviours elevate one’s personal assessment of crime risk more’ (LaGrange, Ferraro and Supanicic, 1992 p. 329). This is very well documented in both national and international surveys of passengers’ experience of safety in public transport, where the biggest influence of fear of crime is being troubled by others’ disorderly behaviour. Anti-social or unpleasant behaviour from fellow passengers has been measured by Danish Passenger Pulse (Passagerpulsen, 2019b) and the UK Transport Focus (TransportFocus, 2016) (Figure 1 and 2).

Environmental theories address elements in the built environment that can trigger fear of crime. The first to point out the importance of incivilities was Albert Hunter: "The “erosion” and “accretions” within the physical environment, the burned out buildings or the litter and the garbage in the streets, lead people to make inferences about the area, and more specifically the type of people who inhabit it, or use it.” “In summary, I am suggesting that fear in the urban environment is above all a fear of social disorder that my come to threaten the individual. I suggest that this fear results more from experiencing incivility than from direct experience with crime itself. “(Hunter, 1978 p.7 p.9). This has since been confirmed in research that signs of disorder or incivilities such as broken windows or lack of maintenance can create fear of crime by indicating a violation of social norms and possible warning signs of underlying crime (Doran and Burgess, 2012; Cozens, Saville and Hillier, 2005; Tulloch, 2000; Wilson and Kelling, 1982). The environment can also create fear of crime via poor urban layout such as blocked prospects and concealment (Fisher & Nasar, 1992), poor lightning, lack of windows and openings in façades, entrapment and deserted areas (Blobaum, 2005; Painter, 1996). Environments that generate fear of crime are consciously or unconsciously perceived as places for possible victimization (Doran and Burgess, 2012 p.54). The social environment is interwoven with the physical as lack of (legitimate) pedestrian activity in the street can create fear of crime. This is partly based on Jacobs’ premises that the ‘eyes in the street’ discourage criminals because they do not want to be seen or caught (Jacobs, 1961), but also that bystanders can be witnesses and seek help from authorities, or help resist the attack (Painter, 1996). In this study the attempt is to filter out the aspect of a socioeconomic parameter from the influence of urban form and the external environment. As mentioned in the introduction section it is an exercise that contributes with knowledge to a larger and more complex construction of fear of crime.

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8 Unité d’habitation is a large building, a ‘residential machine’ or vertical town consisting of apartments, a nursery, shopping and facilities needed for everyday life. The first was built in Marseille in 1952.
Criminology and train stations

This thesis focuses on the topic of fear of crime with regard to the built environment and environmental cues, not on crime itself. However, the so-called Opportunity Theories are mentioned here because they are part of CPTED methodology and because they provide an understanding of the nature of train stations as hot spots of urban activity and thus certain types of crime and public disorder.

Train stations are criminogenic places, as they are sites of convergence that attract offenders and generate crime (Brantingham & Brantingham, 1995). Related crime theories are the Opportunity Theories: 1. The Rational Choice Perspective targets the offender’s decision-making and the risk of getting caught. It takes the position that the offender is someone who thinks, if only for a moment, before acting (Clarke, 2008). 2. Routine Activity Theory (Cohen & Felson, 1979), also called the ‘crime triangle’, consists of a suitable target, a likely offender and the absence of a capable guardian. 3. According to Crime Pattern Theory (Brantingham & Brantingham, 1993), train stations can provide opportunities for offenders to go unnoticed or provide a background for the path of an offender to cross the path of a victim, as train stations are also often nodes in the offender’s routine activity paths. Opportunity crime demands Situational Crime Prevention to reduce the risk.

The relationship between fear of crime and crime is not always equal (cf. the paradox of fear). Places of convergence are most often not perceived as unsafe because of the social aspect, however, some crimes like theft and robbery tend to concentrate in urban activity like major public transport nodes (Brantingham and Brantingham, 1995 p.6). Train stations have temporal trends in crime, and crime is dependent on the station’s level of activity, its place in the network and its accessibility (Irvin-Erickson and La Vigne, 2015; Ceccato and Uittenbogaard, 2014). Certain types of crime relate to the socioeconomic status of the area, and a majority of crime is linked to weak guardianship and high or low urban activity (A. C. Uittenbogaard, 2014).

The analysis of S-train stations is comparable to criminological studies of light rail stations and bus stops where the on-street open construct resembles the S-train station structure. It is important to notice that in these situations the surrounding environment has a high influence on passengers’ fear of crime (D’Arbois De Jubainville and Vanier, 2017; Liggett, Loukaitou-Sideris and Iseki, 2001).

Fear of crime in public transport has shown to be of international research interest because the avoidance behaviour restricts citizens in their freedom of movement (Ceccato, 2013). Fear of crime in public transport is especially high compared to other publicly accessible places for reasons such as the presence of strangers, anti-social behaviour, temporal activity patterns, lack of indication of ownership and territoriality (see also Figure 1 and 2). This has been thoroughly documented in national and international surveys (Københavns Kommune, 2019; TransportFocus, 2016; CrimeConcern 2004, 2004; DB, 2015).

This combination of environmental cues and opportunity crimes makes passengers more exposed to fear of crime at train stations - and possibly more sensitive to the surrounding urban layout, elaborated in the Discussion.
Figure 1. The Passenger Pulse. Passengers’ reasons for concern over personal security. Modified from Passagerpulsen (Passagerpulsen 2019, p.14)

Figure 2. Passengers’ reasons for concern over personal security. Results of UK National Rail Passenger Survey (TransportFocus, 2016 p.12)
2.3 Crime Prevention Through Environmental Design

Crime Prevention Through Environmental Design, or CPTED (pronounced sep-ted), is not a theory but a set of prescriptive concepts and methods for design or analysis based on the premise that modifications to the built environment can reduce both crime and fear (Gibson, 2016 p.iii). It is a practice-oriented approach and is located within the broader school of environmental criminology. CPTED aims to prevent fear and crime through urban design solutions and by reducing crime opportunities and increasing the risks of the offenders getting caught. CPTED ensures “the proper design and effective use of the built environment [which] can lead to a reduction in the fear of crime and the incidence of crime, and to an improvement in the quality of life” (Crowe, 2000, p. 1). Its theories are rooted in architecture and urban planning, situational crime prevention, sociology, psychology and military design (Gibson, 2016; Ekblom, 2013).

CPTED was the initial method of analysis for this thesis, as it is a set of architectural concepts made into design guides that focus explicitly on the experience of fear of crime. It is used as the background for defining types of urban space and plays an important role in the concepts of TOD and design that takes into account passengers’ experiences of fear of crime in transit-oriented developments. CPTED is the underlying background of analysis and is the most elaborate.

Background

CPTED is a part of the change in criminology in the 20th century, as the focus shifted from only looking at the offender to also looking at the environment. This discourse is also present in the Opportunity Theories and in criminology studies by, for example, David Weisburd, which found specific developmental patterns of crime on street segments in the city over many years, showing that crime was consistent and “coupled” with places on the micro-geographical level (Weisburd et al., 2012).

CPTED originates from the US and its theoretical basis for using the built environment to direct social behaviour in relation to the prevention of crime and fear of crime can be traced to several sources. The most influential is Jane Jacobs who proposed a set of principles for urban design that drew attention to crime-preventing design features such as entrance orientation, public-private zoning and, most importantly, natural surveillance in the traditional city of streets and blocks (Jacobs, 1961). Jacob’s ideas became fundamental components of CPTED. In the mid-1960s crime and fear had become a national problem in the US (PCLEAJ, 1967) and criminological research was a focus of great interest.

In 1971 criminologist C. Ray Jeffery wrote the book Crime prevention Through Environmental Design (Jeffery, 1971). Jeffery used experimental psychology in his theories, based on his experiences with a rehabilitative project at a Washington school environment of juveniles. His research was experimental and was largely ignored during the 1970s (Gibson, 2016). The US National Institute of Law Enforcement Assistance Administration (LEAA) and the Department of Housing and Urban Development sought solutions and prescriptive design guides that could improve the unfortunate conditions and welcomed the publication of architect Oscar Newman’s Defensible Space (Newman, 1972) linking specific types of design solutions such as layouts of staircases, hallways and front yards to crime and fear of crime. Defensible Space initially focused on modernist public housing areas. The book was well received and the new methods were quickly tested for use. The LEAA and the Department of Housing and Urban sponsored research and development focusing on ways to make neighbourhoods safer under the slogan “Crime Prevention Through Environmental Design” (Gibson, 2016 p.34), as coined by Jeffery, although his book was much more theoretical than Newman’s and had a psychological approach (Gibson, 2016).
CPTED is a “work in progress” that has developed out of decades of research, theories and practices, and now consists of different principles and theories lumped together (Ekblom, 2013, p.4). Much of this literature is built on concepts that were only later tested in empirical studies. Examples include the human geographer Jay Appleton’s “prospect-refuge theory” (Appleton, 1975) which among other things states that humans prefer landscapes that offer both the prospect and the possibility of refuge (Appleton, 1975). The theory was later empirically tested in urban settings by Clamp and Powell (Clamp & Powell, 1982), Suedfeld et al. (Loewen et al., 1993), Blöbaum (Blöbaum & Hunecke, 2005), and several others. The studies confirm the prospect-refuge theory, as concluded by Blöbaum and Hunecke: “These findings confirm the relevance of lighting, prospect, and possibilities of escape for the design of living in urban public space for men as well as for women. Therefore, characteristics providing prospect, escape, and sufficient lighting should already be considered at the early stage of the design of so called hot spots of fear, such as parking garages, parking places, public parks, and public transportation stops.” (Blöbaum and Hunecke, 2005 p.482). Another example is the “broken windows theory” of Wilson and Kelling stating among other things that vandalism begins and escalates quickly if a place has signs of low maintenance such as broken windows, but also that vandalism attracts crime because possible offenders presume from the environmental cues that residents are indifferent to what goes on in their neighbourhood (Wilson & Kelling, 1982). Sampson and Raudenbush find, contrary to the broken windows theory, almost no correlation between crime and disorder except perhaps for robbery (Sampson & Raudenbush, 1999). The correlation between public disorder and the experience of fear of crime is however confirmed in several studies (Doran and Burgess, 2012), as described in the environmental theories discussed in Section 2.2. These sometimes divergent results related to the theories or concepts have led to discussion and criticism of CPTED. Furthermore, a second generation of CPTED has been proposed (Saville, 2003) which entails social theories and changes reflecting cultural predilections, and even a third generation has been suggested to update concepts and procedures (Cozens et al., 2017; Gibson, 2016; Ekblom, 2013). It is important to say that northern European societies’ take on social sustainability and architecture means that they already include social perspectives in their practices of CPTED (Grönlund, 2012).

Methodology

A pedagogical illustration of the interrelation concepts of CPTED’s fractured methodology was provided by Moffat (Moffat, 1983) and adapted by Cozens, Saville and Hillier in 2005 (P. M. Cozens et al., 2005). This
“CPTED wheel” (Figure 3) communicates the concepts of CPTED and has contributed to its use in conventional practice (Ekblom, 2013).

The CPTED wheel situates the six concepts against the background of the geographical juxtaposition. The six concepts are interrelated and partly overlapping. Their descriptions are mainly based on Cozens’ work (P. Cozens, 2016). The concepts are supplemented with how they relate to the built environments of S-train stations by the author unless other reference is made.

1. **Territoriality** has been mentioned as a CPTED “umbrella” principle. It covers humans’ desire to control and protect space they consider their own while also showing respect for the territory of others. Demarcations of public, public-private and private zones support indications of territoriality and can guide the public use of an area. Landscaping, demarcation, good maintenance, art and signs of personal presence can express ownership and signal attitude and behaviours (Wesley G. Skogan, 1986). This is related to guardianship and positive norms signalling safety and thus influencing fear of crime.

In public space at S-train stations this concept is difficult to establish in the same way as in residential areas because there is a constant flow of strangers and no private ownership. However, territoriality can be achieved by ensuring landscape, surfaces, light and fences clearly signal the borders of the area, furthermore proper design can create a feeling of ownership and responsibility amongst users (APTA, 2010 p.2; EuropeanStandardization, 2009 p.14).

2. **Surveillance, or natural surveillance**, is how people can act as crime preventers by noticing suspicious behaviour and acting on it, and it can be a reassuring element of social control for people who would otherwise experience fear of crime. This is based on the premise that those who are present are willing to act in case of crime. Lighting and the inter-visibility of buildings, placement of entrance doors, front porches and balconies also contribute to natural surveillance. Cameras are also regarded as surveillance but in general referred to as *electronic surveillance.*

At S-train stations the experience of natural surveillance is often established via visual contact to active streets or buildings with active/open facades within 100m of the platform. Especially stations designed as open constructions in suburban areas with low passenger activity rely on visual contact to the urban surroundings.

3. **Access control** is a way of designing buildings and urban spaces so that they encourage legitimate users to find their way around and experience the design as friendly, while also discouraging those with bad intentions. This involves thoughtfully located entrances and exits, fencing, landscaping and elements overlapping with 2. Surveillance. The number of entry points and escape routes are also part of access control and is related to the experience of legibility in urban space which supports the experience of safety.

S-train stations do not have turnstiles or gates and are part of the free urban flow. Here the experience of access control via landscaping and urban design is most important, especially in regards of land-use where drivers of legitimate urban activities should be placed strategically in relation to the station entrance.

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9 100m is the longest visual distance for social recognition (Grönlund, 2013 p.14)
4. **Target hardening** makes physical structures resistant to attack and penetration by criminals and also counters vandalism. It entails elements such as bolts, locks and fences. Extensive use of bolts, locks and barbed wire can create fear of crime because it signals possible criminal activity in an area and Danish planning guides therefore suggest it should be used with caution (Dkr and Trygfonden, 2014 p.9).

Target hardening is only relevant at S-train stations in regards of closing and fencing off areas that are prone to vandalism and need not be publicly accessible.

5. **Image management** covers the physical appearance of an area. If it looks like it is cared for and supervised then this signals orderliness and control. Poor maintenance affects the image of an area and is related to fear of crime (Doran and Burgess, 2012 p.; APTA 2010, p.2)

Cleaning, removal of graffiti and upkeep of areas at train stations is of great importance for the image of using public transport. 25 percent of the passengers who have experienced fear of crime at S-train stations mention low maintenance as a reason (Passagerpulsen, 2019 p.5).

6. **Activity support/facilitating positive use.** Physical design and planning can encourage legitimate activities in a particular place and discourage criminal intent. The rationale is that their presence will deny the offender the opportunity to commit crime.

S-train stations are not manned but some of them have a 7-11 kiosk facing the arrival road. The majority of suburban S-train stations have low activity support at the station, especially those planned after 1960 with car parking and roads around the station.

7. **Geographical juxtaposition** is the context and surrounding environment which might influence crime or fear of crime for better or worse depending on its status and the activities there.

In the case of S-train stations the station neighbourhood is the station’s geographical juxtaposition. This thesis argues that passengers’ experience of fear of crime at the station platform is related to the layout of the S-train station’s surrounding urban area and is thus context-dependent on the geographical juxtaposition.

In the article “Perceptions of Crime Prevention Through Environmental Design (CPTED) at Australian Railway Stations”, Paul Cozens and Tiffany van der Linde write about the geographical juxtaposition of railway stations: “Geographical juxtaposition refers to the influence that nearby land uses and activities may have on the safety and security of a particular site (Newman 1973). This particularly relates to land uses that have a tendency to generate crime, such as prisons, pubs, bottle shops (off-licenses), pharmacies, seedy hotels, vacant lots/buildings, and cash converters/pawn shops (Loukaitou-Sideris 1999; Loukaitou-Sideris et al. 2001) However, it has been asserted that reference to the wider environment and geographical juxtaposition is lacking in the CPTED literature and, consequently, is rarely considered in the design of urban spaces (Cozens 2014). Therefore, it is likely that in addition to the CPTED principles above, the wider environment plays a significant role in shaping perceptions of safety at railway stations (Cozens 2011, 2014)” (Cozens and Van der Linde, 2015 p.76). The results suggest a relationship between passengers’ perception of fear of crime at the station and the station’s surrounding neighbourhood. An analysis of crime-related land-use has not been undertaken for this thesis but the relationship between station neighbourhood types and passengers’ fear of crime at stations supports the findings by Cozens and Van der Linde.
CPTED is used worldwide, however the principles need adaptation for cultural context, a concept such as territoriality may not be universal, the understanding of indications of territoriality can diverge between signs of ownership via decorations and physical or symbolic barriers (Ekblom, 2013 p.4). Some practitioners read CPTED as literally defensible space and use the theories to create gated communities, while at the other end of the spectre countries like Denmark or Sweden use CPTED to provide underlying principles for the safe design of cities (Uittenbogaard, Ahlskog and Grönlund, 2018; DKR and Trygfonden, 2014). Historically, Scandinavian planners focus on the design of public spaces to guide people’s behaviour in order to follow rules or regulations, and to encourage civilised behaviour. Therefore the CPTED framework as described by Cozens, when interpreted by Scandinavian planning practitioners, is seen through the glasses of a social democratic society structure and a focus on social sustainability, accessible environments for all, user involvement and democracy (DKR and Trygfonden, 2014 p.5).

CPTED is not a part of Danish planning law; historically crime and fear of crime have received little attention in planning practice in Denmark. In the mid-1980s a CPTED committee created the Danish standard publication Technical Prevention of Violence and Vandalism (DS, 2003), but it was not until the last decade that the subject slowly has stimulated interest in planning (Grönlund, 2020; Hansen, Austin and NIRAS A/S, 2015; DKR and Trygfonden, 2014; DS, 2003).

Studies of public transport

Some European countries have drawn up their own safety design guidelines for public transport that use methods like CPTED, such as the quite elaborate Dutch design manual of everything from station entrance signs to levels of maintenance for flowerbeds and sidewalks (Huijsmans et al., 2013). The UK’s Network Rail has made Secure By Design (the UK’s version of CPTED) design manuals for stations and emphasises the importance of feedback from passengers and partnerships to integrate them in the process of upgrading the stations (NetworkRail, 2015). The so-called “Secure Stations Scheme” certifies train stations that follow safety design guidelines. This has been a success and 673 stations in the UK are now accredited (Gov.UK, 2018). The method focuses on policing, maintenance, lighting and surveillance and, most importantly, the organisation must commit itself at board level to maintaining a continuous focus on these perspectives. If they fail to report their annual passenger and crime review they lose their certification. This ensures that companies are not filled with “good intentions” but have no actual interest in acting upon the subject. Also continuous attention to the public transport environment is crucial at stations given the high levels of wear and tear, and small changes in social structures in the station’s geographical juxtaposition can have a big influence on crime incidents at the station or on how the station is experienced. Data from the Secure Station accreditation show that crime levels have dropped, however, the dataset is not publicly available but is under analysis10.

Researchers have turned CPTED concepts into an assessment tool for measuring the quality of station design. The article “Development and Application of a Scale to Measure Station Design Quality for Personal Safety” (Rahaman et al., 2016) proposes a scorecard to measure different CPTED parameters in station layouts, such as the number of cameras, gates or sightlines from the platform. These are indexed and prioritised using numerical values. What is highly problematic about this method is that CPTED assessment tools like

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10 Dr. Michelle Rogerson, Department of Behavioural and Social Science at the University of Huddersfield is performing data analysis of the results for future publication.
these are questionable when it comes to measuring fear of crime because humans’ perceptions of fear of
crime are related to the perception of a place, something that is difficult to capture by counting cameras and
sightlines. This is something that Placemaking takes into account by addressing issues of comfort and aes-
thetics.

*The use of Crime Prevention Through Environmental Design in this study*

The CPTED principles used for this research are aligned with the Danish standards for safety focusing on a
friendly environment, zones, visual contact and good robust design materials (DKR and Trygfonden, 2014;

The station neighbourhood types in the article “Understanding fear of crime at train stations through neigh-
bourhood types: a study of the Copenhagen metropolitan area” are defined according to concepts of CPTED.
Embedded in the types are spatial characteristics from concepts of territoruality and eyes on the street in ty-
pology A (Dense Urban Area) and the set back of facades and closed gables along the street in type C (Fra-
gmented Suburb). The pattern analysis showed afterwards that the types of urban space were largely from the
same year of construction.

The article "Fear follows form: a study of the relationship between neighbourhood type, income and fear of
crime at the station" concerns incomes in station neighbourhoods and their relation to fear of crime. The resi-
dential type and ownership in typology C, Fragmented Suburb, are related to public housing, rental property
and lower income levels. These areas date from the time of the industrialisation of the building industry in
the 1960s, and have the characteristics that CPTED concepts point to as problematic.

In the article, “Is it Transit-oriented development? A case-study of S-train stations Copenhagen Finger Plan”
the spatial analysis within 100 m of the station concerns parameters related to CPTED. Parameters such as
low visibility or signals of ownership, access control, guidance and zones are embedded in the TOD analy-
sis. The results of the TOD design guide analysis are consistent with the spatial characteristics of the station
neighbourhood types that are related to fear of crime.

A research contribution from this PhD thesis is the development of a CPTED assessment tool for fear of
crime at S-train stations, developed together with two engineering students, Amalie Nordstrøm Nielsen and
Emilie Alstrup Torp. The method uses CPTED guidelines according to Danish practice in the descriptive
evaluation of urban places, which is then translated into a numeric evaluation of urban space (see Section
4.4). This method is operational for professionals within planning or architecture with a minimum of guid-
ance. It is designed so that practitioners do not need extended knowledge about CPTED but can use the prin-
ciples to evaluate fear of crime in urban surroundings around S-train stations.

Fear of crime is also a research field within psychology and sociology and analysis within these fields of
study would have contributed significantly to the understanding of passengers’ experience of public
transport and urban space, and how some passengers react to certain environmental features and some do
not. However, this PhD seeks to contribute to the transport planning industry by measuring the built environ-
ment’s influence on passengers’ fear of crime at stations via correlations of numeric data. This is motivated
by an industry praxis that bases its plans and administration on numeric data evidence. A CPTED analysis
provides a framework for evaluating the built environment from a perceived safety point of view, by creating
the station neighbourhood types on the basis of CPTED parameters.
2.4 Typomorphology

Typomorphology is a tradition in urban morphology concerned with describing and identifying the character of urban settlements which makes it possible to group spatial characteristics and create an analytical overview. This methodology is used for defining the neighbourhood types in the first research article “Understanding fear of crime at train stations through neighbourhood types: a study of the Copenhagen metropolitan area”

Urban morphology is the study of the patterns and forms of things, and of the processes shaping their transformation over time (Kropf, 2014; Vernez-Moudon, 1994). In urban morphology there are four major traditions: the typological process (process typological), historical geographical (historico-geographical), spatial analytical, and configurational approaches (space syntax) (Oliveira & Partanen, 2015). The typological approach describes the typological processes of buildings and urban tissues and the transformation of urban development, streets, plots, buildings, building elements and types of spaces within the building plot (Moudon, 1994; Caniggia, 1963; Muratori, 1950). The intention of the work is often related to design or prescription (Scheer, 2016 p.3). The historical geographical school is rooted not in architecture but in historical geography and has traditionally no prescriptive motivation, focusing strictly on research and analysis. These processes are also connected with the wider realm of social and economic processes (Oliveira, 2019; Whitehand and Morton, 2004; Conzen, 1960). The spatial analytical approach is an umbrella for a number of analyses that together describe the city as organised complexity. The methods used are GIS, cellular automata, clusters, matrix and agent based models (Kropf, 2009; Batty, 2007). The configurational approach, or Space syntax, is also related to design or prescription and describes patterns of activity in urban space with a special focus on network integration. What distinguishes spatial analytical and configurational methods from other descriptions of urban form is their mathematical approach (Hillier, 2002; Hillier, 1996).

Typomorphology is a descriptive analysis\textsuperscript{11}, it is a combination of the historical geographical and typological approaches based on the concepts of urban tissue and levels of resolution (Kropf, 2018; Kropf, 2009; Samuels, 1999). This methodology involves grouping urban patterns into typologies and classifying them (Moudon, 1994 p.289). Both typological and historical geographical morphology have the street network, the plot and the building as their basic defining elements. Moreover, the historical process is of importance as the built urban type is defined by the time of its conception, use and later mutation, i.e. morphogenetic (Whitehand \textit{et al.}, 2005; Moudon, 1994).

The 84 S-train station case studies are all surrounded by different types of urban planning and public spaces and they vary in their station layouts, planning histories and socioeconomic structures. Typomorphological methodology makes it possible to compare urban form with other parameters such as numeric data on income or passengers’ fear of crime. The analysis is a multiscale approach which both overviews the urban patterns on a metropolitan scale and approaches urban space at street level. It is geometrically structured as the urban patterns are grouped into types and streetscape characteristics related to the experience of fear of crime are then embedded in these types. This type of analysis inevitably taps into a diachronic historical relationship of how the city has developed, as explained by Karl Kropf: “...areas developed in a given phase tend to be built up in a more or less consistent way, using similar forms. The constraints, conditions and design principles applying over the period limit possibilities and lead to similar attributes in building at the various levels. (...) Throughout any one area, the street/block and plot patterns are similar, containing similar buildings in form

\textsuperscript{11} When typomorphology is used as a prescriptive tool, the underlying analysis is descriptive to begin with.
and detail. There is also a tendency for similar kinds of change to occur over a given period. As in the case of new development, constraints, conditions and design principles current at the time tend to result in similar transformations of built areas. (Kropf, 1996 p.256). Therefore a historical geographical analysis of the station neighbourhoods on the regional scale is of relevance for the exploration and analysis of stations perceived as unsafe and their surroundings, as the historical background can explain the occurrence of certain design features of urban space. However, as explained in the methods section, a historical definition of the station neighbourhood types is not operational for traffic engineers for the correlation of data, therefore a categorisation of urban types via letters that describe the spatial characteristics provides the possibility of combining types and correlating data.

Typomorphological scholars\(^\text{12}\), especially the Italian and French Versailles School, aimed to re-establish the dialogue between the city and its architectural history and shared a critical view on modernist urban structures, settlements and their influence on urban space. The Versailles school had a prescriptive ambition to define a new architectural model distinct from modernistic proposals (Pinho and Oliveira, 2009 p.108; Moudon, 1994 p.301; Scheer, 2016). They condemned modern architecture and the profound change it caused in the urban fabric, as well as the environment’s influence on people’s behaviour. In France, the rebuilding of the war-damaged country after World War II elicited massive criticism from intellectuals, as the modernistic housing design changed the French urban landscape. The Versailles School of Architecture’s typomorphological group criticised the change in building types but was also eager to identify the ingredients of good urban design. This group was interdisciplinary and included sociologists and philosophers, unlike typomorphological practice in other countries. Their work was elaborate and precise and included a critique of modernist architecture and planning and its influence on urban life (Castex, Depaule and Panerai, 1977; Lefebevre, 1968). “Lefebevre was first to claim that appropriation, or the domination of material space including the city itself, was the ultimate goal of social life. He argued that contemporary construction and house production methods crushed people’s natural instincts for appropriation and weakened the relationship between people and their environments.” (Moudon, 1994 p.301). This critique of modernist housing resembles the CPTED concept of territoriality as an important prerequisite for creating safety, ownership and norms.

\[\text{Figure 4. Old Town. Enlargement. XX Century city. Fragmented City. City of Seventies. Suburb. Industrial. Commercial and Special Buildings (Colaninno, Cladera and Pfeffer, 2011 p.6)}\]

International morphological analysis has shown how traditional cities like Copenhagen changed from being dense and continuous in their fabric to being looser and more discontinuous as they expanded after the Sec-

\(^{12}\) Typomorphological is used as a common term in this section, inspired by Anne Moudon’s text Typomorphology (Moudon 1994), although some of the scholars mentioned define their work as typological or morphological.
ond World War, becoming modern and adjusting themselves to car infrastructure (Levy, 1999). This provoked planners from the French school of typomorphology to divide urban planning into two distinct ages: Age I, the traditional closed city; and Age II, that of the modern open city (Levy, 1999; Moudon, 1994). The station neighbourhood types defined in this thesis include these two ages as the typologies of Dense Urban Area and Coherent Suburb belong to Age I and the Fragmented Suburb to Age II, the modern open city. An example of a European study with similar neighbourhood type patterns as this study is the article ‘An automatic classification of urban texture: form and compactness of morphological homogeneous structures in Barcelona’ (Colaninno et al., 2011), which defines seven types of homogenous urban structures in Barcelona (Figure 4). The Barcelona example is an automatic classification of urban form, familiar to the research article “The spatial distribution and frequency of street, plot and building type across five European cities”. Here the types of streets, plots and buildings are based on quantitative measurements such as network centrality measures and methodological developments within space syntax, making it possible to compare different cities and neighbourhoods digitally (Pont et al. 2019). These quantitative approaches produce results from statistical analyses and correlations. The qualitative approach to typomorphology presented in this research is also an abstraction, but one based on the architect’s analysis of maps, combined with local historical knowledge and on-site visits.

Typomorphology is not taught at the schools of architecture in Denmark. An example of a typological Danish study is the Bydelsatlases (atlas of towns or urban neighbourhoods) published between 1991 and 1997 by Skov & Naturstyrelsen (the Danish Forest and Nature Agency). Bydelsatlases is a historical description of buildings, streetscapes – node paths and edges – and their architectural qualities, and is used for mapping the preservation of buildings and urban characteristics. To my knowledge neither the word typological nor the word morphology appear in any of the publications as the methodology is not traditionally used in Danish architecture. I have not been able to find a previous typomorphological study of the Copenhagen region, Copenhagen city or areas in relation to public transport13.

2.5 Transit-oriented development

This thesis investigates the influence of the urban surroundings on the experience of public transport. A planning strategy for urban public transport developments that addresses this issue is Transit-Oriented Development (TOD). TOD aims to increase public transport use and promote walking and cycling by concentrating urban developments around rail networks in dense, mixed-use, walkable neighbourhoods.

TOD originated in the 1990s, when traffic congestion had become alarming in the US. The book Stuck in Traffic (Downs, 1992) paints a discouraging picture of infrastructure and urban development where the majority of people spend hours in their cars each day commuting. Scholars and practitioners turned to land-use planning and urban design to reduce automobile use and its ramifications in terms of the environmental and social costs. The downsides of car use were many: CO₂ emissions, oil dependency, congested urban areas.

13 There is a Danish typological study from 2017 by Anne Tietjen and Thorbjørn Jessen about welfare landscapes for the International Seminar on Urban Form (ISUF) 2017 conference (Jessen & Tietjen, 2017). ISUF is an international organization of urban form.
and health problems associated with a sedentary lifestyle. Furthermore, later research confirmed that pedestrian-friendly design promotes social interaction and thus mental wellbeing and community cohesion (Zhu et al., 2014; Suzuki, Cervero and Luchi, 2013 p.34). As a reaction to suburban traffic congestion and to promote walking, cycling and public transport use, the concept of ‘pedestrian pockets’ was introduced in 1989 (Van der Ryn & Calthorpe, 1986), inspired by garden cities and traditional neighbourhood units (Perry, 1927; Howard, 1902), planning concepts that also inspired the Finger Plan’s S-train station neighbourhood units (see Section 3.2). TOD is strongly related to the New Urbanism movement that focuses on traditional neighbourhood structures and that Calthorpe was a founding member of (CNU, 2020).

Pedestrian pockets were conceived as mixed-use, dense urban developments within a five-minute walk of a train station (Doug Kelbaugh, 1989). Peter Calthorpe developed the concept of neighbourhood units into ‘Transit-oriented development’ (TOD), a term he coined in 1993 in the book *The Next American Metropolis* (Calthorpe, 1993). This book defined a series of conceptual TOD designs that were later tested empirically and further developed (Ewing and Bartholomew, 2013; Ditmarr and Ohland, 2004). The designs aim to create sustainable, compact communities with mixed-use neighbourhoods served by public transport and with urban environments that promote walking and cycling (Calthorpe, 1993). The community around the public transport node extends out roughly 800 m, or ½ a mile, a distance that can be covered in about ten minutes on foot. At the centre is the station or bus stop and its surrounding urban space that serves as a community gathering spot, with a high density of residential development to support the transit operations and the neighbourhood’s commercial uses (Calthorpe, 2014; Cervero, Ferrel and Murphy, 2002). This resembles the traditional structure of a railway neighbourhood from the beginning of the 20th century. In that sense TOD is a rebottling of old urbanism where urban design parameters borrowed from Placemaking and Walkability promote dense, diverse, mixed-use cities with access to public transport, low environmental impact and feelings of community (McCann, 2009; Porter, Dunphy and Salvesen, 2002 p.10).

As the concept bridges a whole community, the success of TOD relies on cooperation between policy-makers, traffic planners, investors, urban designers and the general public (Jacobson & Forsyth, 2008). The guidelines emphasise the important need for collaboration between local stakeholders, public-private partnerships and community engagement for a successful outcome (Cervero, Guerra and Al, 2017 p.17; Dunphy, Myerson and Pawlukiewicz, 2003 p.2; Cervero, Ferrel and Murphy, 2002 p.12). However, in the article “A Twenty-Five-Year Biography of the TOD Concept: From Design to Policy, Planning, and Implementation” (Jamme et al., 2019) TOD praxis is criticised for using the ‘D’ for Development in TOD to only focus on land-use development and not development of sustainable communities as originally intended. In other strands of the literature the “D” has been extended to encompass the planning key-words Density, Design and Diversity (R. Cervero & Kockelman, 1997) which are used as an operational framework to measure planning results in land use. This focus on land use is understandable: land use provides operational data that is easy to compare whereas community sustainability is more complicated to measure and demands skills beyond those that traditional planners have.

TOD is being developed as practitioners and academics test and criticise the guidelines, and the present theoretical discussions on TOD bring the design parameters under siege. An example is the 10-minute walking radius, where Qviström, Luka and De Block suggest thinking “outside the circle” and transform the 500-750 m circle into a relational geography approach, a social science notion examining how space and place are forged from relations, with the aim of tracing place qualities (Qviström et al., 2019). This is supported by research on how commercialisation and public space develop around transit stops, revealing amoebic forms around the station based on viewshed patterns (Stojanovski, 2019).
The TOD guidelines were developed into a popular planning concept both within and outside the US (Robert Cervero et al., 2017a), but although TOD design principles are internationally relevant for urban planning, scholars draw attention to the need to adapt them to cultural predilections and practices (Kong and Pojani, 2017; Pojani and Stead, 2015; Curtis, 2008) as well as to the necessity to overcome local institutional barriers in TOD’s multi-level governance approach (Staricco & Brovarone, 2018).

It is important to note that many European cities such as Copenhagen have post-war rail infrastructure developments which are famous regional TODs (Suzuki, Cervero and Luchi, 2013 p.4), however the problem arises at the suburban neighbourhood level where the challenges are modernist urban planning, a car-scale streetscape, low community engagement, and few or no stakeholders. Here the TOD guidelines offer design guides and strategic partnership tools to create more sustainable urban development.

TOD resembles the Danish planning principle ‘Stationsnærhedsprincippet’, the Danish principle of strategic planning close to the station (Hartoft-Nielsen, 2002). Stationsnærhedsprincippet addresses social, environmental and economic perspectives such as accessibility, reduction of road congestion, reduction of CO2, better business for the public transport companies, densification of urban structures, and protection of the green recreational areas in the wedges of the fingers (Hartoft-Nielsen, 2002 p.7). The key focus in stationsnærhedsprincippet is the distances from the station to workplaces and the statistical influence of this on the employees’ use of public transport, however, there is no focus on the experience of urban space. In this way, stationsnærhedsprincippet is comparable with Accessibility-Oriented Development (AOD) that focuses on balancing accessibility to labour force and employment. In AOD high accessibility levels are expected to increase the quality of life of residents living in these areas by reducing their commute time and encouraging faster economic development: “We define accessibility-oriented development as a strategy that balances accessibility to employment and the labor force in order to foster an environment conducive to development. AOD areas are therefore characterized by higher than average accessibility to jobs and/or the labor force.” (Deboosere and Levinson, 2017 p.3).

A significant difference between TOD and stationsnærhedsprincippet is that TOD is concerned with passengers’ experience of urban space and the neighbourhood layout around the station (Cervero, Guerra and Al, 2017) and therefore entails prescriptive design concepts for urban analysis. A significant part of the design concept concerns passengers’ perceptions of safety. This makes TOD the appropriate guide for analysing the design solutions within visual proximity of thirteen S-train stations, testing how the S-train layout meets international guidelines for public transport environments (see article 3).
3 Methods and data

This section describes the methods and main data used for the research, first the typomorphological analysis, then the quantitative and the qualitative data. One aim of the research was to quantify the qualitative analyses in order to make them comparable with data from, for example, traffic engineers. The individual architectural characteristics of the 84 S-train station neighbourhoods were grouped into types and quantified in order to compare them with other quantitative data and bring out relations and patterns. A detailed analysis of thirteen S-train stations from different lines in the metropolitan area revealed aspects of site-specific design and looked more closely at the selected case studies.

The mixed methods used were both qualitative and quantitative. The qualitative methods were oral, with semi-guided and guided interviews and surveys, and also textual, with architectural drawings and analysis, and observational, with visits on site both in the day and at night, photographs and architectural analysis (Yin, 1993). The purpose was to piece together a nuanced picture of the research subject and to shed light on different perspectives of the matter. Therefore the research adopts a mixed methods approach that makes it possible to explore potential connections between qualitative and quantitative information (Flyvbjerg, 2011).

The National Passenger Surveys on passenger fear of crime at the S-train stations are used as an indicator for passengers’ experience of the surrounding neighbourhood. This is plausible because the survey is based on the passenger’s most frequently used departure station and a substantial amount of passengers (80% of all S-train passengers) either walk or cycle to the departure station and thus experience the surrounding urban area (Trafikstyrelsen, 2009).

The typomorphological analysis comparable to numeric data

The subject of train passengers’ experience of fear of crime in relation to the built environment is explored through case studies of 84 S-train stations along the Copenhagen metropolitan commuter rail system. The fact that the various stations have different designs and a variety of urban layouts and socioeconomic structures means that a categorising of types of urban environments is required.

The typomorphological analysis in this thesis takes a multiscale approach which both overviews the urban patterns on a metropolitan scale and approaches the urban space at street level. The familiarities of station neighbourhoods are visualised through patterns of the built environment and not as the lines of plots and streets (like the historical geographical school of morphology) because volumes rather than demarcations define the modernist streetscapes. The analysis is geometrically structured as the urban patterns are grouped into types based on their geometrical structure. In these structures are embedded characteristics related to CPTED such as the streetscape’s level of enclosure, the level of activity on the ground floors and natural surveillance.

This type of analysis inevitably taps into a diachronic historical relationship of how the city has developed, therefore a historical geographical analysis of the station neighbourhoods on the regional scale is of relevance for the exploration and analysis of stations perceived as unsafe and their surroundings, as the historical background can explain the occurrence of certain design features of urban space.

However, the station neighbourhood typologies are not categorised by their age because of case studies like Tåstrup S-train station: the Finger Plan connects former villages with the regional infrastructural public
transport network and sometimes stations like Tåstrup include a small part of a pre-industrial village structure (defined as type A), surrounded by coherent residential neighbourhood patterns (type B) and parts of fractured post-war structures around the station (type C). These combinations make it difficult to base neighbourhood type on age, but by categorising the neighbourhoods according to their streetscape and relation to CPTED and giving the types a code, it is possible to combine the types of urban form into codes that provide information on station neighbourhood type. Thus Tåstrup becomes Bca, because the dominant structure is B but it also contains large parts of C and is built up around A.

Most important for this method is the use of station neighbourhoods in traffic planning and data. Historical geographic names or descriptions are not much use for data calculations in the transport industry, however numbers or letters that represent the information can be utilised.

The establishing of the neighbourhood types: A, central urban area; B, Coherent Suburb; and C, Fragmented Suburb, is explained in the first article “Understanding fear of crime at train stations through neighbourhood types: a study of the Copenhagen metropolitan area”.

It is difficult to reproduce exactly the same study in another national setting, because the station neighbourhood types are based on Danish building culture. However, the method of defining urban types based on a CPTED framework, grouping them into types of form and comparing them to passenger surveys, can be replicated in different cultural settings and at various scales of station network analysis.

3.1 Data

The data used for the mixed methods analysis of the case studies stem from various data sources.

Quantitative data

Income data

Income data from urban areas were retrieved from Statistics Denmark to conduct an analysis that could compensate for socioeconomic levels in passengers’ assessments of station neighbourhoods and thus make a clearer evaluation of the physical environmental components around the stations. A regression analysis was used to assess the relationship between neighbourhood type, passengers’ fear of crime and socioeconomic level. This analysis is important as it aims to separate the experience of urban form from the influence of socioeconomic patterns.

The data come from a radius of 800 metres around all S-train stations, aggregated into 100 x 100 m squares with a minimum of 50 family households totalling a hundred residents in each square to ensure anonymity. The data were GIS-mapped to provide a background map of urban building types illustrating how income follows form in the article “Fear follows form…”. The income data is aggregated within the 800 m to indicate an overall income level for the station neighbourhood as used for the regression analysis.

The National Passenger Survey

A key dataset comprises the quantitative results from the aggregated passenger surveys of fear of crime at stations conducted in 2009-2015 by DSB and in 2016-2018 by Passenger Pulse. A key dataset comprises the
quantitative results from the aggregated passenger surveys of fear of crime at stations conducted in 2009-
2015 by DSB and in 2016-2018 by Passenger Pulse\textsuperscript{14}. The National Passenger Survey (den Nationale Passa-
rigerosshedsundersøgelse NPT) is used to provide an overall picture of which stations passengers feel safe
at and where they feel exposed to fear of crime. The data collection is distributed throughout the year includ-
ing weekdays, weekends and holidays, from 6 am to 11 pm (Passagerpulsen, 2018). The survey is distributed
at Arriva Trains, DSB, Metro and the Nordjyske Jernbaner (railways in northern Jutland). Since 2017 local
trains in Zealand have joined the survey and the aim is to include light rail and buses. The number of ques-
tionnaires distributed on the different routes are continuously adjusted to reflect the distribution of passen-
gers.

The paper questionnaires are distributed and collected at stations and in trains, and the questions elicit pas-
sengers’ most frequently used departure station. They are distributed randomly but in such a way that all pas-
sengers boarding a train at a station are equally likely to be offered a questionnaire. However, there is no
mention in the method description of an equal distribution between e.g. men, women, or transgender, chil-
dren, adults, elderly people or disabled citizens. This is somewhat problematic because these dispositions
influence the individuals’ susceptibility to fear of crime.

Several companies have been responsible for the data collection but the methodology should have remained
the same. COWI was responsible for the data collection from April 1, 2017 to September 30, 2018. The data
is collected over a year with 1/12 of the survey performed every month, and the company in charge must en-
sure that the surveys represent all kinds of ticket types, and are collected over the entire day.

The questionnaire used for the surveys is the same throughout the years, but the survey was taken over by an
independent organisation to ensure that the data would be made publicly available. DSB conducted 87,545
interviews in 2009-2015, and Passenger Pulse (Danish Consumer Council, 2019) conducted 37,904 inter-

Data from NPT from 2009 to 2018 concerning S-train stations is used for this research. The survey was
handed out to approximately 2000 representative passengers on S-train platforms.

The questionnaire asks about general satisfaction with public transport and includes one question eliciting
passengers’ perceptions of safety at stations. Passengers are asked to rate their feelings of safety on a scale
from 0 to 10, 0 being unsafe and 10 being safe. Against the background of an analysis of survey answers, the
scale was divided into three levels of satisfaction that the companies use as guidelines for interpretation of
the data: 0-3, very unsatisfied, 4-6 neutral, and 7-10 positive or very positive (Passagerpulsen, 2018 p.5).

The data from the passenger survey are unfortunately not very precise. The question “How satisfied are you
with safety at the station?” is somewhat diffuse: for example, does it include falling down the stairs or per-
personal assaults? A survey question measuring fear must have a situation-specific stimulus component, which
implies specific kinds of risks and potential consequences (Doran & Burgess, 2012).

Despite the methodological problems concerning equal distribution of surveys and the imprecise survey
question concerning fear of crime at stations, the large amount of data available, from 125,449question-
naires over nine years, makes it possible to draw overall conclusions about passengers’ perceptions of indi-
vidual stations on the S-train network.

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\textsuperscript{14} Neither dataset is publicly available except on request.
Ridership

The data on ridership for each station come from DSB and date from 2015. Ridership is measured on weekdays to calculate an average number for all days and covers people getting both on and off the train (Danish Transport, 2017, p.75). The reason for this is that passenger densities are used in this research to indicate the level of human activity that is related to safety.

The DTU’s Danish National Travel Survey provided data on preferred means of travel and the numbers of passengers who either walk or cycle to their local stations (DTU, 2019).

Qualitative data

Passenger surveys

The qualitative data was drawn from the structured interview survey conducted by Passenger Pulse from October 2018, as they reveal the actual places where passengers feel unsafe and their thoughts about station environments. This is a detailed survey of 1,408 members of the passenger panel about their experiences of safety at stations and the surrounding areas. The questions were context related and also addressed the experience in relation to if the passenger was alone or it was dark. The questionnaires were sent out by e-mail and were anonymous. The study had a small overweight of women and of passengers between the ages of 50 and 79. Elderly people and women are in general regarded as more fearful so this may influence the results.

These data inform the third article on TOD and the experience of specific design features at stations and their surroundings.

It is important to note that all the people asked about how they experience train stations are passengers. People who do not use S-trains and are part of the passenger panel are not asked how they view public transport. It is the author’s opinion, after having conducted several interviews with citizens within the station neighbourhoods, that a complete picture of public transport only can be established if we ask for the opinions of citizens who are not already customers in public transport.

The data results from the Passenger Pulse S-train network survey, from October 2018, are illustrated in the exam report by Amalie Nordstrøm Nielsen and Emilie Alstrup, “Udvikling af CPTED-værktøj til byrumsanalyser ved Danske stationer” (DTU 2019, p.41-46).

Half a year later the Passenger Pulse conducted a similar survey in June 2019 on national scale (Passagerpulsen, 2019 p.25). The research methodology was the same, and the responds to the questions showed the same tendencies as the survey from the S-trains.

Additional qualitative data

Several interviews were held in the course of the research but only two made it to the thesis: the interviews with two planners from DSB and Hvidovre municipality as described in Section 3.2 Ownership and administration. A great deal of fieldwork data was collected continuously throughout the PhD during visits to S-train stations. The data collected consist of a substantial number of day-time photos and registrations of architecture and people flows. The night-time photos were taken at selected stations using a predefined checklist from the TOD analysis.

The articles included in this paper describe in detail the methods deployed.
3.2 The case-study area

The case-study area consists of Copenhagen and its local commuter rail system, the S-train system, its 84 stations and their respective PCAs. The study covers ownership and governance of stations and their immediate surroundings, which are of significance to TOD.

Copenhagen’s regional development plan is called the Finger Plan, as it resembles a hand with the S-train lines represented by the fingers (Figure 5). Urban development runs beside the fingers, along which the S-train provides public transport for residents. This post-war development plan dates from 1947 (Egnsplankontoret, 1947), and although it was never formally endorsed as a planning document, it has guided Copenhagen’s urban form for 74 years. Today the Copenhagen metropolitan area has 1.32 million residents within the 18 municipalities that are part of the S-train system. Copenhagen municipality has 620,000 residents (Municipality Copenhagen, 2018).

Before World War II Copenhagen had expanded to the north, so post-war urban expansion was aimed towards the flat farmland to the south and west of the city (Andersen & Hansen, 2000). The new S-train lines provided infrastructure for the urban expansion. These areas to the south, west and north-west became post-war areas of urban expansion inspired by modernism and including social housing (Nielsen, 2008). Today, socioeconomic maps of the Copenhagen metropolitan area still show high incomes in the centre and north of the region, and lower incomes to the south and west (Figure 6).
Figure 6. The expansion of the S-train network against the background of a socioeconomic map from Cevea 2014.Cevea.dk.

- The West line, (B,Bx), from 1963
- The Køge Bay line, (A, E) from 1972-1983
- The Hareskov Line (A) from 1977
- The Frederikssund Line, the expansion from Ballerup (1949) to Frederikssund in 1989
The S-train system

The infrastructural system of the Copenhagen metropolitan area consists of the S-train system (1937), buses, metro-lines (2002) and some of the best cycle paths in the world (Pucher and Buehler 2008, Gehl 2010). This is also reflected in the vehicle statistics for the region, whereby bikes account for 7% of all transport, calculated in kilometres per person per day. The next addition to the network will be a light railway across the “knuckles” of the Finger Plan, due to be completed in 2025 (Letbane, 2019).

The S-train system has 170 km of tracks, 7 lines with 84 stations and 360,000 passengers a day. On a normal weekday, public transport covers 20% of travelled person km in the region, and 33% in rush hour. Buses have the biggest number of passengers per day, but S-trains have the highest transport share of travelled km per person, followed by buses, regional trains, and then the metro (DTU, 2019; Trafikstyrelsen, 2011 p.2).

Approx. 80% of all S-train passengers either walk or bike to the station and thus experience the urban space in the passenger catchment area (PCA) (Trafikstyrelsen, 2009).

Figure 7. Copenhagen metropolitan area’s public transport network. Modified from UrbanRail.Net 20197
Station layout

Most of the S-train stations on the fingers run along embankments, and inside the city centre tracks are sunk in trenches. The majority of stations on the fingers have entrances at ground level through a tunnel in the embankment, with staircases leading up towards the platform. The majority of the stations are unmanned, though some have a kiosk at the station entrance, and a small handful a kiosk on the platform. S-train stations have different designs, but none of them have ticket booths or turnstiles. Most have an integral kiosk originally for selling tickets, but these were phased out during the 1990s and the premises left empty. Stations are open public spaces, which makes the surrounding urban areas important for experiences of train stations. Many post-war stations have parking areas around them. The urban design associated with S-train stations is described in the third appended article, “Is the Finger Plan an example of Transit-oriented development? A case study of the Copenhagen Finger Plan”. The urban neighbourhoods themselves are described in the first appended article, “Understanding fear of crime at train stations through neighbourhood types: a study of the Copenhagen metropolitan area”.

Figure 8. Avedøre S-train station. 2017
The Finger Plan

A 1947 Transit-oriented development

The diagrammatic principles of TOD drawn up later by Peter Calthorpe in 1993 (Calthorpe 1993) (Figure 10) resembles the diagrammatic drawing of the Finger Plan’s public transport-oriented developments from 1947 (Figure 11). In the centre is the train station surrounded by public functions such as a school, kindergarten, church, police station, cinema and shops. Everything is dimensioned according to the number of residents using the area. Public parks and sports grounds are in the green recreational areas. All functions must be within 800 m of the station, and it is important that everybody can either walk or cycle to the nearest station. The centre of the circle has a dense urban structure (approximately 5,250 residents), the periphery is characterised by lower building density with single-family housing (Egnsplankontoret 1947). The diagram was most likely inspired by Ebenezer Howard’s Garden City (Ward 1992). The original plan of public transport-oriented developments was never implemented, but the conceptual thinking associated with it was initially behind some of the new station areas on the hand’s thumb and index finger.

The background to the Finger Plan

The Finger Plan was not formally endorsed as a planning document until 2007, but it was used to provide inspiration and guidelines for the development and expansion of Copenhagen (Miljøministeriet, 2007; Byplanlaboratorium 2006). It ended Copenhagen’s concentric peripheral expansion and replaced it with a radial, star-shaped expansion (the hand is half a star) based on both existing and new rail networks. The fingers
connect the existing villages in the region, draw in the landscape in the gaps between the fingers, and support urban development close to the train stations. The entire urban development plan is based upon public transport and is interwoven with it.

This was a time when few Danes had cars and the ability to buy a car was restricted by heavy taxes, as there was a shortage of foreign currency. Expanding the radial infrastructure would transport the workforce from the new healthy dwellings in the suburbs into the dense city. The gaps between the fingers were recreational areas and agricultural reserves. The Finger Plan originated in functionalism and the initial drafts were made in the 1930s, where strictly rational functions were seen as underpinning modern society and producing humane living conditions. The driving force of the Finger Plan was to create better lives for the city’s inhabitants. The document has an affinity to natural science in its analytical approach and structure and is a very thorough and detailed piece of work (Andersen and Hansen 2000).

The Finger Plan was a regional planning tool that accommodated urbanisation and expected growth in the post-war period. As time went by, the development of public-transport-oriented urban areas came to be inspired by modernist planning, and the scale and infrastructure of private-car use influenced local urban layouts. Numerous stations on the south and west lines were delayed by ten years due to funding problems and political disagreements, which made many of the initial urban plans fall apart. However, the framework for urban regional development retained its form.

![Figure 10. Diagram for TOD planning (Calterpe, 1994 p.57). The initial diagram of TOD resembles the diagram of the station neighbourhood from the Finger Plan 1947 (Figure 11). Both diagrams have a mercantile centre around the transit stop, surrounded by dense residential areas and secondary residential areas further out.](image-url)
Status of the Finger Plan as a public transport network and guidelines for regional development

Today, although the Finger Plan’s structure is being seriously challenged by various municipalities eager to build on the green areas between the fingers, the key development guidelines in the latest governmental directive, Fingerplan 2019, are still the same as those from 1947. Thus, urban development should preferably occur within the urban zones (in the fingers and the hand), especially where public transport is concerned (Erhvervsstyrelsen, 2019 ch. 2, §3).

Nonetheless, various parameters are challenging the efficiency of the infrastructure of the Finger Plan, one of them being new business developments. From 2000 to 2015 only 62% of new office buildings larger than 1,500 m² built in the metropolitan region were located within the pedestrian catchment area of a station (Hartoft-Nielsen, 2018 p. 124). The problems of getting across or between the fingers requires a modal split
of commuting journeys, which has a high influence on the share of public transport (Santos et al. 2013). Other influences are the rapidly rising fares (Statbank Denmark 2019) and car ownership (Santos et al. 2013), which has increased in the region as the economy has grown and taxes on cars have been reduced (Statbank Denmark 2019). Lastly, a study of 48 European metropolitan areas shows that high network connectivity and coverage is strongly associated with ridership and that a grid-like urban network typology is more efficient than a radial one (Ingvardson and Nielsen 2018).

**Stationsnærhedsprincippet**

In Denmark the Stationsnærhedsprincippet (SNP) (Peter Hartoft-Nielsen, 1997), the principle of urban development near the station, was the universal thought behind the Finger Plan from 1947, as public transport was expected to be dominant in personal transport. However, as urbanisation progressed in the 1960s, 1970s and 1980s, the car became the centre of attention and the urban area focused on accommodating a car structure. It was not until the late 1980s that SNP was brought back as a key guideline in regional and local planning in the metropolitan area (Hovedstadsområdet, 1989). In 2007 SNP was passed as planning law, as the guidelines had not been followed by the municipalities.

The reports “BY og BANE” (city and rail) were made to document the effects SNP has on traffic in the metropolitan region, and thus to inform the revision of the Finger Plan in 2017. Reports 1 and 2 analyse extensive datasets from traffic and workplaces in the metropolitan area (Hartoft-Nielsen & Reiter, 2017). Report 3 sums up the results and concludes that employees at workplaces within a maximum distance of 600 m from the station use public transport significantly more than employees at other workplaces. In Dense Urban Areas the distance increases up to 800 m. This tendency only applies for stations, even if a workplace is well connected to the bus system, it does not have the same effect (Hartoft-Nielsen, 2018). The definition of SNP is that urban development of regional importance and workplaces or institutions that generate passenger traffic must be placed within walking distance of train stations in the rail network. The goal was to reduce car traffic and congestion in the region, create mobility for citizens without cars, and encourage car drivers to use public transport instead. SNP supports densification of urban structures and aims to reduce sprawl, support property investments and provide businesses with access to a workforce within a large geographical area (report no.3 BY og BANE p.12).

This description resembles the principles of TOD, however, the difference between TOD and SNP is that TOD is put into form and customised to accommodate placemaking, and is driven by a more intense recipe of investments and design for retail and commercialisation. It stems from another culture, however the intentions are the same.
Ownership and administration

The ownership and governance of the S-train system and station premises play an important role in the current state of public transport in Copenhagen. In 1997, Banedanmark (Railway Denmark) was separated from DSB (Danish State Railways) as a government agency, and the two organisations divided the railway’s property between them. Banedanmark is in charge of traffic control and the maintenance of the Danish railroad network, including the tracks in the S-train system. DSB is in charge of passenger train operations on most of Denmark’s railways.

Figure 12. Ownership at S-train stations. Red is DSB, yellow is Banedanmark. Drawing approved by Banestyrelsen’s executive board 22/8/1998.

Figure 13. Ownership at regional train stations. Red is DSB, yellow is Banedanmark. Drawing approved by Banestyrelsen’s executive board 22/8/1998.

Figure 14. Ownership at the station: DSB owns the trains, large plots of land used as railyards, the station buildings and sometimes the forecourts, and platform features like buildings, benches, clocks and ticketing machines (marked in red). Banedanmark owns the platforms, the tracks, most of the tunnels, staircases and viaducts, and sometimes the forecourts and the land around the stations (marked in yellow). The urban area close to the station platform is of shared ownership between DSB, Banedanmark, the local municipality and private investors. Drawing approved by Banestyrelsen’s executive board 22/8/1998.

The ownership and governance of train stations and adjacent areas was commented on by two planners and managers from DSB and Hvidovre municipality respectively in two separate individual interviews. When
asked about DSB’s role in incorporating the station into the local municipality, engineer Ole Bjerager, manager at DSB Real Estate, said:

*DSB is a train-operating company that would like to operate trains and preferably nothing more. Managing urban space in various municipalities is far from our core task. We take care of maintenance at the stations, and naturally passenger safety [i.e. practical and technical safety] is a concern of ours.* (6 August 2019). Ole Bjerager.

Bjerager explained that almost every station and station area is unique in its ownership and planning history, having been designed according to what was required at the time of its construction. When the city around the station changes, the stations often stay the same, as there is no economic incentive to fine-tune or redesign them, which would require a joint venture between Banedanmark, DSB and the local municipality, and often the financial interest in and potential benefits of the project are low.

On the opposite side of the table in the collaboration with DSB and Banedanmark are planners from the municipalities. The head of the roads and parks division in Hvidovre municipality explained:

[…]*facilities around train stations are not always on the top of our list – there are several focal points, such as schools and institutions that need financial attention. Furthermore, there is probably a tendency for the municipalities to see public transport as the state’s affair and not something the municipalities have obligations to prioritise.* (26 June 2019) Michael Daugaard.

Daugaard explained that parking areas used by commuters from other municipalities often have lower financial prioritisation, as such investments do not benefit the local municipality’s citizens. Moreover, the mixed ownership of urban spaces at stations makes financial coordination problematic.
4 Main text contributions of the study

4.1 Article 1

“Understanding fear of crime at train stations through neighbourhood types: a study of the Copenhagen metropolitan area”


This article defines the station neighbourhood types of the 84 S-train stations and their surrounding urban environments in the metropolitan area in order to relate their spatial characteristics to passengers’ experience of public transport.

The station neighbourhood types are defined by means of a typomorphological analysis of the built environment within the passenger catchment area (PCA). The theoretical framework for the spatial analysis is based on Placemaking and Crime Prevention Through Environmental Design (CPTED), as the topic of interest is fear of crime. The station neighbourhood types are compared with data from nine years of passenger surveys of fear of crime at train stations from DSB and Passenger Pulse from 2009 to 2018, to explore the relationship between neighbourhood type and fear of crime. The PCA is relevant for perceptions of safety in public transport, as approximately 79% of S-train passengers either walk or cycle to the station from home. Furthermore the stations are open and unmanned, as well as being an integral part of the urban flow and urban space.

The typomorphological analysis identifies three main station neighbourhood types in the Copenhagen metropolitan area: A, Dense Urban Area; B, Coherent Suburb; and C, Fragmented Suburb. A is characterized by its dense urban patterns and ‘classic’ European downtown pattern of city blocks dating back centuries. B is a pre-war suburb with single family houses in a coherent pattern, and C is a post-war suburb with residential areas, services and industry in fragmented patterns. Some neighbourhood types contain significant elements of another type, then a small letter is used to denote it, e.g. a Dense Urban Area (A) with patterns of single family houses (b)= Ab.

With aggregated data from the passenger surveys on fear of crime at stations, a probability distribution (kernel density estimate) is made for the main neighbourhood types. The probability density plot reveals that C, Fragmented Suburb, is most likely to be perceived as unsafe, and B, Coherent Suburb, as the safest.

A measurement of mean and standard deviation of the subcategories is consistent with the main categories: subcategories of B are less safe than pure B, subcategory A+b is safer, and subcategory A+c is less safe. Subcategories C+a or C+b are safer than pure C. So, when typology C denotes a station neighbourhood it reduces safety, and likewise when typology B denotes a station neighbourhood it becomes safer. It is important to note that the measurements only indicate a tendency, as the samples are few.

A geographical mapping of station neighbourhood types provides an understanding of the historical urbanization and later regional planning of the metropolitan area, showing that the pre-war suburban residential areas are close to the city centre and stretch up north, while the Finger Plan’s post-war development, neighbourhood type C, is the next layer of urbanization that stretches to the south and west of Copenhagen.
The results indicate that passengers’ perceptions of safety at stations are related to each station’s neighbourhood type. Fragmented post-war patterns with high degrees of openness influence passengers’ fear of crime at stations. Coherent suburbs are considered the safest, most likely because of the high level of territoriality, public private zones and details of human scale. Dense Urban Area stations are perceived as relatively safe, with few exceptions because of crowdedness, signs of low maintenance and low socioeconomic environments.

The conclusion suggests that, instead of a general approach to station design, a ‘whole journey approach’ that also encompasses an understanding of the surrounding environment is to be recommended, as it influences passengers’ perceptions of public transport. The typomorphological analysis can provide a transport company with background knowledge to understand their business cases and the challenges and qualities embedded in the geography of place. By expanding knowledge of the station’s surroundings, it is possible to target interventions and station design.

### 4.2 Article 2

“Fear follows form: a study of the relationship between neighbourhood type, income and fear of crime at the station”


The second article analyses the influence of station neighbourhoods’ socioeconomic structures on passengers’ fear of crime at the stations. The article explores the relationship between passengers’ fears of crime, station neighbourhood types and income data. The intention is to separate the socioeconomic information in the station neighbourhoods from the passengers’ experience of urban form.

The most influential parameter for fear of crime is socioeconomic factors, therefore it is possible to imagine that stations with high levels of fear of crime are associated with neighbourhood income levels more than the built environment.

The research is based on 84 S-trains stations in the Copenhagen metropolitan area. The area of analysis is the passenger catchment area (PCA), a radius of 800 metres or ½ a mile around the station. A previous study has defined three main station neighbourhood types: A, ‘Dense Urban Area’, i.e. central Copenhagen; B, a ‘Coherent Suburb’ of single family houses; and C, ‘Fragmented Suburb’, post-war developments with fragments of urban forms.

The neighbourhood types are compared with residents’ incomes and passenger surveys of fear of crime at S-train stations. The income data is from 2015 and come from Statistics Denmark. The data are GIS-mapped into squares of 100x100 metres as a background to the urban form and also used in aggregated form for each PCA as indicators of neighbourhood income levels. The passenger survey of fear of crime is from DSB from 2009 to 2015, and the Passenger Pulse from 2016 to 2018.

The distribution of income among the three urban types shows a tendency towards higher incomes in type A, Dense Urban Area and B, Coherent Suburb. This indicates that type A and B neighbourhoods are considered more attractive to live in than neighbourhood C. Neighbourhoods in type C, Fragmented Suburb, have the lowest incomes. Comparing neighbourhood types with passenger surveys of fear of crime, types A and B are perceived as safer than type C.
A multiple regression analysis showed that income levels and feelings of safety are significantly positively correlated: the higher the income, the safer passengers feel at the station.

However, in station neighbourhoods with the same income levels but with different urban forms (neighbourhood types), passenger’s fear of crime follows the neighbourhood type. The research results suggest that fear follows form and that the experience of the station neighbourhood influences passengers’ fears of crime.

The analysis concludes that some of the spatial characteristics of station neighbourhood type C, Fragmented Suburb, is related to fear of crime. Furthermore, residents in type C areas have the lowest incomes and are thus more vulnerable to fear of crime. The GIS mapping of income patterns and urban form illustrate their direct relationship and underline that inequalities in living conditions are influenced by space and architecture.

The article provides statistical evidence of a reciprocal interaction between the station and its surroundings. This evidence is of value to the public transport industry, as it manifests that the station is as a part of the neighbourhood and surrounding environment and not a solitary design unit.

For a local design intervention at a station, a more detailed investigation is needed. However, the methods applied in this research are useful in preliminary analyses of transport systems as a means of identifying vulnerable locations.

4.3 Article 3

“Is it transit-oriented development? A case-study of S-train stations in the Copenhagen Finger Plan”


The main objective of this article is to analyse S-train stations and their urban environments according to ‘ideal’ Transit-oriented development(TOD) design guidelines to determine to what extent their layouts match TOD recommendations and to establish guidelines for Danish practice.

The Finger Plan, Copenhagen’s regional development plan from 1947, is an internationally acknowledged TOD. However, the Copenhagen Metropolitan public transport network only has a modest 18% of transport share, which is contrary to what might be expected for regional urban planning based on public transport. Traffic planners suggest parameters such as modal splitting, more expensive fares and lower taxes on cars, as explanations. However, an extensive passenger survey of fear of crime at stations shows that passengers feel unsafe there after dark and that design solutions at and around stations are a source of fear of crime. Therefore this article considers passengers’ experiences of the S-train stations as a possible part of the explanation.

Thirteen S-train stations on the ‘fingers’ of the Finger Plan are used as case studies, two of which are illustrated in the text. Site-specific comments by passengers are used to supply the case-study analysis. The TOD analysis is based on a table from a Dutch study by Pojani and Stead (Pojani & Stead, 2015) based on literature on international TOD case-study analysis. The table has been turned into a scheme with which to summarize and overview the analysis of the thirteen S-train stations.

The scheme’s total count of topics and dimensions shows clear tendencies in the planning of Danish S-train stations: the pedestrian scale of urban design at S-train stations does not conform to ‘ideal’ TOD design.
guidelines. The topics of place-making and safety in particular are deficient, and passenger surveys of the fear of crime at S-train stations support these findings. The text gives twelve examples of parking at S-train stations that indicate a planning tendency at post-war stations of introducing car parking areas around the station. Parking at stations is not recommended by TOD guidelines because of the low levels of natural surveillance and low human activity, and because it disconnects the station from urban activity.

The Finger plan is an example of TOD on a regional scale, however, the individual S-train stations’ urban design solutions at the pedestrian level does not support TOD guidelines. This constitutes a discrepancy between the TOD scales which is likely to influence the public transport ridership in the region.

The results reveal a development potential for similar international post-war TOD regional plans, in which stations’ urban surroundings were inspired by modernism and car infrastructure. Furthermore the research contributes to academic and professional dialogue on how traditional Transit-oriented development guidelines translate into international contexts and subsequently provide guidance for urban developments in Danish public transport nodes. This constitutes the initial steps in establishing TOD guidelines for Denmark that include partnerships and stakeholders in the surrounding community in order to support the establishment of sustainable public transport environments.

4.4 Abstract for NJAR


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Amalie Nordstrøm Nielsen (Bachelor of Engineering in Architectural Engineering, Technical University of Denmark)

Emilie Alstrup Torp (Bachelor of Engineering in Architectural Engineering, Technical University of Denmark)

This article suggests a method for transforming Crime Prevention Through Environmental Design (CPTED) methodology into an operational urban evaluation guide for architects. CPTED is a complex methodological framework for establishing urban environments that prevent crime and fear of crime, which is relevant for planners and architects to gain access to. This research project condenses CPTED analyses that are relevant for the urban spaces surrounding train stations into a visual, urban assessment tool and guide for safe public transport environments, thus making it highly operational. This CPTED guide analyses and evaluates separate design elements and their influence on fear of crime. The guide’s principal structure is inspired by Transport for London’s ‘Guide to the Healthy Streets Indicators’, though the guide does not measure traffic, pollution or noise, but fear of crime. The analysis has three levels: the station platform, the access road to the station within a hundred metres, defined by the number of people in the streets moving to and from the station, and socioeconomic structures within 600-metre radius of the station. The themes of the urban design indicators are based on conventional CPTED parameters, combined with urban design guidelines from Transit-oriented development (TOD). The dimensions of urban design are evaluated on-site, guided by detailed descriptions in the table. The dimensions are weighted and the sum of elements illustrated in a radar
chart. The guide is tested on three stations, the results showing a close correlation between the CPTED analysis and passenger surveys on fear of crime at the stations. Furthermore, passengers’ comments from the survey on urban design support the findings in the scheme. This initial draft of a CPTED design guide for public transport environments provides a basis for upgrading and redeveloping public spaces surrounding train stations and targets poor urban design solutions.

![Figure 15. Principle drawing of the areas of analysis – the main access roads to the station entrance.](image)

![Figure 16. Two stations’ access roads compared in a radar chart](image)

![Figure 17. A section of the guide’s table](image)

### 4.5 Proceedings of a Ph.D. symposium


The article concerns GIS mapping of different kinds of data in the S-train system and the first test of a CPTED scheme to perform assessments of train-station environments.
Abstract:

This study proposes GIS (Geographic Information System) mapping as a research platform for analysing interdisciplinary data related to urban public transport nodes. The focus of the analysis is to locate and measure parameters that influence passengers’ perceptions of safety at train stations. GIS mapping makes it possible to create layers of geographical information and to identify correlations between interdisciplinary types of urban information like planning typologies and passengers’ perceptions of safety. GIS mapping is a strong communication tool to inform transport decision-makers – politicians, chief executives of the DSB (Danish State Railways) and planning authorities in Danish municipalities – about the different urban parameters that influence passengers’ perceptions of safety at transport nodes. The results indicate that data need strong correlations if they are to communicate a graphic result in GIS and that statistical correlation analyses are needed for correlations that are not graphically traceable. A supplementary part of the study is a sketch for a scheme to find CPTED-related parameters in the built urban environment and thus decipher the urban environment and the influence of the various elements on passengers’ perceptions of safety. The results indicate that the method is functional and must be further developed.

4.6 Report

‘Public transport nodes as urban spaces: evaluation of selected station projects partly funded by the Danish Traffic, Housing and Construction Agency from 2010-2013’ (Transportknudepunkter som byrum: evaluering af udvalgte puljeprojekter fra 2010-2013).

Summary:

The report provides an architectural analysis and evaluation of six projects to rebuild and upgrade train stations or their premises. The station projects were aided with mobility-support funding from the Danish Transport, Construction and Housing Agency from 2010-2013. The stations involved are Esbjerg, Kolding, Odense, Ishøj, Tåstrup and Holte. The projects are described in the text, while drawings, photos and the report itself provide an architectural analysis and evaluation of the projects before and after these changes in light of the application text.

Conclusion:

Project economy: Good design solutions that make people feel safe at stations are no more expensive than poor design solutions. The crucial thing is to know what consequences a design has on peoples’ feelings of fear of crime and behaviour.

Loss of value: The fund’s and municipalities’ investments lose value if, for example, a new bicycle parking area is established next to a deserted building or a tunnel with poor lighting, it discourages passengers from using the facilities.

The report concludes that it is of the utmost importance that local planners and designers are aware of the basic rules of CPTED when investing in mobility projects.
5 Conclusions

This thesis contributes to knowledge about passengers’ fear of crime at train stations. The articles included within the thesis analyse how urban space influences citizens’ perceptions of safety, ranging from trends on the metropolitan scale to design solutions at individual stations.

This concluding chapter is divided into four sections: first the results from the articles, then discussion of the limits of the research and a section with suggestions for industry, and finally a reflection on the research process.

5.1 Research results

The articles in the thesis confirm the initial main research hypothesis: *There is a direct connection between passengers’ experience of fear of crime at the station and the character of the surrounding urban layout.* This section discusses the research questions in order of their appearance in the research, followed by operational guides and future research suggestions for industry.

Results from the research articles

The articles and their research results document the different steps of the analysis. First the station neighbourhood types and their relation to levels of passengers’ fear of crime, second the possible relationship between fear of crime and income, and lastly the urban analysis of space within 100 m of the S-train stations in relation to the above-mentioned phenomena.

“Understanding fear of crime at train stations through neighbourhood types: a study of the Copenhagen metropolitan area”

The first research question, *How can the surrounding neighbourhoods of S-train stations be categorised according to spatial characteristics associated with fear of crime in order to compare the passenger surveys with types of urban space?* is investigated in the typomorphological article: “Understanding fear of crime at train stations through neighbourhood types: a study of the Copenhagen metropolitan area. A typomorphological analysis of stations.” The typomorphological analysis of urban neighbourhoods around S-train stations in the Copenhagen metropolitan area is based on their spatial characteristics related to CPTED and allows them to be defined as “station neighbourhood types”. The analysis outlines three main types of urban form (Figure 18):

Type A, Dense Urban Area, a dense urban pattern of city blocks dating back centuries. This structure has a high level of natural surveillance because of the urban activity in the streets, the many open facades on the ground floor and apartment windows that face the streets. Urban activity is high in the daytime and in some places also at night. Furthermore the streetscape has a high level of enclosure and visual diversity, all features related to perceptions of safety.

Type B, Coherent Suburb, dates from before 1950 and consists mostly of single family housing in a coherent pattern with clear demarcations between public and private zones and a defined streetscape with visual di-
versity. The streets are narrow and the windows face the street, and although often separated by a front garden; passengers’ fear of crime in these station neighbourhood types is low, despite the low levels of urban activity.

Type C, Fragmented Suburb, is a post-war development of fragmented building types with gaps between them. This area has a low level of natural surveillance and the surrounding urban space is dominated by car infrastructure. The physical characteristics of this neighbourhood type do not accommodate social activities in the streets: urban densities are low, the streetscape does not encourage people to spend time in the urban space and it lacks integration because building facades are set back from the street.

![Figure 18. Examples of neighbourhood types A, B and C.](image)

![Figure 19. Examples of station neighbourhood types Ac, Dense Urban Area with significant elements of Fragmented Suburb, and Bca, Coherent Suburb with elements of Fragmented Suburb and minor elements of Dense Urban Area.](image)
The station neighbourhood types are classed as subcategories if the urban fabric carries the main patterns A, B or C, but also contains significant elements of one of the other patterns. For example, if the area surrounding the station is Dense Urban Area, A, and the minor element is C, a small letter ‘c’ is used to denote this: Ac (Figure 19). There needs to be a substantial number of building elements from another type or they need to be central to the station entrance in order to influence the urban area and denote the type.

A second variation in neighbourhood types is marked by the addition of two small letters after the main category. Thus, if the main type is Coherent Suburb B, but it is influenced by a low urban density structure (C) and secondary fragments of a village structure (A), it becomes Bca (Figure 19). This makes it possible to create an overview of a station neighbourhood’s characteristics and use it for comparison with other types of data.

The typomorphological analysis of the Copenhagen metropolitan area is a novel contribution within Danish planning.

The station neighbourhood types are compared with aggregated data from nine years of passenger surveys of fear of crime at stations. The results show that types A and B are regarded as almost equally safe, with a few outliers in A due to crowdedness and characteristics associated with socioeconomically vulnerable areas such as low maintenance. Type C, Fragmented Suburb, is perceived as the most unsafe (Figure 20).

The table of average mean and standard deviations illustrates how type C neighbourhoods are perceived as safer if they are denoted with B or A, and type A and B neighbourhoods are perceived as less safe if denoted with type C (Figure 21). This analysis cannot be interpreted as anything more than an indication of a phenomenon as there are too few examples in each subcategory to produce a solid research result. However, the tendencies in the average mean and standard deviations support the findings in the study.

![Figure 20. A probability density plot of safety in the station neighbourhoods. Neighbourhood type A is the red curve, B is in green, and C is in yellow.](image)
In the article “Fear follows form: a study of the relationship between neighbourhood type, income and fear of crime at the station” the findings from the first article are combined with an analysis of income levels in the station neighbourhoods. The main point is to inquire into the general view that fear of crime occurs in urban areas with social challenges. Socioeconomically vulnerable areas are often and in general related to fear of crime. A strong indicator for socioeconomic levels in urban areas is residents’ income. Income level is not a universal indicator for this, because a retired person might have a low income but otherwise be of a high socioeconomic level (even though most in this category then have a high pension scheme). However, income level can indicate a tendency. Socioeconomically vulnerable areas are related to fear of crime and a strong indicator for socioeconomic levels in urban areas is residents’ income. Therefore the second research question: How is passengers’ fear of crime at the stations related to the station neighbourhoods’ income level? is investigated in the second research article “Fear follows form: a study of the relationship between neighbourhood type, income and fear of crime at the station”. This is an investigation of the relationship between passengers’ fear of crime, urban station neighbourhood types and income levels.

The research results show that fear of crime at stations is strongly correlated with low incomes in the station’s neighbourhood. The lowest incomes are in typology C, Fragmented Suburb, which had spatial features related to fear of crime and was also perceived as the most unsafe (Figure 20 and 22). This result led to the third research question: How influential are the different urban types for the experience of fear of crime when adjusted for income levels? The influence of urban spatial characteristics is made clear by the significant result that if neighbourhood types have the same income levels, passengers’ experience of fear of crime
follows the patterns of neighbourhood type C. This result underlines the influence of urban spatial characteristics on passengers’ experience of fear of crime (Figure 23). This result is a novelty within international research on urban form and fear of crime.

Figure 22. A probability plot of income per capita in each of the main station neighbourhood types. A is red, B is green, and C is yellow.

Figure 23. The relationship between fear of crime, income and station neighbourhood types. The trend-lines illustrate how fear of crime in typology C is lower than in A and B. There is a tendency towards a lower fear of crime in higher income areas within each type. Types A and B have a higher trend-line than type C, meaning that if the population around a station has equal, fixed income levels, then stations in areas of type C feel less safe than stations in type A or B areas.

The last analysis is a detailed architectural analysis of individual S-train stations in accordance with “ideal” TOD design guidelines drawn from the international case-study literature on train stations. The article “Is it Transit-oriented development? A case-study of S-train stations Copenhagen Finger Plan” is a detailed urban analysis of the area within 100 m of 13 S-train stations according to transit-oriented development guidelines. The case studies are from different fingers in the Finger Plan with various types of socio-economic levels and station neighbourhood types, apart from Dense Urban Area. The analysis is structured in a scheme with topics and dimensions that describe how Danish S-train stations’ urban surroundings perform in relation to international TOD design guidelines. This answers the fourth research question How do the close vicinities of Danish S-train stations correspond with international design guidelines for transit-oriented development? The scheme exposes the qualities embedded in the network: the stations have great potential as they are placed at the centre of urban developments with modal integration and cycle paths. However, the stations show low performance in dimensions like safety and public spaces for human use (Figure 24). This tendency is confirmed in qualitative interviews from Passenger Pulse’s 2019 passenger surveys, where passengers expressed fear of crime at the stations and in their surrounding premises.

The analysis shows that the stations in high income areas constructed before 1950, station neighbourhood B, Coherent Suburb, have the best TOD design criteria performance, and the areas around stations from after 1960, station neighbourhood C, Fragmented Suburb, have the lowest performance.

The urban analysis reveals that, while Copenhagen’s Finger Plan is a regional-scale example of TOD, the pedestrian scale of urban design at S-train stations is not quite in line with TOD principles. The prevailing tendency is not to take placemaking and fear of crime into account when designing S-train stations and their immediate surrounding areas. The consequences of not attending to the pedestrian scale show up in the outcomes of the passenger surveys on fear of crime at train stations, where elements like parking areas, tunnels and darkness are mentioned. This means that the S-train stations’ close vicinities do not correspond with design guidelines for TOD.

TOD design guidelines incorporate CPTED parameters and focus on perceptions of safety, and therefore address the fifth research question Are TOD guidelines relevant in a Danish planning context? The TOD guidelines are relevant even though Copenhagen’s regional development is based on a rail network infrastructure, because the station areas do not comply with international design recommendations for transit-oriented environments. Most important are the TOD recommendations for organising governance and partnerships at stations because, as the two planners interviewed for the research article from DSB and Hvidovre municipality express, there is an organisational lack of interest and a lack of financial capacity to take interest in the urban area connecting the station to the neighbourhood. This organisational/policy aspect of TOD is not a focal interest of the urban analysis presented in this research, but an area of central importance for the future development of the urban neighbourhoods around the stations.
<table>
<thead>
<tr>
<th>Station neighbourhood type</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimension 1: Scale</strong></td>
<td></td>
</tr>
<tr>
<td>1.1 Ensure comfortable walking distances between points</td>
<td>13</td>
</tr>
<tr>
<td>1.2 Place commercial uses, jobs, parks, and civic uses within walking distance of transit stops</td>
<td>12</td>
</tr>
<tr>
<td>1.3 Tolerate densities with distance from a station</td>
<td>7</td>
</tr>
<tr>
<td>1.4 Provide sufficient densities to sustain transit investments</td>
<td>4</td>
</tr>
<tr>
<td><strong>Dimension 2: Public spaces for human use</strong></td>
<td></td>
</tr>
<tr>
<td>2.1 Design individual parts of the overall plan with human activity in mind; public spaces should be the focus of buildings and pedestrian activity.</td>
<td>10</td>
</tr>
<tr>
<td>2.2 Add human-scale details</td>
<td>12</td>
</tr>
<tr>
<td>2.4 Design public spaces for a sense of “an outdoor room”</td>
<td>9</td>
</tr>
<tr>
<td>2.5 Ensure that buildings line the streets and are not isolated in lots, and that main entrances and windows face the street.</td>
<td>10</td>
</tr>
<tr>
<td>2.6 Provide large shade trees that form continuous canopies over the street.</td>
<td>9</td>
</tr>
<tr>
<td>2.7 Provide soft transitions from the outdoors to the building</td>
<td>3</td>
</tr>
<tr>
<td>2.8 Create attractive landmarks and gateways to the development.</td>
<td>5</td>
</tr>
<tr>
<td><strong>Dimension 3: Safety</strong></td>
<td></td>
</tr>
<tr>
<td>3.1 Provide physical measures such as good lighting at night.</td>
<td>7</td>
</tr>
<tr>
<td>3.2 Control access in nonpublic spaces through fencing, lighting, and landscape.</td>
<td>5</td>
</tr>
<tr>
<td>3.3 Avoid blank façades</td>
<td>4</td>
</tr>
<tr>
<td>3.4 Ensure adequate sight lines.</td>
<td>9</td>
</tr>
<tr>
<td>3.5 Avoid tunnels, narrow parks, and other entrainment spots or isolated areas.</td>
<td>3</td>
</tr>
<tr>
<td>3.6 Encourage a variety of uses to ensure round-the-clock activity.</td>
<td>0</td>
</tr>
<tr>
<td><strong>Dimension 4: Variety and complexity</strong></td>
<td></td>
</tr>
<tr>
<td>4.1 Break up long streets with parks and other diverse, colorful, and interesting public spaces.</td>
<td>7</td>
</tr>
<tr>
<td>4.2 Avoid monotony, either in terms of appearance or use.</td>
<td>9</td>
</tr>
<tr>
<td>4.3 Avoid uniform planning regulations.</td>
<td>11</td>
</tr>
<tr>
<td>4.4 Avoid large billboards, large on-street trash dumpsters, and high light poles.</td>
<td>8</td>
</tr>
<tr>
<td>4.5 Create a sense of identity (i.e., a common design vocabulary for buildings and public spaces).</td>
<td>13</td>
</tr>
<tr>
<td>4.6 Encourage every price point to live around transit, i.e., provide affordable housing options.</td>
<td>8</td>
</tr>
<tr>
<td><strong>Dimension 5: Connections</strong></td>
<td></td>
</tr>
<tr>
<td>5.1 Design relatively small blocks (perimeter limits is 400–450 m)</td>
<td>7</td>
</tr>
</tbody>
</table>

| Topic: Place-making |
|---------------------|-----|
| **Dimensions**      |     |
| A. Sydän (1972)     | C   |
| B. Anderegg (1972)  | C   |
| C. Hendrie (1976)   | C   |
| D. Brandt-Aitken (1985) | C |
| E. Albertson (1985) | C   |
| F. Talley (1985)    | B   |
| G. Heil (1949)      | D   |
| H. W. Velde (1949)  | B   |
| I. B. Taylor (1954) | B   |
| J. Crummel (1956)   | B   |
| K. Halley (1957)    | B   |
| L. Peterson (1956)  | B   |
| M. Genoff (1963)    | B   |
Figure 24. A table with analysis of 13 S-train stations according to TOD design guidelines of topics and their dimensions. A station has a number 1 if the dimension is present at the station or 0 if it is not. Based on Ponjani and Stead (2015 pp. 133, 134).

The schematic analysis of the 100 m around S-train station provides an answer to the last research question: Do parameters in Danish urban design practice require an alteration of the TOD design recommendations.
to accommodate Danish planning? In relation to the scheme, modifications of TOD parameters to suit Danish design practice and planning conditions are suggested because Danish planning conditions are different from the US planning tradition and urban environments.

A Danish design characteristic is that train stations in Denmark are laid out as part of the urban flow, with open, unmanned constructions and no turnstiles or ticket booths. Another parameter is the low urban density around suburban stations which makes several TOD recommendations for parking design less relevant.

The analysis is an important initial step in formalising a set of methods and guidelines to help Danish planners and decision-makers achieve a successful outcome in creating safe stations that are profitably embedded in their immediate neighbourhoods. This conclusion provides important knowledge for designers and planners because passengers’ reactions to spatial and environmental cues influence their experience of travel and the image of the station. A regional public transport network underperforms if its use is not supported by human scale design.

The construction of train stations taps into fear of crime

A concluding remark on fear of crime and train stations, based on the CPTED analysis and social and environmental crime theories, is that a train station has environmental components that are related to stress, such as noise from trains and crowding of passengers, as well as an architectural character that is quite different from other urban spaces. Here low territoriality is combined with high levels of wear and tear. Furthermore, imbedded in the construct are a social perspective of strangers and the risk of people behaving in disorderly or unpredictable ways. This is bound to influence passengers’ sensitivity to the fear of crime, as the emotion of fear taps into related physical reactions: thus alertness, stress and anxiety are closely related to fear of crime. This makes passengers at train stations vulnerable to fear of crime, as the social and physical environment might amplify the feeling. This knowledge is important for designers and planners of public transport because this context-dependent alertness more than likely amplifies passengers’ reactions to environmental cues and experience of space. The research results emphasise a need to include this knowledge when designing stations. This research contribution provides such information and is a novelty in a Danish context.

Operational guides for the public transport sector and suggestions for future research

The present research has produced several results that can be further developed in future research or planning guides. A significant result of the research is that passengers experience stations in neighbourhood type C to be significantly less safe than stations in the rest of the network, even when adjusted for income. These station neighbourhoods can be improved by changing the urban space around the stations to denser, mixed-use areas with a focus on walkability (and bikeability), and a higher level of urban activity closer to the station, as recommended in TOD. This transformation requires a different structure of collaboration in the public transport sector and the municipalities and regional planning instances involved. The upgrade of station neighbourhoods is however rewarding: it creates safer urban environments that become attractive to work and live in. It enhances the local areas’ economic competitiveness, it reduces local pollution and contributes to bringing down greenhouse gas emissions globally.

A tool for evaluating and redesigning urban space around the station is the CPTED tool described in Section 4.4. Within the different station neighbourhood types there are also variations of safety. Here the CPTED analysis and evaluation of the station’s surrounding public space can inform about the design-level of safety.
The CPTED tool is already operational for practitioners and thus represents the closest objective for future work:

**Making CPTED operational for practitioners**

This research fostered the ambition to make CPTED operational for planners, architects and practitioners in this field because few Danish practitioners are familiar with fear-of-crime preventive measures, although fear of crime strongly influences the use of urban space. The CPTED planning tool is programmatically described in the abstract for the *Nordic Journal of Architectural Research* in Section 4.4. There have been previous attempts to operationalise a CPTED design evaluation guide for public transport facilities by proposing a CPTED parameter scorecard with numeric values for the number of cameras, the lighting, possible sightlines from the entrance to the platform etc. (Rahaman et al., 2016). The problem has been that, while there might be stations where the CPTED scores are good, experience of them is still poor. This calls for another layer of information to encapsulate the placemaking qualities of urban space. Therefore the CPTED assessment tool proposed in this research is adapted for a Danish context and incorporates placemaking-related qualities of scale and experience of direction.

This scheme is a step-by-step tool that asks elaborate questions regarding the characteristics of different station areas. By ticking the box that fits the description of the CPTED element at a station, a comprehensive analysis of the area is gradually made. The results are visualised in a radar chart that also shows how eventual design suggestions will change the chart. This tool can be fine-tuned and developed in use. It provides feedback, and is operational and ready for use in its current form.

**TOD design guidelines**

The driver in TOD is urban activity around stations by means of residential, cultural and commercial centres integrating stations into their local neighbourhoods, initiated by planning and partnerships. The same recommendations can be found in European guides for public transport (EuropeanStandardization, 2009; C40, 2015). A holistic way of working with public transport is essential to incorporate stations and public transport into society. This shift in discourse and move away from stations being separate entities is very important in a Danish context.

The TOD design scheme is not operational as a design tool, but it lists the important topics and features that urban planning and design at stations need to consider, including the importance of various stakeholders in the design process with short-term and long-term design frames in mind. Adapting TOD guidelines for Danish planning contexts makes it possible to incorporate and formalise them in practice and thus provide a basic understanding of what it takes to create sustainable transport.

**Suggestion for a future research project**

A future research topic is the collaboration between stakeholders from DSB, Banedanmark, the municipalities and the government. This is a political science project which entails not only investigating ownership and legal documents, but most importantly decades of organisational practice and hierarchies in established structures. This collaboration has enormous influence on the establishing of public transport environments but does not traditionally belong within the research field of architecture.
5.2 Reflections on the limits of the research

This section presents the limits of the research, first considerations about further theories and methods that could have contributed to the analysis, and second, limits of the case studies and the TOD article, and finally a comment on public transport as a field of research in the Danish context.

Limits to the research

This research only presents a part of a complex picture of elements that influence passengers’ experience of fear of crime. Using large data sets such as a regional network and years of passenger surveys with a generalized question is in danger of producing over-simplistic research assumptions in regards of different types of challenges that might cause fear of crime in a local station environment. The analysis covers far from all aspects, parameters such as light and vandalism plays an important role in peoples’ perception of space, but has not been included because of the its changing character of maintenance. Therefore the results must be seen as an indication of patterns and tendencies where every single case study needs an individual urban analysis as suggested in the article “Is it transit oriented development? A case study analysis of S-train stations in the Copenhagen Finger Plan”.

Mapping of citizens’ fear of crime demonstrate that urban design and architecture influence citizens’ experiences (Doran & Burgess, 2012), however, this thesis can only seek to demonstrate that urban typomorphology relate to where fear of crime occurs. It is possible to demonstrate a relationship between station neighbourhood types and passengers’ experience of fear of crime, but a causal relationship will be difficult to demonstrate even in a much more detailed analysis, as cities are complex constructs encompassing numerous layers of parameters influencing the outcome of analysis. However, other factors that emerged during the research that were also found to influence the experience of fear of crime at train stations and their surrounding environments, are investigated as well.

Methods and theory

A configuralional approach

A space syntax analysis of the station neighbourhood types could have provided insights about connectivity in the urban pattern and contributed an informative layer of analysis of urban flows. This would have added a layer of information to the typologies about “safety by numbers”, as activity on the streets has a great influence on perceptions of safety.

An analysis of facades facing the roads that passengers use most to and from the stations is already included and formalised in the operational CPTED guide, structurally described in the abstract for NJAR. This guide does not use space syntax but instead people-count to and from the station. The most active paths or routes are access roads used for detailed CPTED analysis that informs about the level of fear of crime in the built environment. The access road analysis was undertaken within 600 m of the station entrance. This extensive urban analysis was conducted at Avedøre S-train station, a station neighbourhood type C, Vanløse Station, a station neighbourhood type B, and Sydhavn S-train station, a station neighbourhood type Ac (see external reference). This analysis did not replace the typomorphological analysis but extended it, as would a space syntax analysis.
In the space syntax text “Can streets be made safe?” the result of the space syntax school’s research into crime and street networks found “...a strong correlation between layout type and all kinds of crime, with traditional street patterns the best and the most 'modern' layouts the worst. Even more strikingly, the traditional street-type layouts were occupied by both the best-off and least well-off economic levels. If less-affluent people were living in traditional Victorian streets, then it seems their crime rate was lower, not higher, as would be expected from the British Crime Survey. (...) Rich and poor alike, it seems, benefit from living in traditional streets” (Hillier, 2004 p.43). Although Hillier refers to street networks and the distribution of crime in this text, the same relationship applies for the experience of fear of crime. Both rich and less well-off citizens, it seems, benefit from living in traditional streets. This is consistent with the research findings in article two, “Fear follows form...” where fear of crime follows the urban form even when compensation for income levels is made (see Figure 23).

Qualitative studies

This study examines what causes passengers to have a certain experience in public urban space, and research of cities is immensely complex as cities contain thousands of parameters that may possibly influence this experience. It is difficult to determine if a research result is heavily influenced by an underlying factor such as hearsay pertaining to an area.

There is no doubt in my mind that further investigation of social and psychological aspects of passengers’ experiences of S-train stations’ layouts, as well as hearsay about and images of station neighbourhoods, would have contributed significantly to knowledge of passengers’ behaviour and experience of public transport.

Placemaking

The Danish architect Jan Gehl’s concepts for urban spaces could have been used in this study, however quite early in the research I tuned into CPTED and criminology and found that there was little evidence-based research directly related to Jan Gehl’s concepts. His ideas root in Placemaking and are closely related to Jane Jacobs’ thoughts and projects such as e.g. William H. Whyte’s research on small urban places (a thorough analysis of behaviour and use of public spaces in New York) (Whyte, 1980) and Donald Appleyard’s patterns of people movement in streets with traffic (Appleyard, 1981). Analyses such as these could have contributed to knowledge on urban activity and street design and are closely related to CPTED guidelines of natural surveillance and openness in facades.

Stationsnærhedsprincippet

The Danish planning principle Stationsnærhedsprincippet is a concept close to TOD, however strictly focusing on the strategic placement of workplaces and infrastructure. It is important to underline that the design of urban space in relation to public transport is not a focal point in Stationsnærhedsprincippet and there are no guidelines or analysis in this regard. Therefore the focus of this research turned away from Danish literature.

It is important to acknowledge that the entire idea of the Finger Plan and the station neighbourhood is based on the notion of a traditional urban structure dependent on public transport, a principle that TOD seeks to revitalise. The methodological and theoretical part of this thesis draws on international concepts because there was an abundance of theories, research and case studies related to them. In hindsight a more extensive use of Danish planning literature could have been appropriate, however this escaped my attention because I was focusing on explanations for fear of crime, and little attention is paid to this in Danish literature.
Limits to the field of work

Train stations

This research project does not include an analysis of the interior design of S-train stations. When the research initially began, DSB was approached to take part in the research as an industrial partner, however they were reluctant and kindly asked that the analysis be kept off their premises. Therefore from the start, the stations were excluded from the analysis. I do not find that this choice of focus has weakened the research, as the stations are very open and integrated in the surrounding area. We can see from the Passenger Pulse surveys on fear of crime at the station that except for access to the platform, most passengers comment on the stations’ surrounding environments (Passagerpulsen, 2019a; Passagerpulsen, 2019b).

Typomorphology and transit-oriented development

The last article, “Is it Transit-oriented development? A case-study of S-train stations in the Copenhagen Finger Plan” does not mention the station neighbourhood types. This is regrettable as it would have tied the research together and interlinked the scales and layers of analysis in the thesis, however, it was difficult to find a journal with interest in both TOD design guidelines for planners and urban types and hence this combined focus was removed from an earlier version. Furthermore the article was limited to a maximum of 6000 words because the illustrations that took up space, even though many of them were omitted from the journal publication. Therefore the station neighbourhood types are not mentioned in this last article. The connection between the station neighbourhood types and the TOD design analysis within 100 m of the station is described in Section 2.3 on CPTED and in the Results in Section 5.1. The full array of aspects is not included in the research article.

5.3 Suggestions for the public transport sector and parties involved in urban planning and development.

This section describes the research results and how they can be used to guide the parties involved in establishing public transport. The first suggestion to the industry is of organisational and governmental character. The additional texts focus on urban densification and stationsnærhedsprincippet.

Organisation and governance

It is important to understand the complexity of urban space at train stations from an architectural and social sciences perspective: the duality of place, the paradox of fear, and the methods and guides designed to accommodate these challenges. This knowledge is not accessible to local planners with tight schedules and administrative personnel in the neighbourhoods’ municipalities, nor is it incorporated in Banedanmark or DSB. This knowledge needs somehow to be embedded in the system to guide the redesign and reorganisation of both stations and their neighbourhoods. This involves DSB, Banedanmark, Movia (who administer the buses and bus stops at the station), and most importantly the local municipalities.

The sector does not have an organisation that promotes or integrates train stations in urban municipal planning. If public transport infrastructure, station design and local urban planning were governed as one, knowledge on proper and profitable planning would contribute to the station neighbourhoods and the use of public transport.
The topic of the complex governance of S-train stations was examined in the report “Analysis of Danish railway stations: development, organisation and efficient operation” (Analyse af Danske jernbanestationer. Udvikling, organisering og sikring af effektiv drift) from April 2017, issued by the Ministry of Transport and Housing (Struense & McKinsey Company, 2017). The report concludes that there are a substantial number of problems in the current organisation of the system and suggests scenarios for a restructuring of governance practice. The focus in the report is on organisation and efficiency, but it neglects the perspectives represented by the two planners from DSB and Hvidovre who describe a lack of organisational and financial interest in urban areas that should connect the station to the city. Nor does it take into account architectural analysis or passengers’ experiences of place. This is symptomatic for the industry and why this thesis seeks to address the subject.

The complexities of the ownership and governance of S-train stations and their surrounding areas are of interest to an architectural urban analysis because this urban area connects – or disconnects – the station and the surrounding community. Based on the research conclusions, train stations should be an integral part of planning and governance in the individual municipalities of the station neighbourhoods.

Governance plays an important role in the current experience of S-train stations and their surroundings, as it makes the process of design solutions complicated and financial coordination problematic. Parking areas, pathways and areas close to stations are not the focal points of municipal investments (see Section 3.2 Ownership and administration). As a result, urban spaces around stations often fall between two stools and end up not connecting the station to the rest of the city, or even disconnecting it from its urban area. This is reflected in statements in the passenger survey, where passengers use adjectives such as “deserted” and “sad” about stations and their surrounding urban spaces.

Here the TOD guidelines for engaging stakeholder interest and public participation, private/public and public/public partnerships can create mutual expectations and help ensure positive outcomes (Dunphy, Myerson, and Pawlukiewicz 2003, p.2).

It would improve the urban quality and use of public transport if municipalities had an interest in and financial incentive to make stations and their surrounding premises work as a focal point in the municipality and a place of urban activity. New public–private partnerships can support redevelopments, as suggested by the Expert Group from the Ministry of Transport and Housing in 2018 (Ekspertgruppen, 2018 p.19). However, corporation and coordination are difficult to change without changing the present ownership structure.15

Urban densification and stationsnærhedsprincippet

The results of the typomorphological analysis and the TOD analysis of S-train stations’ immediate urban areas indicate that urban densification within station catchment areas would not only benefit the experience of public transport but also contribute to more sustainable urban development. Here is a potential for urban development in the metropolitan area, especially as the city is expanding to accommodate its growing population. New urban areas are being developed along the harbour front and out into the sea on islands built from

15 These problems are much like the need for coherence and coordination between the different traffic companies, traffic systems and transport forms providing public transport in Greater Copenhagen. Here weak organisation and a lack of any incentive to think across companies inhibits the best solutions for passengers’ travel experience (Als et al., 2017 p. 4).
landfill from excavating the new Metro tunnels. A more sustainable development which would not create traffic problems in the centre of the city would be to densify the areas around S-train stations and create safe and thriving communities where infrastructure already exists. This would accord with stationsnærhedsprincippet and the regional planning document the 2019 Finger Plan (Erhvervsstyrelsen, 2019). Furthermore, the stationsnærhedsprincippet should be expanded with design and planning guides and knowledge of how best to design passenger-friendly environments to support a positive image of train stations and encourage the use of public transport.

Observations of the field of research

A significant observation during the research was the gap between traffic planning and transport engineering on the one hand and the knowledge of architects, psychologists, sociologists and criminologists on the other. For the sake of the future growth of public transport it is important to bridge this gap, which surfaces when modelling transport. Traffic engineers have sophisticated programmes for predicting the use of public transport networks based on models of possible transit, numbers of commuters, local jobs, household types, incomes, car ownership, etc., but their models do not account for the actual experience of being a passenger in places and spaces, that is, the urban environment and perceptions of safety that influence our experience of life and our patterns of travel.

Finally, the experience of studying social and architectural assessments within an engineering environment has been rewarding for understanding the complexity of this particular research topic.

A concluding remark

This research emphasises that S-train stations and their urban environments must be seen as one. To look at the two as different and separate entities is a mistake that compromises the success of public transport. Public transport contributes to a city’s identity, just think of citizens moving in these transport corridors every day or tourists experiencing the city from this angle. Public transport and urban structures should be a joint venture, a partnership that needs a vision and engagement from the proprietors and stakeholders: municipalities, investors and citizens. At the vast majority of S-train stations the task is to conceive a public space that is both accessible to everyone and also fosters a sense of shared concern. This is a complex matter that is difficult to solve for transport companies and municipalities alone.
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7 Appended articles

7.1 Understanding passengers’ fear of crime at train stations through neighbourhood types: a study of the Copenhagen metropolitan area

7.2 Fear follows form: a study of the relationship between neighbourhood type, income and fear of crime at train stations

7.3 Is it Transit-Oriented Development? A case study of S-train stations in the Copenhagen Finger Plan
Understanding passengers’ fear of crime at train stations through neighbourhood types: a study of the Copenhagen metropolitan area

This paper presents a typomorphological analysis of train station neighbourhoods to examine passengers’ fear of crime at the station in relation to the surrounding urban form. The study defines station neighbourhood types in the Copenhagen Metropolitan area within the pedestrian catchment area, an 800m (1/2 mile) radius around the 84 S-train stations. The types are defined through a typomorphological analysis based on urban parameters related to Crime Prevention Through Environmental Design (CPTED) and Placemaking. The types are compared with nine years of passenger surveys of fear of crime at these stations. The analysis establishes three dominant station neighbourhood types and demonstrates the relationship between them and passengers’ fear of crime at the stations. The research underlines the importance of the surrounding urban environment in the design and governance of train stations, and proposes a typomorphological method to identify potentials in regional planning and in upgrade of transit-oriented developments.

Keywords: Typomorphology; Train stations; Fear of crime; Neighbourhood type; Finger Plan; Copenhagen metropolitan area


Introduction

This research uses a typomorphological method as background to the analysis of public transport. This method defines station neighbourhood types and compares them with passenger surveys of fear of crime at 84 S-train stations to examine whether the experience of public transport is related to the surrounding urban form. This analysis investigates the direct relationship between train passengers’ fear of crime and urban form in a regional rail network. Many other urban characteristics such as e.g. light, vandalism or hear-say about an area play important roles in people’s perception of fear
of crime, therefore the results can only be seen as an indication of a relationship between urban form and fear.

In research into transportation planning, transit neighbourhood types define urban areas in relation to the use of public transport (Robert Cervero and Gorham 1995). However, the focus in this article is the influence of urban design on passenger experience of fear of crime in the Passenger Catchment Area (PCA).

Since the 1970s urban studies have underlined the built environment’s influence on citizens’ quality of life and their experience of fear of crime (Doran and Burgess 2012; J. Gehl 2010; Ewing and Handy 2009; Jeffery 1971; J. Jacobs 1961). Fear of crime at train stations can cause passengers on public transport to avoid certain routes, not to travel after dark, or avoid using public transport altogether if they have an alternative (D’Arbois De Jubainville and Vanier 2017; CrimeConcern 2004). Stations are regarded as more unsafe than the rest of the urban environment (Københavns Kommune 2019; Ceccato and Newton 2015; CrimeConcern 2004), and even though they are criminogenic places because of their convergence (Brantingham and Brantingham 1995), the statistical risk of being a victim of crime is far below the fear of crime (CrimeConcern 2004; Warr 2000). Therefore knowledge regarding which urban parameters influence perceptions of safety at train stations are of significant value, as public transport ensures both social and environmental sustainability in urban areas.

This research consists of case studies of stations on the S-train network in the Copenhagen metropolitan area. Approximately 80% of all S-train passengers either walk or cycle to the S-train station and thus they experience the PCA (Trafikstyrelsen 2009). Furthermore, S-train stations have no turnstiles or ticket-booths, being unmanned platforms that are part of the free urban flow. This integral layout makes the urban surroundings of stations important in understanding fear of crime.
This article presents a brief overview of literature and theory on the influence of the built environment on fear of crime, followed by an introduction to typomorphology. The typomorphological qualitative approach is supplemented by a GIS-based quantification of openness proportions in the stations’ neighbourhoods. The results section presents the neighbourhood typologies, compares the openness proportions of the different neighbourhood types, and assesses the conditional probabilities that link types of neighbourhood to nine years of passenger surveys of fear of crime. A visualization of the types on the metropolitan map is discussed in relation to the historical background and geographical context. The conclusion sums up the findings and addresses topics for future research.

**Theoretical background and framework**

The method builds upon a theoretical framework of fear of crime in built environments in combination with typomorphological analyses of cities.

**The built environment’s influence on fear of crime**

The influence of the built environment on fear of crime has been thoroughly examined since the 1970s through criticisms of modernist urban planning. This took off in the 1960s with Jane Jacobs’ criticism of modernist renewal projects in residential areas of New York (J. Jacobs 1961). Jacobs was followed by scholars of architecture (Newman 1972; J. Gehl 1971), criminology (Jeffery 1971) and psychology (I. Gehl 1971), whose research focused on how urban space and design affect residents’ mental states in relation to fear, stress, social exclusion, crime and happiness, as well as their use of public space. Since then, an increasing number of urban studies have extended this field of knowledge, refined by computer-generated isovists, GPS tracking of movements, crowd-sourcing using smart phones, and recently direct measurements of people’s
responses to urban environments by using sensor-wristbands to monitor heart rates and skin conductance (Knöll et al. 2018; König and Schneider 2014).

The spatial analysis of station neighbourhood types is rooted in Crime Prevention Through Environmental Design (CPTED) (Newman 1972; Jeffery 1971) and targets ‘fear of crime’. The analysis also draws on theories of urban form, some of which are related to guidelines for walkability, a measure of how friendly an area is to walk in (Ewing et al. 2016), which has emerged from theories of place-making (J. Gehl 2010; Appleyard 1981; Whyte 1980). These guidelines form part of Transit Oriented Development (TOD) (R. Cervero, Ferrel, and Murphy 2002; Calthorpe 1993), the success of which is dependent on the appropriate urban form of street networks and building patterns (Stojanovski 2018; Vernez-Moudon 1994).

The following five characteristics are suggested in presenting an overview of parameters in the built environment that influence fear of crime in urban environments:

1. Natural surveillance, activity support and mixed use
2. Visual guidelines of territoriality and use
3. Spatial qualities; human scale, enclosure, beauty, design, robustness, visibility
4. Maintenance
5. Light

1. Natural surveillance, activity support and mixed use

Natural surveillance, or ‘eyes upon the street’ (Jacobs, 1961), refers to how public space is over-looked by members of the public as a by-product of public life. In this research natural surveillance means activities in the street by both residents and non-residents (Newman 1972). This relates to activity support, legitimate activities in support of perceptions of safety, the ability to see each other through windows and
balconies, inter-visibility between buildings, entrances opening on to the street, and activities during the day that result from mixed land use (Desyllas, Connoly, and Hebbert 2003; Felson, Clarke, and Webb 1998). Natural surveillance supports normative behaviour, which has a strong effect on perceptions of crime and safety (Desyllas, Connoly, and Hebbert 2003; Jeffery 1971).

2. Visual guidelines of territoriality and use

Visual guidelines emphasize territoriality and use. Zones guide people in how to move and behave and encourage them to assume ownership and control on the assumption that they respect and protect the places they feel are theirs. This supports the understanding of place, as well as of the fear of crime (AGIS 2007; Newman 1972; Jacobs 1961).

3. Spatial qualities

Spatial quality is a complex phenomenon. In this study it is defined by the notions of enclosure, refuge, human scale and complexity (beauty and robustness).

Enclosure is primary in defining space, as it creates a visual overview and coherence related to safety and comfort. The sense of enclosure is eroded if the streetscape is discontinuous, with vacant lots, parking lots, lawns or buildings set back from the road or path (Cullen 1961). A comfortable enclosure ratio ceases somewhere around 1:4, and beyond 1:6 the feeling of enclosure disappears (Harvey et al. 2015; Spooner 2007).

Jay Appleton’s Prospect-Refuge Theory combines enduring aesthetics with a basic primal need for prospect and refuge, that is, the need to feel protected and safe, to be able to see what is coming (the predator), and also to be able to escape from it (Blobaum 2005; Nasar and Jones 1997; Fisher and Nasar 1992; Appleton 1975). This makes streetscapes with tunnels, parking basements and long closed façades
undesirable. This is related to ‘lurk lines’, places close to the individual that are just outside the field of vision, yet near enough to create a feeling of danger regarding what might be lurking there (Warr 1990; Goffman 1972).

Human-scale architecture corresponds to the size of the body and is therefore possible to seize and feel connected to. Empty or out of scale areas can be perceived as unsafe, uncomfortable and dull, possibly leaving residents feeling exposed and under surveillance (AGIS 2007; A. B. Jacobs 1993; J. Gehl 1971).

Complexity, beauty and robustness refer to visual and sensory qualities and are connected to territoriality and ownership. A complex and beautiful environment is visually stimulating and divides walking into manageable stages (Ewing and Handy 2009). Conversely, monotonous building façades can be experienced as long, dull, unstimulating and discouraging for urban life (A. B. Jacobs 1993; J. Gehl 1971).

Neither light nor maintenance is necessarily linked to any particular urban pattern. As both parameters require detailed qualitative investigations of urban areas they are not included in investigations of fear of crime in current research.

Enclosure and natural surveillance are used as background to the measurements of openness proportions in the different types of station neighbourhood.

**Typomorphological analysis of neighbourhood types**

Typomorphology is the study of urban form derived from research into typical spaces and structures (Moudon 1994). It involves grouping urban patterns into typologies and classifying them. Typologies are constituted by types and classifications of urban elements, and the scale can be multiple, including windows, façades, building footprints, plot outlines, villages, cities and metropolitan areas (Moudon 1994;
Urban morphology is the study of patterns and the collective form of things. The scale can range from buildings to cities and territories, but in its narrowest sense urban morphology refers to the study of the urban fabric of buildings, plots and street patterns (Kropf 2014; J. W. R. Whitehand and Morton 2004; Conzen 1960). Both urban typology and urban morphology have the street network, the plot and the building as the defining element (p. 42 Kropf, 2014; p. 147 Vernez-Moudon, 1994). Moreover, they agree on the importance of the historical process, as the type of built landscape is morphogenetic and is defined by the time of its conception, use or mutation (Oliveira 2019; Moudon 1994). Typomorphological analyses of urban form are important for planning practice and design, as they provide a deeper understanding of an urban space (a space to which people feel no personal attachment) and can support its character so it can transform itself into a place (with personal attachment) (Olsson and Haas 2013).

A large body of research is concerned with the relationship between urban form and travel patterns (Stead and Marshall 2001; Ewing 1996). Many of these define neighbourhood types: ‘Neighbourhood type is effectively a composite variable that is used to characterize areas of cities that are relatively homogeneous according to a range of attributes. These attributes typically include the age of development (such as post-war), the style of development (traditional, conventional or neo-traditional, for example) and the street network type (such as grid or loop or cul-de-sac)’ (Stead and Marshall 2001 p.127).

Many American definitions of ‘transit neighbourhood types’ are variations of dense urban pre-war or suburban post-war structures (Robert Cervero and Gorham 1995; Friedman, Gordon, and Peers 1994; Ewing 1996; Southworth and Owens 1993). Some
of the attributes characterizing the different typologies suit the Copenhagen Metropolitan area, although the examples and terminology are American. ‘Transit neighbourhoods’ are central pre-war urban areas of mixed use, reduced street hierarchies, connected streets, on-street parking, high population densities and transit services. ‘Auto neighbourhoods’ have segregated use, hierarchical street networks, partially connected streets, low residential densities, random street patterns and fewer transit services. In international typo-morphological research there are strong similarities between urban typologies, although all cities have diversities in their typologies due to culture, history, climate, use and economic factors.

Methods

The case study

The research for this article is based on case studies of S-train stations in the Copenhagen metropolitan area. The S-train network is the urban rail system in the ‘Finger Plan’ of 1947, a regional infrastructural plan for the post-war development of Copenhagen (Egnsplankontoret, 1947) that largely guided the development of the region from 1947 onwards (Figure 1). The S-train system runs along the five ‘fingers’ based on existing train lines and main roads.

Most of the S-train stations were built between 1953 and 1974 as part of post-war expansion. The system has seven lines and 84 stations, covers the entire metropolitan area, and involves a diversity of urban planning and socioeconomic structures.
The analysis targets the urban layout of the pedestrian catchment area (PCA), an 800-metre (1/2 mile) radius around the S-train station platform.

Figure 1. 'The finger plan' (Egnsplankontoret, 1947).

**The method for creating typomorphological maps**

The analysis of station neighbourhood types is typomorphological, as it describes urban form (morphology) based on the classification of buildings and open spaces by type (typology). The maps show the building footprints (figure-ground maps) that illustrate the relationship between built and open space. They are used in urban morphology studies to visualize the mass-to-void relationship and the fabric of urban patterns (Rowe, E.Koetter, 1979). When looking at station neighbourhood types with streets and building plots on cadastral maps, it looks as if a clear demarcation is present in the urban space. However, the borders and plots in modernist-inspired areas are mostly permeable, and it is often not possible to register them on site. In reality what one experiences is a vast open space, as on a figure-ground map, not a defined space like a cadastral map.

The station neighbourhood types are defined on the basis of their spatial qualities in relation to public space, the street network, the plot, the building, its use and
its time of construction. First, groups of patterns are identified based on the size of the building’s footprint, the building’s use and the time of its conception. Then the distances between the buildings and their orientations towards the street and the street network are identified. The spatial relationships and urban qualities of the different building types are defined. Monuments and public buildings belong to the typology in relation to which they were built and planned (year and building style).

The 84 station neighbourhood types are GIS-mapped to show their geographical distribution in the metropolitan area (Figure 10).

**The passenger survey: fear of crime at S-train stations**

The typo-morphological studies are compared with passenger surveys to determine whether the layout of the transit area can be related to the experience and fear of crime at the station. The passenger survey of fear of crime at S-train stations contains 125,449 responses from nine years of surveys. The data stem from DSB (the Danish State Railways) from 2009-2014, followed by Passenger Pulse (the public transport passenger survey) from 2015-2018 (Forbrugerrådet Tænk, 2019). The survey was handed over to a public passenger organ in 2015 to ensure public access to the data. It runs throughout the year based on approximately eight thousand questionnaires handed out yearly to a representative customer segment on S-train platforms between 6 am and 10 pm. The question about fear of crime at the station reads: ‘At the station: how satisfied are you with…..safety at the station?’ Passengers rate their perception of safety (or fear of crime) on a scale from 0 to 10, 0 being unsafe and 10 being safe. The station in question is the one they depart from (Forbrugerrådet Tænk, 2019).

**The openness proportions of the three neighbourhood types**

Urban density is normally measured by means of a floor area ratio (FAR), but the
experience of urban space and urban density in S-train station neighbourhoods is not as closely related to FAR as to the experience of a continuous streetscape and enclosure. The openness proportions make the experience of the streetscape disintegrate and are related to low urban densities and the lack of social control, i.e. eyes in the street. Neighbourhoods outside central Copenhagen with a high FAR are often modernist-inspired building structures with open greens or open parking spaces. People living in the buildings do not linger in urban spaces, as they have few activities to watch or participate in. Here, therefore, urban density is measured by the amount of open space in relation to the building footprint.

By using a GIS-based calculation of open space within circles of 25 metres width around the station platform (principle drawing in Figure 2) the percentage of open space within each circle is calculated (see Appendix for Python code). Each ring is a point on the graph. From 25 to 300 metres there is a point for every 25 metres, with thereafter only one point per 100 metres because the law of large numbers makes the graphs flatten out. Each graph has nine or ten examples of stations that are typical neighbourhood types without parts of other typologies.

Figure 2. Principal drawing method.
Results

**Definition of neighbourhood types**

As the focus of this study is the station, the urban area surrounding the station entrance identifies the neighbourhood type. If the predominant part of the station neighbourhood belongs to the same typology, it becomes a main category. The three main neighbourhood types identified are: A, Dense Urban Area; B, Coherent Suburb; and C, Fragmented Suburb (Figure 3).

![Figure 3. Neighbourhood types A, B and C.](image)

These neighbourhood types have subcategories if the urban fabric carries the main patterns A, B or C, but contains significant elements of one of the other patterns. For example, if the area surrounding the station is A and the minor element is C, a small letter ‘c’ is used to denote thus: Ac (Figure 4). There need to be a substantial number of building elements from another type or they need to be central to the station entrance in order to influence the urban area and denote the type.

A second variation in neighbourhood types is marked by the addition of two small letters after the main category. Thus, if the main type is Coherent Suburb B, but it is influenced by a low urban density structure (C) and secondary fragments of a village structure (A), it becomes Bca (Figure 4).
Figure 4. Sydhavn station, neighbourhood type Ac (left) and Tåstrup station, neighbourhood type Bca
**A: Dense Urban Area**

A, the Dense Urban Area type (Figure 5), is located in central Copenhagen and consists of five-storey blocks of buildings with closed internal courtyards. The city centre dates from the seventeenth century, while the urban areas to the south, east and north-east of the centre were built for the working classes in the nineteenth and twentieth centuries.

This neighbourhood type has a high density, and the building footprints, the road network and the open plazas testify to tight planning and organization of the urban structure. The building scale is human, and the building materials are robust, with ornaments and high visual complexity. Here there is mixed use (ground-floor shops, with apartments on the first to fifth floors), connected streets in ‘X’ intersections, on-street parking and high population densities. There is a distinct sense of enclosure: in
some streets the enclosure ratio is 2:1, the street being ten metres wide and the buildings twenty metres tall. The level of natural surveillance is high: the façades have many windows and balconies, and the ground-floor shops are glass-fronted. There is activity and people on the street during the day, and in some areas also at night.

The large voids in the figure-ground plans represent the harbour, lakes and park areas, with their remains of seventeenth-century fortifications. These areas are demarcated with fences, greenery or stemmed trees towards the sidewalk. Some of the large voids alongside the tracks are railroad yards, for example, Svanemøllen, Bispebjerg and Dybølsbro stations (Appendix, Figure 1). The railroad yard creates a void next to or around the platform, and despite the Dense Urban Area, passengers may experience the station as having low natural surveillance.

The S-train stations in typomorphology A are either in an open trench or above ground, or else they run along an embankment. One station, Nørreport, is underground. This station is in the centre of Copenhagen and is a combined metro, S-train and regional train station with a high degree of activity: approximately 208,000 passengers a day (buses and regional trains not included) use the S-train and metro platforms.

**B: Coherent Suburb**

Station neighbourhood type B, Coherent Suburb, have a considerably lower degree of land occupation than A, the Dense Urban Area type (Figure 9). Most of the building mass consists of one- to two-storey single family housing. The building footprints are small and are spread out in a homogeneous pattern with lines and blocks juxtaposed in a consistent manner. The infrastructure is slim, the streets are well connected in ‘X’ intersections and the hierarchy of roads disappears, providing a coherent pattern to the suburb. Most of these areas close to Copenhagen were built between 1900 and 1950,
some of them being the remains of old village structures like Tåstrup (Figure 4). The distances between the façades on each side of the road are between twenty and forty metres, but, as is typical of this suburban neighbourhood type in Europe, the front gardens have trees and hedges along the sidewalk which create a clear demarcation between private and public spaces. The enclosed public space is mostly ten metres or narrower, and people on each side of the road are within talking distance of one another. These areas have a variety of building designs and details. Most of the buildings were constructed using non-industrialized building processes. Here is a tradition of ornaments and of a clear demarcation of private, semi-private, semi-public and public spaces through greenery, fences, hedges, front lawns, doorsteps, balusters, etc. The scale is human, with a high level of territoriality, visual diversity and defined space. Natural surveillance varies: some have people passing through, open windows towards the road and activities on the front lawns, while others are more remote, with low levels of activity or high hedges towards the street.

In this neighbourhood type, the train tracks are mostly on an embankment above ground, and the coherent pattern of houses encloses the station, leaving little or no space to park cars or buses. In some areas the level of natural surveillance can be low close to the station, as many gardens have high fences, hedges and greenery facing the road to create privacy.
Figure 6. Top: Coherent suburban area. Neighbourhood type B. Bottom: Examples of
eighbourhood type B. Left: Pattern of Gentofte >1950. Centre: Cadastral map

C: Fragmented Suburb

Type C, Fragmented Suburb (Figure 7), contains fragments of different types of urban
fabric or groups of types, divided by wide infrastructural patterns or undefined land-use,
which create gaps between the fragments. The different fragments may be areas of
multiple-storey buildings consisting of social housing, single family housing, factories,
industrial areas, large shopping centres etc. What is significant is the lack of interaction
and connectivity between them. This neighbourhood type differs from A and B in
having larger areas of open space in between ‘islands’ of built environment, leading the
spatial characteristics of this contemporary city to be referred to in the Danish literature
as ‘leftover landscapes’ (Nielsen, 2001). Here the spatial hierarchy is multiple, and the
organization of elements gives the impression that they are drifting apart. This
neighbourhood type stems from post-war development continuing up until the present
day.

This post-war development has given rise to types inspired by the modernist
ideas of the early twentieth century, when industrial work, recreation and family life
were separated and systematized. Functionality and health were the most important
factors in architectural planning, and open green areas were thought of as the best way
to create cities. The ‘car age’ had arrived and was a central concern of planners,
meaning that the scale of the infrastructure for cars set the standard for these urban areas
(Nielsen, 2008). This, combined with thoughts about open green spaces and segregated
traffic, created cities with low building densities and low levels of social interaction.

The modernist-inspired typologies in these areas are shaped by the
industrialization of the Danish building sector that took place from the 1950s. The use
of concrete elements, the enthusiastic exposure of assembly techniques and the
dimensions of assembly-line crane tracks informed public housing settlements, as well
as the planning of entire areas. This new fast building technique accommodated a
growing population, urbanization, industrialization and economic growth (Nielsen,
2008) (Realdania, 2010) in most western countries.
Station neighbourhodd type C is characterized by low urban density and low walkability; the roads are broad, and there is plenty of parking around the station. There is low urban activity with no active façades, a low sense of enclosure and few active ground floors.

The railroad tracks and platforms are on an embankment, within which the staircase and elevator to the platform are often located, accessible from a tunnel entrance. There are trees and greenery on the banks and around the entrance, as well as parking for bicycles. This layout can cause low visibility, and the tunnel entrance can promote a feeling of low possibilities of escape (Figure 8). The original plan was to have a ticket vendor and shops or a kiosk at the station, but the ticketing became automated and later digital, the offices are now closed, and the premises are vacant. Some stations have a kiosk at the tunnel entrance.
Several type C areas have a large mall just next to the station, but the buildings present a closed or windowless façade to the station entrance, and most buildings close to the stations do not use the full potential of activity from a transport node. This is unfortunate when it comes to natural surveillance and fear of crime (Figure 8, right).

Figure 8. Left: Tunnel entrance from Avedøre station. 2017. Centre: Inside the tunnel entrance, 2017. Right: Karlslunde station with a shopping facility presenting a blind façade to the station entrance, 2017.

**Openness proportions and neighbourhood types**

The three graphs show the openness proportions of each of the station neighbourhood types. A, Dense Urban Area, have the densest footprints, an average of 70.8% open space and also divergent curves, mostly because of the parks and lakes in central Copenhagen. The grey line with high density within the first 90 metres represents Copenhagen Central Station, which has a large station building and a roof construction covering the tracks. B, Coherent Suburb, have higher openness proportions of 83.7% and very even patterns, with almost the same level of openness for all station neighbourhoods within 800 metres. The patterns in type C are more even than in A, with an average openness proportion of 83.1%. The yellow line with high density within the first 65 metres is Ballerup station, which has a mall at the station.

According to urban design guidelines for transit-oriented development (TOD)(Calthorpe, 1993), in promoting sustainable urban planning around train stations,
densifying the urban area around the station is important to enable human activity (natural surveillance). The graphs reveal that urban space do not densify around the S-train stations in terms of building footprints.

Figure 9. Above: neighbourhood type A. Centre: neighbourhood type C. Below: neighbourhood type B.

The neighbourhood types on a map

The historical background and explanations for the location of the urban patterns are illustrated in Figure 10, a GIS mapping of neighbourhood types.
Figure 10. The three neighbourhood types on a map of Copenhagen.

The map shows that Dense Urban Areas are concentrated in the centre of Copenhagen. B, Coherent Suburb, is a suburban zone of single family houses extending to the north. The northern municipalities became well established early because of the attractive landscape, which housed the summer residents of wealthy families and the nobility. The western and southern parts of Greater Copenhagen had large areas of undeveloped land, leading to a larger distribution of both public housing and industry. This meant that the
modernist influence on planning was stronger in these areas (Nielsen, 2008)(Realdania, 2010). Historically Copenhagen expanded to the north of the city because of the attractive landscape, which housed the summer residents of wealthy families and the nobility. The larger part of the area was built before 1950 and falls into the Coherent Suburb neighbourhood type.

C, Fragmented Suburban Area, is the peripheral neighbourhood type that spreads to the north-west, west and south of Copenhagen. This area represents the post-war expansion of Copenhagen, which involved a great deal of public housing and industrial planning. The Finger Plan sought to establish an even distribution of residents around Copenhagen by planning the western area and the southern coastline (Egnsplankontoret, 1947).

**Comparing neighbourhood types with passengers’ fear of crime**

As already mentioned, the passenger surveys from Passenger Pulse and the DSB provide data on mean perceptions of safety at each station, based on interviews with 125,449 passengers. An estimate of a probability distribution (a kernel density estimate or KDE) is made for each of the neighbourhood types A, B and C. Only a single mean value for each of the 84 S-train stations exists, as the data come in aggregated form. As a result, there are too few samples in each sub-category to produce a precise distribution of them. However, it is possible to produce an average weight and a standard deviation for each type of station neighbourhood (Figure 11).
Figure 11. Left: Density plot: the likelihood (probability density) of the three different neighbourhood types being perceived as safe. Neighbourhood type A is the red curve, B is in green, and C is in yellow. Right: main types A, B and C and subcategories, average mean and standard deviations.

The three curves show the likelihood of each neighbourhood type being perceived as safe. The normative value goes from unsafe 0 to safe 10, where the average for each station goes from 6.3 to 9.4. Looking at the red curve, A, Dense Urban neighbourhood, shows a wide distribution ranging from stations perceived as comparatively less safe and more safe. The deviations are due to special circumstances around three type A stations perceived as unsafe: Nørreport, Sydhavnen and Nørrebro, because of they are crowded and have signs of low maintenance and a low socioeconomic environment (see Appendix for elaboration). They differ from other type A stations, which are perceived as safe.

The green curve, B, Coherent Suburb neighbourhood, has a leftward skew, though the majority of probability mass show that stations in this typology have a high probability of being perceived as safe. Type B stations also have the highest mean safety score (7.71).
The yellow curve, C, Fragmented Suburb, has an average value of 7.35, being the lowest of the three main types. Type C also contains the station with the lowest mean safety score.

The means, Avr, in Figure 11, right, show that type A (Dense Urban Area) and B (Coherent Suburb) are the safest and type C (Fragmented Suburb) the least safe. The mean and standard deviations (Std) of the subcategories are consistent with the main categories: subcategories of B are less safe than pure B, subcategory A+b is safer, and subcategory A+c is less safe. Subcategory C+a,b or ba is safer than pure C. Only one sub-category, C+ab, deviates from the categories.

Further investigation is needed into how these values and distributions change over time. Access to disaggregated data and similar data from previous years may indicate a direct relationship between neighbourhood types and fear of crime.

Discussion

It is important to underline that this research has an aggregate empirical character as it investigates the direct relationships between train passengers’ fear of crime and urban form in a regional rail network. A comparison between large scale analysis and years of aggregated passenger surveys runs the risk of being over-simplistic in its assumptions; findings must be seen as an indication of tendencies rather than a definite result. Other parameters apart from urban layout may influence passengers’ fear of crime. Therefore, the results of this analysis must be interpreted with caution. It is possible to demonstrate a relationship between fear of crime and neighbourhood typologies, but a causal relationship, even in a much more detailed analysis, will be difficult to demonstrate, as cities are very complex and there are many parameters influencing the experience of
fear of crime. As Bill Hillier puts it: ‘The intimacy with which social and spatial processes are bound to each other, whether by markets sending rich people this way and poor people that, or bureaucracies assigning bad families to one estate and good families to another, means that we can never examine the spatial distribution of crime against the background of a social and economic tabula rasa’. (Hillier 2004 p.32).

Although Hillier refers to street networks and the distribution of crime in this text, the same relationship applies for the experience of fear of crime.

An investigation of activity flows in relation to urban density or land use would have contributed substantially to the analysis of neighbourhood types. It should be noted that the figure-ground plan analysis provides an overview of the urban fabric but only covers the built environment, not greenery, trees or their canopies, which can provide enclosure, scale and aesthetic quality. The foliage disappears in winter, but the trees still create a sense of space. The urban typologies of a built-up area are regarded as providing a framework for future detailed analyses of S-station neighbourhoods in the Copenhagen metropolitan area. A forthcoming article with a detailed analysis of thirteen S-train stations in the regional rail network follows up on an urban design analysis of the neighbourhoods in relation to fear of crime and Transit-Oriented Development guidelines. Central to the discussion of fear of crime in public spaces is the influence of socioeconomic structure, as this is related to low perceptions of safety in public spaces (Pantazis 2000; Taylor and Hale 1986). The article ‘Fear follows form: a study of the relationship between neighbourhood type, fear of crime and income’ (Strandbygaard 2020) presents a correlation between perceived safety at stations, neighbourhood types and income levels in station neighbourhoods.
Conclusion

This study has defined three neighbourhood types in the Copenhagen metropolitan area on the basis of parameters related to the experience of urban space: Dense Urban Area, Coherent Suburb and Fragmented Suburb.

In post-war planning the Fragmented Suburb type is perceived as the most unsafe, which confirms existing research on the experience of modernist inspired areas. This type has low levels of natural surveillance, large-scale building structures, and urban space dominated by car infrastructure. The physical characteristics related to this neighbourhood type do not accommodate social activities in the streets: urban density in this regard is low, the streetscape disintegrates as building façades are drawn back from the street, and there are few activities for citizens in the public space.

Dense Urban Area-type S-train stations are perceived to be safer, with the exception of a few stations. The Dense Urban Area station neighbourhood type has a high level of natural surveillance because of the urban activity in the streets, shop windows on the ground floor, and windows from apartments facing the streets. Especially in the summer, many cafes spill on to the streets. The streetscape has a high level of enclosure and visual diversity. The tables from the analysis of openness proportions in the three types support the typomorphological analysis of urban space.

The Coherent Suburb type dates from before 1950 and consists mostly of single family housing with clear demarcations between public and private zones and a defined streetscape with visual diversity. The streets are narrow, and the windows face the street, although often set back by a front yard. These areas are seen as safe despite the low level of urban activity.

The relationship between station neighbourhood type and passengers’ fear of crime at S-train stations strongly indicate that passenger experience of public transport
is related to the station’s neighbourhood type. This suggests that the focus on fear of
crime preventing measures in station design is more important in some urban areas than
in others. As a preliminary analysis of station catchment areas, the GIS analysis of
openness proportions is operational and can visualize the structures of urban
densification in passenger catchment areas. The typomorphological method is suitable
for a preliminary analysis of urban transformations of public transport-oriented
developments. Furthermore, the deeper understanding of the characteristics of a place
allows its potentials to be explored and used in an urban regeneration. In the present
case the analysis can be used to support Danish State Railways create an overview of
their business and of the challenges and qualities imbedded in the geography of place.

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Appendix

Appendix. Figure 1. Dense Urban Area: Typomorphology A. Railroad yards from left: Bispebjerg station, Dybbølsbro station and Svanemøllen station.

Appendix. Figure 2. Dybbølsbro platform and railroad yard below the bridge, 2019

Neighbourhood type A stations perceived as unsafe

Nørreport, Sydhavnen and Nørrebro stations are perceived as unsafe because they are crowded and show signs of low maintenance and a low socioeconomic environment. Nørreport station is crowded, with noise and pollution from the trains underground. There is a high degree of wear and tear, there are social delinquents present, and
passengers fear being pushed or pickpocketed, all aspects related to a congested station (Forbrugerrådet Tænk, 2019). Sydhavn station is rated in subcategory C and contains large areas of open undefined land, industry and heavy car infrastructure, which create areas of low natural surveillance and a lack of enclosure (Figure 6). The urban area has a large group of socioeconomically vulnerable citizens, and alcohol consumption in public spaces is common. Nørrebro station has areas of low prospect around the station, with graffiti and tags, and evidence of low maintenance. It belongs to a part of Copenhagen with a history of significantly low socioeconomic structure and incidents of gang-related violence, which influence fear of crime at the station. The other typomorphology A stations are perceived as relatively safer.

**Python code for density curves**

```python
import arcpy, matplotlib.pyplot as plt, math, csv

def main():
    # initialise workspace and settings
    arcpy.env.workspace = r"X:\DenmarkWork\GIS_OutputSHPs"
    arcpy.env.overwriteOutput = 1
    stations = r"X:\DenmarkWork\Geodatasets\St_C.shp"  # ensure this is set to the desired subset of stations for analysis
    buildings = r"X:\DenmarkWork\Geodatasets\bygning.shp"
    stIDs = stPoints(stations)
    stBuffer(stIDs, stations, buildings)

    # spatial reference?

def stPoints(stations):
    # Link the stations variable with the shapefile containing the desired PT stations to buffer
    field = "ID"
    # Pull out the unique station IDs, for iterating over
```
```py
stIDs = [row[0] for row in arcpy.da.SearchCursor(stations, (field))]
#uniqueValues = set(values)
print(stIDs)
return stIDs

def stBuffer(stIDs, stations, buildings):
    Station_set = str('Korrekt_Togstations_C')
    buffDist = [25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300, 400, 500, 800]
    # add heading into CSV file
    with open('%s.csv' % (Station_set), 'w') as csvFile:
        header = (""+buffDist)
        writer = csv.writer(csvFile, lineterminator = "\n")
        writer.writerow(header)
    for ID in stIDs:
        #stNm = '%s' % ID
        # Do analysis on a station-wise basis
        arcpy.MakeFeatureLayer_management(stations, "stopsLyr")
        # Select the point corresponding to the current station, from the master shapefile
        sqlExp = str("ID = %d" % (ID))
        arcpy.SelectLayerByAttribute_management("stopsLyr", "NEW_SELECTION", sqlExp)
        # Retrieve name and Perceived Safety Score of station
        with arcpy.da.SearchCursor("stopsLyr", (["Name"], sqlExp)) as cursor:
            for row in cursor:
                stNm = row[0]
                # Initialise variables inside station-wise namespace
                stationWise_data = [stNm]
                print('Analysing %s - %d' % (stNm, ID))
                #print('safety score', stSafety)
                # Create a shapefile containing the point for the current station only
                outfileName = str("st%d.shp" % (ID))
                stationLayer = str("StLayer")
                arcpy.CopyFeatures_management("stopsLyr", outfileName)
```
arcpy.MakeFeatureLayer_management(outfileName, stationLayer)
# Create multiple buffer(s) around the current station,
bufferStClass = str("stBuffers%d.shp" %ID))
arcpy.MultipleRingBuffer_analysis(stationLayer, bufferStClass, buffDist)
arcpy.MakeFeatureLayer_management(bufferStClass, "bufferLyr")
for dist in buffDist:
    # Make buffer distance into separate feature class
    outfileName2 = str("st%dBuffer%dm.shp" %(ID, dist))
    sqlExp2 = str("distance = %d" %(dist))
arcpy.SelectLayerByAttribute_management("bufferLyr", "NEW_SELECTION", sqlExp2)
arcpy.CopyFeatures_management("bufferLyr", outfileName2)
    # Find buildings which fall within (intersect) buffer
    outfileName3 = str("st%dIntersect%dm.shp" %(ID, dist))
arcpy.Intersect_analysis([outfileName2, buildings], outfileName3)
    # Calculate areas for the buildings in the intersection
    arcpy.AddGeometryAttributes_management(outfileName3, "AREA", "", "SQUARE_METERS")
    # Identify area of buffer
    arcpy.AddGeometryAttributes_management(outfileName2, "AREA", "", "SQUARE_METERS")
    # Calculate building footprint and open space proportions
    field = "POLY_AREA"
    bufferArea = [row[0] for row in arcpy.da.SearchCursor(outfileName2, (field))]
    buildCover = [row[0] for row in arcpy.da.SearchCursor(outfileName3, (field))]
    buildFootProp = (sum(buildCover))/(sum(bufferArea))
    openSpaceProp = (1 - buildFootProp)*100
    # Append data for specific buffer distance, to chart for specific station
    stationWise_data.append(openSpaceProp)
    print("Calculated data for distance %dm, Foo Bar!" % (dist))
    # Write Data to Spreadsheet
    print(stationWise_data)
    with open('%s.csv' % (Station_set), 'a') as csvFile:
        writer = csv.writer(csvFile, lineterminator = '
')
        try:
            writer.writerow(stationWise_data)
        except:
stationWise_data[0] = ID
writer.writerow(stationWise_data)
dist = str(dist)
csvFile.close()
return

if __name__ == "__main__":
    main()
Fear follows form: a study of the relationship between neighbourhood type, income and fear of crime at train stations

Abstract

In pursuing fear-reduction strategies in public transport, the total experience of accessing rail stations should be taken into account. This article correlates passengers’ fear of crime at stations with neighbourhood types and income data within the pedestrian catchment area. The research is based on data on land use around 84 S-train stations in the Copenhagen Metropolitan area and nine years of passenger surveys on fear of crime at these stations. The study reveals a significant positive correlation between low income and fear of crime: the lower the income in an urban area, the more unsafe passengers feel at the station. When controlling for the relationship between income, safety and neighbourhood type, if the population around a station has equal, fixed income levels, then stations in neighbourhood types associated with low incomes have the lowest ratings of safety. This indicates that train passengers’ sense of security is connected to neighbourhood type and the city’s
physical characteristics. This is an important finding for urban designers and planners working on the integration of public transport and station design in urban areas.

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1 Introduction

Recent passenger surveys in Copenhagen and previous international research shows that passengers’ fear of crime in public transport is higher than in other public spaces and much higher than the actual risk of becoming a victim of crime (Københavns Kommune, 2019; Cozens & Van der Linde, 2015; Ceccato, 2013; CrimeConcern 2004; Warr, 2000). Research has demonstrated how passengers’ fear
of crime at railway stations and crime patterns can be linked to the characteristics of the urban environments that surround the stations (Uittenbogaard, 2014; Ceccato, 2013; Loukaitou-Sideris, 2005). This influences travel choices, such as walking to the station and choosing the means of transportation and the time of travel (Liggett et al., 2001; Loukaitou-Sideris et al., 2002).

When train stations in general are perceived as unsafe urban locations, it presents a significant societal problem since a cornerstone of environmentally and socially sustainable societies is the ability of citizens to move freely within and across the city by public transport (Ceccato, 2013).

This article explores how passengers’ experience of fear of crime at train stations relates to the surrounding urban area. Previous research on this theme has established a relationship between station neighbourhood typologies and passengers’ fear of crime (Strandbygaard, forthcoming). However, socioeconomic factors are influential in determining an individual’s experience of fear of crime (Farrall et al., 2007; Doran & Burgess, 2012). Therefore this article provides an analysis of the relationship between income, urban form and fear of crime in order to contribute to the body of knowledge in the field and to analyse their separate influence on fear of crime at S-train stations.

The research is based on 84 S-train stations in the Copenhagen metropolitan area and their passenger catchment areas (PCAs) or in Danish, ‘Det stationsnære område’
(the urban area near the station) (Hartoft-Nielsen, 1997), as well as a walking distance of 800m or a half-mile radius around the station (Cervero et al., 2017). This research combines typo-morphological\(^1\) analysis of station neighbourhoods\(^2\) within each station with income data for the PCAs and the passenger surveys of fear of crime.

The data on passengers’ fear of crime come from nine years of quarterly surveys at S-train stations: 125,449 passenger surveys from the DSB (Danish State Railways) and Passenger Pulse, an independent transport survey organization. The survey is based on the passenger’s most frequently used departure station. Approximately 80% of all S-train passengers either walk or cycle to the departure station and thus experience the surrounding urban area (Trafikstyrelsen, 2009). Furthermore, the S-train stations are open unmanned platforms with visual contact with their surroundings and a part of the free urban flow. This integral layout makes it relevant to turn the analysis of fear of crime at these stations in the direction of the surrounding urban area.

The aim of this research is to analyse the connection between the urban layout and the experience of train stations, and thus contribute to knowledge about passengers’ experience of train stations. Data on this relationship can support decision-makers

\(^1\) That is, grouping urban patterns into typologies and classifying them.
in the transport industry in creating better stations and transit areas by recognizing that urban parameters influence passengers’ experiences of train stations.

The study consists of a string of analyses. The first one defines the station neighbourhood types and the second compares them to the passenger surveys on fear of crime at stations. The third analysis defines the relationship between income and station neighbourhood types, and the last is a correlation between fear of crime at the station, station neighbourhood types, and income.

The article is organised as follows. Section 2 outlines the theoretical background and describes the social and environmental factors that influence fear of crime, followed by examples of research on urban typologies and socioeconomic factors. Section 3 presents the case study and the preliminary work on the typologies. Section 4 describes the data and methodology used. Section 5 presents the results and discusses the relationships between income levels, fear of crime and neighbourhood types. Section 6 provides a summary of the research results while section 7 discusses the limitations to the study. The paper ends with section 8, recommendations for future research.
2 Theory and literature review

2.1 Fear of Crime

‘Fear of crime’ is defined as ‘the fear of becoming victim of crime; the perception of the risk of becoming a victim of crime; feelings of safety; perceptions and responses to the threat of crime and criminal victimization; worry, concern and anxiety about victimization and crime,’ (Vanderveen, 2006, p.18). ‘Fear of crime’ is a broad term that covers the feelings of both anticipated fear and actual fear (Garofalo, 1981), or formless fear and concrete fear (Ferraro & Grange, 1987), where the formless or anticipated fear does not relate to any particular crime. Fear of crime is not necessarily related directly to symbols of crime (such as broken windows or syringes left on the ground), but may also be linked to feelings of anxiety or low perceptions of safety due to the nature of the local urban layout, such as dark or deserted areas (Painter, 1996; Doran & Burgess, 2012).

The fear of crime may reflect a state of anxiety caused by the impact of different social factors: thus, low socioeconomic status is connected with fear of crime. Several theories and hypotheses posit this relationship: for example, demographic theories examine whether individuals’ fear of crime is associated with previous experiences of crime or feelings of vulnerability (Farrall et al., 2007; Doran & Burgess, 2012). The ‘victimization hypothesis’ posits a positive relationship
between direct experience of victimization and fear of crime (Skogan & Maxfield, 1981; Doran & Burgess, 2012). The ‘Indirect Victimization Hypothesis’ recognizes that ‘non-victims’ also experience fear of crime under the influence of what they hear of others’ encounters with crime. This also relates to the exposure to crime through social networks, the media and to interpersonal communication in social media (Taylor & Hale, 1986; Hanson et al., 2000; Doran & Burgess, 2012). The ‘vulnerabilities hypothesis’ assumes that different sociodemographic groups have different experiences of fear of crime. This theory addresses exposure to risk, loss of control and the seriousness of the consequences of this for your life – the more vulnerable you are, the greater the consequences (Killias, 1990; Warr, 2000).

Skogan and Maxfield (Skogan & Maxfield, 1981) separate social vulnerability from physical vulnerability. Physical vulnerability refers to one’s ability to resist an attack and recover from it. Social vulnerabilities reflect the individual’s position in society and include income, residential status, educational level, ethnic background, whether one lives alone and previous experiences of victimization. Social theories relate to the social environment surrounding the individual and focus on the influence of different social factors in the individual’s environment: thus Shaw and McKay’s ‘social disorganization hypothesis’ (Shaw & McKay, 1942) linked delinquency rates to community characteristics. This theory has since been extended to cover the fear of crime as well (Ralph B. Taylor & Covington, 1993).
A number of surveys investigating the relationship between socioeconomically deprived residential areas and fear of crime have been conducted in the Nordic countries, confirming the research outlined above. The annual report of the Danish National Police, Tryghedsmålinger 2018 (Rigspolitiet, 2018a) 2018b, shows that people in so-called SUB areas (especially vulnerable urban areas) have higher levels of fear of crime than in other parts of Denmark. A report by the Swedish National Council for Crime Prevention indicates that women and men are more exposed to violence in socioeconomically vulnerable areas, and that women in these areas are more afraid than women in other urban areas (BRÅ, 2018, p. 23). These surveys underline the fact that low-income areas have higher levels of fear of crime.

2.2 Environmental factors: the built environment and fear of crime

Environmental factors, especially the relationship between the built environment and fear of crime, have become an area of increasing interest within criminology (Ryan et al., 2010; Doran & Burgess, 2012; Ceccato, 2015). Based on Crime Prevention Through Environmental Design (Jeffery, 1971; Newman, 1972) and theories of urban form, the following five parameters are suggested in order to present an overview of the body of knowledge connecting the built environment with fear of crime. The characteristics are embedded in the neighbourhood typologies (Strandbygaard. forthcoming).
First, natural surveillance, or ‘eyes on the street’ (J. Jacobs, 1961), monitoring residents and non-residents alike, can support positive normative behaviour through social control and thus lower the fear of crime (Jeffery, 1971). This is supported by mixed land use with activities in the street day and night. The ability of residents to see each other through windows, entrances, balconies and so forth supports the surveillance (Felson et al., 1998; Desyllas et al., 2003). Second, visual guidelines and clear demarcations between public and private spaces encourage residents to assume ownership and control of their own areas. This encourages normative behaviour and thus enhances feelings of safety (Jacobs 1961; Newman, 1972; AGIS, 2007). Residential status has an influence here, as areas of home ownership exhibit higher levels of territoriality and social control than areas of rented accommodation (Greenberg et al., 1982).

Third, spatial qualities and human scale are also significant. Out-of-scale areas can be perceived as unsafe, possibly leaving residents feeling exposed and under hostile surveillance (A. B. Jacobs, 1993; Knöll et al., 2018; Gehl, 2010). Enclosure defines spatial qualities, creating a visual overview related to feelings of safety. The sense of enclosure is eroded if the streetscape is discontinuous, with vacant lots, parking lots, lawns or buildings set back from the road (Cullen, 1961). An enclosure ratio ceases to be comfortable somewhere around 1:4, while beyond 1:6 the feeling of being enclosed disappears (Spooner, 1995; Harvey et al., 2015). Complexity, beauty and robustness are key visual and sensory qualities linked to senses of territoriality and
ownership (Jacobs, 1993; Gehl, 1971). Fourth, maintenance signals community cohesion, reveals the norms followed by local residents and indicates whether anyone will intervene in the event of a crime (Goffman, 1972; Wilson & Kelling, 1982). Fifth, light has an overwhelming effect on perceptions of safety, as without it, it is not possible to see what might be lurking in the darkness (Peña-García et al., 2015). All of these parameters influence residents’ perceptions of safety in the built environment and are embedded in the different types of station neighbourhood. Neither maintenance nor lighting is incorporated into the present analysis, as they both require a detailed, micro-level investigation of urban areas that differs from the typo-morphological analysis of the urban fabric surrounding stations that is addressed in the present research.

2.3 The relationship between neighbourhood and socioeconomic structure

Urban typo-morphology classifies urban space into types based on detailed classification by the types of the elements that shape its urban form: streets, plots and buildings, and to follow variations and mutation over time (A.V. Moudon, 1992; Anne Vernez Moudon, 1994). The interest in urban typologies and socioeconomic structures is rooted in urban sociology and the work of the Chicago School, for which the city was conceived as a mosaic of urban areas containing different socioeconomic residential groups (Park & Burgess, 1925). Swedish urban typo-morphologists argue that neighbourhood type encompasses not only density variables in the form of residential densities (Rådberg & Friberg, 1996), but also social structure and development tendencies (Engström, 1988; Stojanovski, 2018).
Neighbourhood type is an aggregate variable that incorporates building types, their use and history, the spatial qualities of public spaces and street networks. It is argued that this mosaic of neighbourhood types is correlated with the socioeconomic status of its residents (Engström, 1988). Following up on research into Swedish typologies, in 2011 the Swedish company Spacescape made a graphic visualization of how neighbourhood types in Stockholm are related to socioeconomic status and certain urban qualities (parks, playgrounds, libraries, public transportation, street crossings, etc.) (Bremberg et al., 2015). Figure 1 shows that suburbs dating from 1960-1990, indicated by the purple dots, have fewer urban qualities and a lower socioeconomic index than the detached housing estates indicated by the green dots or inner-city areas indicated by the orange dots at the top of the Y axis.

Others have sought to establish a systematic quantifiable method of analysing urban form and determining the morphological parameters that support the neighbourhoods’ gentrification process (Venerandi et al., 2017). Their findings show that ‘sanctuary areas’ of fine-grained, perimeter block-based urban form with low traffic levels characterize gentrified neighbourhoods. These areas share many of the same characteristics as Jacobs and Appleyard’s ‘good’ urban districts (A. Jacobs & Appleyard, 1987) consisting of well-managed environments that are relatively devoid of nuisance.
The illustration is translated into English. (Bremberg et al., 2015, p.60).

3 The case study and background analysis

This section presents the case study, the definition of neighbourhood typologies and their location in the Copenhagen metropolitan area in order to provide the reader with a historical and geographical context.

3.1 The case study

The research is based on case studies of S-train stations in the Copenhagen metropolitan area. The S-train system is the urban rail system in the so-called ‘Finger Plan’, a regional infrastructural plan for the post-war development of Copenhagen from 1947 (Knowles, 2012; Egnsplankontoret, 1947) that largely
guided development in the region thereafter. The Finger Plan resembles a hand placed over a map of Greater Copenhagen (Fig. 2): the S-train system runs along the five fingers based on existing train lines and main roads. The system has seven lines, 170 km of track and 84 stations. It covers the entire metropolitan area and therefore includes all types of urban planning and socioeconomic structures.

Figure 2. The Finger Plan (Byplanlaboratorium, 1993, front page)

3.2 Classifying and mapping station neighbourhood types

In a previous study, station neighbourhood types were classified and mapped on the basis of their building types, their use and history, the spatial qualities of public
space related to fear of crime, and the street network (Strandbygaard, forthcoming). The three main neighbourhood types are: A, Dense Urban Area; B, Coherent Suburb; and C, Fragmented Suburb (Fig. 3). The neighbourhood types are outlined in ArcMap by displaying only the buildings’ footprints or figure-ground plans in order to reveal the degree of urban compactness, that is, the distances between volumes and their sizes, how they define streets and urban spaces and the degree of enclosure. The street network, the plot and the buildings’ use and time of construction also determine the building typologies. Public buildings or monumental elements belong to the typology within which they were built and planned (year and building style). As the focus of this study is the station, the public space surrounding the station entrance, defined by a degree of visual proximity of approximately a hundred metres, identifies the neighbourhood type. If the main area of the 800 m walking radius belongs to the same type, it becomes a main type. The neighbourhood types also have subcategories for cases in which the urban fabric can be defined mainly as type A, B or C, but also contains significant elements of one of the other patterns. Thus, if the area surrounding the station is classed as A and the minor element is C, a small letter ‘c’ is used to denote the latter, resulting in a subcategory marked ‘Ac’. In these cases there must either be a substantial number of building elements from another typology or they need to be sufficiently central to the station entrance to exert an influence over the urban area and thus denote the neighbourhood type.
Figure 3. Examples of the three main station neighbourhood types.

Type A, the **Dense Urban Area**, mostly consists of five-storey courtyard building blocks with closed internal courtyards and streets with an enclosure ratio as high as 1:2, the street being ten metres wide and the building twenty metres high. In central
Copenhagen this type dates back to the seventeenth century, while the urban areas to the south, east and north-east of the city centre were built for the working classes in the nineteenth and twentieth centuries. Type A has windows towards the street, cafés or shops on the ground floor. There is a high degree of building compactness, and in many areas a high level of urban activity and natural surveillance. This urban typology has a high level of urban activity and natural surveillance, features that relate to the experience of safety.

Type B, the Coherent Suburb, has a considerably lower degree of compactness than the Dense Urban Area. Most of the building mass consists of one- to two-storey detached single-family housing. The building footprints are small and are spread out in a homogeneous pattern, with elements juxtaposed in a consistent manner. Most of these areas close to Copenhagen were built between 1900 and 1950, when the age of the car had not yet arrived and the building industry had not yet become industrialized. This building typology has front gardens with trees and hedges along the sidewalk creating a clear demarcation between private and public spaces. The scale is human, and there are high levels of territoriality and visual diversity, as well as clearly defined spaces. This points towards an urban typology associated with perceptions of safety, despite the relatively low level of urban activity.

Type C, the Fragmented Suburb, differs from the other types in having larger areas of open space in between the building mass. The spatial hierarchy is diverse, the
organization of the building footprints open. This neighbourhood type stems from post-war development continuing up until the present day and consists, among other building typologies, of apartment blocks and social housing projects with common green areas. The scale of the infrastructure for cars has set the standard for these urban areas (Nielsen, 2008). Large-scale parking requirements, combined with planning ideals about single-use areas, open green spaces and segregated traffic, have generated low building densities, a low feeling of enclosure and low levels of social control, streetscape features associated with low perceptions of safety.

3.3 Spatial distribution of neighbourhood types in the Copenhagen metropolitan area

The map of neighbourhood types according to the definitions in section 3.2 and their location in the metropolitan area (Fig. 4) shows that type A, the Dense Urban Area, is concentrated in the centre of Copenhagen, the oldest and densest part of the capital. Type B, the Coherent Suburb, is the next layer of building typology around the central urban area, extending to the north. Before the 1950s, before private cars shaped urban planning, residents who could afford their own houses and gardens moved here and into the hilly and popular northern area close to the beaches and forest. In the 1950s, the western and southern parts of Greater Copenhagen had large areas of undeveloped land, and this led to an extensive distribution of both public housing and industry as part of the modernist-inspired post-war expansion of
Copenhagen. Thus, type C, the Fragmented Suburb, is the most characteristic of these areas. This map provides a geographical overview of the initial results.

Fig 4. Neighbourhood types in the Copenhagen metropolitan area.

4 Methodology

The following briefly describes the passenger survey used to measure fear of crime at stations, the method for estimating and visualizing the neighbourhood typologies'
level of fear of crime, and finally it describes the income data and how they are connected to neighbourhood typologies.

4.1 The passenger survey: fear of crime at S-train stations

The data on experiences of safety at train stations used here come from nine years of quarterly passenger surveys. The passenger survey dataset has two sources: DSB conducted 87,545 interviews in 2009-2015, while Passenger Pulse (Forbrugerrådet Tænk, 2019) conducted 37,904 interviews in 2016-2018. The questionnaire used was the same, but the survey was taken over by an independent organization to ensure that the data would be made publicly available. The survey is handed out every quarter to approximately two thousand representative passengers on S-train platforms between 6 am and 10 pm. The questionnaire asks about general satisfaction with public transport, with one question eliciting passengers’ perceptions of safety at the station. Passengers are asked to rate their feelings of safety at their most frequently used departure station on a scale from 0 to 10, 0 being unsafe and 10 being safe. Both data suppliers concur that a rating of 7-8 is considered a healthy station and that 5-6 is a low rating for a station.

The passenger survey is based on individual passengers’ experiences of fear of crime at their departure stations, but the many years of data, the station layout and the high level of passengers walking and biking to the station also makes it possible to use the survey as an indicator for passengers’ experiences of their station neighbourhoods.
4.3 Fear of crime in relation to station neighbourhood types

In order to demonstrate the probability of each neighbourhood type being perceived as safe, a probability density graph of safety and station neighbourhood types has been drawn up. The passenger survey provides data on mean safety perceptions at each station from January 2009 to September 2018. An estimate of a probability distribution (a kernel density estimate or KDE) is made for each of the neighbourhood types A, B and C.

4.4 Income in relation to station neighbourhood types

The relationship between income and neighbourhood type is visualized in a probability distribution of income for each of the neighbourhood types A, B and C. The income level per capita is used as a key indicator of socioeconomic status. The income data are drawn from Statistics Denmark (Statistics Denmark, 2019) for 2015 and are aggregated for each of the 84 station neighbourhoods. The income data from Statistics Denmark for 2015 is displayed in a 100m x 100 m grid income map of station neighbourhoods as illustrated in Figure 9. Grids without colour have fewer than fifty individuals and are therefore illegal to record in order to protect anonymity.
5 Results

5.1 Fear of crime in the different station neighbourhood types

The three curves in Figure 6 show the probability of each neighbourhood type being perceived as safe as described in section 2.3. The green curve, Coherent Suburb neighbourhood type B, is perceived as the safest, having the highest mean perceptions of safety (7.71). The yellow curve, Fragmented Suburb, type C, has a mean value of 7.35, being the lowest of the three main types.

Fig. 5. Densities of the three different types being perceived as safe, 2009-2018.
5.2 Income levels of the different station neighbourhood types

Figure 6 shows income levels for the different station neighbourhood types. There are clear similarities with the graphs visualizing levels of fear of crime in Figure 5. Figure 6 shows that types A and B have almost the same income levels with wide spans between them, while type C generally has low-income levels.

Figure 6. Densities of income from 2015 for each station neighbourhood type
5.3 Urban form and income patterns

Figure 7.1 Colour indications of income per capita

Fuglebakken, type Ab, between to income areas in Copenhagen city.
Albertslund, type C, west of Copenhagen
Charlottenlund, type B, north of Copenhagen
Figure 7. Examples of patterns of urban form and income: station neighbourhood types: Fuglebakken, type Ab. Albertslund, type C, and Charlottenlund, type B.

The visualization of the relationship between urban form and income in Figure 7 shows how patterns of urban form are directly related to levels of income. The differences are caused by single family houses being more expensive to live in than apartments, or by ownership most often requiring a higher income than renting. Some geographical areas are associated with high social status, such as north of Copenhagen, and therefore the colours of high income are an even darker blue (see Figure 4).

5.4 Levels of fear of crime at stations in relation to neighbourhood incomes

The relationships between station neighbourhood types, fear of crime and income levels are illustrated in Figure 8. There is generally an increase in feelings of safety in high-income areas, although there are also quite large local variations (R2 only 0.24).
Figure 8. The relationship between stations’ income levels in 2015 and fear of crime at stations in 2009-2018.

Figure 9 shows the relationship between fear of crime and levels of income distributed among the three urban types, while Table 1 presents statistics for the three types. As can be seen, there is a tendency towards a lower fear of crime in higher income areas within each type. Types A and B have a higher trend-line than type C, meaning that, if the population around a station has equal, fixed income...
levels, then stations in areas of type C feel less safe than stations in types A or B areas. All stations of type A (with the exception of Nørrebro) are located in a quite narrow interval of high-income areas (annual incomes of around DKK 190K to 240K). The interpretation must be that these areas are more attractive. Since the income range is so narrow, there is hardly any relationship between income and fear of crime for this type (R2 is close to zero). There are more type B stations in the dataset, and the income range is greater than in type A (from around DKK 170K to 250K). Observations of type A fall almost completely within the variation of type B, hence there is no evidence for differences between these two types and fear of crime. Within type B, there is an increasing feeling of safety when income levels rise. When correcting for income level, Type C is characterized by a lower level of perceived safety compared to the other two neighbourhood types. Type C is generally characterized by low-income areas, although in a wide range from DKK 120K to 220K. One clear conclusion is that type C areas are less attractive and hence are populated by groups with lower incomes than the other two types. However, the fear of crime is higher in neighbourhood type C than the low income levels would indicate.
Table 1. The three types A, B and C, the number of stations in each category, their mean safety scores and standard deviations.

<table>
<thead>
<tr>
<th></th>
<th>Count</th>
<th>Mean</th>
<th>Sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Income</td>
<td>17</td>
<td>198.458</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td></td>
<td>7.63</td>
</tr>
<tr>
<td>B</td>
<td>Income</td>
<td>32</td>
<td>207.951</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td></td>
<td>7.71</td>
</tr>
<tr>
<td>C</td>
<td>Income</td>
<td>35</td>
<td>177.404</td>
</tr>
<tr>
<td></td>
<td>Safety</td>
<td></td>
<td>7.35</td>
</tr>
</tbody>
</table>
Fig. 9. The relationships between fear of crime, income levels and station neighbourhood types.

The linear distribution of types shows that the stations that are perceived as less safe are those with the lowest income levels (Fig. 9). However, there are outliers in the graph: for example, Nørreport station (type A, Dense Urban Area) is an old underground station with a high number of passengers, 111,005 a day in 2015.
(metro, buses and regional trains not included). The platforms are narrow, the tunnels noisy, and passengers’ fear aspects are associated with the characteristics of a congested station, so this outlier was expected. Carlsberg is a new station in a popular urban area. Åmarken station should have a low fear of crime according to its socioeconomic level, but the station area is type C, and this could account for the higher level of fear. The station is close to a busy road, drawn away from urban activities with a large parking lot both in front of and behind the station. The station had only 2,500 passengers a day in 2015, which makes the area deserted outside peak hours. At Åmarken station the effect of the built environment stands out from the effect of income. A micro-level analysis of Åmarken is required to be able to assess in greater detail the influence of local characteristics on passengers’ fear of crime.

Lastly, in order to analyse the relationship between fear of crime, neighbourhood type and average income levels simultaneously, a multiple regression analysis was carried out. The results show that income levels and feelings of safety are significantly positively correlated, as an increase in the average income of DKK 100,000 a year results in a 0.419 increase in the perceived safety level. At the same time, stations of type C have a 0.33 lower score for perceptions of safety than those of types A and B.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-6.908**</td>
<td>24.54</td>
</tr>
<tr>
<td>Type C</td>
<td>-0.3335**</td>
<td>-3.93</td>
</tr>
<tr>
<td>Income (1,000 DKK)</td>
<td>0.00419**</td>
<td>3.15</td>
</tr>
<tr>
<td>N</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.421</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. A multiple regression table of station types, income and fear of crime. *p<0.05, ** p<0.01.

6 Conclusion

This article has investigated the correlations between neighbourhood type, incomes and fear of crime at train stations in the Copenhagen metropolitan area. The spatial characteristics of the station neighbourhood types suggest that type C, Fragmented Suburb, is more vulnerable to fear of crime than the other neighbourhood types, both in general, but also when adjusted for socio-economic level. Furthermore, residents in type C areas have the lowest incomes and thus, according to social theories explaining fear of crime, are also more vulnerable. Types A and B have almost the same income patterns, but type B, Coherent Suburb, is perceived as the safest station neighbourhood type. Type A, Dense Urban area, is regarded as relatively safe except for a few outliers.

Although the correlation between income levels in the station neighbourhood and fear of crime at the station gives weight to social theories of fear of crime, the
The present study also underlines how tightly socioeconomic structures and the built environment are woven together. The strong relationship between the typologies of urban form and household income levels illustrate how inequalities in living conditions are influenced by space and architecture, as the built environment may or may not favour the experience and use of urban space. The impact of the built environment on fear of crime is supported by the significant result that, in neighbourhoods with the same income levels, passengers’ fears of crime follow the neighbourhood typology. Thus, the results indicate that passengers’ experience of stations are influenced by the surrounding urban area.

7 Discussion

The findings of this research support previous results on urban types and income (Bernow et al., 2011). Furthermore, the relationship between fear of crime, neighbourhood type and income in relation to passengers’ experience of stations emphasizes the influence of urban form on our daily lives.

The typological approach is used in research on traffic planning to estimate circulation and travel flows, place characteristics and accessibility (Stojanovski, 2018). This article supports this knowledge by addressing fear of crime within this methodological context.

The growing international interest in Transit Oriented–Development (TOD) design guides emphasizes the influence of urban layout within a 800 m radius of the station on the use and integration of public transport (Thomas et al., 2018).
Lastly, it is important to acknowledge that many other parameters than urban type or socioeconomic structure influence passengers’ perceptions of safety, such as the media, hearsay about an area, actual crime and street-lighting. Therefore, the results of the analysis are an indication only and must be interpreted with caution.

8 Recommendations

The methods applied in this study can support planners and decision-makers in strategically developing train stations through an integrated approach that includes the design of the neighbourhood and that addresses the advantages and disadvantages of the types presented. The typomorphological methodology can identify vulnerable urban layouts and provide strategies for the transformation of these areas, like densification, streetscape design and street networks and flows, to support the use of public transport, walking and bicycling to the station and enhance the perception of safety. This not only decreases car dependency and cuts down carbon emissions, it also creates better urban environments for citizens to meet.

Suggestions for future research include analysis of viewshed distance within the station area to see how the different station neighbourhood types perform according to TOD design guidelines. Although the U.S. TOD strategies would need

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3 The visual distance of approximately 100 meters from the station platform
modification for purposes of Danish planning practice and culture, the guidelines could potentially support station neighbourhood typology C in the S-train system.

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https://innovationsfonden.dk/en/about-innovation-fund-denmark#accordion1552

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https://doi.org/10.4135/9781412959193.n281
Abstract
This article analyses the immediate surroundings of S-train stations in Copenhagen’s regional development plan, the ‘Finger Plan’, in accordance with ‘ideal’ Transit-Oriented Development (TOD) design guidelines. The results suggest that, while the Finger Plan provides a regional-scale public transport network, it is not supported by the pedestrian scale of urban design at S-train stations. Placemaking and especially safety at the stations are deficient, findings supported by passenger surveys. The research results stress the importance of attending to the pedestrian experience of regional scale TOD and makes the initial draft of modifications to TOD design guidelines to accommodate Danish planning practice.

Key words: Transit-Oriented Development, the Copenhagen region, urban design guidelines, the Finger Plan, passengers’ fear of crime, post-war regional planning


Introduction
The concept of Transit-Oriented Development (TOD) (Calthorpe 1993) is receiving increasing attention currently outside the U.S., as planners from all over the world are using TOD to guide urban developments around train stations and major bus stops to encourage the use of public transport. The aim is to create socially and environmentally sustainable communities with dense urban structures, mixed uses and walkable environments within a five- to ten-minute walk around the station (Curtis 2008; Guerra, Cervero, and Tischler 2012; Pojani and Stead 2015; Lyu, Bertolini, and Pfeffer 2016; Niu et al. 2019).
TOD aims to create communities that are less dependent on cars. In the U.S. the car had already become the favourite means of transportation by the 1920s, shaping not only urban planning but also the whole of American culture, but in Europe the old dense urban structures had integrated railways and stations (Renne and Wells 2004). After WWII, moreover, many European cities expanded their rail corridors to accommodate the expected post-war urban growth, which ensured public transport on a regional level (Staricco and Brovarone 2018). Among these post-war plans was Copenhagen’s celebrated Finger Plan (Robert Cervero 1998; Knowles 2012; Staricco and Brovarone 2018). The Finger Plan resembles a hand placed over the image of greater Copenhagen (Egnsplankontoret 1947, front page). The palm of the hand is Copenhagen, with 620,000 residents in 2019, while the fingers are the various regional developments, covering a total of 1.8 million residents, including the central area. The local commuter rail system, the ‘S-train’, runs through the fingers, supplemented by buses, metro-lines and some of the best cycle paths in the world (Pucher and Buehler 2008; Gehl 2010). The newest addition to the network is the metro’s City Line, while a forthcoming light rail system across the ‘knuckles’ (Figure 1).

The regional plan has provided its residents with access to rail infrastructure within the last seventy years; in this respect, it works as a realization of modern regional TOD principles. However, contrary to what might be expected, the S-train system has a modest 5% transport share of travel distance in km per person per day in the region (TU DTU 2019, 3 p.6). As will be argued later there are many possible explanations for this. However, what is of interest for this analysis of TOD design are passenger surveys from 2009-2018 conducted by the DSB (Danish State Railways) and Passenger Pulse (Forbrugerrådet Tænk 2019) showing that many passengers feel unsafe at S-train stations. Copenhagen’s safety index for 2019 shows that perceptions of the safety of
urban areas around S-train stations are below average for a public space, and respondents rate S-train stations as among the most unsafe places in the city (Københavns Kommune 2019, p. 13).

To elaborate on the results of the passenger surveys mentioned above, in 2018 Passenger Pulse carried out a detailed passenger survey focusing solely on passengers’ experiences of safety at S-train stations (Passagerpulsen 2018; Passagerpulsen 2019). This survey indicates that fear of crime or the absence of urban qualities at stations may influence transport share. It is this survey that has prompted the following analysis based on guidelines from TOD.

The objective of this article is to investigate how public spaces within the TOD of the S-train stations on a pedestrian urban-design scale support the use of public transport. The analysis covers public spaces in visual proximity to the stations, that is, up to approximately 100 metres around the station (Stojanovski 2019). The method is based on previous case-study research of TOD (Pojani and Stead 2015). The analysis covers thirteen S-train stations, two of which are presented here. The results are compared to passengers’ comments from the survey to determine whether the TOD dimensions are correlated with passengers’ perceptions of urban space.

The present article exposes the challenges and strengths of Danish planning practice at S-train stations by looking through the lens of the international TOD guidelines. The analysis contributes to the academic debate on these guidelines for planning practice and brings forward possible shortcomings in post-war public transport networks.

The article first briefly describes the design principles associated with TOD and the adaptation of TOD to international contexts, followed by a short introduction to the ‘Finger Plan’. The methods section describes the case-study examples and the passenger
surveys. The methodological framework for the analysis forms part of the results section, where a scheme of thirteen case studies is used to evaluate the TOD guidelines in relation to the Danish context. The two illustrated examples of local urban-design solutions for S-train stations are evaluated in relation to the TOD guidelines and compared to passengers’ comments from the passenger survey. The discussion relates the issues of governance, ownership and historical causation to the findings. The conclusion sums up the results.

**Background**

**Transit-Oriented Development**

The car is the main factor in American urban development, and the American culture of mobility and the urban planning history that created the background for TOD is quite different from the European. European urbanization is older, has significantly higher urban densities, a higher number of work trips made via public transport, and more people commuting by bicycle or on foot (Renne and Wells 2004). In many ways, the concept of TOD is a repackaging of what was once the traditional city layout (Jacobson and Forsyth 2008; Qviström and Bengtsson 2015; Robert Cervero, Guerra, and Al 2017; Staricco and Brovarone 2018).

It is important to note that a large proportion of the TOD guidelines are universally applicable to contemporary urban planning due to their focus on the social experience of urban space and lends from concepts such as ‘placemaking’ (Gehl 1971; Whyte 1980; Appleyard 1981; Placemaking 2019) and ‘walkability’ (Ewing and Handy 2009; Jeffrey et al. 2019). The safety dimensions of the guidelines are related to ‘Crime Prevention through Environmental Design’ (CPTED) (Newman 1972; Cozens, Saville, and Hillier 2005), which addresses issues such as avoiding poor lighting, entrapment, or the feeling
These concepts are integrated or partly integrated into the TOD guidelines.

**TOD design principles outside the U.S.**

The interest in TOD has flourished worldwide, and cities with little resemblance to U.S. urbanism such as Singapore, Hong Kong and Tokyo are implementing the TOD guidelines (Zacharias, Zhang, and Nakajima 2011; Chow 2014; Niu et al. 2019).

A Dutch study by Pojani and Stead (Pojani and Stead 2015) reviewed the TOD guidelines with the aid of a forum of Dutch planners. The TOD methodology builds on the case-study research of Jacobson and Forsyth (Jacobson and Forsyth 2008) by providing a systematic overview of the TOD guidelines based on the general literature on ‘good practices’ drawn from case studies of TOD developments in the USA (Ewing 1996; R. Cervero; Ferrel, and Murphy 2002; Dunphy, Myerson, and Pawlukiewicz 2003; Porta and Renne 2005; Ewing and Bartholomew 2013). Jacobson and Forsyth evaluate the guidelines through a comparative analysis of seven American TODs. This framework and additional TOD literature (Calthorpe 1993) formed the design guidelines and principles for the Dutch comparative study, as well as a comparative analysis of Beijing by Kong and Pojani (Kong and Pojani 2017), and they also form the methodological background to this study.

The two comparative analyses show similarities in their preferences for relating TOD design to basic human needs, such as human activities in urban spaces, safety, pedestrian comfort and scale, visual variety, natural elements and complexity. However, specific design aspects are linked to national and cultural ideas and practices and require adaptation to local conditions. For instance, Beijing has a much higher urban density than Western cities, there is a strong tradition of mixed uses and street vending, the
sidewalks are wider, and personal security is less of a concern. Examples of the Dutch adaptation of TOD include a recommended TOD radius of two to three kilometres to accommodate the impact of cycling, moderate building heights, a regional TOD hierarchy, urban design related to the retrofitting of existing stations, and heritage protection.

Figure 1. Copenhagen’s public transport rail network. The letters A-M refer to the sample stations used in the methods section. Source: UrbanRail.net
The Finger Plan

The main idea behind the Finger Plan was to have dwellings within walking distance of train stations, which is also the basic principle of TOD. It ended Copenhagen’s concentric peripheral expansion and replaced it with a radial, star-shaped expansion (the hand forms half a star) based on both existing and new rail networks. The fingers connect the villages in the region and support urban development close to the train stations. The Finger Plan of 1947 was never formally endorsed as a legal planning document, but it was used to provide guidelines for the expansion of Copenhagen (Byplanlaboratorium 2006) until 2007, when it was made into a formal regional planning document (Miljøministeriet 2007).

The Finger Plan accommodated urbanisation in the post-war period at a time when few Danes had a car. Expanding the radial infrastructure would transport workers from their dwellings in the suburbs into the city, like other post-war regional public transport networks at that time.

Today, the planning directive for the metropolitan area ‘Fingerplanen 2019’ (Erhvervsstyrelsen, 2019) stresses that urban developments should preferably happen within the urban zones (in the fingers and the hand), especially where public transport is concerned (ch. 2, §3. Erhvervsstyrelsen, 2019). Nonetheless, different parameters are challenging the efficiency of the infrastructure of the Finger Plan, one of them being new business developments. From 2000 to 2015 only 62% of new office buildings larger than 1,500 m² in the metropolitan region were built within the pedestrian catchment area of a station (Hartoft-Nielsen 2018, p.124). The problems of getting across or between the fingers requires a modal split of commuting journeys, which reduces the share of travels by public transport (Santos et al. 2013). A study of 48 European metropolitan areas showed that high network connectivity and coverage is
strongly associated with ridership and that a grid-like urban network typology is more efficient than a radial one (Ingvardson and Nielsen 2018). Other influences are the rapidly rising fares (Statbank Denmark 2019) and car ownership (Santos et al. 2013), which has increased in the region as the economy has grown and the taxes on cars have gone down (Statbank Denmark 2019).

Research and statistics offer a number of reasons for transport shares, but one possibly influential parameter not touched upon is the design of S-train stations and their TODs in the Finger Plan.

Methods

Thirteen S-train stations were analysed in accordance with the TOD guidelines, two of which are illustrated in this article.

As mentioned, the methodological background to this analysis is the table of TOD principles and practices identified in the study by Pojani and Stead (Pojani and Stead 2015) (Appendix, Table A.1 and 2).

The focus of this article is on design, therefore the dimensions of ‘process’ are not examined in the case studies.

A partial result of the analysis is a list of the TOD topics and dimensions that need adjusting to accommodate the Danish planning context.

The case-study examples

None of the case-study examples are from the central Copenhagen area (the palm of the hand), as this has a very different urban structure and planning background than the fingers.

The two sample S-train stations presented here are on the same railway line. They represent two different types of neighbourhood planning for S-train stations.
Brøndbyøster was built on bare fields in the 1950s. Tåstrup S-train station, conversely, dating from the 1960s, is part of an old village structure. The analyses of the two examples are supplemented with passengers’ comments on the station from the passenger survey of perceived safety.

An illustration of twelve S-train station parking areas (Figure 2) exemplifies the planning tendency in the Finger Plan and relates it to the TOD guidelines.

**Passenger survey on perceived safety at the station**

The passenger survey of passengers’ perceptions of public spaces, pathways, entrances and exits at S-train stations was carried out by Passenger Pulse in 2018 (Passagerpulsen 2018). Details of the survey methodology can be found in the Appendix.

This survey is the only one of its kind to be conducted in Denmark targeting perceptions of safety at stations in relation to other passengers, the urban space and the station’s design features.

**Results**

**A case-study analysis of thirteen S-train stations in relation to ‘ideal’ TOD design**

The table analyses thirteen S-train stations with regard to a number of ‘ideal’ TOD design solutions within visual proximity of the stations.
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</thead>
<tbody>
<tr>
<td>1.1 Ensure comfortable walking distances between points</td>
<td>13</td>
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<tr>
<td>1.2 Place commercial uses, jobs, parks, and civic uses within walking distance of transit stops</td>
<td>12</td>
<td>1</td>
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<tr>
<td>1.3 Taper densities with distance from a station</td>
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<td>0</td>
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<tr>
<td>1.4 Provide sufficient densities to sustain transit investments</td>
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<tr>
<td>Dimension 2: Public spaces for human use</td>
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<tr>
<td>2.1 Design individual parts of the overall plan with human activity in mind: public spaces should be the focus of buildings and pedestrian activity.</td>
<td>10</td>
<td>1</td>
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<tr>
<td>2.2 Add human-scale details</td>
<td>12</td>
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<td>0</td>
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<tr>
<td>2.4 Design public spaces for a sense of “an outdoor room”</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>2.5 Ensure that buildings line the streets and are not isolated in lots, and that main entrances and windows face the street.</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<td>2.6 Provide large shade trees that form continuous canopies over the street.</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2.7 Provide soft transitions from the outdoors to the building</td>
<td>3</td>
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<tr>
<td>2.8 Create attractive landmarks and gateways to the development.</td>
<td>5</td>
<td>0</td>
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<td>Dimension 3: Safety</td>
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<tr>
<td>3.1 Provide physical measures such as good lighting at night.</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>3.2 Control access to nonpublic spaces through fencing, lighting, and landscape.</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>3.3 Avoid blank facades</td>
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<tr>
<td>3.4 Ensure adequate sight lines.</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<tr>
<td>3.5 Avoid tunnels, narrow paths, and other entrapment spots or isolated areas.</td>
<td>3</td>
<td>0</td>
<td>0</td>
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<tr>
<td>3.6 Encourage a variety of uses to ensure round-the-clock activity.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>Dimension 4: Variety and complexity</td>
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<tr>
<td>4.1 Break up long streets with parks and other diverse, colorful, and interesting public spaces.</td>
<td>7</td>
<td>1</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>4.2 Avoid monotony, either in terms of appearance or use.</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>4.3 Avoid uniform planning regulations.</td>
<td>11</td>
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<tr>
<td>4.4 Avoid large billboards, large on-street trash dumpsters, and high light poles.</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
<td>4.5 Create a sense of identity (i.e., a common design vocabulary for buildings and public spaces).</td>
<td>13</td>
<td>1</td>
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<tr>
<td>4.6 Encourage every price point to live around transit, i.e., provide affordable housing options.</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<td>Dimension 5: Connections</td>
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<tr>
<td>5.1 Design relatively small blocks (perimeter limits is 400–450 m).</td>
<td>7</td>
<td>1</td>
<td>0</td>
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<td>1</td>
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<tr>
<td>5.2 Provide pedestrian-friendly street networks</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<tr>
<td>5.3 Avoid cul-de-sacs.</td>
<td>12</td>
<td>1</td>
<td>0</td>
<td>1</td>
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Table 1. The capital letters in front of the station names are mapped on to Figure 1. A station has a number 1 if the dimension is present at the station or 0 if it is not. Based on Pojani and Stead (Pojani and Stead 2015, pp. 133,134) (Appendix. Table A.1 and 2).
The vertical column ‘sum’ shows planning trends. These indicate that the Finger Plan is an example of regional public transport development, as every station is located at the centre of the local neighbourhood, with modal integration through connections between buses and trains (dimensions 7.1 and 7.5). There is a comfortable walking distance between points, and commercial uses, jobs, parks and civic uses within the proximity of the S-train stations (dimensions 1.1 and 1.2). This also shows a strong tradition for people to cycle or walk to a station via pedestrian-friendly pavements, which form a continuous network (dimensions 5.2 and 6.2).

The numbers in the table show that the stations north of Copenhagen (J, K, L, M) date from before 1965 and have pedestrian-friendly environments and a high level of design quality.

The many zeros in the table indicate design obstacles or differences in relation to S-train stations when compared with the ‘ideal’ TOD guidelines. Dimension 3 especially, the perception of safety, has a very low total score.

*The S-train stations fail to meet the following TOD dimensions:*  
Dimension 1.4: ‘Provide sufficient densities to sustain transit investments’. Only a few S-train stations have enough passengers and sufficient urban density to sustain transit investments.

3.2: ‘Control access in non-public space through fencing, lighting, and landscape’. The many 0’s reveal a Danish design tendency to provide open access to areas around buildings.

3.5: ‘Avoid tunnels, narrow paths or other entrapment spots or isolated areas’. Most stations have pedestrian tunnels, tunnel entrances and areas for car parking or other car infrastructure.
3.6: ‘Encourage a variety of uses to ensure round-the-clock activity’. S-train stations are often in urban areas with low levels of urban activity and low densities, making it very difficult to create round-the-clock activity.

*Topics and dimensions that need adaptation to Danish practice*

2.7: ‘Provide soft transitions from the outdoors to the building’, and 2.8: ‘Create attractive landmarks and gateways to the development’. Public transport in Denmark is part of the urban flow, with open, unmanned constructions with no turnstiles or ticket booths. This requires a discussion of the possible disadvantages of the Danish layout.

5.3: ‘Avoid cul-de-sacs’. In the Danish planning context, a more relevant topic than cul-de-sacs is the segregation of traffic. Most modernist areas have segregated traffic networks. As the level of urban activity is low, a shared network would support a higher level of human activity.

6.3: ‘Set maximum and minimum sidewalk widths’. In Denmark, local planning regulations adjust the dimensions of sidewalks to reflect capacity and use.

6.6: ‘Allow two- or four-lane streets maximum’. It is very rare for more than four-lane streets to occur in any urban Danish context.

8: ‘Car movement and parking’. In Copenhagen suburbs with low urban densities and low activity levels, the majority of the car-parking parameters are not relevant.

*Summary of the tendencies in the passenger survey*

An overview of the survey shows that 8% of all the respondents feel unsafe after dark at stations, and 38% sometimes feel unsafe. That suggests that 46% of respondents are
reluctant to use the station after dark (Passagerpulsen 2018, p. 23). This constitutes a problem, as Denmark has limited hours of daylight in the winter (seven hours in December). This can be related to Topic 1, Dimension 3.1: ‘Provide physical measures such as good lighting at night’, and 3.6: ‘Ensure a variety of uses to ensure round-the-clock activity’.

The results of the survey also show that areas that are perceived as unsafe close to stations include underpasses, access to station platforms (often via a tunnel entrance and staircase) and areas around the station that have poor lighting (Passagerpulsen 2018, p. 22). This lends weight to TOD guidelines topic 1, Placemaking, Dimensions 3.1, ‘Provide physical measures such as good lighting at night’, and 3.5, ‘Avoid tunnels, narrow paths, and other entrapment spots or isolated areas’.

The interviewees’ written comments on different aspects of the public transport-oriented environment show that 65% of passengers sometimes felt unsafe on their way to or close to the station. For 17% of respondents the main reason for feeling unsafe was the experience of being alone in the station or of the surrounding area feeling deserted.

Several other factors than the stations’ surrounding area affect passengers’ sense of safety, such as the influence of other people. However, the passenger survey indicates that the urban environment has a significant influence on perceptions of quality and safety.

**Case study: Brøndbyøster**

Brøndbyøster S-train station dates from 1952 and was planned together with the brick-built residential area to its south. The area to its north dates from after 1965, was built using precast concrete slabs, and has taller buildings than the area to its south.
The tracks are on an embankment, the station entrance goes through a tunnel, as is typical of S-train stations, and trees and shrubbery surround the platform, so that there is little or no visual contact with its surroundings. There is a kiosk on the platform, which only a few other S-train stations have. Most stations either have a small convenience store at ground level or are unmanned with vacant premises. The station had 6,474 passengers per day in 2015, and the passenger survey rates it among the stations that were perceived to be most unsafe from 2009 to 2018.

*TOD analysis of Brøndby Øster S-train station*
Brøndbyøster S-train station

Dimension 3: Safety. Good lightning at night. High light poles light up the path, but the sides of the path are dark with low visibility.

Dimension 1: Scale. Residential area north of the station. Modernist planning inspires the area with large building slabs in a park structure. The area seems deserted and distances long.

Dimension 2: Public space for human use. Small shops close to the station on the north side: a flower shop, pizzeria, pub and two doctors. The buildings are from the 60's and not scaled for today's retail, but represent a human scale and some urban diversity.

Dimension 3: Safety. The landscape slopes down towards the station's tunnel entrance. Trees and shrubbery surrounds the path. The station has a tunnel entrance and the landscape slopes down under the embankment, creating blind angles, low prospect and no visual contact to the street level, which creates perceptions of low safety.
Dimension 3: Safety
The tunnel entrance to the station. Tunnels are notorious for creating fear of crime due to blocked escape/entrapment and low prospect, as well as change in light.

Dimension 4: Variety and complexity
Main street south of the station. The streetscape is human scale with windows facing the street but monotonous urban design, which does not encourage urban activity.

Dimension 5: Connections
Shrubbery and the backsides of buildings towards the pedestrian path and bike rack north of the station. This is not an attractive place to be standing alone, and especially not at dark, as no one can see you, and no urban activity is surrounding the path.

Dimension 6: Pedestrian and cyclist orientation
Pedestrian crossing, bike path (dotted black) and bike parking at the south entrance. There are sidewalks and bike paths alongside the roads.

Dimension 7: Public transport in urban pattern
The entire planning of the area focuses on the train station, which is visual in the geometry. The north side of the station has modernist planning and the facades does not create a continuous street, but stands in a park-like structure.

Dimension 8: Car movement and parking.
On-street car parking around the station entrances creates a drop in density, activity and eyes on the street at the station.
Passengers’ comments on the station

Question: ‘Can you describe why the ways to or around the station are uncomfortable or why you feel unsafe?’

Answer: ‘No. But stations are unmanned and deserted’. Woman 60. She uses it every other week, lives within 1 km of the station and knows the area well.

Question: ‘Can you describe why you sometimes feel unsafe at the station after dark?’

Answer: ‘(I feel unsafe) If there are groups of young people who do not ‘belong’ there. Fortunately, that’s rare.’ Male 45. He uses it every other week, lives within 3 km of the station and knows the area quite well.

Question: ‘Can you describe why you don’t feel the station is comfortable?’

Answer: ‘The area seems sad and worn down’. Women 70. She only travels by train once every quarter, she lives within 2 km of the station but does not know the area very well.

These passengers’ comments on the experience of Brøndbyøster S-train station support the TOD analysis, emphasising that the public space of the station has room for improvement, and that the low level of urban activity around it influences perceptions of safety.

Case study: Tåstrup

Tåstrup station dates from 1847, having been a station on the first railway line in Denmark, which linked Copenhagen and Roskilde. Tåstrup village was there a long
time before the railway and grew when it became a railway town. The station became an S-train station in 1963, and the building to the north of the station, with shops on the ground floor and parking in front, also dates from that time. A new shopping mall opened in 2013 at the southern entrance to the station connects the latter to the pedestrian shopping street and its attractive scale and activities.

Tåstrup S-train station had 8210 passengers per day in 2015. Passengers’ perceptions of safety at the station are reflected in a low average in the passenger survey from 2015-2018 (measured from after the mall opening in 2013). Before the mall existed, passengers’ perceptions of safety at the station were low.

*TOD analysis of Tåstrup S-train station*
Tåstrup S-train station

Dimension 3: Safety. Good lightning at night. High light poles makes it difficult to identify persons. Alongside the sidewalk are areas of shadows/darkness and low prospect.

Dimension 3: Safety. Good lightning at night. Inside the mall the fitness-centre lights up. Dark corners with dumpsters around the station's tunnel entrance creates low safety.

Dimension 1: Scale. Tåstrup Main Street has a village structure with small shops and mixed use. It has a pedestrian scale and within 100 m of the station there is a church, a community centre and a pedestrian street.

Dimension 2: Public space for human use. The shops and amenities all face the streets in the neighbourhood, with windows and doors opening up towards the sidewalk/public area. The building design of the station mall however, have TOD dimensions related to poor safety.

Dimension 3: Safety. The station mall has large-scale constructions, reflecting surfaces, corners, dead-ends and blind angles, creating a barrier around the station. The shops are vacant, and the perception of safety at the station has not gone as much up as expected when the commercial interests were integrated at the station.
Passengers’ comments on the station

Question: ‘Can you describe why the ways to or around the station are uncomfortable or you feel unsafe?’
Answer: ‘The bicycle parking (at the mall) has dark corners. Young boys hang out there, and they smell of hashish or alcohol. On the ground are kickstands from bicycles and clipped wire locks. Not all pathways are equally well lit in the area’. Woman 64. She uses the station four times a week or more and knows the area well.

Answer: ‘I would like the empty shops in the station mall to be rented out. Otherwise, it is nice and lively with restaurants, Kvickly (a supermarket) etc. I would also like the young guys around the bike racks to go somewhere else. You almost have to ask them to move when you want to get to your bike’. Women 53. She uses the station four times a week or more and knows the area well.

Question: ‘Can you describe why you sometimes feel unsafe at the station after dark?’

Answer: ‘The tunnels are gloomy’. Male 70.

Answer: ‘If there are no other people there, I feel uneasy’. Women 59. She uses the station four times a week or more, lives within 3 km of the area and knows the area well.

Question: ‘Can you describe why you don’t feel the station is comfortable?’

Answer: ‘There is no cosy waiting area and no toilet’. Women 58. She only travels by train once every quarter and lives more than 3 km from the station but knows the area quite well.

The comments from the passenger survey support the TOD analysis of Tåstrup station: the bicycle parking design, the tunnel and the empty stores in the mall are perceived as unsafe. More activity is needed at the station in order for passengers to feel safe outside
rush hour. The analysis shows the potential of connecting the station to the pedestrian street in the village, and it exposes the need for architects and planners to pay special attention to the pedestrian experience when building around train stations. The mall could potentially provide the station with urban activity, but its poor building design has failed to live up to the task. Furthermore, no attention has been paid to designing a new solution to the station’s main problem, the tunnel entrance. Most likely it is considered too expensive to redesign or is not interesting enough with regard to its potential financial returns for investors.

**Examples of parking around S-train stations**

Trends in relation to parking at S-train stations are illustrated in Figure 2. This relates to TOD topic 2: Facilities and logistics, Dimension 8.3: ‘Move parking away from the platform to open up prime real estate for development’. 8.5: ‘Prefer enclosed parking over surface parking lots’, 8.6: ‘Wrap parking structures with service and entertainment establishments’. 8.7: ‘Place surface parking at the back of buildings and wrap with walls and hedges’.
Figure 2. Twelve examples of car- and bus-parking areas around S-train stations

The examples of parking illustrate how parking areas and the embankment area alongside the tracks and the roads, taken together, form an extensive passive area around the station. This creates low levels of urban activity and disconnects the station from the rest of the city by creating a distance between them. A joint count of approximately 35 S-train stations built after 1963 shows that they have surface car-parking around the station. Stations from before 1963 tend to have less car-orientated layouts.

Discussion

This article has argued that, while the Finger Plan is an example of regional TOD that
supports the use of public transport, the public spaces at S-train stations leave room for improvement. Although only an analysis of a substantial number of S-train stations will provide a full overview of the urban design solutions, the thirteen case studies of stations from the different lines provide a strong argument for the design situation being discussed here.

It is important to underline that, in comparison with cities based on car infrastructure, the Copenhagen Metropolitan area is public transport-oriented. Nevertheless, looking at the stations from an urban-design point of view, the challenges are evident. This is most likely caused by the time of the planning and issues of subsequent ownership and governance. The majority of stations date from before placemaking and walkability found their way into planning departments. By the 1960s, the enthusiasm for private car ownership and modernist planning flourished, and at the S-train stations urban spaces grew into car-scale and modernist-inspired structures. Therefore, the older stations dating from 1937 and 1953, most of them situated along the northern fingers, have more walkable urban environments, while the rest, approximately 40 stations out of 84, have other urban dimensions. In addition, at the beginning of the development process many TODs experienced difficult planning procedures due to the then state of the economy and politics, leading to many of the original intentions being altered.

Although new stations in Copenhagen focus more on pedestrians’ experience of public spaces (Bendixen and Benktzon 2015), the TOD analysis of Tåstrup S-train station illustrates the importance of continually raising this awareness of placemaking principles in local municipalities’ planning systems.

The complex ownership and governance of the S-train stations also plays a part: the stations, street furniture, buildings and forecourts have different ownership between
private investors, local municipalities and the DSB (Appendix, Figure A.1). This makes the process of design solutions complicated and financial coordination troublesome. In addition, many municipalities regard public transport as a business that has to take care of its own customers. Thus the urban space close to a station is not the focal point of municipal investment, and it ends up disconnecting the station from the rest of the city. This is reflected in statements from the passenger survey, where passengers use adjectives such as ‘deserted’ areas and ‘sad’ environments about the urban spaces surrounding the stations.

**Conclusion**

This article argues that Copenhagen’s Finger Plan is an example of regional TOD, but the pedestrian scale of urban design at many S-train stations is not quite in line with TOD recommendations. The research is based on a case-study analysis of thirteen S-train stations with different layouts, two of which are presented in detail. The article tested ‘ideal’ TOD design guidelines from the case-study literature to see how the S-train stations follow the principles of TOD design. As a partial result, we suggest modifications to TOD parameters to suit Danish planning practice. The analysis exposes a prevailing tendency not to attend to placemaking and safety in the design of S-train stations and their surrounding areas, as reflected in the passenger surveys.

The analysis also indicates that urban densification within station catchment areas would benefit from the experience of S-train stations, an urban development potential in a metropolitan area that is currently struggling to find room for its growing population.
In view of these and previous international research findings it is clear that design templates from one country cannot be transposed to another without local context-specific adaptation. However, the TOD guidelines are very relevant for Denmark, and their future evaluation for the Danish context by means of a workshop similar to that of our Dutch colleagues would be of significant value to planning practice and decision-makers in municipalities, transport companies and the central administration.

Internationally, this analysis leaves room for further reflections, as many urban post-war developments in Europe, like the Finger Plan, have expanded urban rail corridors into regional networks, however, many of these have catchment areas inspired by modernist planning and car infrastructure. Here adapting TOD to local contexts can benefit the work at hand.

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Appendix

List of TOD guidelines from Pojani and Stead

Table 1. Key Urban Design Topics, Dimensions, and Guidelines for TOD Derived from the Academic Literature

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Recommended Guideline or Approach</th>
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<td><strong>Topic 1: Place-making</strong></td>
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| Dimension 1: Scale and density | • Ensure comfortable walking distances between points (i.e., TOD encompassing a half kilometer or a five-minute-walk radius, doubled for major stops, with placement of homes near transit at sufficient density).  
  • Place commercial uses, jobs, parks, and civic uses within walking distance of transit stops to allow for trip linking or consolidation.  
  • Taper densities with distance from a station (i.e., a “wedding cake” density).  
  • Provide sufficient densities to sustain transit investments (i.e., set minimum floor-area ratios, and do not exclude tall buildings and intensive development). |
| Dimension 2: Public spaces for human use | • Design individual parts of the overall plan with human activity in mind.  
  • Make public spaces the focus of building orientation and pedestrian activity (i.e., cluster benches and sitting ledges, provide special public art, allow for flexible use, accommodate outdoor dining, encourage water features, and discourage large setbacks, i.e., more than 6 m from the street edge).  
  • Add human-scale details, such as architectural features and textures on buildings, street furniture, colorful vegetation, public seating, a mix of building colors, and plantings.  
  • Design public spaces for a sense of “an outdoor room”; a recommended minimum height-to-width ratio is 1:3.  
  • Ensure that buildings line the streets and are not isolated in lots; ensure that main entrances and windows face the street.  
  • Provide large shade trees that form continuous canopies over the street.  
  • Provide soft transitions from the outdoors to the building (design porticos, arcades, low fencing, stoops, and shelters).  
  • Create attractive landmarks and gateways to the development.  
  • Provide physical measures such as good lighting at night.  
  • Control access in nonpublic spaces through fencing, lighting, and landscape.  
  • Avoid blank façades (provide transparent façades with nonreflective glass).  
  • Ensure adequate sight lines.  
  • Avoid tunnels, narrow paths, and other entrapment spots or isolated areas.  
  • Encourage a variety of uses to ensure round-the-clock activity. |
| Dimension 3: Safety | • Break up long streets with parks and other diverse, colorful, and interesting public spaces.  
  • Avoid monotony, either in terms of appearance or use.  
  • Avoid uniform planning regulations.  
  • Avoid large billboards, large-on-street trash dumpsters, and high light poles.  
  • Create a sense of identity (i.e., have a common vocabulary for buildings and public spaces).  
  • Encourage every price point to live around transit, i.e., provide affordable housing options. |
| Dimension 4: Variety and complexity | • Design relatively small blocks (i.e., a proposed average block perimeter limits is 400–450 m).  
  • Provide pedestrian-friendly street networks that directly connect local destinations (i.e., pedestrian cut-through paths).  
  • Avoid cul-de-sacs.  
  • Avoid barriers such as highways or large parking lots.  
  • Prefer grid street networks. |
| **Topic 2: Facilities/Logistics** |
| Dimension 6: Pedestrian/cyclist orientation | • Apply traffic-calming devices such as signal timing, speed bumps/tables, medians, undulating roads (chicanes), small curb radii, lower speeds, and narrow roadways. Provide buffers that separate moving traffic from pedestrians (i.e., through landscaping elements such as trees, flower boxes, or grass strips, or special features such as different materials or curb bulwarks).  
  • Provide a continuous network of sidewalks.  
  • Set maximum and minimum sidewalk widths (for sidewalks to accommodate pedestrian traffic but not appear empty); a recommended range is 1.5–7 m.  
  • Provide bike stations at major stops.  
  • Provide secure bike parking at more minor stops.  
  • Allow two- or four-lane streets maximum (with rare exceptions)  
  • Locate transit stops in the center of the community rather than the periphery.  
  • Ensure high-quality design of the main transit stop.  
  • Provide attractive, comfortable, informative, and sheltered transit stops.  
  • For underground stations: open up stairs and escalator area for easy and pleasant access.  
  • Ensure modal integration, i.e., connections between buses and trains. |
| Dimension 7: Transit in the urban pattern | * (continued) |
List of TOD guidelines extracted from academic TOD literature by Pojani and Stead (Pojani and Stead 2015, 133-134).

In the present article, two of the dimensions of the scheme have been grouped into a single question according to their original source by Jacobson and Forsyth, as the meaning of the text becomes fractured when it is split into several sentences (dimensions) in the scheme. The Dimensions are 2.1 and 2.5 (P.56 Jacobson and Forsyth 2008, p. 56).

**Methodology from the passenger survey**

According to this semi-annual passenger survey, which has been conducted since 2009, passengers consistently felt more unsafe at some S-train stations than at others (Forbrugerrådet Tænk, 2019). The motivation for the survey was to elaborate why.
The survey was conducted from 12 to 22 October 2018 and was completed by 1,408 members of the passenger panel, consisting of citizens who have volunteered to participate in surveys concerning public transport. They received a link by email and filled out the questionnaire electronically. The questions had pre-coded answer options, rubrics for comments also being provided. As the passenger panel has a preponderance of members who travel frequently by public transport, those who rarely use public transport are not well represented in the survey.

One limitation of the passenger survey of perceived safety at S-train stations is that it has a bias towards women and respondents over fifty. This influences the results, as women and the elderly are in general more sensitive to the fear of crime (Skogan and Maxfield 1981; Box, Hale, and Andrews 2019). However, of the 1,408 passengers interviewed, 89% know the area around the station quite well and are frequent users of public transport. This has a positive influence on perceptions of safety, as people feel safer in familiar environments (Yavuz and Welch 2010; Garofalo 1981).
Fragmented ownership of stations and station areas.

Banedanmark (Railway Denmark) is the company in charge of traffic control and maintenance of the Danish railroad network. In 1997, DSB was branched off Banedanmark as a government agency, and the two organizations divided the railway’s property between them. DSB took the trains and large plots of land used as railyards,
the station buildings and sometimes the forecourts, and platform features like buildings, benches, clocks and ticketing machines (marked in red on Figure 1). Banedanmark owns the platforms, the tracks, most of the tunnels and viaducts, and sometimes the forecourts and the land around the stations (marked in yellow on Figure 1). The urban area close to the station platform is one of shared ownership between DSB, Banedanmark, the local municipality and private investors. Planner Ole Bjerager from DSB explains that almost every station and station area is unique in its ownership. When the city around the station changes, the station and its surrounding area often stay the same, as there is no economic incentive to fine-tune or redesign them. This would require a joint venture between Banedanmark, DSB and the local municipality, and often the financial interest in and potential benefit of the project are only modest. Many S-train stations have an empty station building from the time when stations were staffed with ticket sale facilities or kiosks.

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In order to create better public transport environments and encourage more people to use public transport, it is important to have a comprehensive understanding of passengers’ experience of train stations and their urban surroundings. A crucial perspective is citizens’ fear of crime at train stations, which is higher than in other public places and can discourage the use of public transport. This thesis targets passengers’ fear of crime, their experiences of the built environment at S-train stations and the station neighbourhoods in the Copenhagen metropolitan area. The results reveal a strong connection between a station neighbourhood’s general characteristics and passengers’ fear of crime at the local station. This thesis suggest a categorization of station neighbourhood types in the Copenhagen metropolitan area and explore how their income levels and urban form influence passengers’ experience of train stations. The research uses the concepts of Transit Oriented Development and Crime Prevention Through Environmental Design and provide suggestions for the future design and governance of stations to achieve sustainable public transport.

The study contributes to the international body of knowledge on passengers’ fear of crime at train stations.